ASSESSMENT OF FIRE RISK LEVELS OF INDUSTRIAL BUILDINGS IN BIYAGAMA EXPORT PROCESSING ZONE AREA: A CASE STUDY

Nalaka Prasanna Jayarathna Liyanapeli

(149384L)

Thesis submitted in partial fulfilment of the requirements for the degree Master of Science in Safety and Health Management

Department of Building Economics

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Candidate’s Declaration

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

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Supervisor’s Declaration

The above candidate has carried out research for the Master’s thesis under my supervision.

Name of the Supervisor: Professor Lalith de Silva

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Signature of the Supervisor   Date

Acknowledgement

I would like to thank all the health and safety managers /executives of the selected factories in Biyagma export processing zone for giving me an opportunity to visit their factories to do an in-depth study of the fire safety systems within their premises. I am also grateful for their participation in the survey and helping me in getting validated the data .In addition to that for support made by them in order to get better quality result.

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Abstract

To meet the needs of growing population and changing consumption patterns, productions and services have to be changed and increased drastically. Due to this reason, industries change rapidly, and with these changes, massive alterations happen in industrial buildings to accommodate new production and service requirements. This research aims to explore any significant changes of fire risks levels in industrial buildings due to those changes happening with the time, as compared to initial approval stage of the building plan. A case study was performed with randomly selected five manufacturing plants in Biyagma Export Processing Zone and surroundings, based on the Questioner/Check list developed after studying local and foreign fire safety rules and regulations applicable to manufacturing plants. Structured interviews were conducted to obtain data, validated with responsible persons for fire and safety in selected factories.

According to the results, it was evident that, due to alterations, significant changes of fire risks levels in industrial buildings occur with time, as compared to the initial building plan approval stage. In addition, it revealed that existing Sri Lankan fire safety rules and regulations are not sufficient to ensure fire safety at working places, and Sri Lankan industries are not complying more than 41% with existing best fire safety requirements/standards, which are practiced by the British and the Europeans. Further, Sri Lankan laws and regulations cover 5% and 40% of fire safety requirements respectively, out of the prescribed rules and regulations by British and European.

The necessity of having strict monitoring mechanism was recognised to ensure the factories comply with fire safety requirements when approving building plans for new constructions and for any significant changes, and periodically, with the age of the building.

This research will help the community by introducing a new user-friendly fire risk assessment tool to assess the level of fire risks and help industries to take necessary actions to fulfil the gaps, thereby ensuring life safety of employees and business continuity.

Key words: Fire risk assessment, Five barriers, Fire resistance, Fire protection measures, Fire scenarios.

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List of Abbreviations

ICTAD: Institution for Construction, Training, and Development

IFE: Institution of Fire Engineers (UK)

BS: British Standards

NFPA: National Fire Protection Association (USA)

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1. INTRODUCTION

1.1 Introduction

With the beginning of industrial revolution in Britain in 1700′s, industries spread to Europe and United States and to the rest of the world. The use of machinery and factories led to mass production, and currently, industries have become more and more complex with technology development. Today, industrialization is a key factor determining the development, and most developing countries are moving towards industry-based economies. To meet the needs of growing population and changing consumption patterns, productions and services have to be changed and increased drastically. In addition, production processes and technologies are also changing rapidly to meet the needs of the fast moving world (Marsden, 2009).

Due to this reason, industries change rapidly, and with these changes, massive alterations happen in industrial buildings to accommodate new production and service requirements. These changes happen so fast in highly competitive and dynamic business environments, where "Various elements of a building will change throughout its working life beginning as soon as it is completed" (Browne, 2003). The problem is, the extension of fire systems, modification of fire protection systems, and firefighting systems, are not changed accordingly with these modifications or alternations (Connolly, 1999; Winkworth, 1999). Numerous examples can be sought of buildings that made major changes to their internal layouts or use, without altering fire systems (Williams, 2006). Further, according to the author, less attention is given to maintenance and testing of critical fire systems, even though fire systems have been installed. According to Charles (2009), poor management of fire systems can pave the way to comprehensive risk assessment and protective measures ineffectual.

It is a common truth that most factories/industries make major changes relevant to the factory building layouts for the expansion of production capacities, changes of production systems and technologies, and increasing number of employees etc. (Marsden, 2009). With time, these alterations/changes greatly affect the level of fire safety design objective of the initial building. Conversely, most these alterations are performed without proper approval of fire authorities/fire consultants (Law, 1998). According to the factories ordinance and BOI guidelines, it is necessary to obtain prior approval before making any significant changes to buildings. However, as a general practice, extension of fire systems or modification of fire protection systems are not adjusted to suit these modifications or alternations (Connolly, 1999; Winkworth, 1999). Therefore, it is necessary to have a proper mechanism to review the existing guidelines relevant to fire safety in buildings that has not been improved in parallel to the speed of changing of complexity of the buildings and technology (Wasswall, 2009).

Buildings are becoming increasingly complex (Wasswall, 2009) and most buildings are not properly maintained in terms of fire protection systems according to standard requirements, since there is no proper mechanism to monitor the fire safety of buildings by the respective authorities/institutions (Law, 1998). According to Browne (2003), most industrial people are not aware of those regulatory requirements to comply in a situation where the absence of a legal framework or monitoring mechanisms for the violation of regulations. Therefore, there are significant changes in the level of fire safety compared to the initial building approval stages of buildings (Browne, 2003; Connolly, 1999; Winkworth, 1999).

These conditions could lead to disastrous situations in case of fire, considering the number of employees working in these factories. According to the experts, management of these aspects need to take place over each stage in a building's lifetime: planning, construction, occupations and use, maintenance, alteration and extensions, and change of use (Cox, 2005; Ellicott, 2006). Further, fire safety levels can be weakened when the buildings get older and due to changes (Ellicott, 2006; Williams, 2006). Another issue here is the changing of the occupier or the business due to various reasons. In these cases, details of all fire safety measures need to submit to the new occupier and their maintenance staff, in order to properly review, maintain, and repair them. According to Ellicott (2006), "It is well known in most of the cases, they are not handed over to new building owner or the occupier."

In a normal condition, fire hazards cannot be fully illuminated and fires occur always. This makes it having effective fire prevention strategy, together with means for detecting a fire at an early stage, and plans for effective response to the emergencies to minimize possible damage (Laluvein, 2006). “Businesses are not naturally resilience to major fires which can threaten the safety of employees and others and cause massive disruption to normal working operations” (Hindsson, 2009). “Many firms go out of business following small fires” (Cooke, 1998). Analyzing statistics revealed that over 50% of companies that experience a fire will go out of business, even though property damage and loss of business are coved by the insurance (Hewitt & Bressington, 2006).

Since the occurrence of a fire is highly uncertain, one can never know how many fires will occur in a given building or set of buildings during any specific period of time (Laluvein, 2006; Lund, 2001). Therefore, to reduce the risk, highest fire safety levels should be maintained throughout the lifetime of the building. This issue has been widely recognized and so it says complying with local acts can produce a much safer building (Everton, 2006). A common misunderstanding among building owners is, if the relevant authorities sign off the building, it means the building is fully fire safe (Oliver, 2010). Anyway, the main objective of any fire protection measure including the local acts is to ensure the life safety within the building, while the second objective is property protection by reducing physical damages (Marshall, 2006a).

Consequences of a fire in a particular building is highly uncertain, and thus, it makes extremely difficult to evaluate the available alternatives when making decisions relevant to fire safety of buildings (Lund, 2001; Wit, 2011; Yaping, 2013). Therefore, designers, owners, and managers of the building have a great responsibility to eliminate, minimize, and control fire risks in possible fire damages and disasters (Hewings, 2009; Wit, 2011). Further, according to the authors, the level of fire safety in a building should be assessed at the design stage or after completion of building construction. Building regulations can be used as a guidance for designers to decide how to provide a minimum standard of fire safety relevant to the means of escape and structural fire precaution measures (Babrauskas, 2005; BS EN 1990:2002+A1, 2005; Cann, 2009; Dickerson, 1998; Sibert, 2006). According to Everton (2006), complying with local act can produce a much safer building.

In the building approval stage, relevant authorities review basic fire safety requirements of the building before they approve the building for construction. In addition to that, fire service department or local fire services should approve all building plans before approving them by relevant local authorities. Ultimate objective of this is to safeguard the life of employees in a fire situation, ensuring their safe evacuation to a place of safety (Day, 2006; Hewings, 2009; Marchant, 1999).

Not complying with above procedures could lead to disastrous situations in case of fire, considering the number of employees working in these factories (Kuligowski, 2008; Lundin, 2005; Wasswall, 2009). Further to the expert, management of these aspects need to take place over each stage in a building's lifetime: planning, construction, occupations and use, maintenance, alteration and extensions, change of use, etc. In addition, when buildings gets older due to so many changes including fire safety measures of the building could be weakened (Cox, 2005; Ellicott, 2006; Williams, 2006). Next problem is changing the occupier or business due to various reasons (Ellicott, 2006). In such a situation, all the details that is relevant to the fire safety measures should provide to the new occupier and their contractors to properly maintain and repair them (Ellicott, 2006).

In addition, to obtain fire services in case of a fire, there is a requirement to obtain a fire certificate from the nearby local government authority (Brown, 2003; Glibey, 2002; Todd, 2016). However, up to now, this is not a legal requirement in Sri Lanka. Anyhow, as a general practice, most industries obtain and annually renew these certificates by making payments to relevant authorities. To renew this certificate, a responsible officer of the fire service department should visit the site and advise to ensure fire safety of the building and facilities required to respond to them in case of fire emergencies (Browne, 2003; Glibey, 2002; Marsden, 2009; Merchant, 1999a; Todd, 2016). However, these things are not properly practiced since they are not legal requirements covered by law (Factories Ordinance, 1942).

The result of all above is, significant changes in fire safety measures in industrial buildings, exposing employees to a greater risk in case of a fire (Connolly, 1999; Cox, 2005; Wasswall, 2009).

1.2 Problem

It is noted that many changes happen in factory buildings, production processes, number of employees, and level of maintenance of fire protection system, after approving the initial building plan (Browne, 2003; Connolly, 1999; Winkworth, 1999). Despite the prevailing legal framework for obtaining approval for the significant changes in factory buildings, these things are not generally practiced (Glibey, 2002; Wasswall, 2009). Even minor changes could drastically compromise fire safety of buildings and the absence of a monitoring system relevant to the fire safety of factories could aggravate the situation (Brown, 2003; Glibey, 2002; Hartle, 2004).

Many experts have pointed out that fire authority need new laws to inspect premises to ensure that the fire precautions are appropriate and adequate. Fire authorities will have to implement and maintain an enforcement programme, which clearly explains how the authority will determine the frequency of inspection (Law, 1998).The fire brigades should have established a schedule for visiting the facilities and upgrade the collected data (Hartel, 2004), as even minor changes could severely compromise fire safety of a building. Absence of a monitoring system relevant to fire safety of factories could transfer the situation from bad to worst (Hartle, 2004; Law, 1998; Todd, 2016).

1.3 Research Question

Are there any significant changes of fire risk levels in industrial buildings due to changes happened with the time, compared to the initial building plan of the approval stage?

1.4 Research Objectives

Ultimate objectives of this research are,

1. Identify rules and regulations applicable to fire safety of factories.
2. Identify the existing rules and regulations covered by the laws, regulations, and guidelines.

3. Develop a tool to measure fire risk levels of industries.
4. Measure the level of fire risks in industries with the latest fire safety rules and regulations.
5. Give suggestions that can be followed by authorities to improve fire safety of employees and develop a fire risk assessment tool that can be used by maintenance engineers and health and safety managers.

The purpose of this research is to address the research question. According to Factories ordinance act of 1942 and General guidelines for factory building 2011, the factory-inspecting engineer or the director of the board of investment zone should check fire safety of buildings with approvals of fire service department, when accepting the proposed building plans to start a factory or making changes to factory buildings.

One of the main purpose of this research is to evaluate the fire risk levels of industrial buildings after the initial approval relevant to existing rules and regulations, and identify the gaps of fire risks. If the factories are approved by relevant authorities when starting and making changes according to factories ordinance act and BOI guidelines, later, there should not be any significant changes in fire risk levels of the factories.

To achieve the above objectives, an in-depth study will be carried out relevant to the all local, British, and European rules, regulations, and standards, which are applicable to the fire safety of industries along with studies relevant to local rules and regulations. The only law available to the safety and welfare of factory employees in Sri Lanka is the Factory ordinance act of 1942 and BOI guidelines. BOI guidelines can be regarded as a law for factories located within the export processing zones. However, now there is a procedure where all building plans and proposed changes should have approval by the fire service department and local fire authorities. In this case, fire service authorities consider many local and foreign regulations and standards. After identifying all the applicable rules, regulations and standards for the factories, the other objectives can be achieved by assessing fire risk levels of the factories against the above standards and regulations. As a consequence of that, the fire safety levels of the factories can be identified against the best standards and practices of the world.

In order to achieve the third objective, a simple fire risk assessment tool will be developed. This tool will enable to evaluate the fire risk level of the factories by themselves. To perform a comprehensive fire risk assessment, an in-depth knowledge on the subject and experiences are required (Connolly, 1999; Marchant, 1999; Todd, 2016). However, any person with little understating about factory layouts and with a basic knowledge of performance and maintenance level of their fire safety systems can use this new fire risk assessment tool intended to develop. He/she has to fill the questioner and asses the level of fire risk, fulfilling requirement of above questioner as per given parameters. The result automatically calculates the level of fire risk and the level of compliance against the latest fire safety standards applicable to world-class level factories.

Therefore, the fourth objective can be achieved by assessing fire risk levels of the factories against these standards and regulations, and identify fire safety levels of the factories against best practices of the world.

The final objective of this research is to pinpoint any significant gap in the prevailing system to relevant authorities to develop a framework to ensure the factories comply with latest fire safety rules and regulations with the time. Hence, the above findings based on the objectives suggest relevant authorities to improve fire safety of employees by fulfilling the above necessities in rules, regulations, and guidelines, by incorporating new laws and legislations.

