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Assessment of Fire Risk in the Readymade Garment Industry in Dhaka, Bangladesh

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Abstract

Readymade garments are the most important export item from Bangladesh, yet the working conditions and fire safety records in the factories are often not up to the standard. Despite a number of initiatives to curb fire accidents in the garment industry, there are still a significant number of fire occurrences in this industry. Unfortunately, there is no comprehensive statistics on the current status of fire provisions and management practices in the readymade garment factories in Bangladesh. Given the management practices (soft issues) are often as important as structural fire safety measures, yet difficult to regulate, this paper develops a Fire Risk Index (FRI), the first of its kind in Bangladesh, for soft parameters in the garment industry. FRI for 60 random garment factories are developed through surprise inspections to understand the current status of fire risk due to inadequacies in the soft parameters. Results show that the mean FRI is 2.8 on a scale of 5.0, which indicates an alarming condition. Locked exit doors, lack of emergency announcement system and lack of fire drills are the three worst performers among the 24 investigated parameters and require immediate attention from the regulators and stakeholders. We also observed a U-shaped relationship between FRI and factory size. Factories that are members of the industry's trade lobby generally have better fire safety practices than the non-members. Given the importance of the readymade garment sector in many developing countries, poor fire safety record and lack of information of fire safety, our approach of developing an FRI for the industry can be very useful to understand the immediate concerns and thus to curb fatalities and injuries from fire accidents in this sector.

Assessment of Fire Risk in the Readymade Garment Industry in Dhaka, Bangladesh

1. Introduction

Readymade garments are the largest export sector in Bangladesh, with more than 78% of the country's total foreign earnings generated from this sector. Bangladesh is also the second largest apparel exporter in the world with a total export of USD $17.91 billion in the fiscal year of 2010-11 (BGMEA 2012). The garment sector has enjoyed a significant growth in Bangladesh for the last three decades. From a humble beginning of 12 enterprises in 1978, the garment industry currently consists of 4,500 factories of various sizes (Muhammad 2011), although around 3,500 are currently operating (Prothom Alo 2013). Almost all of these factories are distributed primarily in the two of the largest cities – Dhaka, the capital and Chittagong, with Dhaka hosting over 70% (Muhammad 2011). Since this is a highly labor intensive industry (hence Bangladesh's competitive advantage through its abundant supply of unskilled cheap labor) the sector is also the largest industrial employer in the country with around 3.6 million people directly working in these factories. Inclusion of backward and forward linkages would further increase the number of employees dependant on this sector. Unfortunately, given the labor intensive nature of the industry, the density of workers on factory floors is very high. This high density of workers results in a large number of injuries and fatalities in the event of an accident.

The readymade garment industry is a highly competitive industry and cost-saving is highly valued, but, given the lack of a safety culture in the country in general, cost-cutting measures often affect the health and safety of the workers. Clothing is easily flammable and as such fire is one of the most frequent and damage inducing accidents in these factories in Bangladesh. Fire is also purported to be the largest cause of on-the-job injuries and fatalities in this sector.[1] Each new incident of fire and related damage adversely affects the reputation of the industry abroad, especially since the working conditions in the manufacturing sectors in the developing countries is a general cause of concern in many developed countries. Given the importance of fire safety in the garment sector, there have been concerted efforts from the government, the industry lobby (Bangladesh Garments Manufacturers and Exporters

[1] Although a recent structural failure of a building hosting a number of garment factories caused more than a thousand fatalities, which overshadows the fatalities due to fire accidents.

Associations, BGMEA) and the international buyers of the apparel products, to improve the fire safety culture and this has indeed reduced the fire incidents and losses significantly.

However, the battle has not been fully won yet. Despite the various measures, rules and regulations implemented in the past decades, there are still several instances of fire outbreak in the garment factories every year, resulting in significant losses of lives, livelihoods (through injuries), equipments and materials (Ahmed and Hossain 2009). These incidents raise questions about the effectiveness of existing fire prevention and fire fighting rules, regulations and practices and whether more could be done to limit fire occurrences and fire induced losses of lives and injuries. Especially, enforcement of the rules and regulations and day-to-day health and safety management practices on factory floor is a major issue. In order to improve the fire safety in this industry, it is important to understand and quantify the current state of affair in fire safety of the garments factories in the country. As is common in any developing country, there is a lack of data on fire safety in Bangladesh, and, although there are a few studies on fire safety status in general (e.g. Islam and Adri 2008), no comprehensive fire safety assessment of the garment factories were undertaken before. In the wake of a recent fire disaster at a garment factory that killed more than 100 factory workers (BBC 2012a), fire safety evaluation of the industry became even more important.

