

FIRE AND SAFETY ENGINEERING IN THE GARMENT FACTORY OF BANGLADESH

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Abstract

In Bangladesh businesses are growing at an ever fast rate. New businesses are opening everyday in every possible sector. Taking purchasing power parity into account Bangladesh is the 44th largest economy in the world. Bangladesh is also listed in the N-11 (next 11) by the Goldman Sachs Group, Inc. Among all the industries, at present textiles and readymade garments industry are the top ones. Recently WTO has ranked Bangladesh as the 4th largest exporter of readymade garments in the world. This sector contributes for 75% of foreign currency earning for Bangladesh. Textiles and Readymade Garments sector contributes 13% of GDP and employs more than 3,000,000 people. It has brought benefit and blessings for millions of people in the country. This industry has played a significant role in elevating economic and living standard of millions of families all over the country.

Along with bringing blessing for the nation, textile and RMG industry also hold the record of experiencing some worst industrial accidents in the country. Taking advantage of poor surveillance of concerned authorities rules, laws and codes are often violated in construction sector of our country and factory buildings are no exception. It is popularly believed and often proven true by incidences that the building codes are only maintained in paper works and hardly during the construction phase. Later as the owner focuses on the interior works, machine placement etc. the floors are often over loaded with machineries, causing more population load during operational hours, narrowing circulation spaces, thus making it difficult for the people to access the emergency route during an emergency. Many factories do not arrange regular drill; therefore the workers discover themselves in an alien situation whenever an emergency situation arises, causing panic, stampede etc. that further escalate the degree of casualty.

On the basis of the situation of most recent Bangladeshi factory fire it is very obvious that any person unconscionably may lose his or her life in the name of garment manufacturing any time. In our presentation we will review the current situation of fire and safety in garment factories with respect of the global parameters, their lacking and the modification that has to be made. The common equipments that are being used in our garment factories are Fire extinguishers, Fire sprinklers, smoke alarms. But the structure of the buildings are so poor that fire escape are not that much effective for large number of workers. Besides they do not follow the building code properly. Even the number of equipment used in a garment factories are not that much. In our presentation we will highlight the lacking of equipment being used and needed for the factories, the solution to this problem on our point of view on the basis of current situation of Bangladesh,

Keywords: Industrial Safety Engineering, Fire Safety, Risk analysis, Fire, RMG.

Declaration

This is to declare that the project “FIRE AND SAFETY ENGINEERING IN THE GARMENT INDUSTRIES OF BANGLADESH” and related audit were carried out by the authors under the supervision of Asst Prof. Dr Abu Raihan Md Harunur Rashid, Department of Mechanical and Chemical Engineering, Islamic University of Technology (IUT).

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1 Introduction

Bangladesh, a country categorized in the list of developing countries is growing every day in terms of economy and business expansion. New businesses are opening each day in every possible sector ranging from agriculture to sophisticated information-communication technology (ICT) industry. At present out of all the businesses running in Bangladesh, the readymade garments sector of the textile industry has taken the lead in earning maximum foreign currency and employing a vast figure of populations in this sector. In the recent times Bangladesh showed significant improvement in various business sectors, readymade garments industry being the prime one.



Figure 1: RMG Factory of Bangladesh

1.1 Background

In April 2010, the USA based research agency Standard & Poor's (S&P) awarded Bangladesh a BB-rating (less vulnerable in the near-term but faces major ongoing uncertainties to adverse business, financial and economic conditions) for a long term in credit rating. In the context of South-east Asia the rank is below India but well over Pakistan and Sri Lanka. Bangladesh has been giving continuous efforts in elevating its economic condition. Foreign grant and loan has decreased from 85% in 1988 to 2% in 2010 (Rashid, 2009). The per capita income in 2009 was US\$ 610.10, whereas the world average was US\$ 7,880 (United Nations Statistics Division, 2009). However, according to IMF taking purchasing power parity in account Bangladesh is ranked as the 44th largest economic power in the world at US\$ 257 billion. Bangladesh is also listed in the N-11 (next 11) by the Goldman Sachs Group, Inc.

Two third of the employment of Bangladesh is in the agriculture sector. According to FAOSTAT in the global context Bangladesh ranks as the 4th largest producer of rice. Bangladesh also ranks as the 11th largest producer of tea and holds high ranks in other agricultural productions such as jute, mango etc. Although agriculture sector ensures most of the employment, more than three quarters of export earnings of Bangladesh is from the readymade garments sector. At present readymade garments sector is the highest export earning sector of Bangladesh’s economy (FAOSTAT, 2011).



Figure 2: Employment and foreign currency source Bangladesh

1.2 Statement of the Problem

In the list of good achievements Bangladesh has earned some bad records as well. There have been calamities like labor unrest for pay rise, over load of work to workers by managers, death due to accidents and disasters caused by collapse of buildings or major fire break out. It is popularly believed that in Bangladesh the safety of labors in readymade garments industry is often a neglected issue for the people who are in the driving hand of the industry. The recent accidents such as fire breakout at “Hamim Garments” caused death of 26 people, injury to 100 others and a financial loss to the owner also. It is popularly believed that improper design, high population load and mismanagement of floors and circulation systems in the factories are major contributors to such incidences. In the conditions as above this dissertation proposes to evaluate the design of garments factories from a safety point of view especially in case of a fire breakout. The guide law for construction of buildings in Dhaka and Chittagong, Mahanagar Nirman Bidhimala – 2008, has put on some parameters to architects, engineers and land developers to provide various life saving facilities in building projects at Dhaka and Chittagong as mandatory rules. An example of such parameter may be the mandatory requirement for emergency exits at every 23m interval (Mahanagar Imarat Nirman Bidhimala, 2008). At present the system is strictly followed during the construction phase of a building. But after the construction phase is complete, new tenants and floor owners take possession of the generally open floor spaces and

design or decorate the interiors according to their own demand. This sometimes narrows down circulation zones or makes the circulation system complex making the journey to emergency exit a tough one. An earlier work with “Space Syntax- depthmap” by the author on interior spaces in offices (Vulnerability Study of Office Interiors in Dhaka in Case of Disaster) indicated such problem. As shown below, when considering the radial distance⁴ a floor or a zone in a building may appear safe, however when metric distance⁵ is considered the floor or the zone might not be considered. Now a study can be carried out to find out how and why the design process of readymade garments related factories lead to the evolution of such hazardous spaces and how the issues of hazard can be minimized.

1.3 Objective of The Study

The objective of the study is to find the problems in the garment factory regarding fire and safety engineering with the help of Accord and Alliance. Because from the recent history, it has become the major factor for Bangladesh. The other objective of the study is to create a benchmark for the Bangladeshi garment factories to minimize the economical loss and life loss. The study is done after visiting some factories and working with some fire fighting equipment like smoke and heat sensor. However in this study, only alarm system is counted as the major component for studying fire and safety engineering.

1.4 Definition of terms “Fire and Safety Engineering”

Fire engineering is the application of science and engineering principles to protect people, property, and their environments from the harmful and destructive effects of fire and smoke. It encompasses fire protection engineering which focuses on fire detection, suppression and mitigation and fire safety engineering which focuses on human behavior and maintaining a tenable environment for evacuation from a fire. In the United States fire protection engineering is often used to include fire safety engineering.