1.5 Structure of the Thesis

Chapter 1- Introduction

This chapter describes facts behind changing the level of fire risks after receiving the approval for construction and changes in industrial buildings. Further it explains changing of factory layouts and fire protection systems are continues processes and to keep fire safety in a highest standards, it require continues monitoring and evaluation. It also shows, these constant monitoring and evaluation process does not happen despite legal requirements. The chapter further explains the research problem and its background, research objectives, and the research methodology. Finally, analytical techniques and limitations of the study are explained.

Chapter 2- Theoretical /Conceptual Framework

This chapter mainly describes the theories behind the formation of checklist, and the theories based on research methodology and objectives. It explains the input parameters described by Young (2008) and how a fire develops in an enclosed space in a large building, called as a *compartment*. These deterministic parameters can be determined before executing a fire safety design or fire risk assessment. Random parameters are those that cannot be determined in advance during fire safety design and risk assessments. Young (2008) explains it because of these random parameters, many types of fires can develop from small fires to flashover fires. This research totally depends on the main theory, which construct a complete set of possible fire scenarios and connect possible fire scenarios that can be constructed in each of the five basic fire barriers.

Chapter 3- Literature review

Chapter 3 broadly reviews existing literature on fire risk assessments and theories of fire risk assessments. In addition, it analyse the available information on changing the building throughout its lifetime and its impact on fire safety designs and performance of fire safety systems. This comprehensive literature review revealed that no research performed on the selected topic, pertinent to Sri Lankan Industries. Therefore, the purpose of this research is to clarify this issue.

Chapter 4 – Analysis and Findings

This chapter will seek how the formulated research problem should be examined in a logical manner, paying attention to theoretical/conceptual framework and empirical evidence in the literature. Latter part of chapter describes the research methodology in detail together with data sources.

Chapter 5 - Conclusions and recommendation

This chapter summarizes main results of the study derived from material presented in the main body of the study. It will also show the method to resolve questions raised, and finally, recommendations for future research.

1.6. Limitations of the Study

There are few limitations in the research:

For this research, five factories located in Biyagama export processing zone and surrounding areas were randomly selected. All these factories are heavy manufacturing factories that undergo numerous changes with time.

This research has few limitations and factors that could affect the overall result of the study:

1. These companies were randomly selected; hence, their levels of fire safety drastically differ from one company to another due to many reasons. One main factor is the absence of legal framework to evaluate fire safety levels of factories. As this complies with fire safety standards, rules and regulations totally depend on the management attitude towards fire safety of the factory. Management of some factories have identified the importance of fire safety, so they attempt to maintain the highest fire safety levels within their premises. Similarly, management of some factories pays less attention to fire safety of factories since they lack the understanding on the importance of fire safety, and there is no legal framework to monitor the compliance level, as pointed out earlier. Therefore, due to the above facts, selected five companies may not represent the exact population, and hence the result may differ from the actual results.

2. The second limitation is, here an equal weightage is given on 252 points, developed to measure fire risk levels under the main five barriers. A good example is, same marks (100 marks) are given for complying with below two points.

(1) “Have the doors been fixed with self-closing devices?” and,

(2) “Does the standby fire pump available and does it meet standard requirements?”

Even though same weightage/marks is given to comply with both requirements, it does not mean in case of fire, having a self-closing device for fire doors and not having standby fire pump will make the same impact on the safety of life or property. However, each listed point should be considered as equally important since there is no way to give different weightage for different points.

3. Another point is deciding the level of compliance with some points is more or less judgmental and can differ from person to person. As an example, in the point 152, “Is the fire pump in good condition and tested weekly?,” and deciding the compliance level from 0 to 4, it is possible to refer weekly checking sheet for the second part of the question, but deciding whether the pump is in good condition is questionable and judgmental.

4. Sometimes validating the data may need to depend on some persons and there may be limited access to verifying the validity of data. An example is, “Is equipment fuse rating suitable for the purpose they are being used for?” In this case, one has to depend on the data provided by the electrical engineer or the maintenance manager, as there is no possibility of checking the fuse rating by opening the electrical panels.

5. Some randomly selected factories for this research are older than ten to fifteen years. Most engineering managers and safety officers who were present during the initiation of factories or the initially approved building plan are not available now. Thus, it can only be assumed that basic fire safety requirements were present during the inception of factories and relevant authorities have correctly reviewed fire safety levels of building plans and advised responsible persons of the factories for necessary changes, at the time of approving the constructions and making changes of factories.

6. Another important aspect is, it was difficult to find literature relevant to Sri Lankan context, as all available literature were from other countries. This was a limiting factor for this research.

2. LITERATURE SYNTHESIS

2.1 Introduction

After reviewing factories ordinance act, BOI guidelines, ICTAD fire regulations, and other important materials relevant to fire safety of industrial buildings, the need for a comprehensive review of past and current literature relevant on same subject was revealed. In this chapter, an in-depth study was conducted on all local, British, and European fire safety rules and regulations relevant to the industries. In addition to that, a comprehensive review on how to conduct a fire risk assessment was carried out, reviewing articles in various journals and research papers.

2.2 Fire Safety of the Industrial Building

Fire safety is the set of practices intended to reduce the destruction caused by fire (Wikipedia, 2017 January). Further to that, fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. “Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building” (Wikipedia, 2017 January). According to the expert fire, safety levels in a building should assessed starting from the design stage or after completion of the building (BS 9999, 2008; Cann, 2009; Merchant, 2001; Todd, 2016). Normally, complying with local acts can produce a much safer building (Everton, 2006). Accordingly, it is clear that there is a significant role to play with relevance to fire safety of a building in the process of building plans approvals to ensure that the fire safety designs of buildings meet fire safety regulation requirements.

Fire risk assessment has been defined as the assessment of risks to the people and property, because of unwanted fires (Young, 2008). Fire risk management is a process and needs to have regular inspection and maintenance procedure to ensure reliability of the system (Cann, 2009; Hartle, 2004; Young 2008). After approving building plans, fire risk assessment should be executed in planned intervals or after any major change of buildings (Cann, 2009; Young, 2008). According to the above authors, it is clear that fire risk assessments, inspections and maintenance of the fire protection systems should be performed in regular intervals or in any major lay out changes of the buildings. Based on the above findings it can be recognised, the changes of the buildings are common with the time and as a result of that fire safety level of the building is changed.

Further to Young (2008), fire risk assessment can be performed in two ways as *simple risk assessment* and *comprehensive risk assessment*. In a simple risk assessment, the probability of a certain unwanted fire scenario is considered and the consequence of each scenario is discovered. In a comprehensive risk assessment, all probable unwanted fire scenarios and their consequences are considered (Young, 2008). Accordingly, there are five main barriers to be deliberated during the fire risk assessment process. They are,

1. Fire initiation
2. Fire growth
3. Smoke spread
4. Facilitate occupant evacuation
5. Facilitate fire department intervention

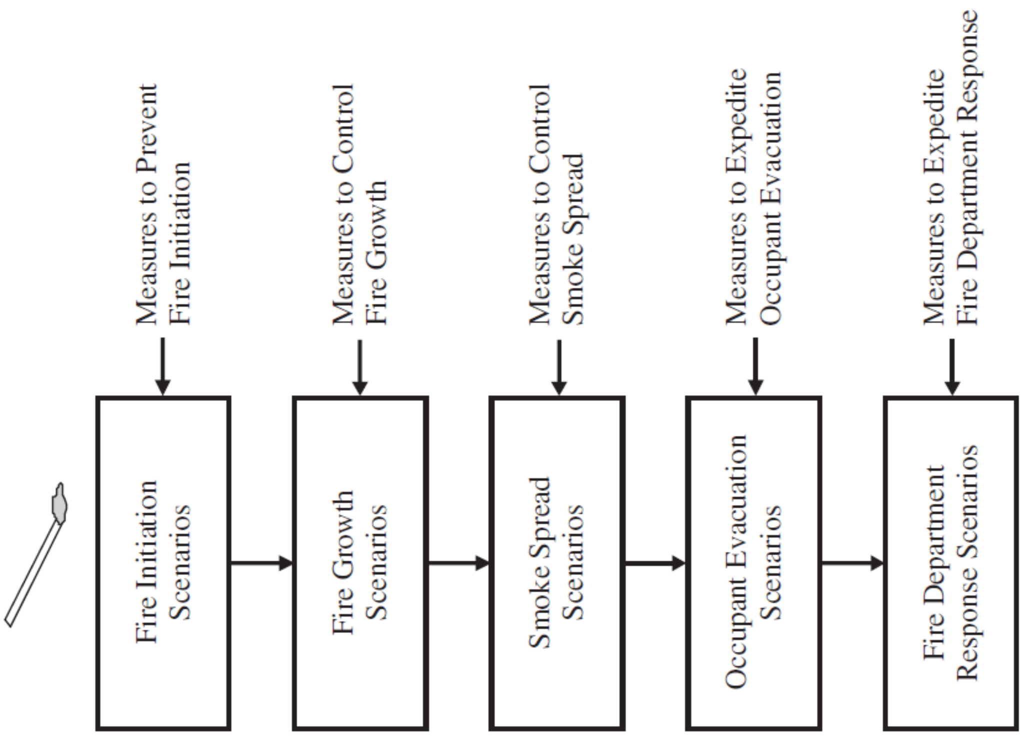


***Figure 2.1*: A complete set of possible fire scenarios can be constructed, based on connecting the possible fire scenarios that can be constructed in each of the five basic fire barriers**

(Source: Young, 2008)

Barriers 1, 2, and 3 try to control the development and spread of a fire, whereas barriers 4 and 5 attempt to expedite the evacuation and rescue efforts (Young, 2008). Fire resistance of building structures and layout plans play a major role in fire safety of the buildings relevant to above barriers (BS9999, 2008;Chow, 2005; ICTAD, 2006; Johansson, 2001; Marsden, 2009 Marshall, 2006; Wassall, 2009; Wikinson, 2006:). Structural members and non-structural barriers are provided to prevent the spread of fire and smoke, or to prevent structural collapse during an uncontrolled fire (BS9999, 2008; BS EN 1990:2002+A1, 2005; Hewings, 2009; Winkworth, 1999; Wit, 2011). Structural collapse can be minimised by increasing the fire resistance of structural elements and it is a measure of their capability of maintaining their function (e.g. separating or load-bearing function) in case of a fire (BS EN 1990:2002+A1, 2005; Connolly, 1999; Lund, 2001; Wit, 2011; ICTAD, 2006). In order to ensure the function of above barriers and function of structural elements, provision are made in Factories ordinance, BOI fire guidelines, and ICTAD fire regulations. In Factories ordinance, under various sections, provisions are made for means of escape, opening direction of fire doors, fire exit signs, requirement for audible warning, fire training, and employees training on evacuations, etc. Similarly, general guidelines for factory buildings (2011) ensure fire safety of factories in board of investment zones. However, ICTAD (Institution for construction training and development) fire regulation is the detail document currently available in Sri Lanka, with relevance to building fire regulations. This is drafted by tri-party experts such as Fire service department, The Sri Lanka branch of Institution of fire engineers (UK), and officials of institutions for construction training and development (ICTAD fire regulations, 2005); it is a regulation and not a law. It is a well-known factor that most factory buildings are constructed by contracting companies and to obtain the contract, they have to register their companies in ICTAD in various categories depending on the size and other parameters of the company. Therefore, it can be assumed that they need to comply with ICTAD fire regulations when they construct buildings. Therefore, building approval procedure by factory inspecting engineers or the directors of BOI would be one of the best method to ensure fire safety of occupants. Similar to that according to the above authors, changing of the fire structural elements may cause a significant impact of the fire safety level of the building. Accordingly, it is clear that getting the approval for the significant changes from relevant authorities as prescribed by factories ordinance and BOI guidelines. It is very much important to maintain the highest fire safety level within a building. On the other hand, it implies that there could be significant deviations in fire safety measures of the building, if it is not complying with the above requirement.

2.3 Factory Building Approval Procedure

According to the Factories ordinance act of 1942, before construction, extension, and conversions of the building, the factory-inspecting engineer should approve building plans.

"Occupying any factory registration should be done on and after the notified date; no person shall be the occupier of any factory, unless such factory is registered" (Factories ordinance act, 1942).

On and after the notified date, no person shall commence,

(a) Construction of a factory building on any site; or

(b) Make any extension to any factory building; or

(c) Conversion of any other building into a factory building, unless the Chief Factory Inspecting Engineer or the District Factory Inspecting Engineer (Factories ordinance act, 1942) has approved the plans for such construction, extension, or conversion.

Similar to that, if the factory is located with the board of investment, building plans should be approved by the director of the particular export-processing zone. Summary of the requirements are given below.

- Plans and specifications of all buildings and other civil structures, mechanical, and electrical installations, should be submitted to engineering approvals.

- Department for approval before construction activity commences.
- For buildings within the export processing zones, the approval of the local authority does not apply.
- No work should commence at the site without approval of the director (General guidelines for factory building, 2011).

In addition to that, it has been clearly mentioned in the same ordinance, that the occupier should inform and get approval from the factory-inspecting engineers on following matters:

"If, after the grant of a certificate, it is proposed to make,

- material extension, or
- material structural alternation of the factory premises, or
- to increase materially the number of persons, or
- to begin to store or use explosive or highly inflammable material in the factory, or
- materially to increase the extent of such storage or use,

the occupier shall give a written notice of the proposal to the factory-inspecting engineer."

According to the above facts, it is evident that if any one need to make a change in relevance to the above, they need to inform relevant authorities and obtain their approval. However, this is not happening properly as a general practice (Law, 1998; Wasswall, 2009). Ultimately, all above changes in fire safety measures in industrial buildings takes place, exposing employees to greater risks in the case of fire. Above findings are very much important and the author has observed the same in Sri Lanka. This is one of the key finding of this research trying to discover, "the relationship between the reducing the fire safety levels of the industrial building with the time".