Accordingly, this research investigates a 'random' sample of garment factories from two regions within Dhaka city to assess their current fire safety status. We develop a fire safety index (first of its kind in Bangladesh) based on various parameters which are weighted using experts' opinion in order to rate the factories. Special emphasis of the current work is on understanding the status of the 'soft' parameters in fire safety management (e.g. whether there is water in the dedicated water tank for firefighting at the time of inspection) rather than on the 'hard' parameters (e.g. whether there is a dedicated water tank for firefighting), which is often the focus of the fire safety certification process.

We are also interested in understanding if any of the soft parameters are uniformly poor across all factories and if there is a relationship between the fire safety/risk status with the size or location or other characteristics of the factories. Knowledge about such parameters or potential relationships will allow regulators and policy makers to narrow their focus on the specific parameters and the factories more inclined to have an increased fire risk and thus enable efficient use of the available resources in ensuring fire safety in this industry. To our knowledge, such a relationship was not addressed in fire safety literature before. Also, given the poor working conditions in the garment sector in many other developing countries and the importance of fire safety in improving the working conditions, this research has practical implications and applications beyond Bangladesh.[2]

This paper is organized as follows. Section 2 discusses the background and importance of fire safety in the context of garment industries in Bangladesh. Section 3 presents the research methodology, describing the choice of parameters, development of the fire safety index and data collection process. Section 4 presents the results, while section 5 concludes.

2. Fire Safety Protocol in the Garment Sector in Bangladesh

Any new building, be it residential, commercial or industrial, in Bangladesh has to follow the Bangladesh National Building Code of 1993 (BNBC-93), which was published in 1993 but made legally binding only in 2006. The BNBC-93 has extensive provisions for designing and constructing buildings for fire safety, and it is widely acknowledged that strict adherence to the code would reduce fire risk of the building to an acceptable limit. However, the building stock housing the garment factories are often built before 2006, and even for those built after 2006, the adherence to fire safety design is not always strict, due to a lack of enforcement. Therefore there can be deficiencies in fire safety by design and construction.

According to Bangladesh Fire Services and Civil Defense Authority (BFSCDA) regulations, every garment factory has to obtain a fire safety certificate initially from the regulators to start the business and this certification is to be renewed every month by a visiting inspector from BFSCDA. In practice, however, inspection of the factories takes place once or twice a year due to a shortage of manpower. Unfortunately, the timing of the inspections can be leaked ahead, giving the factories ample opportunity to prepare for the inspection. Also obtaining the certificates is not very difficult due to corrupt practices and lack of competence among the inspectors. Thus, although on paper all the garment factories are compliant with fire regulations at the time of inspection, they may not always remain so at any random point in time, which is more important from the safety perspective.

[2] For example, a fire in a garment factory in Karachi, Pakistan recently resulted in 289 fatalities (BBC 2012b).

BFSCDA uses a checklist for the fire certification of the garment factories. Most of the parameters on the checklist are ‘hard’ in nature, by which we mean that the safety parameter is 'passed' through construction or buying of equipments. However, even after a garment factory is built to the fire specifications of BNBC-93, which ensures it passes the 'hard' parameter, safety on the factory floor can vastly differ due to different management practices. For example, in order to ensure ease of egress during an emergency, BNBC-93 stipulates a minimum corridor width of 1.1m for a factory building with more than 50 occupants. Fig. 1 shows an example where the ‘hard’ parameter for corridor width is met during design and construction, but due to deficient management practices the corridor is occupied by piled up boxes which reduces the effective width of the corridor and makes the passing of hard parameter useless in practice. We call these management practice related parameters the ‘soft’ parameters, which can often have critical impact during a fire incident.

[Fig. 1 about here]

Recent statistics show that the garment sector had the highest number of work-related fatalities among the different industrial sectors in 2009, although this statistics include some non-fire accidents as well (OSHE 2009). Newspaper investigations of some of the recent fire outbreaks in the garment factories in Bangladesh show that most of the factories were equipped with fire fighting equipments. Still, a significant number of fatalities resulted from the fire incidences because of panicked stampede and locked and blocked exit doors, both of which can be attributed to a lack of proper fire management practices (Huda and Ahmed 2011). Deficient management practices can include an absence of water in the water tank for the sprinkler system or fire pumps (Fig. 2), lack of maintenance of the fire extinguishers (Figs. 3 and 4), locked or blocked emergency exit ways impeding emergency evacuation (Fig. 5) etc. Unfortunately the checklist during the BFSCDA certification process or during the foreign buyers visit to the factory floors to check compliance (which acts as a control as well) primarily focus on the ‘hard’ parameters for fire fighting and evacuation and do not investigate all of these potential ‘soft’ sides of fire safety management. Thus there is a gap between fire safety ‘on paper’ and that in practice. Also, despite the importance, almost nothing is known about the present status of the ‘soft’ parameters in fire safety management and practices in the garment sector (or any other sector) in Bangladesh. This research aims to fill this gap as well.