Fire protection engineers identify risks and design safeguards that aid in preventing, controlling, and mitigating the effects of fires. Fire engineers assist architects, building owners and developers in evaluating buildings' life safety and property protection goals. Fire engineers are also employed as fire investigators, including such very large-scale cases as the analysis of the collapse of the World Trade Center. NASA uses fire engineers in its space program to help improve safety. Fire engineers are also employed to provide 3rd party review for performance based fire engineering solutions submitted in support of local building regulation applications.

2 Research Methodology

This chapter shortly describes the methodology following which the research will be conducted.

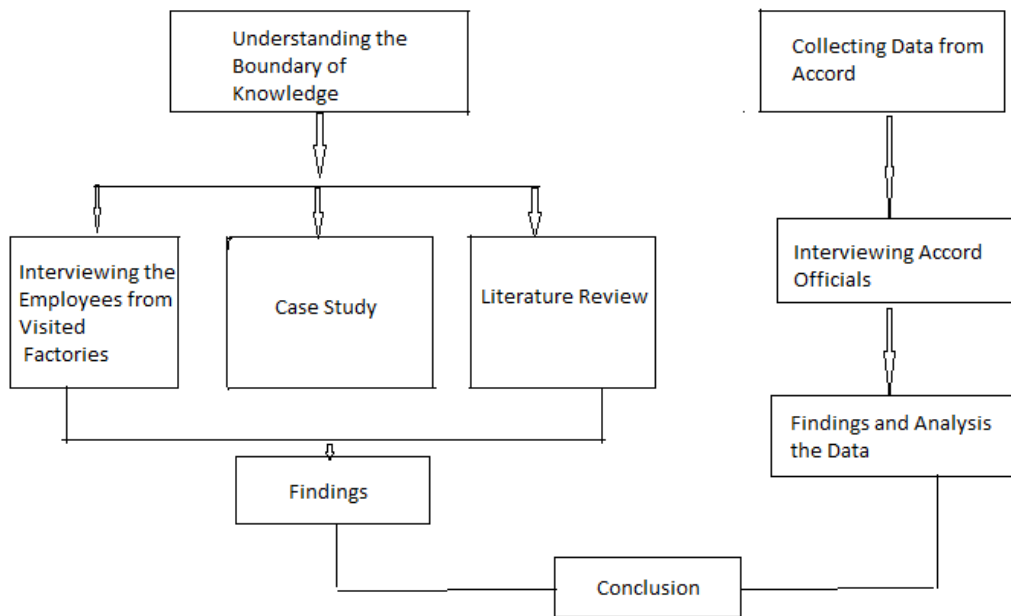


Figure 3: Methodology Diagram

The methodology diagram is shown above. There is two parts in our methodology. They are-

- 1) Visiting garment factories,
- 2) Collection of data from Accord.

2.1 Visiting Garment Factories

The methodology diagram for the dissertation is given above. As it can be seen in the illustration, the dissertation is divided in two major parts. One part (understanding the boundary of knowledge) consists of interviewing the employees of different factories, case studies and literature review. Aim of this portion is to understand the existing boundary of knowledge from primary and secondary sources.

2.2 Collection of Data from Accord

Another part consists of Collection of data From Accord to evaluate and understand the parameters, requirements that has to be ensured by the Garments factory owners to ensure the safety properly. Findings from this portion will be compared with the other part. . The finding and analysis of outputs are compiled to give a conclusion.

Case study of previous events:

Case study of accidents in RMG industry with relation to fire and evacuation has been studied and elaborated in detail. Reports on various accidents related to fire in textile industry were reviewed.

Literature Review:

For ensuring the understanding the existing boundary of knowledge, high emphasis was given in literature review. Many literatures on garments industry are available, but most of them focus on labor rights, gender issues etc. which are not relevant to this thesis. Less literature with relevance to design, safety and accident issues are found. While conducting the literature review focus was given on literatures containing safety issues of garments industries.

Key Informant Interview:

Interviews were conducted with prominent RMG factory owners, designers and fire experts. Inputs of interviews have been a vital asset for the fire and safety engineering.

Analysis:

This chapter puts together all the findings from case study, literature review and Data analysis to construct a cumulative solution for attaining highest possible level of safety in RMG factories.

Conclusion:

Finally findings from all the parts of the dissertation are put together to form a concrete conclusion for “Design of Readymade Garments industry for Fire Safety”.

3 READYMADE GARMENTS INDUSTRY

This chapter describes some historical background and current condition of the industry in both local and global context. As described in chapter 1.4 in some of the articles here the term “fire and safety engineering” is used to imply the readymade garment industry.

3.1 Readymade Garments Industry in Global Context

3.1.1 History of the Industry

The exact date of when people started wearing clothes is not clear. There are different estimations about when people started wearing clothes. One of the studies says that men started wearing clothes 190,000 years ago. Anthropologists believe that the earliest clothes were made from skin, vegetation etc. (Travis, 2009). Till the 17th century the textile industry was more of a cottage industry localized within certain transportable zones. The clothiers fabricated the cloth via various processing, all carried out in their courtyards. The clothiers would keep a portion of their product for the nearby market and carry most of their products on horseback to relatively distant areas for selling their products. There are also evidences of silk being imported to Europe from China via the Silk Road. Cotton being one of the earliest clothing materials in India made its first steps in Europe only during the medieval period. Later cotton came up as the prime clothing material globally.



Figure 4: Garment industries in medieval times

3.1.2 Rapid Growth during the Industrial Revolution

The textile industry experienced booming growth during the industrial revolution of the 18th and 19th century. It is one of the industries to get maximum advantage from the Watt engine⁸. With the invention of the “flying shuttle⁹” by John Kay in 1734 C.E mass production of yarn and cloth became a mainstream industry. The industry while getting geared up with advanced technology of those times also experienced labor protects against introduction of “flying shuttle” as the labors feared job loss. However, soon it was realized that because of the dramatic increase in rate of production the demand also increased. James Watt’s modified steam engine with separate condenser added another muscle to the industry in 1761. The industry received its biggest blessings in 1764 with the invention of “Spinning Jenny¹⁰” by James Hargreaves. This invention elevated the thread production capacity of a single labor by eightfold and subsequently much further (Britannica Encyclopedia, 2011).