Traditionally, building fire regulations are mostly prescriptive-based (Lundin, 2005; Wikinson, 2006). Further to authors, prescriptive-based regulations specifically state what its user should do in any given case in achieving a safe design. This makes implementation of prescriptive-based regulations a straightforward process (Lundin, 2005). The same can be said for the evaluation process of design under prescriptive-based regulations. Further to the authors, the user will implement what the prescriptive regulations specify as requirements. ICTAD fire regulations are also prescriptive type regulations. In the prescriptive regulations, the user need to implement what the prescriptive regulations specify as requirements. If the requirements in the regulations are not fulfilled, the design is considered as ‘none complying’ (Akashah, Kayan, & Ishak, 2013). In most countries around the world, fire regulations are still very perspective and only a little room for designers and architects are given to design the buildings beyond that (Smiedt, Schoonbaert, & Morgean, 1999). This offers less flexibility for the user of prescriptive-based regulations to come up with different solutions to fulfil the requirements, as it senses that there is only a certain way to provide the level of safety required (Morgean, 1999).

In performance-based regulations, design objectives are clearly defined without mentioning how these objectives need to be fulfilled. Designers will be given a chance to meet design objectives by either one of the two methods: a deemed to satisfy method or design based on calculations (Akashah, Kayan, & Ishak, 2013). As per the above mentioned, it is clear and easy to identify the deviation of ICTAD fire regulations since it is a prescribed based regulation.

Building regulations describe how designers should provide a minimum standard of fire safety in relation to the means of escape and structural fire precaution measures (Brown, 2003; Dickerson, 1998; Wassall, 2009). Therefore, technical expert’s direction to find out is unnecessary in cases where fire safety has been compromised in the buildings constructed according to the prescriptive based regulations.

Consequently, it is easy to measure the fire risk level by identifying the noncompliance levels of the buildings under the prescribed based regulations. This is the theory going to be applied in this research when developing a tool to measure the fire risk levels of the industrial buildings. Based on the above facts, it is clear that fire risk levels of the buildings can be assessed measuring the noncompliance levels owing to the most of referring standards and regulations are prescribed based documents.

2.4 Common Changes in Industries

It is identified that so many changes occur with relevant to every aspect of the factory environment in this highly competitive and dynamic business environments (Brown, 2003; Williams, 2006; Witt, 2011). In addition, these changes happen when various contracting people carry out major repairs (Cann, 2009; Glockling, 2012). These subsequent alterations will then be performed to accommodate changes in the business practices of the end users, right through to major refurbishment schemes for new tenants or owners (Brown, 2003). It is obvious that the changes in a normal factory environment are mostly relevant to changes of fire load due to increased storages, changes in combustibility of raw materials, changes due to poor maintenance of fire protection and fire fighting systems, lay out changes affecting evacuation pathways and fire exits, and changes of fire résistance of the elements and structures. Researchers have clearly proven these factors (Brown, 2003; Gough, 2002; and Paap, 2004). Careful observation of these changes reveal that most of them are the requirements, which needs to be notified and obtain prior approval, according to the Factories ordinance and BOI regulations as described earlier. However, except in few cases, obtaining approvals for these changes do not happen as a general practice (Law, 1998; Marsden, 2009; Wasswall, 2009). The result of this is serious violations of safety of employees in a fire situation, making uncertain their safe evacuation to a place of safety (Marchant, 1999; Sugden, 2002).

2.5 Effects of Changes on Main Barriers

2.5.1 Fire initiations

Businesses are not naturally resilience to major fires that can threaten the safety of employees and others, and cause massive disruption to normal working operations (Hindsson, 2009). Fires within buildings can be divided in to two major types, namely fuel- and vent–controlled fires. In above both types of fires, growth rate is decided by the amount of fuel and oxidizer available (Marsden, 2009; Young, 2008). When factories expand and their productions change in to new raw materials that are highly combustible and flammable, fuel load rise drastically. Fire safety must be carefully considered in the storage of combustible materials because it decides the potential fire load, intensity, and duration, of fully developed fire (Gough, 2002; Paap, 2004). “Large industrial buildings are not necessarily at high risk: it is how they use and what goods are used, what goods are stored, and how they create the risk” (Marsden, 2009). Combustible goods including electrical items, food wrapped in paper, polythene wrapped items in cardboard cartons with polythene packing, and those often stored on wooden pallets and shrink wrapped in polythene, will burn violently, especially when stacked on top of each other to the height of 10 m or more (Gough, 2002). The heat release rate is limited to the maximum heat release rate possible, based on either the amount of fuel in the compartment or the oxygen that can be supplied to the fire from the compartment and through ventilation openings (Nichou, Kashef, Torvi, Hadjisophocleous, & Reid, 2002). According to the above facts, it is clear that change of level of storages and level of their combustibility impose a greater fire risk. This has been widely recognized by many standards and regulations as well. It has been clearly mentioned in factories ordinance act, it is required to get prior approval for material extension, and in case of increase of combustibility of materials. However, these are the common changes frequently happen in factories, which pays the least attention in building plan approval. All these factors have been taken in to account when developing a fire risk assessment tool as it causes significant impact on fire risk levels of the industrial buildings.

In addition, interior fittings, furnishings, and decorations also can greatly influence the risk in the operational phase, but these are not regulated by building regulations. According to Gough (2002), in most cases, with time, less attention is paid to maintenance of self-closing devices and operating condition of roller shutters and broken windows, due to intensive production demands. Such possible changes in the use of the building must be assumed in the design phase (Lundin, 2005).

Because of fire, the value of loss of human lives is not measurable. Similarly, an acceptable level of financial loss is also difficult to quantify. Increase of raw materials, finished good storage, and generation of high amount of combustible wastes, could mess the housekeeping of factories and increase the like hood of starting fire and its severity (Gough, 2002). In many cases, it was evident if a building is not designed to arrest the spread of fire, entire facilities and the equipment can be destroyed within few minutes (Beardmore, 2006; Christoper, 1998). Designing means, separation of storage with fire resistance structures, maintaining self-closing fire doors, keeping unprotected areas of the walls according to the standards, fire resistance of load bearing and non-load bearing walls and columns, limited size of compartmentations, maintain minimum travel distance, and means of escapes and flammability levels of walls and ceiling (BS9999, 2008; ICTAD fire regulation, 2006). Fire protection measures for these type of changes that increase the possibility of fire initiation include, fire prevention education or the use of fire-retarded material in furniture, walls, and ceilings, which would help to reduce the probability of occurrence of this event and the consequential risks (Young, 2008). According to the above facts fire prevention education, good housekeeping and fire-retarded materials play a major role in preventing the initiation of a fire. However, in a normal factory environment less attention is paid for these basic fire prevention measures. In addition to that, there are no any legal requirements to monitor these basic requirements. It is important these parameters in assessing the fire risk levels. While developing a tool to measure the fire risk levels these factors should be considered.

2.5.2 Fire growth and spread

Fire hazard can never eliminate; fires will always occur. Therefore, it is necessary to include a fire prevention strategy by means of detecting fire and the provision for effective response to minimize potential damage (Laluvein, 2006; Sugden, 2002). An early fire detection is required to minimize fire damage and effective fire response. Recent research indicates that suitable steps are not being taken to inhibit the internal fire spread in buildings (Sugden, 2002).

A simple example is, once a building is occupied, the first thing that happens is that the user installs IT and communication system with cables, which breach the walls and floors (Sugden, 2002). These cables should go through the fire stopping ducts and cavities (BS 9999, 2008; ICTAD fire regulation No. 22, 2006). Therefore, when performing fire risk assessment under such situations, it needs to evaluate the ability of buildings to limit fire developments and spread in its various spaces by virtue of layouts, design features barriers, etc. (Cann, 2009; Winkworth, 1999; Young, 2008). When considering the fire growth and spread these changes are frequently happened neglecting the requirement of the fire stoppers.

Employee training play a significant role to inhibit fire growth in to serious levels. When staff members detect a fire and if they have relevant fire fighting equipment, they may be able to tackle the fire, before it develop into serious levels (Johansson, 2001; Young, 2008). “It is well recognized that occupants extinguish a many small fires before they are able to grow” (Winkworth, 1999). The possibility of extinguishing fires by staff members would depend on their training and amount of firefighting equipment they possess (Johansson, 2001). However, in many cases it can be observed the training on fire prevention for the staff is not happening properly. In addition, there is no proper mechanism to give refresher training and maintaining a required number of trained fire team members throughout the year. Employees turnover in lower grades are high in the factories in the export-processing zone. Proper mechanism should be implemented to fill the required fire team members when the trained fire team members are leaving the organizations.

A fire can grow in to dangerous levels such as spreading to storage materials, if not successfully controlled at its initial stage by the staff (Glockling, 2012; Gough, 2002). Even in structures of very low combustibility, occupant goods can provide fires yielding megawatts, not kilowatts (Babrauskas, 2005). When some of the industrial buildings are modified, most walls are replaced with glass as per architect designs (Chow, 2005; Wood, 2006). There is the possibility of breaking the glass system consisting of windowpanes, frames or accessories, thus resulting in big fires, involving the entire building (Chow, 2005; Wood, 2006). In order to prevent spreading fires through the breaking of glass, fire-resisting glass should be installed. The problem associated with uninsulated glass such as a wire glass, is that glass is highly conductive, and is transparent much to the radiation (Jackman, 1998; Wood, 2006). Conveyer belts also helps to spread the fire in buildings from once place to another (Gough, 2002). According to above authors, it is evident that replacing the fire resistant glasses by normal glass in windows and doors, could impose a huge impact on fire spreading increasing the fire risk levels in the buildings. It has been noticed in many factories; maintenance staffs are unaware on functions of the fire resistance glasses and fire resistance doors. In addition, most of the time these glasses are replaced by normal glasses due to the high cost of the fire resistance glasses. Ultimate result of all above changes increase the possibility of fire and smoke spreading and it increases the level of fire risk of the buildings.

One other factor that helps to spread the fires is permanently opened roller shutters in buildings, which is used to move machines, forklifts, and goods, between buildings (Hewings, 2009; Lund, 2001). Open spaces in separation walls between two sections of the building gives similar results due to modifications (Lund, 2001; Wikinson, 2006). Fire protection measures for inhibiting the fire growth include sprinklers, compartmentation, and door self-closers, which would help to contain these fires and reduce their consequential risks (Young, 2008). Sprinklers have proved its ability to control efficiently and effectively, the size of fire and its extinguishment (Barrett, 2006; BS EN 12845, 2004; Dickerson, 1998; Lund, 2001).

According to them, a sprinkler was developed in to property protection. They were designed to limit the growth of fire, which otherwise might have become large and cause heavy losses. Further to Young (2008), reduction in risk depends on the reliability and effectiveness of these fire control systems. Several input parameters decide how a fire develops in an enclosed space in a large building, i.e. a compartment (Marshall, 2006; Wikinson, 2006).

There are few important parameters considered in fire initiation and growth in a building (Young, 2008), which can be both deterministic and random. Deterministic parameters include:

- Fuel type
- Fuel load
- Compartment geometry
- Ventilation conditions

These parameters can be determined before performing a fire safety design or a fire risk assessment. Random parameters are those that cannot be pre-determined and include:

- Ignition source

• Ignition location
• Fuel arrangement

Due to pre-arrangement of these random parameters, many fire types can be developed in to flashover fires (Young, 2008). Accordingly, it can be assumed, that in a factory environment, numerous changes could happen because of countless layout changes and production system changes that affect the above random and determined parameters.

One of the most successful ways to control fire development is the use of automatic suppression systems (Barrett, 2006; Dickerson, 1998; Lund, 2001; Young, 2008). However, when changes happen with relevant to expansion and extension, normally, these systems are not extended nor modified (Marshall, 2006b). Apart from that, even though it is extended, a proper evaluation would not take place with respect to water pressure and pump capacities, to ensure smooth functioning of these systems (Marshall, 2006a; Connolly, 1999; Winkworth, 1999). According to the above authors, it is apparent; in many cases, the extension and modification of fire systems are not done when changes are taken place layouts of the factories. This is an important finding as the author has observed the same as well. The author highlight this key factor throughout this research which could alter the fire safety level of the industrial buildings.

As a step of reducing a freely spreading fire, large buildings are divided in to individual spaces called as compartments, constructed and lined with suitable fire resistant materials (BS 9999, 2008; BS EN 1990:2002+A1, 2005). If the fire does occur, the structure is protected against the effects of fire and contained for a period of time within one compartment, thus reducing fire spread through secondary ignition and limiting the movement of flame and smoke (BS 9999, 2008; BSEN 1990:2002+A1, 2005; Jackman, 1998; Marshall, 2006). In many cases, it has been observed that less attention is given to compartmentation and fire resistance requirements of the structural element of the buildings. According to above authors, the doors of the compartments should be fire resistant in order to meet the design objectives. Nevertheless, most of the compartment doors of the factories are normal doors and self-closing devices of the doors are not maintained properly. On the other hand, some of the factories have not been divided in to the compartments. In certain cases, the compartment walls have been removed later due to the requirements of the production. These are some of the noticeable factors, which could increase the level of fire risk of the factory buildings.

2.5.3 Smoke spread

Smoke spread is the common term for the spread of heat, toxic gases, and smoke particles in a building (Young, 2008). Physical separation of smoke and people is conventionally achieved using walls and doors, and is specified in the regulations of smoke control known as a containment; this is usually specified in a prescriptive code and a standard (Glibey, 2002; Hewings, 2009). When a fire breakouts in a building, doors are the potentially one of the most important elements in containing flames, smoke, and toxic fumes (Marshall, 2006a; Wood, 2006). In addition to that, when building design becomes increasingly complex, currently there is an increased tendency of installing engineered systems such as a fan and shafts to control smoke within buildings (Hewings, 2009; Marsden, 2009). Third party accreditation and registration for installing such a system is vital to ensure the reliability of these systems (Marsden, 2009). However, under Sri Lankan context, practices of third party accreditation or verifications is not noted. At least, there is no mechanism to obtain factory inspection engineers' approval for these systems, as it is not included in the law (Factories Ordinance, 1942).