[Fig. 2 about here]

[Fig. 3 about here]

[Fig. 4 about here]

[Fig. 5 about here]

Since the soft parameters are primarily related to management practices, they can often be fixed quickly, and any prior announcement of an impending check can lead to temporary changes to floor safety. One major focus of this research, therefore, is to ensure the secrecy of the inspection to avoid any announcement bias. Also, since our objective is to have a general understanding of the fire safety status in the garment factories in Bangladesh, we ensured the 'randomness' in the selection of the factories once the general locations of the inspections have been decided.

3. Research Methods and Data

3.1. Fire Risk Assessment Methods

There are various techniques for fire risk assessment in buildings, all of which can be classified into four broad categories – checklists, narratives, indexing and probabilistic methods (Watts and Hall 2002). Among these, checklists and narratives are qualitative in nature while indexing and probabilistic methods follow a quantitative approach. A checklist approach checks the performance of the building (or, in present case, the garment factory), generally in a yes/no format, with respect to a set list of standards or codes relevant to fire safety. BFSCDA follows the checklist approach when certifying a garment factory for fire safety. On the other hand, narratives are generally a list of recommendations relevant to fire hazard mitigation. Comprehensive narratives such as the National Fire Code by NFPA (2000) in the USA describe various hazardous conditions and methods to mitigate or eliminate them. Checklists and narratives, however, are not very useful in communicating the general fire safety/risk status of a building, although they are useful for implementing mitigating actions for individual buildings.

Probabilistic or statistical methods are mathematically rigorous, and are generally well grounded in theory and data in order to quantify the fire risk. Common techniques involve fault tree analysis, event tree analysis, decision tree analysis and influence line analysis (Watts and Hall 2002). Probabilistic methods are very detailed and require an excellent record of past fire incidents to derive accurate probabilities for different fire hazards and consequences (Lo 1999). Since such record is rare in Bangladesh, and most other developing countries, it is difficult to apply probabilistic methods of fire risk analysis in these countries, despite the superiority of the technique in quantifying the risk.

Fire risk indexing, also known as risk ranking, point system or numerical grading, is the oldest quantitative method for fire risk assessment, and is still the most widely used. Risk indexing involves assigning values to some preselected fire safety or fire risk related parameters (or attributes) and then combining them arithmetically to arrive at a single risk index, which numerically summarizes the fire risk of the specific building. Risk index models can also vary in complexity and can involve varying degree of 'scientific' underpinning. The risk indexes can be used to compare the performance of different buildings, and are a cost effective and quick method for fire risk assessment. Despite the mathematical superiority of the probabilistic methods, Hultquist and Karlsson (2000) found that probabilistic methods and index models resulted in the exact ranking of four multi-storey buildings in Sweden. Given their results and the lack of data, expertise and resources to apply the probabilistic approach in Bangladesh, risk indexing method is followed in this study.

Risk indexing is a way of evaluating multiple attributes into a single value and various risk indexes differ primarily in the number and types of parameters (attributes) considered and the arithmetic functions used to summarize these parameters. Among various types of fire risk rating, the most popular ones are Gretener's index, FRAME index, Dow's Fire and Explosion Index, Fire System Evaluation System (FSES) Index and Hierarchical Approach (Sakenaite and Vaidogas 2010, Rasbash et al. 2004). In most of these indexes the parameters are grouped into various categories describing various aspects of fire safety, e.g. fire prevention, egress, compartmentalization, detection and alarm, emergency response etc.

For the current work, we follow a linear additive model of the following form in order to determine the Fire Risk Index (FRI) for the soft parameters:

$$FRI = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

where, x_i is a dimensionless score or grade points for parameter i, w_i is the importance of parameter i and n is the number of total parameters. The weight w_i is used to incorporate the variations in importance of the parameters relative to each other and is generally determined by expert opinion and/or from past data, if available. The grade points or scores x_i reflect the 'measure' of the danger, consequence or safety offered by a particular parameter i. Since the units of measurement for different parameters are different, x_i is expressed as a normalized dimensionless number so that they can be added together (Watts and Kaplan 2001). This FRI can be easily included in developing a much broader Fire Risk Index involving other categories of 'hard' parameters as long as the relative importance of soft and hard parameters can be established.

3.2 Development of the Parameters and Weights

Generally, the garments factories are required to follow the regulation of fire safety set by BNBC-93 as well as the BFSCDA regulations for the 'hard' parameters. Although the BFSCDA checklist contains some soft parameters, they are not comprehensive. There is also no other standard set by any regulating authority to ensure the operational safety and fire management practices in the garment factories (although in some cases the buying foreign company sets additional rules and inspections). The soft parameters were initially selected using BFSCDA's checklist, literature review and discussion with two fire safety experts. A pilot survey was then carried out at two factories to ensure that the identified parameters are 'measurable' during inspections and the parameters are then fine tuned to produce the final list of 24 (i.e. n=24) soft parameters.