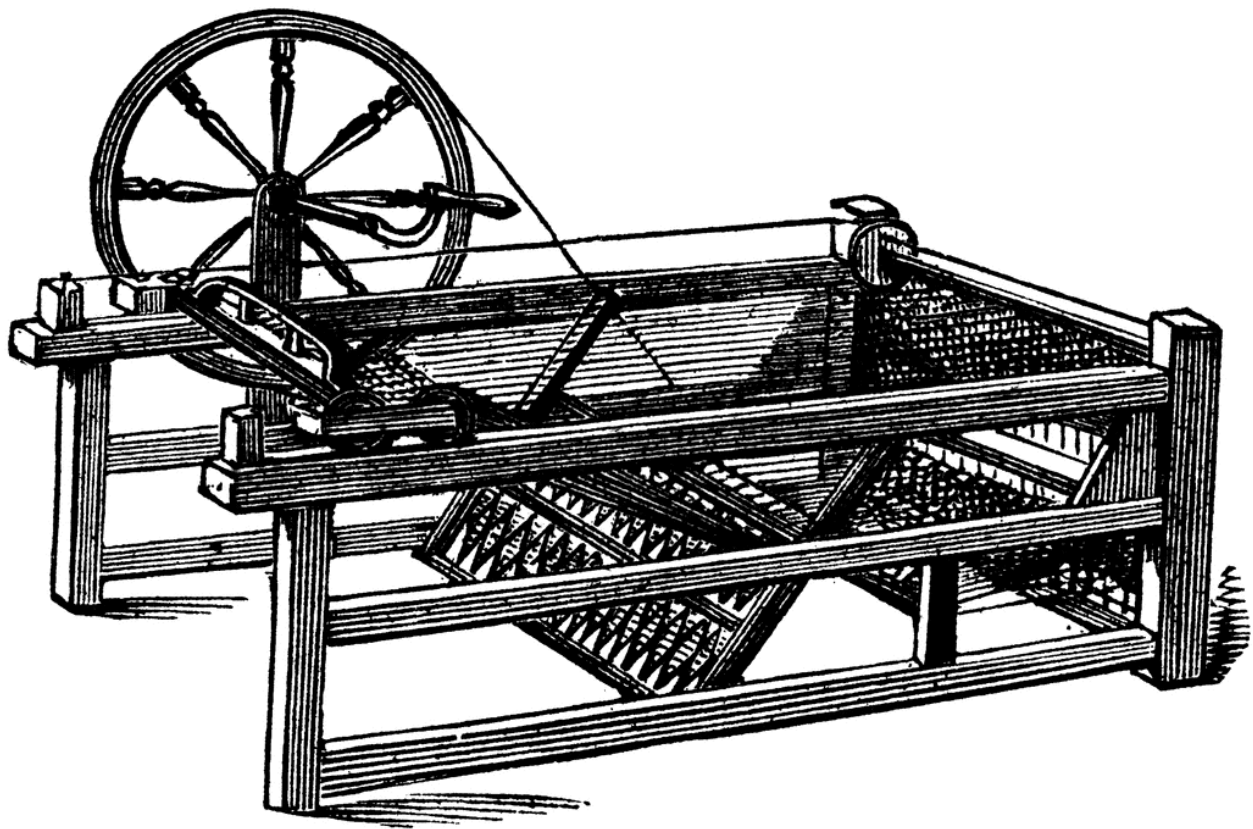


Figure 5: Spinning Jenny

3.1.3 Current Global Scene of Textile and Readymade Garment Industry

Current statistics mostly compose of the economic and financial status. It is also discovered during the literature review that currently in a more liberalized environment, the industry is facing competition as well as opportunities. According to recent statistics, at present the global textile market is worth of more than \$400 billion. It is predicted that Global textile production will grow up to 50 % by 2014. The world textile and apparel industry has gone into a phase of transformation since the elimination of quota in the year 2005. Many new competitors as well as consumers have entered the global market with their immense capabilities and the desire to grow (Textile Exchange, 2006).

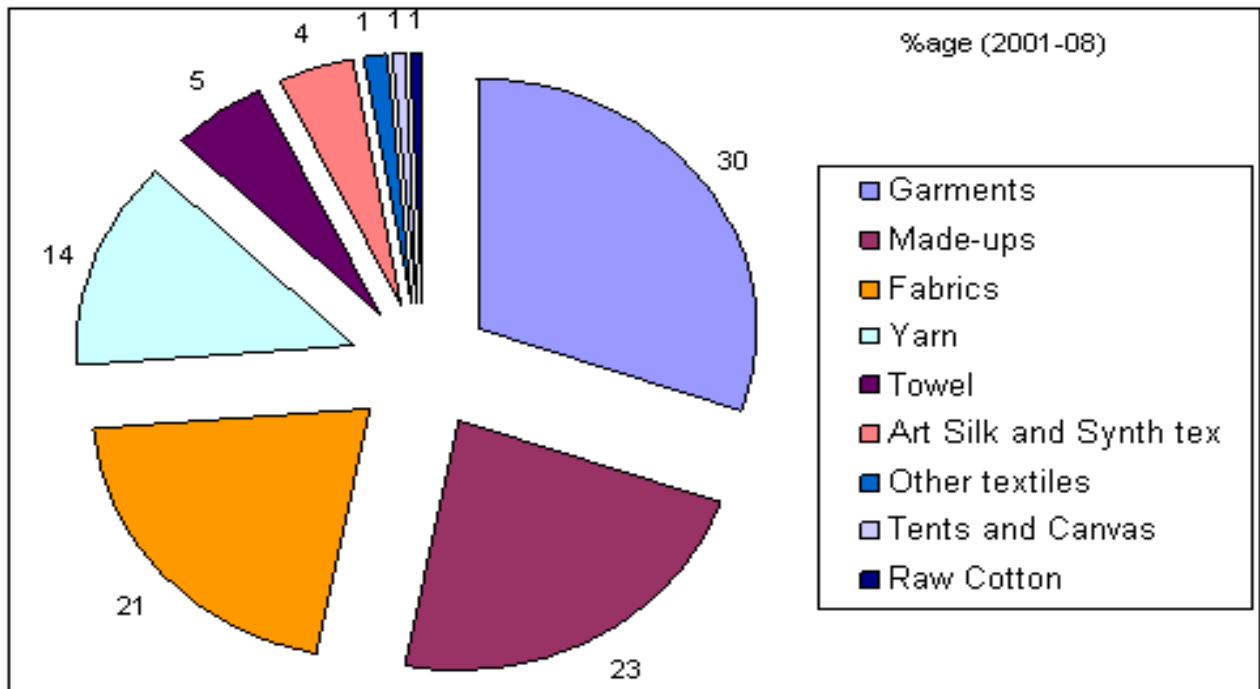


Figure 6: Trend of world textile and apparel industry

3.1.4 Benefits and Dis-benefits of the industry

The readymade garments industry has blessed the civilization in many ways. Till the early days of industrial revolution it has accommodated employment for millions of people all over the world. The industry has played a significant role in elevating living standard of the masses (mostly the middle class and lower income people). Even in the present days, readymade garments industry is still a major industry in the world and one of the highest earning sectors for many countries of the developing world such as Bangladesh, Cambodia, and Vietnam etc.



Figure 7: Anonymous readymade garments industry

On the anonymous side of bringing blessing for the masses, readymade garments industry is also responsible for causing some unforgettable disasters and severe violation of human rights in the history of civilization. During the time of its inception as an industry in Europe during the 18th century it invited workers from villages to the industrial towns. It showed and gave them good hopes and lives. However during the early days it had a very unpleasant working environment and was often called as sweatshop¹² to signify its murkiness. The collapse and subsequent fire of the Pemberton Mill¹³ in 1860 claiming 145 lives and the fire at Triangle shirtwaist Factory¹⁴ in 1911 claiming 146 lives are marked as black spots of the industry. In addition to these, suppression of labor rights, abuses of child labor are long known bad sides of the industry. Fortunately massive improvement has occurred in the safety and labor rights issue over the centuries. Significant reduction of the incidences as stated above has occurred.

3.1.5 Technical Aspects of the Textile Industry

Textile industry is a broad term. It has numerous wings of source materials and systems of processing and production. To keep the chapter specific and focused only cotton is referred to as the source material and its processing is described in this chapter. The textile industry as a whole begins from cotton tree and ends at the retailer shop from which the product is sold to end customer. In the long process there are numerous technical aspects involved. Six basic steps of textile industry (cotton based) are as below.