As modern commercial buildings generally become more sophisticated, they are installed with an intelligent heating and ventilation system with air conditioning as a standard to control the smoke movement in case of fire (Hewings, 2009; Jackman, 1998). Further to Jackman (1998), it is recognised that air circulation has the potential to destroy compartmentation, both due to the possibility of the system spreading fire and smoke via the ducts, and by the fire exploiting the grills needed for make-up air. ICTAD fire regulation mention about a smoke control system for high-rise buildings and basements, but not for the industrial or commercial buildings.

Poor standards can severely compromise fire safety of buildings (Sugden, 2002). It is proven by the statics declared by famous insurance companies where 43% of serious fires in which they were involved were due to poor construction standards (Sugden, 2002). Lack of proper maintenance also can reduce its effectiveness within few minutes (Marshall, 2006).

Maintenance of fire doors are important to control the smoke spread (Marshall, 2006a; Wood, 2006). Under normal situations, door closers are changed more frequently over the years than fire doors. However, both their roles play equally important roles to ensure a door is in a correct position against the frame and that the door is sealed correctly during a fire (Nowell & Wood, 2006). It can be seen that maintenance of these doors and self-closing devices are not performed well, and these are the areas that receive less attention in factory maintenance (Ellicott, 2006). Therefore, fire safety designers must take in to account how ageing affect various fire safety designs and systems, to determine the requirements for operation and maintenance, and to decide the time to replace vital components of the system. If the protection system has a shorter lifetime than the building, as is the case for most fire alarm and sprinkler systems, the building must be designed in such a way that it is possible to replace these systems later (Lundin, 2005; Williams, 2006).

The smoke spread in a building should analysis start from recognized burning which could generate the smoke and assess the ability of the building to maintain its integrity for selected time period during the occupants escape phase and beyond (BS 9999, 2008; BS EN 1990:2002+A1, 2005; Winkworth, 1999; Witt, 2011). In ICTAD fire regulations, under various chapters and regulations, all requirements are given to maintain the acceptable condition of buildings to selected target spaces such as compartments, stairwells, lobbies etc. for the selected period, ensuring the safety of occupants in escape phase (ICTAD fire regulations, 2005). Fire protection measures to prevent the smoke spread before occupants evacuate include door self-closers, smoke control, and stairwell pressurisation, which could help to contain the smoke and reduce its substantial risks. The risk reduction depends on the reliability and effectiveness of these smoke control systems (Young, 2008). According to the above findings, it has been noticed that a less attention has been paid in maintaining self –closers of fire doors and maintaining the smoke extraction systems. In many factories, this is one of the area, which is given a least attention, as they don’t have a clear understanding on behaviour of smoke and its consequences in a case of fire.

2.5.4 Occupant Evacuation

One of the main principles of fire engineering strategies is to protect the structure stability that allow occupants to escape safely once a fire starts (Marsden, 2009; Yaping, 2013; Young, 2008). This is usually presented by available safe egress time (ASET) and require safe egress time (RSET) analysis (Marsden, 2009; Yung, 2008). Above requirement is ensured by the Factories ordinance act of 1942; "Every factory shall be certified by a factory inspecting engineer as being provided with such means of escape in case of fire for the persons employed. If any premises with respect to which no such certificate is in force are used as a factory, the occupier shall be guilty of an offence and liable on conviction thereof to a fine not exceeding twenty-five thousand rupees."

Even though it is mentioned in the law, under normal factory environment, numerous lay out changes happen frequently without obtaining proper approval from relevant authorities (Brown, 2003; Glibey, 2002; Wasswall, 2009). These changes directly influence escape routes and maximum travel distances (Day, 2006). Sometimes these changes happen faster than the frequency of evacuation drills, hence most employees are not fully familiarised with their escape routes (Gough, 2002; Kuligowski, 2008). It is clearly mentioned in the Factories ordinance act, "Effective steps shall be taken to ensure that all the persons employed are familiar with the means of escape in case of fire and their use and with the routine to be followed in case of fire." Building regulations effectively require developers to build fire safe structures (BS9999, 2008; Wasswall, 2009; Wikinson, 2006). A main objective of this is to take steps to inhibit the spread of smoke by keeping fire in the compartment of origin, but it only takes a small change to allow a fire to spread (Hewings, 2009; Sugden, 2002; Wikinson, 2006).

A well-designed smoke control should be able to maintain smoke free escape condition at low level to allow the building to be evacuated with minimum risk of some inhalation, injury, or death (Hewings, 2009; Wassall, 2009; Young, 2008). A well-designed detection system will assist to achieve the life safety of building occupants (BS 5839-1, 2013). In addition, if the constructions, repairs, and maintenance, are not complying with quality standards, it can create an extreme situation of premature collapsing of the building, which can be a threat to occupants and fire fighters (Ellicott, 2006; Wit, 2011; Young, 2008). Similarly, maintaining stability of the structure to ensure required egress time, training employees to respond to emergencies and evacuate safely, play a vital role in safety of evacuates (Hewings, 2009; Wit, 2011). For a safe evacuation, evacuation plans must include updated details specific to the particular premises, and need to comply with fire risk assessment results (Day, 2006). According to the author, these plans should alter as per the changes relevant to factory layouts. The problem is, updating of these do not happen parallel to the alterations of the building, thereby increasing the level of fire risk by delaying occupants' evacuation.

According to Williams (2006), frequently it is noticed that during modifications, less attention is paid to emergency lights and exit signs. This could be a reason to increase the evacuation time of occupants (BS5266-1, 2011). Further, he states many examples of buildings that have made major changes to their internal layouts or use without emergency lighting system being altered. In some instances, even though the lighting installation are completed, regular maintenance of emergency lights are ignored with time (Hewings, 2009; Williams, 2006).

Essential features of the required fire safety assessment in a work place base on the nature and capabilities of people who make up the workforce in any type of building (Marchant, 1999). When analysing people movement, two factors are considered. Normally, they take time to become aware of the fire and take time to evacuate from the building (Day, 2006; Winkworth, 1999). Under normal conditions, occupants are likely to engage in several activities during their evacuation that could delay their evacuation process. Such activities can include gathering information, preparing for the evacuation by gathering their personal belongings, assisting or even rescuing others, alerting others in the building, changing stairs, and fighting the fire (Day, 2006; Kulongoski, 2008). If occupants confront unfamiliar changes, this could increase delay in several fold (Day, 2006; Young, 2008).

A building is deemed to provide a sufficient level of life safety for occupants if the amount of time needed for evacuation of the building (evacuation modelling results) is less than the time when conditions become indefensible for occupants inside the building due to any alteration or modifications (Kuligowski, 2008). Employees' behaviour during a building fire evacuation is the result of a behavioural process and it should be considered how the modifications and alterations affect this procedure (Kuligowski, 2008; Young, 2008).

Further to Kuligowski (2008), these processes initiate with new signs and information from the physical and social environment. Here, signs need to be recognized and interpreted before the decision is made on what needs to be done. Occupants repeat this process several times during an evacuation, as they are engaged in a variety of different activities, both before and during evacuation. Therefore, unfamiliar modifications and alterations increase the time of this process that sets employees in a greater risk.

As has described in few instances, the reliability of a protection system depends on the level of operation and maintenance of systems (Cox, 2005; Lundin, 2005). Many experiments have been conducted on how the protection systems will work in actual situations in a building, ensuring the set objectives of both design phase and the operational phase (Lundin, 2005).

To ensure safe evacuation, many fire protection techniques are available such as fire alarms, voice communication, protected exit routes, refuge areas, and evacuation training and drill, etc. (Young, 2008; BS 9999, 2008; ICTAD 2006). Risk reduction depends on the reliability and effectiveness of these early warnings and evacuation systems, and the implementation of regular occupant training and evacuation drills.

2.5.5 Fire Department Response

Safety provision for fire fighters is one key factor of fire risk management in the work place (Christopher, 1998; Marchant, 1999). During building design stage, it is necessary to consider providing sufficient time for fire fighters and other fire serves people to carry out their operation (Beardmore, 2006; Brown, 2003; BS 9999, 2008; Marsden, 2009). Design of the building is one of the main concerns for any fire service, as it greatly affect the efficiency and effectiveness of fire service operations (Hartle, 2004). In general, fire protection measures are considered inadequate to deal with any potential fire (Gough, 2002). A fire risk assessment should evaluate the ability of structural parts of the building to resist and withstand the excessive deformation or collapse during a fire (Brown, 2003; BS 9999, 2008; Chow, 2005; Marsden, 2009; Winkworth, 1999; Young, 2008). Paying careful attention during the initial building planning stage, the building can be designed to provide sufficient time to fire fighters to bring the flame under control before it make any significant damage to the building structure (Beardmore, 2006; Brown, 2003; Marsden, 2009). Fire fighters' safety must be considered and it should be part of the building safety in any fire engineering design (Marsden, 2009; Young, 2008). Therefore, any kind of modification and alteration, which is not familiar or expected, affect fire fighters' speedy intervention with the rescue and fire fighting operation, thereby increasing the level of fire risk of the building.

Some modules are developed to calculate the efficiency of fire service involvements to determine the expected fire department response and intervention times (Nichou, Kashef, Torvi, Hadjisophocleous, & Reid, 2002). In the process of fire risk assessment, fire department involvement should be considered to succeed in extinguishing a fire, since the outcome of the fire heavily depend on the involvement of the fire department (Cann, 2009; Christopher, 1998; Connolly, 1999; Johansson, 2001; Young, 2008). Risk reduction depends on the reliability of early notification, obtaining their approval with familiarised visits, and adequacy of fire department resources (Cann, 2009; Johansson, 2001; Yung, 2008). The fire brigade should have a schedule for visiting the facilities and need to take necessary action to update collected data. Warehouse facilities change occupancies often, so periodic review may be more important for these occupancies than for others (Gough, 2002; Hartle, 2004). "New law required to fire authority to inspect premises to ensure that the fire precautions are in place and adequate. In particular, fire authorities will have to implement and maintain an enforcement programme, which clearly explains how the authority will determine the frequency of inspection" (Law, 1998). According to Todd (2016), it is very rare that fire service officers issuing a certificate for the premises, where employees are exposed to material risk harm from fires. According to all above literature, the fire brigade frequent inspections in a premise is very much important to deal with a fire effectively in case of a major fire situation. In addition to that, their advices on changes of building layouts and their frequent familiarization visits with layout plans are also play a significant role in a case of fire. According to above literature, it is evident these inspections and visits are not happened under normal conditions and it increases the level of fire risks of the buildings.

The above comprehensive literature review revealed that no research has been carried out assessing the fire risk level of industries with relevant to the Sri Lankan setting. All available research are based on foreign research studies and most of them are common fire risk assessment for commercial buildings. In this research, it is intended to assess fire risk level of selected factories in Biyagama export processing zone and surrounding areas. In addition, research on measuring the effectiveness of Sri Lankan fire safety rules and regulations against modern fire safety rules and regulations was not found either. Therefore, it will be more useful to conduct this research on above identified areas. It would help to reveal new findings relevant to the fire risk level of Sri Lankan industries, and effectiveness of the existing laws and regulations comparing to the modern world.

3. RESEARCH METHOD

3.1 Introduction

Fire safety is the set of practices intended to reduce the destruction caused by fire (Wikipedia, 2017 January). There are several input parameters, which determine how a fire can develop in an enclosed space, i.e. a compartment (Wikinson, 2006; Young, 2008). According to Young (2008), these parameters can be divided in to two as *deterministic* and *random,* as described previously.

In a compartment, due to the arrangement of above parameters, many fires develop, starting from a small fire to flashover level. As per Young (2008), it is better to consider the past fires because of these random parameters, rather than considering these parameters individually, which can result many possible fire growth scenarios. There are three types of fires, which could result as an arrangement of random and deterministic parameters:

1. Smouldering fires
2. Non-flashover flaming fires
3. Flashover fires

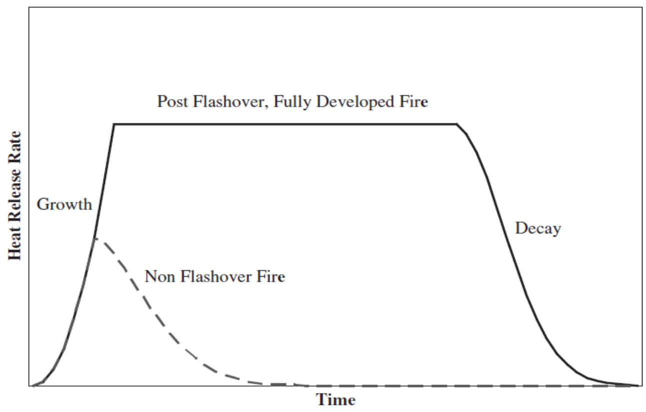


***Figure 3.1*: Typical heat release rate curves of flashover and non-flashover fires**

(Source: Young, 2008)

The probability of success or failure of fire suppression systems will result in three types of fire growth scenarios (Young, 2008).

Any fire risk management system should include regular inspection and maintenance of fire protection systems to ensure that these systems can maintain their reliabilities (Cann, 2009; Winkworth, 2009; Young, 2008). Fire risk assessment can be achieved in two ways as *simple risk assessment* and *comprehensive fire risk assessment*. In a comprehensive risk assessment, all probable unwanted fire scenarios and their consequences are considered. According to Young (2008), there are five main barriers, which need to consider during a fire risk assessment process as follows:

1. Fire initiation
2. Fire growth
3. Smoke spread
4. Facilitate occupant evacuation
5. Facilitate fire department invention

The barriers have many functions in a building, and one of them is to prevent or delay the movement of products of combustion and spread of fire. Therefore, failure of barriers make a significant influence on the building performance beyond the room of origin (EN 1991-1-2, 2002; Wikinson, 2006; Winkworth, 1999; Wit, 2011).