The weights, w_i of Eq. 1, can reflect a variety of factors explaining 'importance', but it can be further difficult to compare those importance factors. For this research, the weight reflects the importance of the parameters in terms of potential consequences. That is, a soft parameter is given the maximum weight, 5, if an expert deems that deficiencies in this parameter will cause high damage to both life and goods, while the weight is minimum, 1, if the expected damage is minimal. In order to avoid a difference in the perception among the experts on the 'measure' of importance (Dodd and Donegan 1994), a weighting scheme was presented to the experts to guide their scoring, see Table 1.

[Table 1 about here]

The list of soft parameters and the weighting scheme are then presented to ten experts. These experts are chosen from the academics and the professionals who are directly involved with fire safety or disaster management. They include four academics involved in disaster management and fire safety design of buildings, three officials from BFSCDA, one official from Bangladesh Army in charge of fire protection, an engineer from National Housing Authority, and an urban risk reduction specialist from the Comprehensive Disaster Management Program. The experts provided their grades for the selected soft parameters as per Table 1 using their own judgment about the parameters and their importance.

Advanced techniques, such as Analytical Hierarchy Process, Fuzzy theory, Reliability Interval Method, Grey Relational Model or simulation approach have been applied in the literature in order to generate reliable weights for the parameters from expert judgments (Lo et al. 2005, Zhao et al. 2004, Lo 1999). However, given the lack of resources to generate such measures and noting Watt's (1991) third axiom of fire risk – '*a totally objective or scientific way to measure fire risk does not exist*' – we follow the simple process of averaging the weights for each parameter. In order to ensure that the weights are not significantly influenced by the extreme values offered by one or two experts, we remove the maximum and minimum weights for each parameter and then average the weights by the remaining eight experts. Table 2 presents the list of the soft parameters and their associated weights from the expert opinions. Fig. 6 presents the summary of the experts' opinions through a bubble chart.

[Table 2 about here]

[Fig. 6 about here]

3.3 Performance Grading for the Parameters

During the field inspection of the garment factories, each of the parameters is given a grade point, x_i in Eq. 1, for each factory, ranging from 1 to 5, depending on the factory's performance in that parameter. Since the performance of the soft parameters are sometimes difficult to measure quantitatively, for many of the parameters the grade points were awarded based on qualitative observations (e.g. accessibility to fire hydrant, or workability of announcement system). The scale of grading has been formulated by consultation with the experts, management and workers of the garments factories, and BFSCDA. Table 3 presents the grade point used. For a few parameters, where quantification was possible, the grading strategy is based on the measured quantity. For example, if the dedicated water tank for fire-fighting is full, then the grade point is 5, but if the tank is 45% full, then it has a 55% deviation from the 'ideal' case, and thus assigned a 3 as per Table 3. Detail description of the definition of grade points for each parameter in Table 3 is available in Huda and Ahmed (2011).

[Table 3 about here]

3.4 Data Collection

The FRI developed above is applied on real data collected from the existing garment factories in Dhaka. One of the most difficult aspects of this research was to obtain credible data while ensuring the 'surprise' element during the data collection inspections. Since the garment factories are resistant to visits by external visitors, especially to outsiders wanting to investigate their fire safety performances, it was necessary to obtain assistance from the BFSCDA.[3] The researchers were introduced to fire safety inspectors, who were instructed by the higher authority within BFSCDA to accompany the researchers during site visits. Although the inspector of a particular region was informed about the impending visits a day before, the names of the factories to be visited were not revealed. Given that there are a large number of factories within the jurisdiction of each inspector, it was assumed that it would not be possible to leak the information ahead of time to all of the factories, or even if leaked, all of the factories will not take actions given the lack of precision about the inspections. The inspectors were also informed that the results were for academic purpose only and the names of the factories would remain confidential. This way any potential announcement bias was avoided.

In the absence of strict land use plans, the garment factories are spread throughout the Dhaka city, although there are a few clusters where the concentration is much higher. Two such regions were chosen for inspection and a total of 60 factories were inspected, which represent around 2.4% of all the garment factories in Dhaka. 35 of these are located in Mirpur region, which is an area of mixed land use, while 25 are in Tejgaon, which is the major industrial area in Dhaka. Within each region, all the garment factories were listed alphabetically by name, and then chosen randomly using Microsoft Excel's random number generator. The sample can thus be described as stratified (by region) random. A purely random

[3] Earlier attempts of random inspection by BUET students were not successful.

sample from all Dhaka regions was not possible due to management and resource limitations. Given the largest concentration of garment factories in these two regions in Dhaka, there are reasons to be optimistic that this sample would adequately represent the current status of the industry although further efforts to increase the spatial coverage and sample size in future will be beneficial. A further 20 factories did not allow immediate entry of the researchers despite the presence of the fire inspectors. Although some of these factories asked the researchers to return another day, they were not inspected further because of the potential for announcement bias. Also, the significant number of refusals to enter the factory gives confidence that the inspections were not leaked ahead in time.