- a. Cultivation and harvesting
- b. Preparatory process
- c. Spinning

- d. Weaving
- e. Finishing
- f. Marketing

Of all the steps given above Step-a (cultivation and harvesting) occurs in cotton fields mostly under natural conditions. Steps – b, c, d and e occurs at various types of processing plants. Marketing is the absolute business part of the chain.

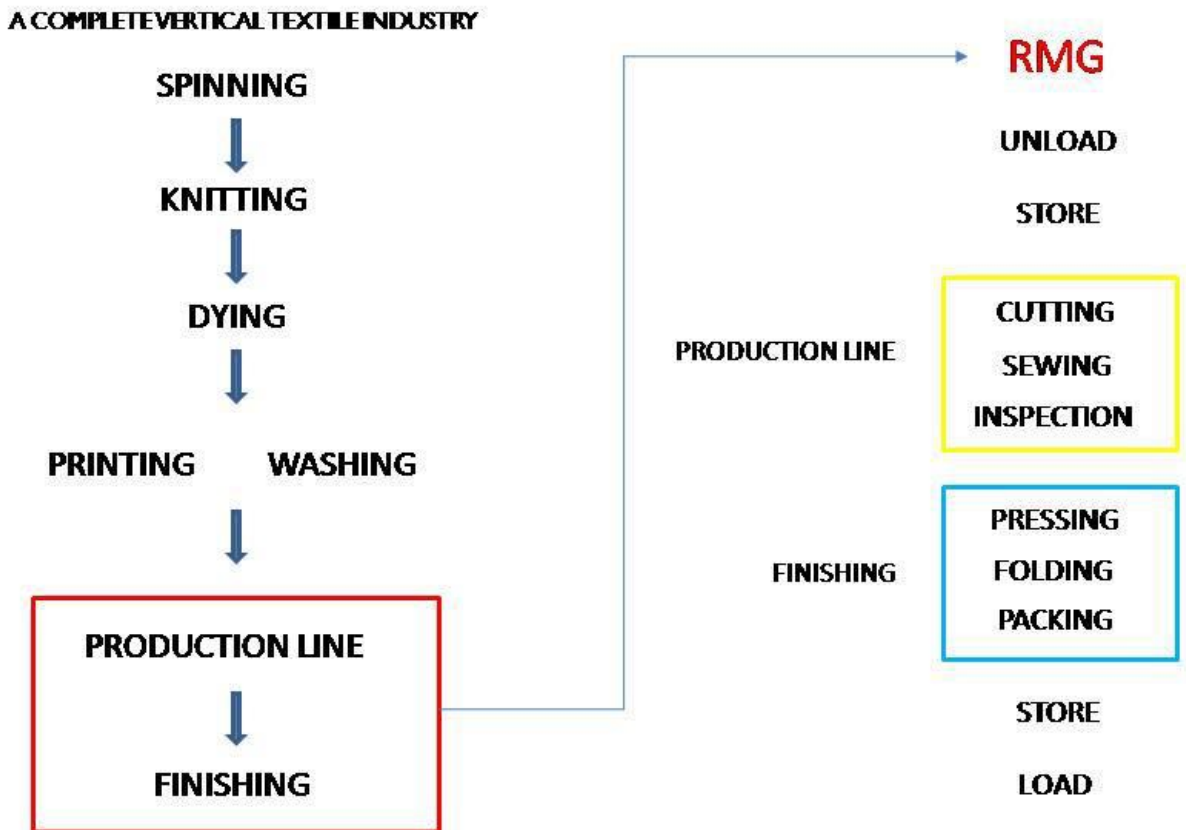


Figure 8: Order of events in readymade garments industry

3.1.6 Type of Readymade Garments and Their Capacity to Project Fire Hazard

The capacity of a readymade garments industry to project a fire hazard depends on the specific type of fabric being processed and the specific operation within the production system which a certain type of readymade garments is undergoing. For example, the risk of a fire related accident is high with synthetic fabric or felt materials. Reciprocally the risk is much less with natural cotton. On the other hand, out of many operations conducted in a textile industry the risk of fire is one of the highest in the dyeing section, where fire may lead to catastrophic explosions (Warsaw).

3.2 Textile and Readymade Garment Industry in Bangladesh

3.2.1 Inception Phase of Textile and Readymade Garments Industry in Bangladesh

Readymade Garments industry had its roots in Bangladesh in 1980s. Actual reason for its rooting in Bangladesh dates back to the 1950s. In the 1950s the labors in western world became highly organized, forming trade unions. This and various other simultaneous movements“ ensured stronger labor rights, higher wages, subsequently elevating the cost of production in a high rate. The investors in the west shifted to countries and places like Hong Kong, Taiwan and Korea for having low labor cost. In this scene, the Multi-Fiber Agreement (MFA15) was made in 1974 restricting the amount of imported clothes from developing to developed countries. This agreement imposed a maximum 6% increase of rate of export each year from developing to developed countries. Due to MFA and various other parameters, the investors shifted towards countries outside the parameter of MFA and other agreement(s) such as Bangladesh. In the 1980“s when readymade garments industry just made its toddling footsteps in Bangladesh, some Bangladeshis workers received training from “Korean Daewoo Company”. After accomplishing their training courses and returning to Bangladesh, some of them started their own business as entrepreneurs in the readymade garments industry (Commonwealth Secretariat, ed., 2004).



Figure 9: Readymade Garments factory in Bangladesh (Siliconeer, 2010)

At the time of its inception as an industry Tea and Jute were the largest exports earning sources of Bangladesh. The demand for jute was diminishing because of the admission of polypropylene products into the global packaging industry. With the diminishing international demand and

constant threat of natural calamities such as flood jute soon lost its glory as the prime export product of the nation. The domestic demand for tea was also growing at a steep rate; therefore a significant amount of tea became consumed at the domestic market. With the drive out of jute and significant drop in export of tea, within two decades of its inception into the market readymade garments industry took the pinnacle as the prime export good of the country. Cheap labor and low conversion rate further catalyzed the growth of the industry by attracting foreign investors

3.2.2 Present Status of Textile and Readymade Garments Industry in Bangladesh

Readymade Garments industry at present is the highest foreign currency earning source of Bangladesh. Recently WTO has ranked Bangladesh as the 4th largest exporter of readymade garments items in the world however The Economist has ranked Bangladesh as the 3rd largest exporter of readymade garments commodities. Three quarter of total export earning of the country comes from the readymade garments sector. In 2002 the total export earnings from readymade garments industry was US\$ 5 billion. In the fiscal year of 2009-10 the export earnings from readymade garments sector was US\$ 12.6 billion. In the 1980s there were only 50 factories employing a few thousand people. In 1990 the industry employed 400,000 people. The figure grew to 2 million in 2004 and at present the industry employs 3 million workers, of whom 90% are females. In general estimated populations of 10-12 million are benefitted from this industry. The number of enterprises in this sector elevated from 800 to 2000 in the span between 1991 and 2004. At present textiles and RMG sector contributes to 13% of GDP which was only 3% in 1991. Most of the readymade garments industries are owned by Bangladeshi entrepreneurs, leaving only 5% of the industries in ownership of foreign investors.