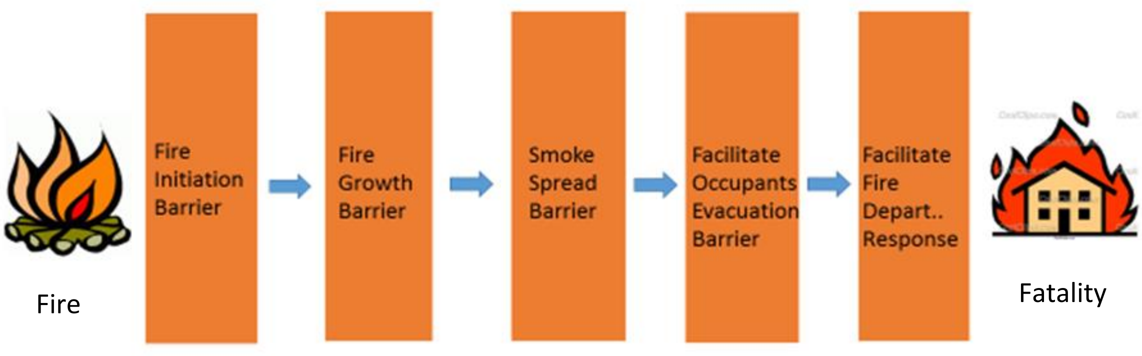


***Figure 3.2*: Five major barriers between fire and fatality**

(Source: Young, 2008)

3.2 Fire Scenarios

A fire scenario is a sequential set of fire events linked together by the success or failure of certain fire protection measures (Young, 2008). A fire event is an occurrence that is related to fire initiation, fire growth, smoke spread, occupant evacuation, or fire department response (Cann, 2009; Young, 2008).

Examples for fire events: A fire suppression system failed or a fire developed into a post-flashover fire, or the fire exit blocked so the occupants could not evacuate on time and trapped in the building, or the fire department responded in time and rescued the trapped occupants, etc.

A fire protection measure is a measure that can be a fire protection system, such as sprinklers and alarms; or a fire protection action, such as occupant evacuation training and drills (Cann, 2009; Young, 2008).

3.3 Fire Events

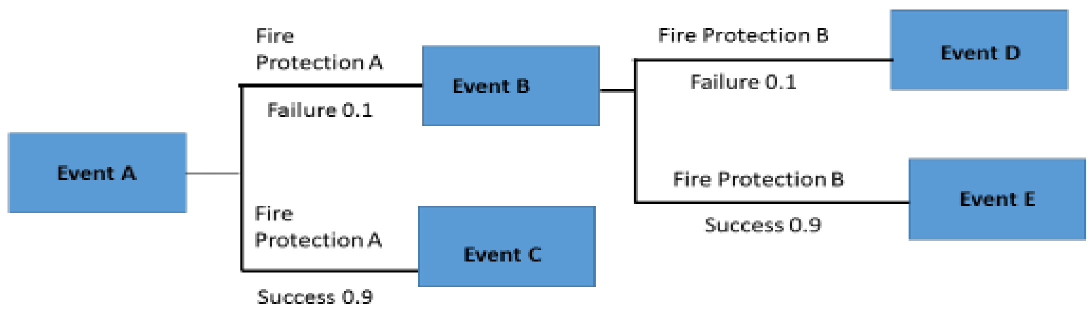


***Figure 3.3*: A simple event tree where an initiating event can lead to different events depending on the success and failure of fire protection measures at branch points**
(Source: Young, 2008)

The above simple event tree illustrates, how an initiating event can be leaded in to two different fire events depending on the success and failure of the fire protection systems. Event “A” can lead to two different events either “B” or “C” based on the success and failure of the fire protection system “A”. Failure of fire protection system “A” (Failure rate 0.1%) lead to the event “B” and success of the protection system “A” lead (success rate 0.9%) to the event “C”. Similar to that success or failure of fire protection system “B”, can lead to the two different events called event “D” and “E”.

A simple example of a fire scenario is the following set of events linked together by the failure of fire protection measures: a fire develops into a post-flashover fire, the alarm system does not activate and the occupants receive no warning signals and are trapped in the building.

Another simple example is the following set of events linked together by the success of fire protection measures: a fire does not develop into a post-flashover fire, the alarm system activates, and the occupants receive the warning signals and evacuate the building.

In real-world fires, fire scenarios are much more complex and the possible number of fire scenarios can be many (Young, 2008).

Normally there are so many fire protection measures in buildings to protect people and property. Few of them are in place to control the development of a fire and prevent spreading of the fire from one compartment to other parts of a building. Similarly, some other fire protection measures are there to provide early warnings to people and help them to evacuate to a place of safety before it develop into critical levels. In addition, protection measures notify fire departments for their early involvement to rescue and control the fire (Cann, 2009; Young, 2008).

Therefore, fire risk assessment process are based on identifying possible fire scenarios that are depended on the success and failure of fire protection measures, to assess the level of fire risk.

Further, fire safety measures include those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts. “Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building" (Wikipedia, 2017 January).

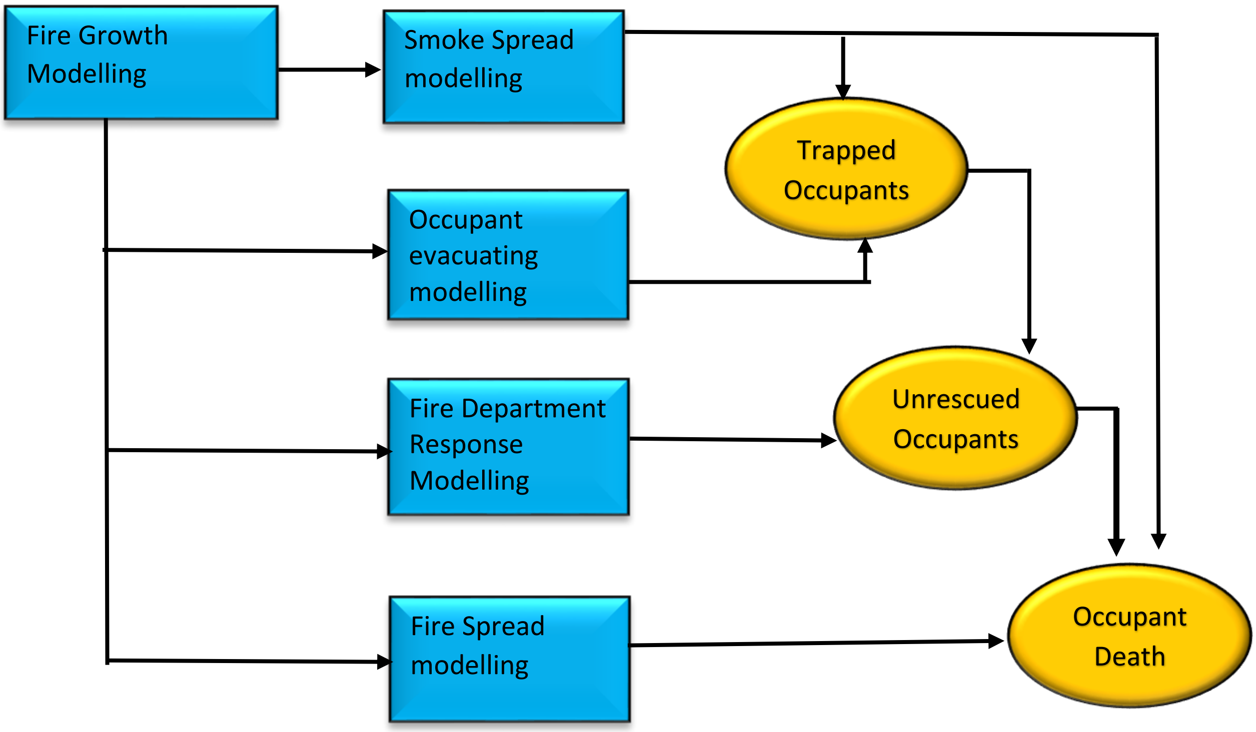


***Figure 3.4*: A theoretical model of fire events that can lead to occupant deaths**

Fire risk assessment should be executed in planned intervals or in major changes of the building. "Fire risk assessment is the assessment of risks to people and property as a result of unwanted fires" (Young, 2008). According to Sibert (2006), it is a process which examine the work activities of the work place aiming to identify the like hood of a fire occurring and the degree of harm it cause to people. Fire risk assessment helps to identify whether it requires further measures to ensure the safety of occupants by either reducing the like hood of the fire or increasing fire protection measures (Cann, 2009; Sibert, 2006).The primary purpose of any fire protection measure is to ensure life safety within the building. Protecting the property by reducing the amount of physical damage caused is also important, as it will reduce the financial loss and disruption to business (Glockling, 2012; Marshall, 2006b).

3.4 Conceptual Framework and Research Method

For this case study, five randomly selected manufacturing factories operating in Biyagama export processing zone and surrounding were selected. These randomly selected factories are having the possibility of representing the rest of the factories in Biyagama exporting processing zone. The selected factories contained a large amount of common characteristics of industries in Biyagama exporting processing zone. Company "A" is a large-scale tyre manufacturing plant and company "B" is a press. Company "C" produce laminated sailcloth, sail bags and accessories for boats. Company "D" and "E" are large scale two different types' of textile manufacturing plants.

A comprehensive checklist was developed after an in-depth study of local and foreign (British and European) latest fire safety standards and regulations relevant to below-mentioned five key areas of fire risk assessment. In addition to that, some of the identified points in literature review that could make impact on deterministic parameters are included to the above checklist.

1. Fire initiation
2. Fire growth
3. Smoke spread
4. Facilitate occupant's evacuation
5. Facilitate fire department intervention

Quantitative checklist method was selected for the assessment of fire risk levels of these industries. The developed checklist completely depend on the above theoretical background. In-depth studies relevant to above five barriers revealed 252 rules, regulations, and standard requirements, applicable to fire safety of industries. Therefore, with this development of checklist, the first objective of the research could be achieved. The developed checklist was totally based on the theoretical framework established for this research. In addition to that, it was crosschecked with the below listed experts in the field. At these meetings, it was found that no barrier other than the given five barriers, exist.

Table 3.1: Panel of expert- crosschecking & Validation.

Organisation	Position
Sri Lanka branch of the Institution of fire engineers (U.K)	President
Sri Lanka branch of the Institution of fire engineers (U.K)	Immediate past president
Fire service department	Chief fire officer
Fire service department	Deputy chief fire officer

Information for the present study was collected using the above checklist from the selected five factories.

1. All checkpoints were listed under the five barriers described in the theoretical background and later validated by industry experts.
2. With relevant to fire initiation barrier, 80 checkpoints were identified under following sub topics:
    - Factory registration and other general points
    - Responsible person’s duties
    - Designation of Fire wardens
    - Fire Safety committees and managers
    - Fire training
    - House keeping

- Flammable liquids and other storages
- Electrical equipment and controls
- Fire assessment, inspection and audits
- Smoking
- Kitchen and cooking
- Maintenance
- Site security and arson

3. Similarly, 135 check points were identified under fire growth and spread barrier, relevant to the industries related to below sub topics:

    - Fuel types
    - Fuel loads
    - Compartment Geometry
    - Ventilation
    - Fire extinguisher
    - Fire Hydrants
    - Fire hose reels
    - Fire pumps
    - Fixed carbon dioxide systems
    - Sprinklers
    - Inert gases fixed systems

- Dry powder chemical fixed system
- Fixed foam systems
- Water spray and projector systems
- Wet and Dry riser system
- Dry powder system
- Rooftop and cavity barriers
- Compartmentation

4. Under the smoke spread barrier, 10 points were identified.
5. With relevant to occupant evacuation, 56 checkpoints exist under below categories:

    - Fire exit and corridors
    - Emergency lighting
    - Fire safety signs and notices
    - Disable access and escape
    - Fire alarm system
    - Fire detection systems

6. Under the facilities for fire service barrier, six number of applicable points were revealed.
7. In addition to checking the effectiveness of main barriers, some checkpoints have been included to measure the deterministic parameters. Checkpoints included, measuring the deterministic parameters such as quantity of the fuel type, fuel load, compartment geometry, and ventilation.

8. Many checking points were listed to measure the number of fire protection measures and evaluate the effectiveness of those systems.
9. One important component of fire risk assessment is effective maintenance of above fire safety measures and protection systems. Hence, there are checking points to measure the effectiveness of maintenance levels of above protection systems.

10. Finally, there are some questions to check whether the relevant approval was obtained from relevant authorities from time to time to ensure whether the significant changes comply with fire safety rules and regulations.

Altogether, there were more than 252 questions/check points, completely based on the above theoretical frame work developed, to effectively measure the level of fire risk in industrial buildings.

In addition to checking whether each point is complying or not, a scale was developed here to measure how effectively these points are complied. Under each point, there are five levels from “0” to “4” to evaluate the effectiveness of complying with each points based on complying percentages. Thus, in the calculation phase, complying percentage and level of effectiveness of each point could be obtained more accurately to measure the level of fire risk. Finally, level of fire risk is achievable by giving a more realistic value for the level of fire risk, qualitatively. A Five rating scale, developed to measure the level of compliance quantitatively for each point of the checklist, is as below:

Table 3.2: Levels of Compliance

Rating	Compliance percentage	Complying level
0	1-20	Very Low
1	21-40	Low
2	41-60	Medium
3	61-80	High
4	81-100	Full comply

Checklist is categorized into two main sections. In the first section, all above requirements are measured against the requirements prescribed by the Factories ordinance and BOI general guidelines for factory buildings, 2011. These are the existing legal documents currently available with relevant to the building fire safety in Sri Lanka. Based on the result of the above analysis, it is possible to accomplish the second objective of this research.

In the second section of the above checklist, five areas are measured against the requirements of ICTAD fire regulations, and in the absence of ICTAD fire regulations, with relevant to British and European standards.

An empirical study was conducted by going through the checklist one by one, in selected factories. For this study, every part of the selected factories were thoroughly inspected together with all fire protection systems. In addition, by only observing the requirements against existing standards, regulations and guidelines of all above findings were validated after interviewing relevant safety officers, maintenance managers, etc. Document reviews such as examining the approved building plans and checking the inspection and service report with the assistance of respective authorities would be a part of the validation process.

Based on the above rating scale, equations were developed to automatically calculate the level of risk quantitatively. This user-friendly sheet can be used as a fire risk measuring tool. Therefore, fourth objective of this research could be achieved.