The number of employees in each factory was either directly collected or calculated. BGMEA membership status of the factories was collected from the BGMEA Directory.

4. Results

4.1 Fire Safety Status of the Factories

In our grading strategy, a larger grade point refers to a safer situation. Therefore our Fire Risk Index is in an inverse scale – a higher FRI means less risk. Fig. 7 presents the distribution of FRIs for the soft parameters for all factories in the sample. The mean FRI for the 60 factories is 2.8, which shows that the fire safety practices are significantly below the ideal value of 5. The qualitative definition of the grade points for individual parameters in Table 3 is applicable to our final FRI values as well. Noting that we defined 'good' as a deviation of up to 30% from the ideal value and awarded it a grade point of 4, it is alarming that not a single factory in our sample could achieve an FRI above 4. This indicates that every factory deviates at least 30% from the ideal FRI. Only 5 (8.3% of the sample) factories have an FRI above 3.5 and more than 60% of all factories have an FRI below 3. This result is of concern, since it reveals that the operations of otherwise safe hard parameters can be significantly impaired during a fire outbreak.

[Fig. 7 about here]

In order to identify the performance of the factories for each soft parameter, the grade points (without expert weights) are plotted as a box and whisker plot for all the garment factories in Fig. 8, in descending order of importance of the parameters. The boxes represent inter-quartile ranges, diamonds represent medians and the whiskers represent 5^{th} and 95^{th} percentiles. Clearly there are large differences among the parameters in their distribution among the factories. Out of the 24 parameters, 17 have a median grade point of 3, indicating *at least* 50% of the factories scored 3 or less in those specific parameters. 4 parameters have a median grade point of only 2, and, alarmingly, these 4 parameters are among the most important parameters. Especially, locked exit is identified as the most important parameter in maintaining fire safety in the garment factory – yet its median grade point is only 2, and 75% of the factories have a grade point less than 3. The 4 worst performances are in locked exit, fire drill practices, announcement system and presence of gas mask. Once again, the first 3 of these parameters are ranked among the top ten in terms of their importance, and therefore require immediate attention from the regulators and stakeholders.

[Fig. 8 about here]

A total of 15 parameters are common in our study and BFSCDA's checklist. Since all of the factories in the sample are working in full swing, it can be inferred that they have passed BFSCDA's most recent checklist, at least on paper. In an ideal scenario, the garment factories should score near perfect grade points for each of these 15 parameters. However, the modified FRI (FRI_{chklst}) for these common factors only (i.e. when i in Eq. 1 represents the common parameters, n=15) is still only 2.83, which is significantly less than the ideal index of 5. This indicates large deviations of on-site risk index for the regulated parameters and decisively shows that there is a significant divergence between regulatory certification and on-site fire safety practices. The FRI_{chklst} for checklist parameters is marginally larger than the modified FRI based on our additional soft parameters (FRI_{add}), which is 2.74, and the difference is statistically significant through a paired t-test (t=2.199, p=0.016). Therefore, the factories perform better for the parameters in the checklist than those added in this study, which is not surprising. However, it is still a cause of concern that for 24 of the factories (40% of the sample), the FRI_{add} for non-checklist parameters are larger than the modified parameters for checklist parameters.

Considering ten of the most important parameters (highest weights by the experts), the modified FRI (FRI_{top10}) is 2.74, which is smaller than the average FRI of 2.80. Using a paired t-test the difference is statistically significant (t=2.567, p=0.006). Therefore there are significant causes for concern, given the potential large impact of these ten important parameters. This also hints that there is possibly an inefficient allocation of resources among the factories with respect to fire risk mitigation activities whereby resources are not devoted to the most important parameters.

4.2 Fire Safety Status and Factory Type

A second important objective of this research was to investigate the relationship, if any, between fire safety performance and factory characteristics. Given the lack of financial information about the factories, we use number of employees to represent the size of a factory. We intend to test two simple hypotheses. In the first one, it is hypothesized that fire safety in larger factories are better, i.e. there is a linear relationship between FRI and factory size. This follows from the natural expectation that as the factories grow larger, worker power becomes stronger and factory management becomes more worker-friendly. Our second hypothesis follows from the environmental Kuznets curve hypothesis (Yandle et al. 2002) which states that environmental pollution increases with increasing per capita income and then starts decreasing, following an inverted U pattern. In a similar analogy, we hypothesize that the concerns about fire safety and thus FRI deteriorates during the initial phases of expansion of a garment factory, but then, as the company grows, management become more worker-friendly and improves its management practices to reduce fire risk.