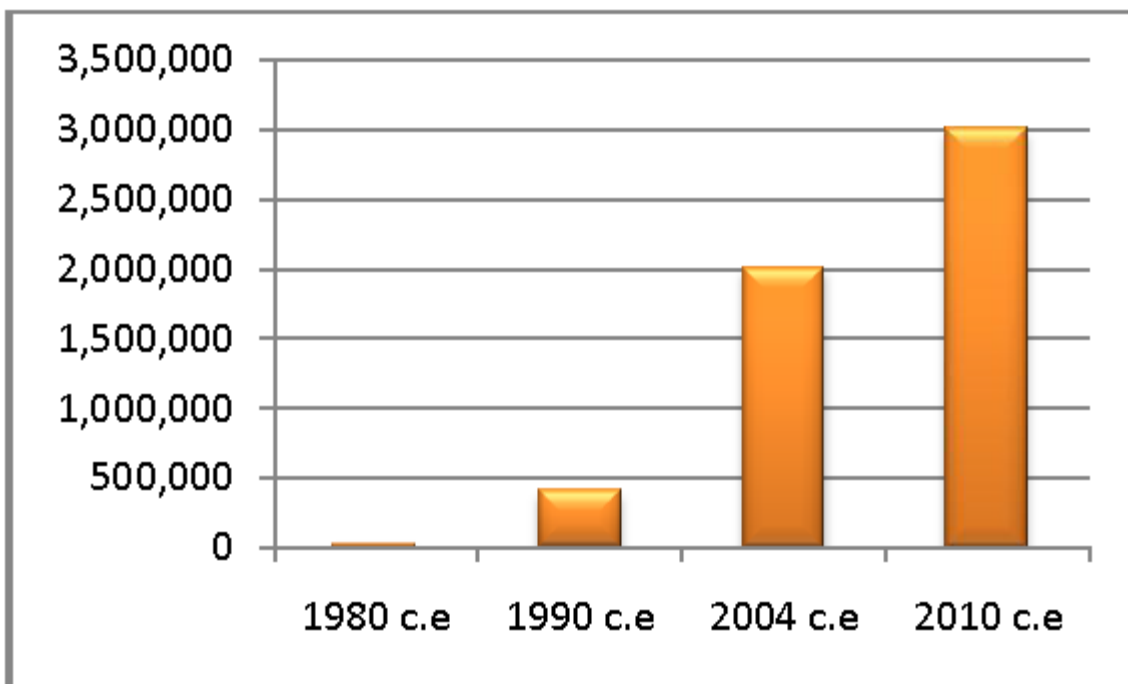


Figure 10: Rise in employment from 1980 – 2010

(Khondker, Razzaque, & Ahmed, 2005)

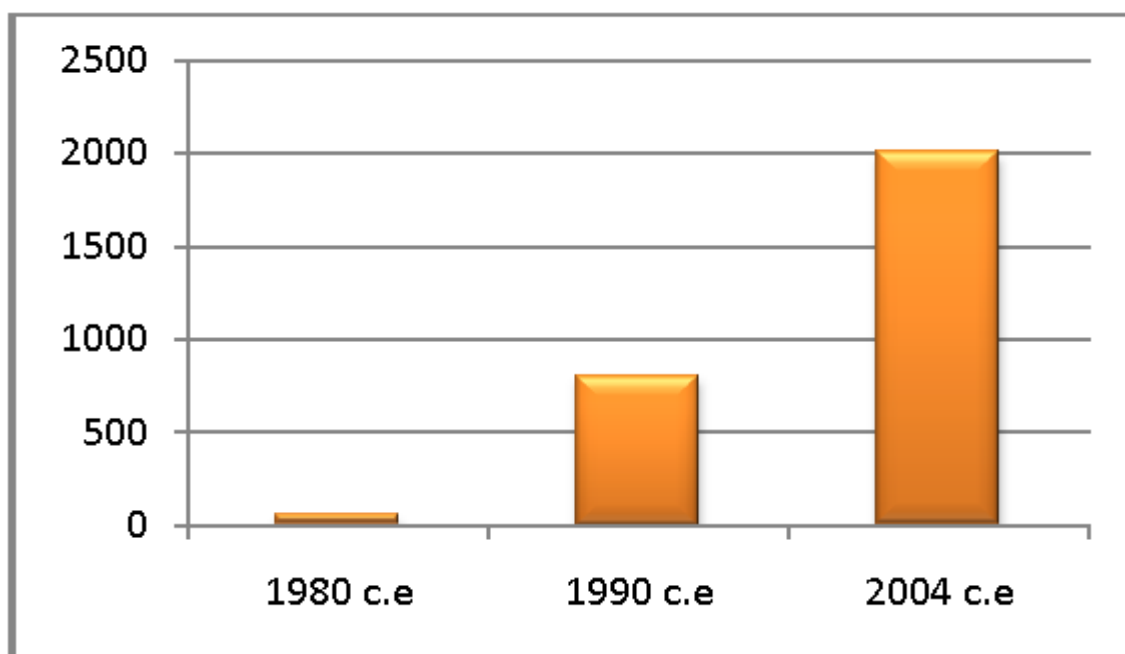


Figure 11: Rise in number of enterprises 1980 – 2004

(Khondker, Razzaque, & Ahmed, 2005)

4 ACCIDENTS IN THE INDUSTRY

The readymade garments industry has provided source of income for millions of people. It has been playing a vast role in elevating living standard of mass people, especially in the developing countries. On the other hand, the industry also holds the record of experiencing some worst industrial accidents as well. The accidents happened were of various types such as building collapse or fire breakout. The first disaster in the readymade garments industry took place at Pemberton Mill, Lawrence, Massachusetts in 1860 claiming 145 lives. In 1911, the Triangle shirtwaist Factory fire in New York claimed lives of 146 workers. The industry has been hit by various such disasters in Bangladesh as well. In recent time, the fires at Garib and Garib Sweater Factory and Hamim Group in 2010 are two of the worst accidents in the readymade garments and garments industry of Bangladesh. Some critics have put Bangladeshi readymade garments industry right up there with Chinese coal mining as one of the most dangerous industries in the world (New Internationalist Magazine, 2005).



Figure 12: Hamim Group's Factory in blaze, 14 December 2010 (Bilaj, 2010)

4.1 Accidents in Readymade Garments Industry of Bangladesh

It is popularly believed and often proven true by incidences that the building codes are only maintained in paper works and hardly during the construction phase. Later as the owner focuses on the interior works, machine placement etc. the floors are often over loaded with machineries, causing more population load during operational hours, narrowing circulation spaces, thus making it difficult for the people to access the emergency route during an emergency. After the collapse of Spectrum Sweater Factory and Shahrair Fabrics industry in Savar, Dhaka on 11 April 2005, which claimed 74 lives, Neil Kearney General Secretary of the Brussels-based International Readymade Garments, Garment and Leather Workers' Federation claimed that such accidents are „*the inevitable consequence of the race to the bottom now under way as a*

result of unregulated trade in readymade garments and clothing. ... [R]esponsibility lies with the World Trade

Organization, which turns a blind eye to any suggestion that there is a link between trade and the conditions under which goods are manufactured, and with the Government of Bangladesh, whose authorities apply neither planning rules nor labor laws.