After calculating all risk levels of selected five factories, data analysis helped to find out whether there is significant deviations comparing to the latest fire safety rules and regulations, in which the fifth objective was achieved.

4 RESULTS AND ANALYSIS

4.1 Results

Research analysis and findings totally depend on the in depth study of the factories, based on the developed checklist and the structured interviews conducted to validate data. All the areas were thoroughly inspected through going one by one in developed risk assessment sheet under the various topics. A document review was also conducted where it is required in order to verify the data. As a part of the validation process, discussing with the relevant health and safety mangers and maintenance managers was done. Finally, all the collected data uploaded to the developed risk assessment tool. Fallowing are the result and analysis of the data.

Table 4.1: Summary of Complying status of Local and Foreign standards and five barriers

(Source: Checklist survey data)

Company Name	British and European standards	Local Standards	Fire Initiation	Fire Growth	Somke Control	Facilitate Eva	Fire Brigade Intervention
A	31.91	43.47	29.71	27.61	25.00	24.5	35.71
B	53.55	59.09	51.09	37.39	38.89	48.5	46.43
C	58.70	64.20	60.14	40.65	38.89	49	75.00
D	73.41	79.55	77.90	47.17	41.67	66.5	78.57
E	75.37	82.67	76.45	49.78	58.33	67.5	78.57
Total Average	58.59	65.80	59.06	40.56	40.56	51.2	62.86

Table 4.1 illustrates the full summary of the analysed data of all the selected factories. Factory "A" shows the lowest complying level with British and European standards as well as local standards. Opposite to that, factory "E" shows the highest compliance level to both local and foreign best fire safety standards.

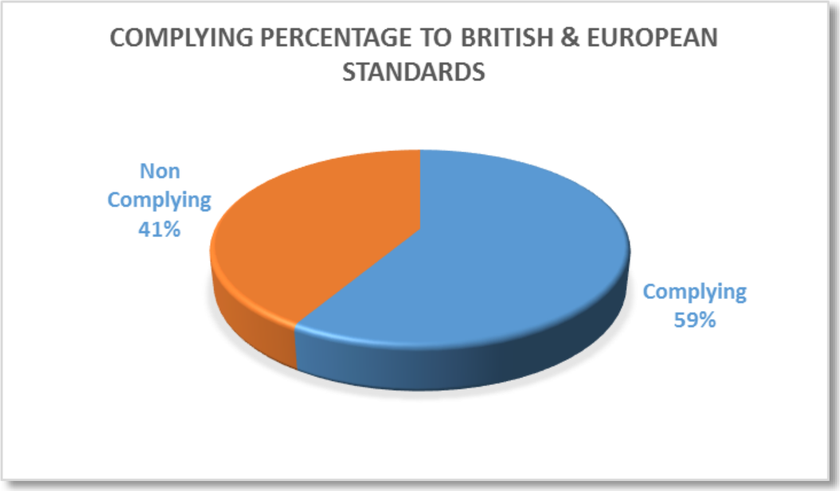


***Figure 4.1*: Average percentage complying with British and European fire safety standards**

(Source: Questionnaire survey data)

It is apparent that on average, Sri Lankan industries do not comply with more than 41% of the best fire safety standards and practices applicable to the industries, as compared to British and European. Based on the above analysis, it can conclude that fire safety levels of the Sri Lankan industries are far behind to the best fire safety practices as compared with British and Europeans standards.

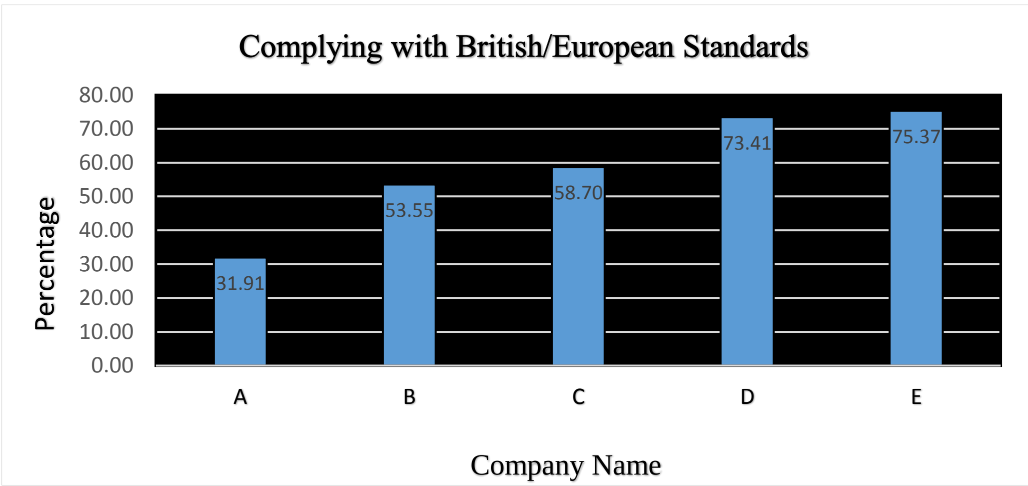


***Figure 4.2:* Percentages complying with British and European fire safety standards**

(Source: Questionnaire survey data)

Figure 4.2 illustrates the complying levels of each factory with British and European fire safety standards. According to the above-analysed data, there are some factories like "A", where the level of compliance of fire safety is less than 1/3 of the best fire safety standards and practices. Based on the above finding it was revealed that fire safety level of some factories in Sri Lanka are far below the required level. It was found that the absence of proper monitoring mechanism together with the absence of legal requirements to regulate the fire safety requirements, alteration of the building without getting proper approval from the fire service department and other relevant authorities are the causes for the above deviations.

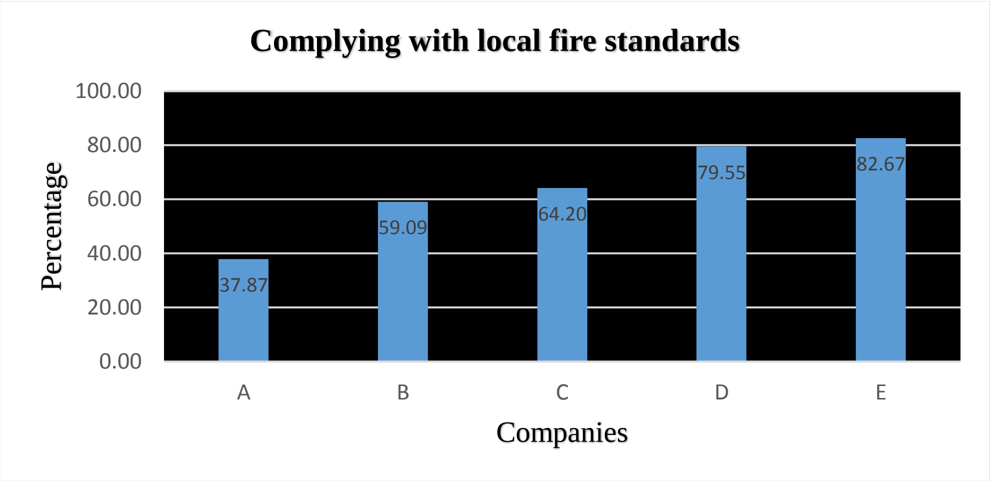


Figure 4.3: **Percentage of complying with local fire safety standards**

(Source: Questionnaire survey data)

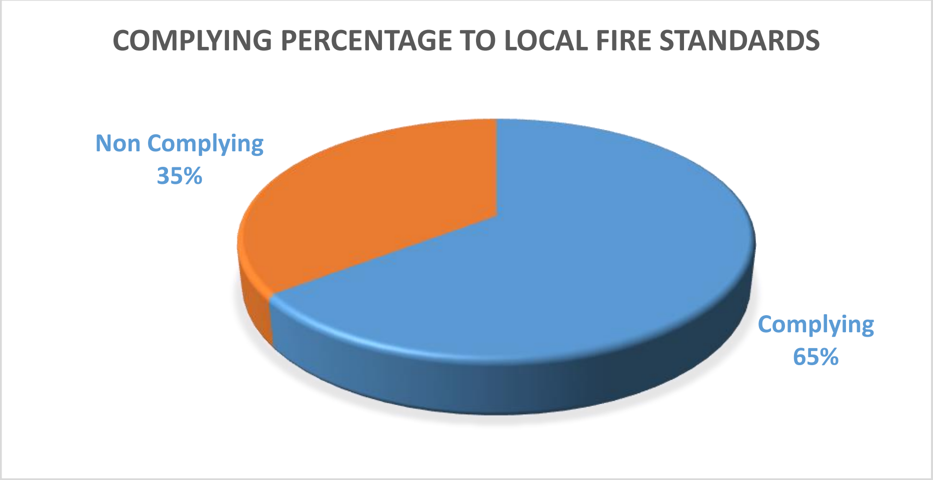


***Figure 4.4:* Average percentage of complying with local fire safety standards**

(Source: Questionnaire survey data)

Figure 4.4 illustrates that, as an average, Sri Lankan Industries are not complying with 35% of related local fire safety requirements prescribed by various laws and regulations. In addition to that, figure 4.3 shows the complying levels of each factories with local fire safety rules and regulations. This is an important finding since there is a vast room to improve the fire and safety levels of the industries by making them comply at least with local fire and safety rules and regulations. However, comparing complying levels to British and European best practices shows that Sri Lankan industries comply more with local fire safety standards.

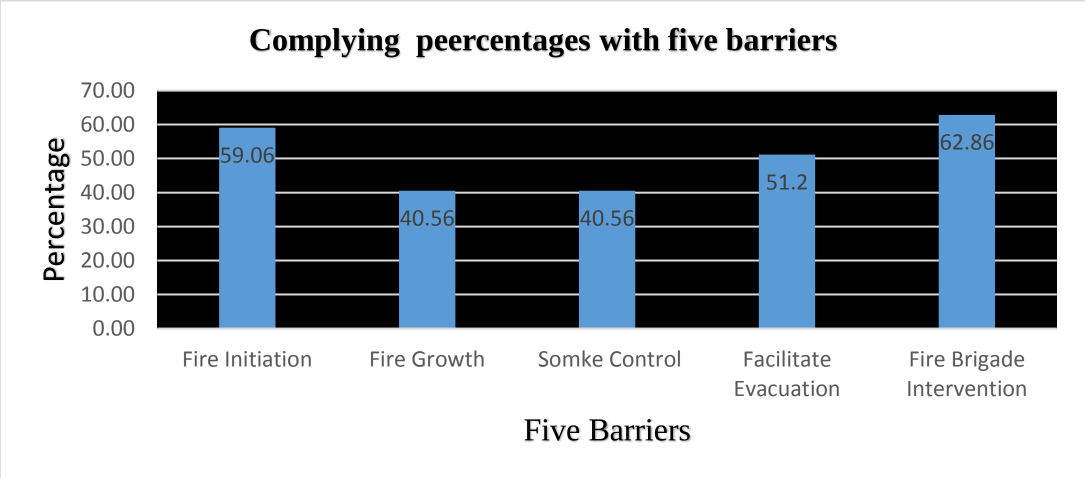


***Figure 4.5:* Percentage of complying with five major barriers**

(Source: Questionnaire survey data)

According to Figure 4.5, most Sri Lankan Industries show less complying percentages to fire growth barrier and smoke control barrier. Similar to that, it is clear that Sri Lankan industries display less compliance with fire growth and spread barrier, Smoke control barrier, and facilitate occupant evacuation barrier, as compared to fire initiation and facilitate for fire brigade intervention. Figure 4.2 shows that complying percentages of above three barriers are respectively 40.56%, 40.56%, and 51.2%. This is an important finding since most parameters (checklist points) that come under the above three areas are the parameters which could be subjected to change in normal factory environment with time. While it provide the answer to present research question, it is clear that there is significant changes of fire risks levels in industrial buildings due to the changes happening with time, as compared to initial building plan approval stages.

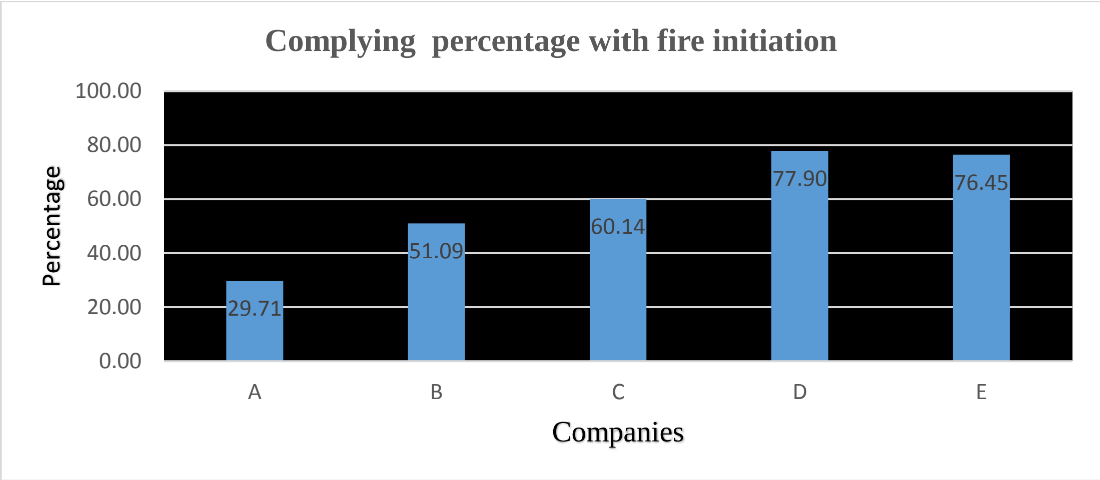


Figure 4.6: **Percentages of complying with fire initiation barrier**

(Source: Questionnaire survey data)

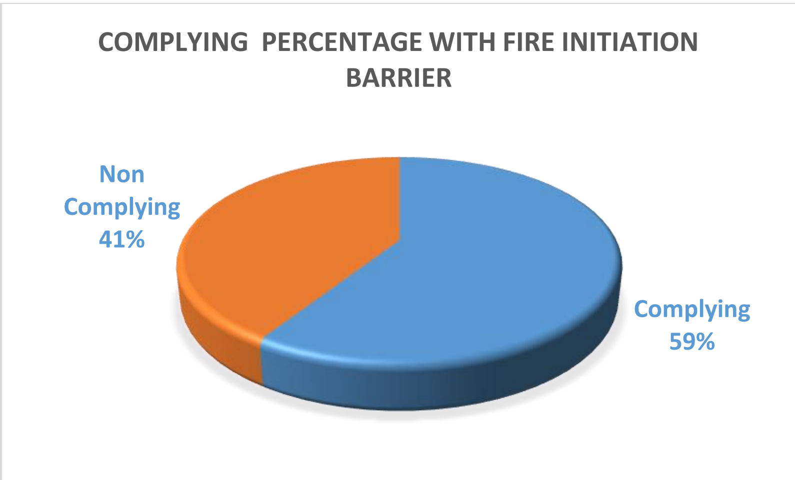


Figure 4.7: **Average percentage of complying with fire initiation barrier**

(Source: Questionnaire survey data)

Despite the vast variation among industries complying with fire initiation barrier as an average, companies are complying over 59% with fire initiation barrier.