Fig. 9 presents a plot of individual FRI of each garment factory against the number of employees in those. A Pearson’s correlation coefficient of 0.15 reveals that the linear correlation is not strong, indicating our first hypothesis may not be correct. Fig. 9 also visually establishes that there is no discernible linear trend among the FRI and factory size. A closer look reveals that the factories show a U shaped pattern, which becomes stronger if the very small factories at the bottom left corner is not included. This lends support to our second hypothesis that the garment factories, in general, are on a growth trajectory where workers' fire risk is initially increased, but as they grow more, safety is then improved. Given the larger investment and consequently larger risk associated with a failure to get a fire safety certification (either from BFSCDA or foreign buyers), a large factory has larger incentive to invest in better fire management practices. For smaller factories, no systematic fire risk pattern can be observed. It must be mentioned here that the employment measure has been constructed from a number of sources, and may contain some error. Therefore, the noisy signal for small factories may be a result of a lack of reliable data on factory sizes.

[Fig. 9 about here]

Our next categorization involves BGMEA membership. Given that BGMEA is an association of the garment factories, and works for the improvement of the industry as a whole, it can be hypothesized that BGMEA member factories would have better safety practices than the non-BGMEA factories. The modified FRI for BGMEA members is indeed marginally larger than for non-BGMEA members (2.89 vs. 2.75). Although the difference is not statistically significant at 90% confidence level through two sample t-test (t=1.20, p=0.118), it is likely that there is low power in our sample as one of the sample group contains only 21 factories. Therefore the choice of 85% confidence level is not entirely unjustified, and the differences are significant at this confidence level. Comparing the FRI from the ten most important parameters (FRI_{top10}), we find a clear indication that BGMEA members are significantly better at 95% confidence (2.89 vs. 2.65; t=1.80, p=0.038). The FRIs for BGMEA members are also less widely dispersed than those for non-members, with a coefficient of variation of 15.4% for member factories and 17.3% for non-members. This indicates a *relatively* more uniform distribution among the BGMEA members. However, since the BGMEA members are under-represented in our random sample, it is likely that the FRI of the industry as a whole is possibly marginally better than the mean FRI of 2.8.

In order to enhance our understanding of the differences in individual grade points for all soft parameters for the BGMEA members and non-members, we plot a spider diagram as in Fig. 10. Although non-BGMEA members have marginally better score for six parameters, BGMEA members outscore non-BGMEA members in fourteen parameters, many of those by a wide margin. Notably, BGMEA members perform better than the non-BGMEA members in each of the eight most important parameters, i.e. parameters with the largest weights by the experts. Since BGMEA membership is not conditional on fire safety performance of the factories, it can be concluded that membership improves the day-to-day safety management practices. This is possibly due to better dissemination of information on safety practices and strategies through BGMEA workshops and peer to peer learning among the members.

[Fig. 10 about here]

Investigation into potential differences based on geographical location does not reveal any systematic differences between the factories in Mirpur and Tejgaon. Although there are some differences for individual parameter scores (Fig. 11), the average FRIs for the factories in the two locations were 2.81 and 2.78 respectively. Two sample t-test ($t=0.197$, $p=0.422$) clearly indicates that there is no statistically significant difference of FRIs at different locations at any reasonable confidence interval. Therefore the influence of location is minimal on the FRIs in our sample. As such, our results can possibly be extrapolated to generalize the findings in other locations as well, unless a location has some special characteristics (e.g. an export processing zone).

[Fig. 11 about here]

4.3 Impact of Weighting Parameters

In order to test the stability of our results, we investigate the sensitivity of the results with respect to various strategies to summarize the experts' weights of various parameters. As mentioned earlier, we removed the highest and lowest importance scores of the experts and averaged the other eight scores to determine the weight of each parameter while determining the FRI above. In addition, we use the modal scores and average of all ten expert scores in order to test the sensitivity of the FRIs. It is clear from the results of Table 4 that the average FRI or its dispersion remains almost the same for all three weighting schemes. Therefore our results are not biased due to the specific choice of one scheme to summarize the experts' weights.