Table 1: Deaths in fire accidents in garments industries in Dhaka (Fire Service and Civil Defence, 2011)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	32	05	N.A	12	05	09	10	13	N.A	N.A
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	60	N.A	N.A	N.A	23	23	62	N.A	43	02
Year	2010	2011								
	50									

In Bangladesh, most of the accidents in readymade garments industry have occurred from fire and its subsequent impact on human mind (panic, stampede etc.). Other incidences like collapse of buildings (readymade garments industry) have also claimed high toll on human lives and property. In an interview a key personal of Fire Service and Civil Defense claimed that if incidences like stampede and panic could be eliminated than there might not have been any loss of human lives in most of the cases of fire in RMG factories. He also mentioned that if the management conducts regular drills and if all the workers are well trained and oriented, panic and stampede can be totally avoided. A video on a fire incidence in a factory was collected for the purpose of this dissertation. There within 2.5 minutes of ringing the fire alarm, all the workers were able to evacuate the building. All the workers evacuated smoothly without causing any panic or stampede. According to a report by “World socialist Web Site” since 1990 more than 350 people have lost their lives in garments factory fire in Bangladesh (Perera, 2010).

The table below provides year wise data on the number of accidents, their causes and frequency and casualties caused by the incidences:

Table 2: Accidents in textile and RMG industry 2007-2010 (Fire Service and Civil Defense, 2011)

Year	No. of incidences	Reasons for fire	Frequency	Percentage (%)	Injured	Dead
2007	326	Electric short circuit	229	70		
		Cigarette	32	10		
		Spark	25	8		
		Welding spark	18	5		
		Overheat	22	7		
2008	89	Electric short circuit	65	73	209	43
		Cigarette	9	10		
		Spark	4	4		
		Welding spark	5	6		
		Overheat	6	7		
2009	293	Electric short circuit	212	72	150	2
		Cigarette	28	10		
		Spark	19	7		
		Welding spark	21	7		
		Overheat	13	4		
2010	220	Electric short circuit	154	70	42	50
		Cigarette	22	10		
		Spark	17	8		
		Welding spark	12	5		
		Overheat	15	7		

According to the statistics of “Fire Service and Civil Defense¹⁶” on average 70% of all fires in textile and RMG industry occurred from electrical short circuit, 10% due to cigarette, 8% from other types of sparks, 5% from welding sparks and 7% due to overheating of equipments.

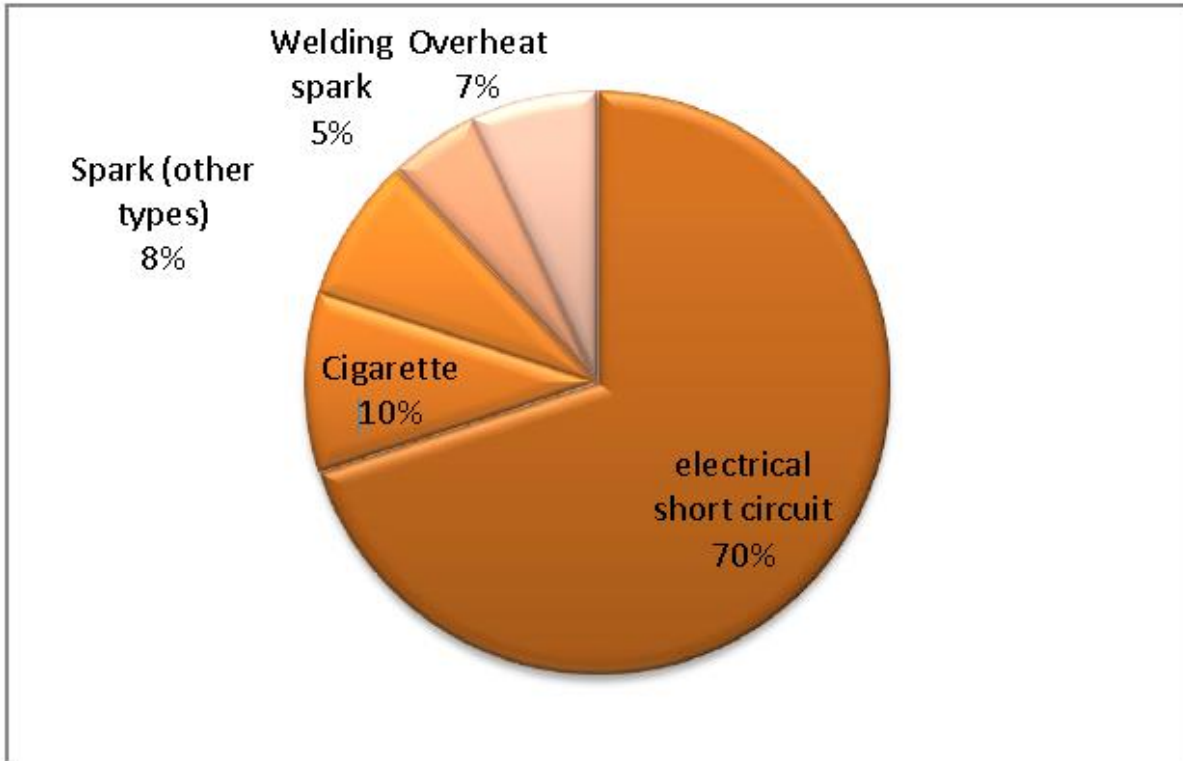


Figure 13: Reasons for fire at textile and RMG industries 2007-2010 (Fire Service and Civil Defence, 2011)

Figure 13 shows statistics of fatalities at readymade garments factories in Dhaka. Here it can be noted that more than two-third of all reasons of fire is electric short circuit. In a casual interview an electrical engineering consultant claimed the factory owners' attitude for saving construction cost as a triggering factor for this. The owners' in the intention to cut down construction cost often do not invite proper engineers or consultants to prepare proper electrical design for the factory. Even if the design is done, sometimes the owners do not install specified equipment, rather purchase substandard products rather than what is referred by the consultant. The substandard equipments fail to control proper electrical flow, causing over heat, spark or fire. On the other hand an industry owner claimed that sometimes the suppliers do not provide them equipments with proper specification with the intension to make extra profit. It is often impossible for the owners to find out if they have been provided with specified equipments or not since they do not have expertise in electrical design field. However, he also claimed that recently few of the factory owners have taken steps to ensure that only equipment and design specified by the consultant is realized at site

4.2 Literature review

For ensuring the understanding the existing boundary of knowledge, high emphasis was given in literature review. A lot of literature on garments industry is available, but most of them focus on labor rights, gender issues etc. which are not relevant to this thesis. Less literature with relevance to design, safety and accident issues are found. Therefore the literature review is kept here as a sub-chapter. This sub-chapter shortly describes the gist and findings from literature reviews. While conducting the literature review focus was given on literature containing safety issues of garments industries.