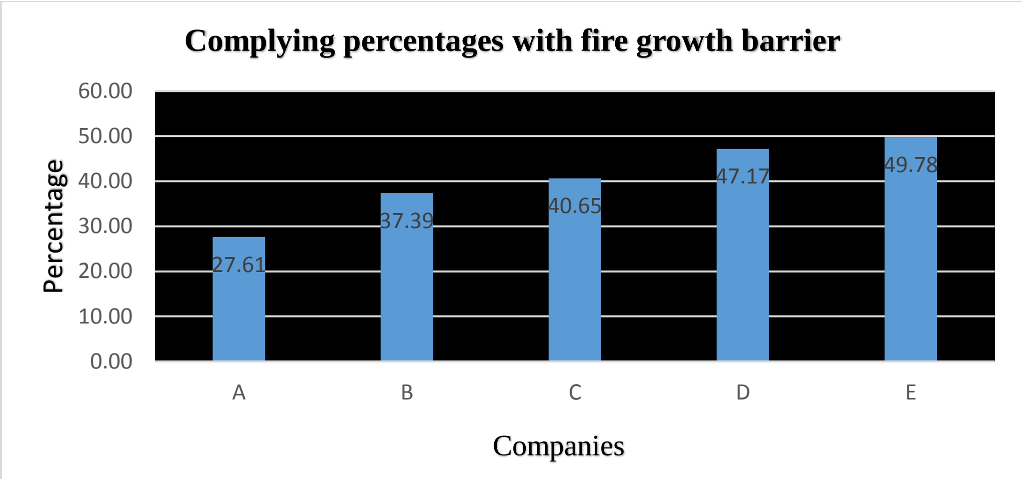


Figure 4.8: **Percentages of complying with fire growth and spread barrier**

(Source: Questionnaire survey data)

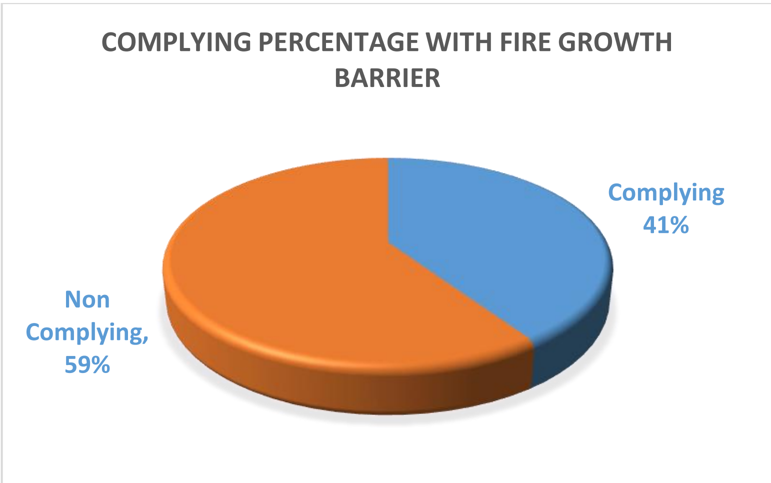


***Figure 4.9:* Average percentage of complying with fire growth barrier**

(Source: Questionnaire survey data)

Analysed data reveals that complying with fire growth and spread barrier is one of the poorest among fire barriers. Changes of fuel load, compartment geometry, ventilation levels, fire safety systems maintenance levels, fire exits, pathways, and compartmentation, could directly affect the fire growth and spread barrier. In addition, these parameters could change with time in a dynamic business environment, as explained earlier.

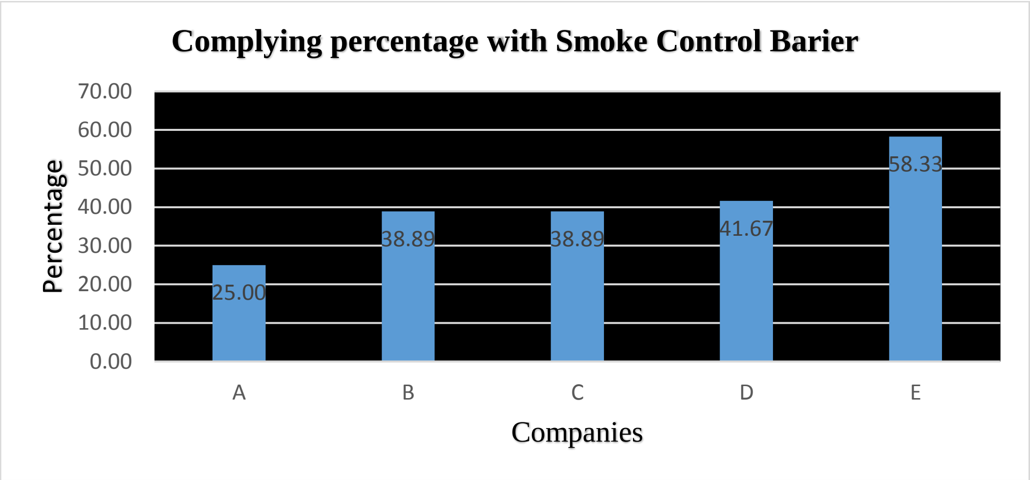
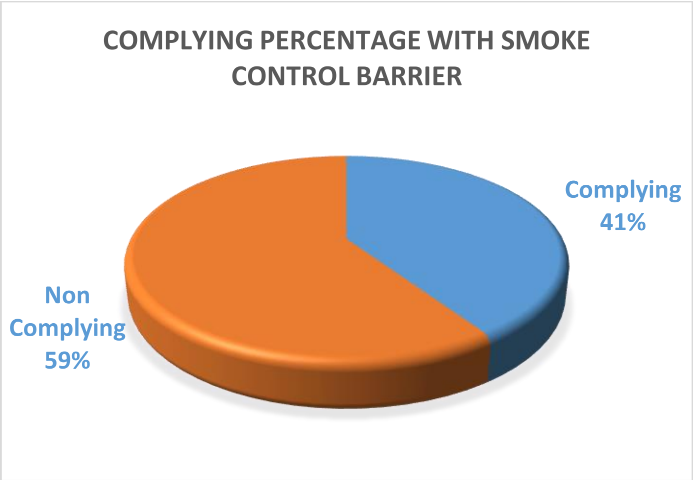


***Figure 4.10*: Percentages of complying with fire smoke control barrier**

(Source: Questionnaire survey data)



***Figures 4.11*: Average percentage of complying with smoke control barrier**

(Source: Questionnaire survey data)

Analysed data indicate that both fire growth and smoke spread barrier figures are identical.

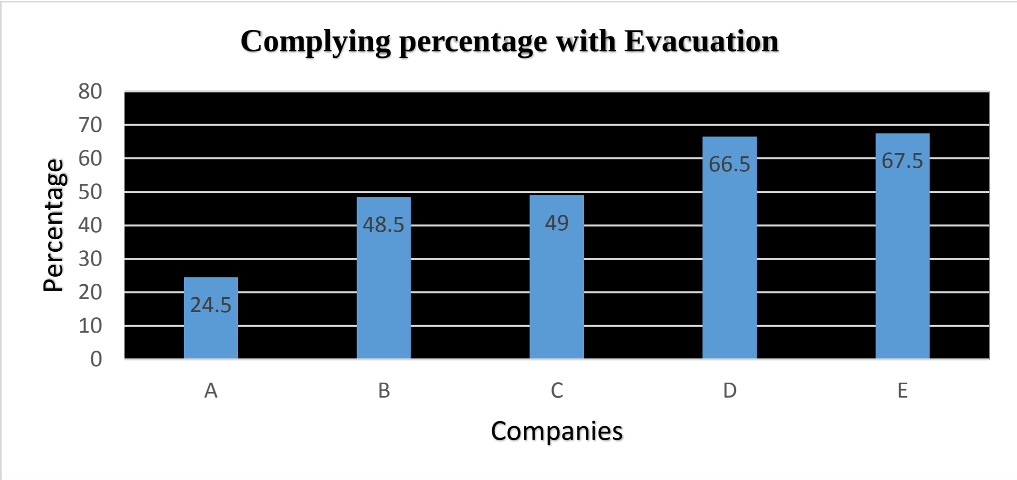


***Figure 4.12:* Percentages of complying with evacuation barrier**

(Source: Questionnaire survey data)

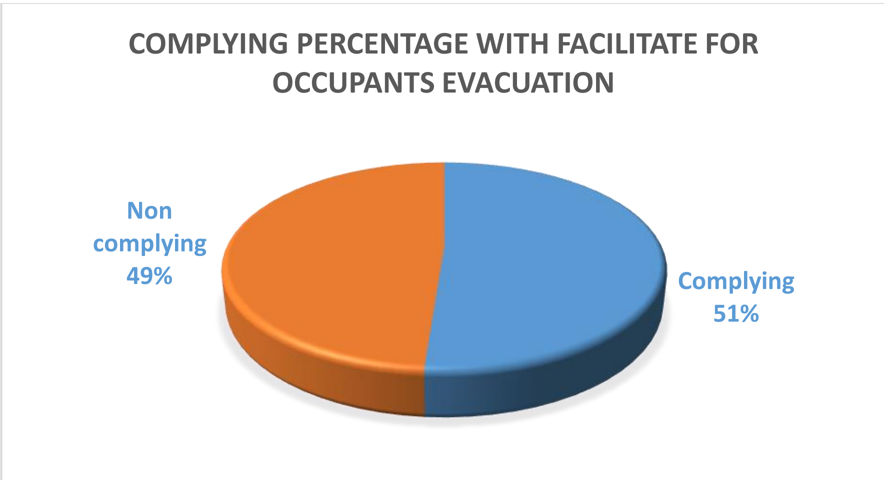


Figure 4.13: **Average percentage of complying with fire evacuation barrier**

(Source: Questionnaire survey data)

Analysed data shows that in comparing fire growth and spread barrier, and smoke spread barrier, Sri Lankan industries are more complying (51%), which facilitate occupants' evacuation barrier. This may happen due to two reasons; the first one is, most parameters involved in facilitating occupants' evacuation such as fire exits, fire corridors, and fire alarm systems, are the main areas reviewed by relevant authorities before granting permission when factories apply for expansions and changes, as given by the Factories ordinance acts and other local requirements. The second one could be key parameters such as fire exits, fire alarms, and training for evacuation, covered by laws in Sri Lanka.

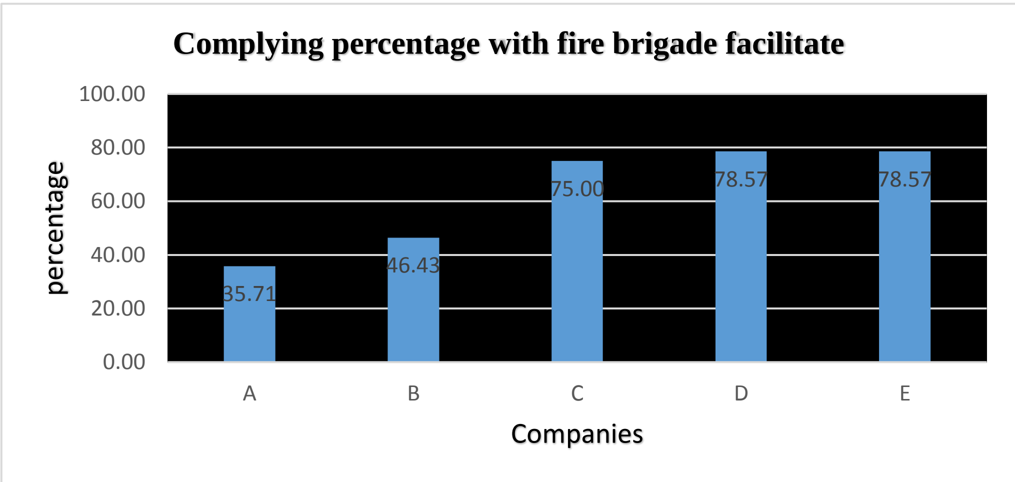


Figure 4.14: **Percentages of complying with facilities for fire brigade invention**

(Source: Questionnaire survey data)

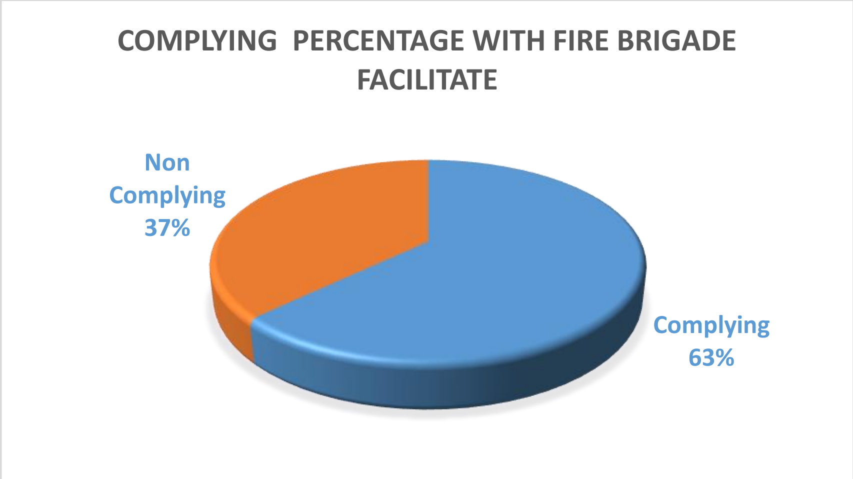


Figure 4.15: **Average percentages of complying with facilities for fire brigade intervention**

(Source: Questionnaire survey data)

Research finding reveals that Sri Lankan industries highly comply (63%) with these areas, compared to all other barriers. The underlying reason may be that access for fire brigade vehicles, providing fire brigade inlets, and head clearance for fire brigade vehicles, are the key main areas in approving the building plan, and though the factory changes with time, there is less opportunity for changes to happen in these areas, as it affect normal factory operations.