[Table 4 about here]

5. Conclusions

A Fire Risk Index, the first of its kind in Bangladesh, was developed to understand the current fire safety status in the readymade garment industry in Bangladesh, which is known to be vulnerable to fire accidents. Emphasis was on the day-to-day fire safety management related parameters, which we call soft parameters here, instead of structural parameters of fire safety/risk analysis. Although in recent years, there have been significant efforts to improve the structural elements of fire safety, there still is a large scope to improve the fire safety in the garment factories in Bangladesh, especially with regard to the soft measures. By avoiding the announcement bias through surprise visits to the factories, we found clear evidence that on-site fire safety situation is substantially different than the certified situations. It is therefore important that the enforcement and regulatory certification processes are further strengthened. Especially, measures must be taken to ensure that the regulatory inspections contain an element of surprise in order to reveal the safety risk associated with management practices.

The distribution of FRI of the 60 factories investigated reveals that the performance of these garment factories is less than satisfactory in general. Mean FRI was only 2.8 (5 is maximum) and 67% of the factories had a score less than 3. The poor performance in the most important parameter, locked/unlocked exits is especially alarming. The garment factories also performed particularly poorly in two other very important parameters – fire drills and emergency announcement systems. Although almost all of the parameters require attention from the regulators, these three parameters together warrant urgent attention from the regulators and the industry in order to avoid catastrophic consequences of a fire in the garment factories. Since changes in regulatory practices are a slow process, BGMEA can step in to disseminate information to improve performances in these three parameters.

Attempts to unearth a relationship between FRI and factory characteristics were moderately successful, and a U-shaped distribution in the FRI with respect to the factory size could be observed. There is strong evidence that the BGMEA member factories performed better than the non-members in the ten most important fire risk parameters, although the evidence is less strong when all soft parameters are included. This indicates BGMEA should be further proactive to improve its membership base and continue the good practice. However, it must also be noted that even the BGMEA members still have large improvements to make.

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Figures

Fig 1: Clear width of an exit corridor reduced by piled up boxes.

Fig 2: Empty overhead water tank for fire fighting.

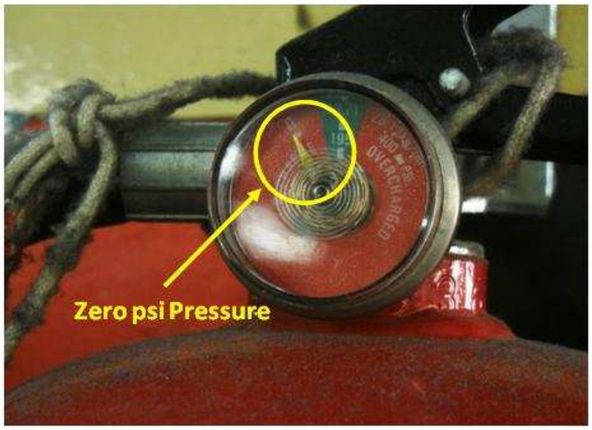

Fig 3: Fire Extinguisher with Zero Operating Pressure.

Fig 4: Fire Extinguisher with No Nozzle.

Fig 5: Exit Door Locked and Blocked by Furniture.

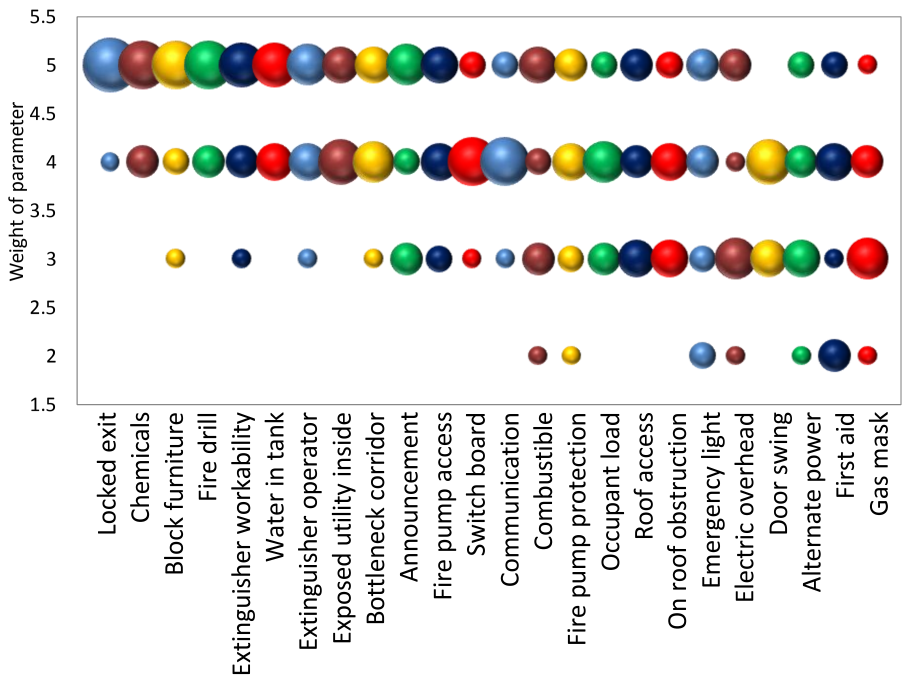

Fig 6: Bubble chart for experts' weight for each parameter (size of bubble represent no of experts awarding the weight in the y axis to the parameter in the x axis).