Figure 14: Stampede causes a large number of casualties

Qurratul-Ain-Tahmina and Khadiza Khanam (2001) conducted a study on various readymade garments industry in and around the capital. In most of the cases (focus of the study was on Choudhury Knitware) the reasons for casualty were stampede followed by locked / blocked exit route, panic, workers being unable to use the fire fighting equipments, suffocation and inhalation of toxic fumes etc. Industry managements were found to be totally unaware of the need and importance of the means of escape. Negligence of the authorities in preparing an emergency situation work plan and rehearsing it in regular basis came out as major reasons for such catastrophic disasters. Similar findings came out in a later study by S Akther, AFM Salahuddin, M. Iqbal, ABMA Malek and N Jahan (2010). To add to these findings the later work by (Akther, Salahuddin, Iqbal, Malek, & Jahan, 2010) also placed two possible suggestions for reducing chances of accidents. (S Akther, 2010) discovered that some issues are easily identifiable and correctable¹⁷ whereas some issues require well planned operation¹⁸. The causes of fire and the reasons for subsequent casualties as found in both works of S Akther (2010) and Qurratul-Ain-Tahmina and Khadiza Khanam (2001) are given below. For ensuring the understanding the existing boundary of knowledge, high emphasis was given in literature review. A lot of literature on garments industry is available, but most of them focus on labor rights, gender issues etc. which are not relevant to this thesis. Less literature with relevance to design, safety and accident

issues are found. Therefore the literature review is kept here as a sub-chapter. This sub-chapter shortly describes the gist and findings from literature reviews. While conducting the literature review focus was given on literature containing safety issues of garments industries

(Akther, Salahuddin, Iqbal, Malek, & Jahan, 2010) further added causes such as unplanned work environment, disorganized workers, electric short circuit, faulty electrical wiring, smoking materials, boiler explosion, kitchen stove and carelessness, fire from existing structure, poor building design etc. as contributing sources for fire breakout in a garments factory. It is also found that cause of death is usually not the fire directly. Most of workers have died due to stampede, locked exit route, inadequate number of stairs, deliberately blocked pathways, smoke and suffocation. S Akther (2010) further discovered that since many readymade garments factories are installed in city core areas in buildings originally designed as office space or residence, which are not designed for operation of factories and are naturally build in congested manner, fire can easily pass from one building to the next. The authors have marked the close positioning of readymade garments factories as a major threat to the industry as it may pass fire from one factory to the next very easily. At present the concern of the factory owners regarding fire hazard is increasing at a few areas. Some of the industries have ensured proper installation, arrangement and training of the safety equipments such as fire alarm etc. However proper planning and machine layout is still not practiced broadly and the authors believe that without a composite development such as proper planning of the factories, a full proof fire safe environment cannot be achieved. The findings of the paper in relation to fire safety are given below:

- a. Management is not aware enough for safety
- b. Not enough fire exit doors and ventilation for air circulation of industry building
- c. Most of the garment industries do not use safety sign according to the ILO conventions
- d. Most of the fire and smoke alarm bells do not work in garment industries and
- e. Many garment industries do not have fire and smoke alarm systems.

Recommendations of the authors: The recommendations in relation to the thesis topic are given below:

- a. Sufficiently wide fire exit doors and enough ventilation with proper maintenance for air circulation should be designed for industry building
- b. Regular fire drills should be held, minimum twice in a year
- c. Safety management training for all kinds of worker
- d. Proper exit sign and safety sign should be applied in appropriate areas of the industry
- e. All the buildings of garment industries should have proper announcement system as to how to get out of the buildings

From the literature review of various sources it is clear that the major reason for casualties in a fire breakout in a factory is not the fire itself. Rather the triggering components for fire (electrical

short circuit etc.) and the subsequent impacts of the fire on human mind (panic causing stampede etc.) are the major reasons of casualties. The major reasons for fire are given below: gist reasons for fire and the causes are given below:

Table 3: Causes of fire in RMG factories

Causes of fire
Unplanned work environment
Disorganized workers
Electric short circuit
Faulty electrical wiring
Smoking materials
Boiler explosion
Kitchen stove and carelessness
Fire from existing structure
Poor building design
Lack of concern of industry owner in this issue

Table 4: Reasons for casualties in RMG factories

Reasons for casualties
Stampede
Locked exit route
Inadequate number of stairs
Deliberately blocked pathways
Smoke and suffocation

4.3 Safety Regulations for Readymade Garments Industry

As millions of people around the world work at readymade garments industries and the industries also contain certain characteristics and materials which may cause threat to life, most of the countries have their own codes, laws and regulations to ensure the safety of lives and properties in the industry complexes. Bangladesh being the 4th largest producer of readymade garments items also has records of some worst accidents in the readymade garments industry. This section elaborates the safety regulations for RMG industry of Bangladesh and some other countries.

4.3.1 Fire and Safety Regulations Given by BGMEA in Bangladesh

- ▶ BGMEA (Bangladesh Garment Manufacturer and Export Association) has published the standard of maintaining firefighting equipment. Those are:
- ▶ fire extinguisher minimum 1 per 1000 square feet, at least 25% of workforce will be fire trained employee,
- ▶ at least 8 bucket should be at each floor,
- ▶ the number of first aid box should not be less than 1 per 150 worker,
- ▶ at least 2 fire hose in each floor connected with water tank,
- ▶ minimum of two control switches of fire alarm should be on each floor,
- ▶ fire drill should be at least once in a month, every factory should have 2 fire exit with 1.5 meter width staircase,
- ▶ at least 2 fire mask per 150 workers,
- ▶ at least 75000 gallons water in tank per 100000 square feet,
- ▶ Minimum six smoke detectors in each floor (Distance from one smoke detector to another one must be 15 feet), minimum 50 emergency lights per 100000 square feet, minimum two heat detectors per floor [BGMEA (2015)].

4.3.2 Fire and Safety Regulations Given by Accord in Bangladesh

GENERAL BUILDING REQUIREMENTS:

Parking: Parking of personal motor vehicles shall not be allowed in existing buildings unless the parking area is separated by 1hr fire resistive rated construction or automatic sprinkler protection is provided.

Existing Buildings: Existing buildings greater than 2 stories with nonrated construction shall not exceed 2000 m² (22,000 sq. ft.) per floor unless automatic sprinkler protection is provided throughout.

Automatic sprinkler system: Automatic sprinkler systems shall be provided throughout all new and existing high-rise buildings.

Fire detection and alarm system: An automatic fire detection and alarm system shall be provided throughout all new and existing high-rise buildings.

Table 5: structural instruction

Minimum widths:

Structural Element	Fire Resistance Rating
Exit doors (existing)	0.8m (32 in.)
Exit doors (new)	1 m (40)
Aisles	0.9m (36 in.)
Corridors	1.1m (44 in.)
Stairs (existing)	0.9m (36 in.)
Stairs (new)	1.5m (59 in.)
Stair Landings (existing)	0.9m (36 in.)
Ramps	1.1m (44 in.)

Emergency power: An emergency power system shall be provided to supply power to the following loads:

1. Automatic fire detection systems.
2. Fire alarm systems.

3. Smoke control systems.

Duration: Emergency power shall be provided for a minimum duration of 60 min.

Fire alarm system: An automatic fire alarm system shall be provided throughout all new and existing buildings containing an atrium.

Smoke control: Smoke control required by the engineering analysis in new and existing construction shall be designed.

B) FIRE PROTECTION CONSTRUCTION:

Fire wall: A fire-resistance-rated wall having protected openings, which restricts the spread of fire and extends continuously from the foundation to or through the roof.

Alarms: An approved audible device shall be connected to every automatic sprinkler system and shall be activated by water flow equal to the flow of one sprinkler.

Water supply.

Spacing: Extinguishers shall be placed so that maximum travel distance to the nearest unit shall not exceed 30m (100ft).

Fire Alarm and Detection.