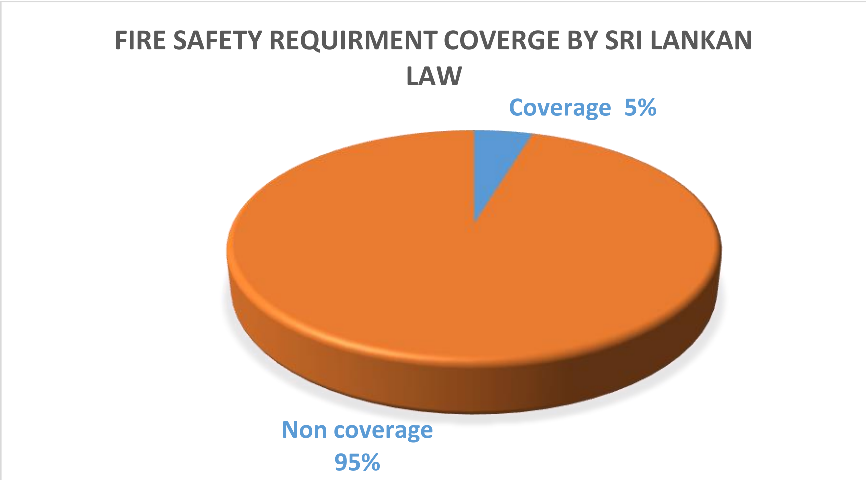


Figure 4.16: **Percentages of fire safety requirements coverage by Sri Lankan law**

(Source: Questionnaire survey data)

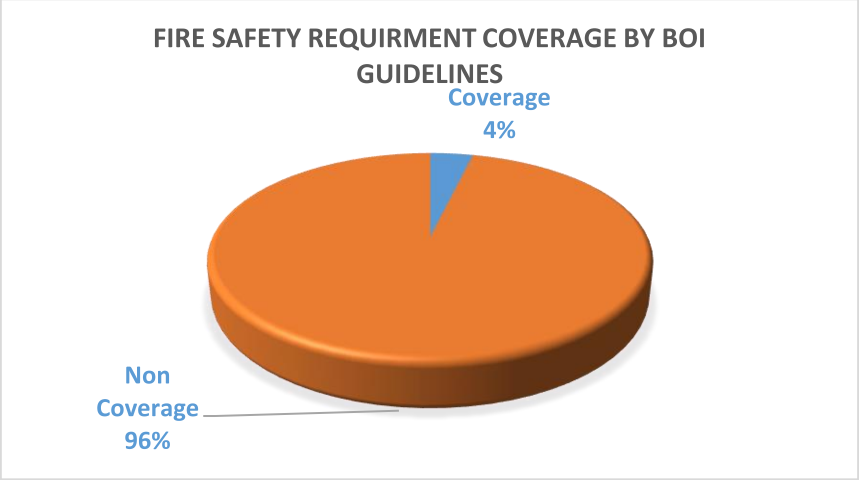


Figure 4.17: **Percentages of fire safety requirements coverage by BOI Guidelines**

(Source: Questionnaire survey data)

According to the above data, it is clear that coverage of fire safety requirement of buildings is less than 5%, as compared to the available best fire safety rules, regulations, and standards. This is not sufficient under any circumstance to ensure that industrial buildings are fire safe.

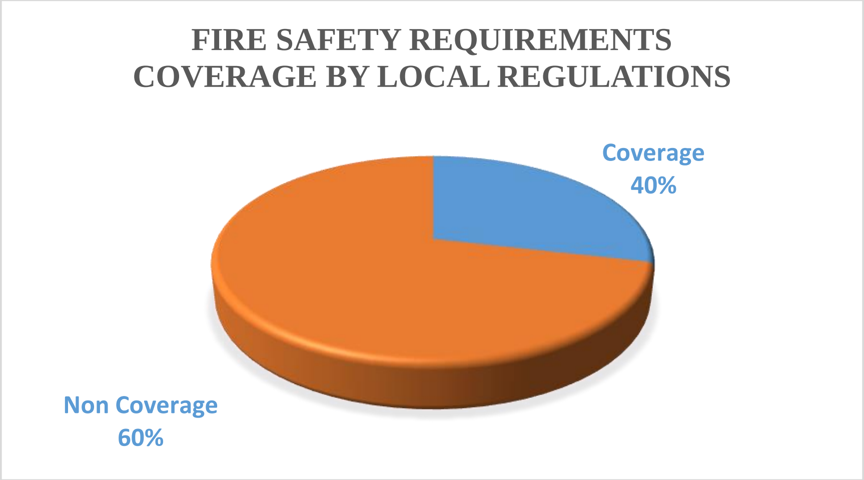


Figure 4.18: **Percentages of fire safety requirements coverage by Local Standards**

(Source: Questionnaire survey data)

Comparing to British and Europe one of the key finding according to the figure 4.18 is, local fire safety standards and regulations are covered only by 40 % of applicable fire safety standards, regulations and best practices of the industries. This indicate that there is much room to improve the fire safety level of the local factories by introducing standards and regulations of the developed western countries.

One of the most important result of this research was developing a tool to measure the fire risk level of the industries, which has been attached in appendix 01. This risk assessment tool is a new finding and it is a user-friendly tool. Anyone can use the tool who has a slight knowledge on basic fire safety requirements and maintenance levels of fire protection systems in their factories.

In addition to that, it was confirmed that there are no barriers other than the five main between the fire and fatality. This validation was done through discussion with four experts. As explain in table 3.1 in page 36, three out of four validated that there are no more barriers other than the five barriers that was identified in section 2 figure 3.2.

5. SUMMARY AND CONCLUSION

According to the Factories Ordinance (1942) and General guidelines for factory buildings (2011), proposed building plans should be approved by either the factory inspecting engineer or the director of the Board of investment. However, it proved that after receiving approval for initial building plans, most factories make massive changes due to many reasons. Browne (2003) said, "Various elements of building will change throughout its working life, beginning as soon as it is completed." It is clear that according to Marsden (2009), alterations to fire safety features in the building are performed without proper approval from the fire service department and other relevant authorities. In addition, fire extension/modification of fire protection systems are not changed together with modifications or alternations of buildings (Connolly, 1999; Winkworth, 1999). Also, Wasswall (2009) pointed out the need of revised guidance on fire safety in buildings has not changed promptly, parallel to the speed of changing of complexity of the building.

Another problem, highlighted according by Browne (2003) is, most industrial people are not aware on regulatory requirements to comply in situations in the absence of legal framework or monitoring mechanisms for the violation of regulations. Further, when buildings get older and due to above mentioned changes, fire safety measures of the building weaken continuously (Williams & Ellicott, 2006). However, fire service department should visit the site and advice to ensure fire safety of the building and facilities required to respond in case of fire emergencies; yet, under normal conditions, this does not happen (Glibey, 2002; Marchant, 1999; Marsden, 2009). All above facts are critical since research indicates that it is often the poor management, maintenance, and alterations to buildings, which mostly compromise to their fire safety integrity (Browne, 2003; Williams, 2006); even minor changes could drastically compromise fire safety of a building.

"Fire risk assessment is the assessment of risks to the people and property as a result of unwanted fires" (Young, 2008). According to the author, five main barriers are needed to consider during a fire risk assessment process; fire initiation, fire growth smoke spread, facilitate occupant evacuation, and facilitate fire department intervention. The literature review revealed that, to ensure functioning of above barriers and functions of structural elements, provision has been made in the Factories ordinance, BOI Guidelines, and ICTAD fire regulations. Laws have enacted in same ordinance to obtain the factory-inspecting engineer's approval before construction, extensions, and conversion of the building. However, Marsden (2009) has brought up that this approval procedure is not functioning properly. We have discussed and clearly shown how these changes affect five barriers, separately increasing the fire risk level of the building significantly. The result is a huge gap in the fire risk level as compared to the initial building approval stages, exposing the occupants to a greater fire risk.

It was possible to find more than 252 points applicable to fire safety of the industries, while reaching the first objective of this research. According to the analysed data, it is clear that Sri Lankan industries do not comply over 41% with existing best fire safety requirements/standards practiced by the British and Europeans. Similarly, Sri Lankan laws cover only 5% of fire safety requirements out of the prescribed rules and regulations by British and European standards. BOI guidelines cover only 4% out of the British and European fire safety requirements. Further to the same analysed data, Sri Lankan local regulations cover only 40% of the total applicable laws and regulations compared to British and European standards. Therefore, based on the above findings, it is evident that existing Sri Lankan fire safety rules and regulations are not sufficient to ensure fire safety of working places for the large working community of Sri Lanka. Based on that, it is possible to achieve the second objective of this research.

Based on the above identified 252 applicable rules and regulations, a tool was developed to measure the fire risk levels of industries using the checklist method achieving the third objective of this research. Under each point, there are five levels from "0" to "4" to evaluate how effectively comply with each points to get a value that is more realistic for the level of fire risk. During the calculation phase, complying percentage and level of effectiveness of each point could be obtained separately, and finally, the level of fire risk will be quantitatively provided. With this newly developed tool, the fourth objective of this research could be achieved [Figure 4.2 presents the calculated fire risk levels of each company].

Research findings indicate that Sri Lankan industries comply less with fire growth and spread barrier, Smoke control barrier, and facilitate occupant evacuation barrier, compared to the initiation and facilitating fire brigade invention. When the content of each barrier is crucially analysed, it shows that most parameters included in these three sections are the key points, which should be reviewed by the building plan approving authorities before granting approval. An example is, covering key parameters under these three barriers are fuel loads, compartment geometry, ventilation and opening, requirements of fire extinguisher, fire hydrants, fixed fire protection systems, compartmentations, fire exits and corridors, fire alarm and detection systems, emergency lighting and fire safety signs, etc. Sri Lankan laws and regulations have covered all these parameters. Figure 4.3 clearly shows a significant gap in complying with these three barriers (respectively 40.56%, 40.56%, and 51.2%). Therefore, the analysed data provide the answer for this research question and open the pathway to the fifth objective of the research. Based on that, it can state that significant changes of fire risks levels exist in industrial buildings due to the changes happening with the time, compared to the approval stage of the initial building plan.

Above are the key parameters that need to pay attention during the changes in the factory environment due to various reasons, as was discussed in detail previously. In addition, above fire growth barrier and smoke control barrier are the key points that help if a fire occurs and the structure is protected against the effects of fire and contained for period of time within one compartment, thus reducing fire spread through secondary ignition and limiting the movement of flame and smoke (Marshall, 2006). These barriers have many functions in a building; one is to prevent or delay the movement of products of combustion. In addition, barrier failure has a major influence on the building performance beyond the room of origin (Winkworth, 1999). Therefore, the respective authorities should follow a strict monitoring mechanism to ensure that the above fire safety parameters are met by the industries at any given time, ensuring life safety of the working population of a country. In addition, it was noticed that during the past two - three years, several factory fires occurred in Sri Lanka, and one important points here was, within a very short period, these factories were fully destroyed due to fires. The reason behind this may be the causes revealed here, such as less complying with above fire barriers and absence of a monitoring mechanism from respective authorities.

According to research findings, relevant law making authorities, institutions, and government departments, should pay immediate attention to revise existing laws and regulations, and should ensure that new laws and regulations comply with the world's best fire safety requirements. This research finding should be a revelation to them to confirm life safety of the most valued asset, "the working population" of the country. If so, the fifth objective of this research could be achieved.

Therefore, following suggestions are made to relevant authorities to fill the above gap while achieving the fifth objective of the research:

1. There should be a proper mechanism to review fire safety requirements of the factories when approving building plans for new constructions and significant changes. In this case, factory inspection engineers/Board of investment directors may not be able to review these requirements by themselves. Hence, factory inspecting engineers/BOI directors should take the assistance from fire services, together with their approval for building plans since the fire service department members have more knowledge and experience in the latest fire safety regulations and standards practiced by developed countries.
2. There should be a strict monitoring mechanism to ensure that factories comply with fire safety requirements periodically. Currently there is no such mechanism.
3. The fire brigade should establish a schedule for visiting the facilities and need to keep updating the collected data. It is also suggested for fire brigades to adopt a risk assessment methodology to identify significant changes of those facilities and cases where standard resources cannot assure a timely and an effective response to a significant major incident risk.

Further, it was possible to develop a fire risk assessment tool that can be used by factory maintenance engineers, health and safety managers, etc. One main problem with relevant to the fire risk assessment is, executing a comprehensive fire risk assessment requires an in depth knowledge on fire safety standards and fire related experiences. This tool will eliminate the above barrier and it can be used with a limited understanding about the factory layout and system maintenance. It automatically calculate the level of fire risk at the end of filling the questioner. This research could help the community at large, and if the industries widely use this tool to assess the level of their fire risks and take necessary actions to fulfil the gaps, it will ensure life safety of the employees and business continuity.

All above bring forth a good opportunity to perform research on fire risk level of the industrial buildings to identify how the changes of these buildings affect fire safety of the building and assess the level of risk due to such changes. Further, there is a wide opportunity to conduct research on this matter, relevant to Sri Lankan context.

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APPENDIX

Appendix 01

Fire Risk Assessment Checklist