Manual alarm: A fire alarm system that activates the system alarm(s) and occupant

Automatic alarm: A fire alarm system that activates the system alarm(s) and occupant notification devices by automatic initiating devices.

4.6 Problem Identification

From all the studies done earlier (case studies and literature reviews) and the statistics presented above it is clear that fire itself is a minor reason for causing death and injury. Major reason for the casualties are stampede (25%) and unable to exit (38%) totaling to 63%. Both these issues may be solved from design perspective. In such visiting factories might be the most rational and appropriate idea to find out the problems regarding the exit system and circulation pattern of the buildings. The problems are given below:

- 1.To maintain Accord given regulations , productions are being hampered in some of the Garments factories that the owners have complained.
- 2.That is why after passing through the follow up from Accord, they keep breaking the regulations.

3. Most of them are small factories that can not bear all the expenses to follow the Accord suggested equipments.

4. Many officers even do not know the placement and proper use of the equipment's properly.

5. Temperature variations , humidity , dust particles and other parameters are being neglected for the fire and safety design installation causing false alarm and making the workers careless about alarm.

6. Every company must have a safety engineer to observe the safety related activity, but every company does not recruit safety engineers.

7. Fire drills are not done in every month.

8. Often factory owners are not building owners. Factory owners rent (part of) the building. Often buildings house multiple factories. In particular, smaller factories, which work as subcontractors, do not own a separate building. This split leads to a division in responsibilities between the owner of the building and the owner of the factory. It seems to us that, until now, the focus has been very much on the factory owner, and not so much on the building owner.

9. The Fire Service and Civil Defense (FSCD) in Bangladesh are involved in the process, but seem to have a limited role.

4.7 Research question

Based on the introductory study, literature review, case studies, KII etc. research questions as below is established:

1. What types of standards are given by accord?
2. How many smoke and heat alarms is needed to cover your whole factory?
3. What type of fire prevention system are you using?
4. How many false alarm are you getting through the sensors?
5. Do you do fire drills among the workers?
6. What is time interval between 2 drills?
7. Does the control panel work properly?
8. What is the number of follow up of accord in your company?
9. Are you using fire doors?
10. Are you using magnet in the fire doors for automatic control?
11. Are they working properly?
12. Are you buying the instruments from the buyer certified by accord?

13. Are you setting up all the system by the company certified by accord?
14. Can emergency escapes be locked for security reasons?
15. Is open burning allowed?
16. How do you carry out a fire risk assessment?
17. What type of self closing device you are using?
18. How much time do you required to evacuate the building?
19. Do you get the data from the drills?
20. What is the free area of the store room?
21. Does the fire safety rule hampering your production?
22. Are you interested more to increase your production or the safety?
23. How many fire extinguishers are you using?
24. What is the distance between 2 extinguishers?
25. What is the gap between 2 sensors?
26. Where are you using the smoke sensors?
27. Where are you using the heat sensors?
28. Why are you using them in different sections?
29. Do you have a separate room for transformers and boilers?
30. Are they situating at outside of the building?
31. Do you have enough first aid box in each sections?
32. What is the maximum travel distance for a worker to the nearest exit?
33. Do you have enough man power who are trained on fire fighting skills?
34. Did you pass the last follow up?
35. What are the new points from the last follow up?
36. What are doing to recover the new points?
37. Are your boss friendly enough to work on fire and safety?
38. How many workers are working in each floor, sections and in the company?
39. How many sections are there in your company?
40. Do you check everything in a month whether they are working or not?
41. Do you have enough free space on the roof?
42. How much time it take to reach the fire fighters?
43. Are the rooms isolated from each other?
44. What is the time interval for each follow ups by accord?
45. Does your fast aid box contain enough medicines?

5 Benchmark

5.1 Modification of rules

Regarding Accord given regulations Garments Factories must maintain certain criteria for ensuring safety. Among which some are not necessary for Small factories .Sometimes their productivity is being hampered .That is why after passing through the follow up from Accord, they keep breaking the regulations .That is why there should be some modification in the regulations for such kind of factories.

5.2 Reducing Equipment Price

As the price of Fire fighting equipments are being imported form abroad and government tax is also high ,the price of the equipments are high .So many small garment factory owners can not afford to install such kind

5.3 Fire Safety Management

Fire safety management of the garments factories are not that much satisfactory .For a large unit they are not even user friendly and they do not have constantly updated, real time fire safety information .So a secure and user friendly fire safety management should be implemented which can be accessed 24/7.

5.4 Regular Training and Fire Drills

To cope up with the deadly situation of massive fire explosion workers and employees must be trained according to designed escape plan .That is why there should be a regular routine for fire drills .Fire fighters must be trained properly to handle any kind of situation.

5.5 Regular Fire Risk Assessment

Explosion can happen from any kind of damaged equipments(Boiler, Generator ,Transmission system) .So every industry must do regular fire risk assessment through regular checking and inspection by authorized agencies .

5.6 Checking Parameters

Temperature variations , humidity , dust particles and other parameters are being neglected for the fire and safety design installation causing false alarm and making the workers careless about alarm.

5.7 Safety Engineers

For checking and maintaining all the working necessary equipments, designing fire drills , regular risk assessment reporting there should be enough number of experienced Fire and Safety engineers to do the tasks properly

5.8 Access to Information

Nowadays every employee don't know the information of the fire and safety management of the company. It should be known to all. So the facility should be increased so that everyone can access all the information of the company for their betterment in fire and safety management.

6 CONCLUSIONS

It has been discovered that there are a few triggering points for various events that ultimately result in catastrophic accidents. The reasons for fire and the reason for casualty are identified in the dissertation; simultaneously the need for proper interior design and necessity for proper circulation and location of emergency exit is also highlighted by the space syntax simulations.

Reason for fire: In Section 4.1 it was discovered that in more than 70% of the cases fire was ignited from electrical short circuit. Therefore in the electrical design must be considered as a prime issue of concern while a factory is being designed and constructed.

Reason for casualty (I): Building permissions are given on the basis of open plan. From the analysis it has been discovered that in some cases, the interior design and machine layout causes a massive change in use pattern, circulation system etc. which might sometimes be hazardous for the buildings' users. From the software runs and succeeding analysis it is discovered that higher length of travel to reach emergency exits, small exit size, distance of a point from the exit, high population density, improper location, inefficient catchment angle of emergency exit at RMG factories may be marked as major reasons of vulnerability to RMG workers. Strong efforts to reduce these troubles may reduce vulnerability of RMG factories, elevating them to a higher level of safety.

Reason for casualty (II): It was established in Section 4.5 that the circulation issues contribute largely in determining the casualty level in case of fire in an RMG factory. Stampede and being unable to exit together came up as the major reasons for casualty. In the software runs in Chapter 06 and their subsequent analysis in Chapter 07 worked out that various factors regarding circulation such as length of travel, obstruction on the exit way and un-designed circulation system; positioning of exit such as improper catchment angle, exit away from high concentration zones; insufficient number of exits etc. to contribute towards determining the vulnerability of RMG workers. To conclude it can be said that management issues and design issues cumulatively contribute towards determining the level of vulnerability of workers in RMG factories. High emphasis needs to be given in electrical design to reduce the chances of ignition of fire. Space syntax depth map analysis may help designers to solve circulation issues in a way to ensure more smooth evacuation and management needs to ensure regular drill and clear circulation routes to ensure flawless exit in emergency situations.

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