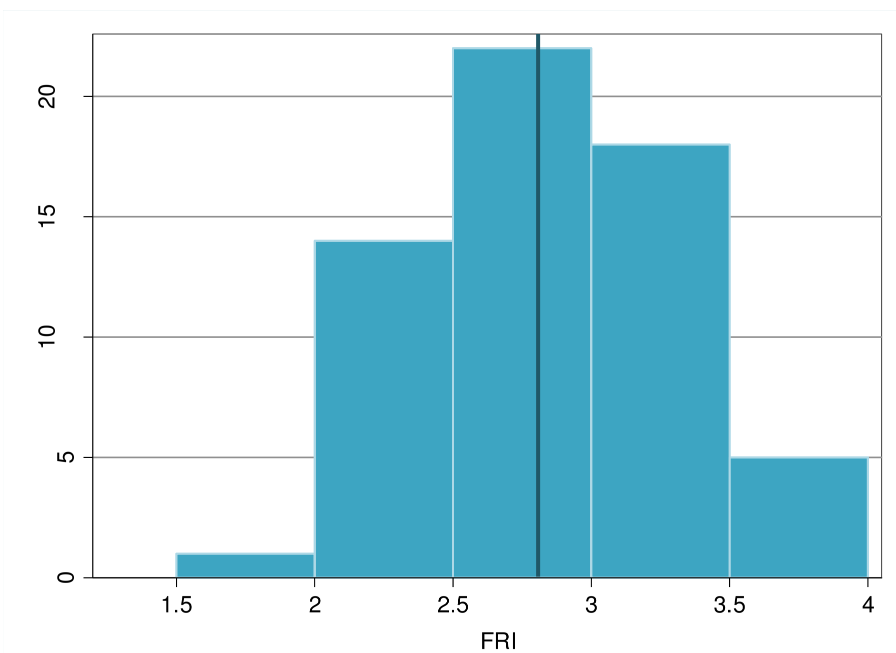

Fig 7: Frequency distribution of FRIs in 60 factories. Dark blue vertical line represents mean FRI.

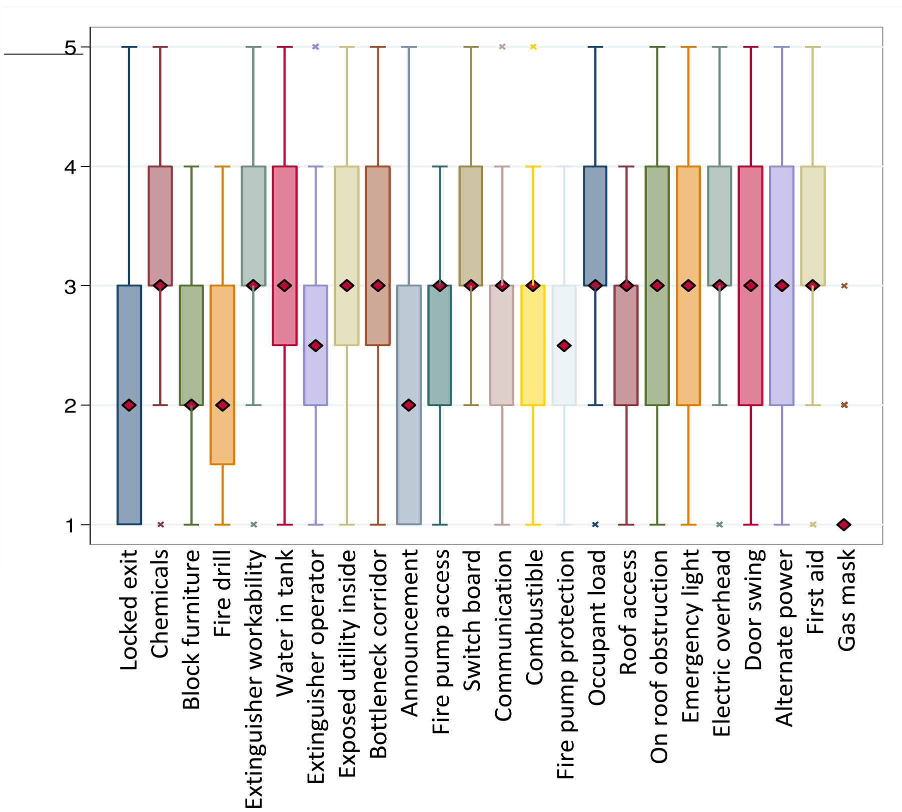

Fig 8: Box plot distribution of the scores for different parameters for whole sample.

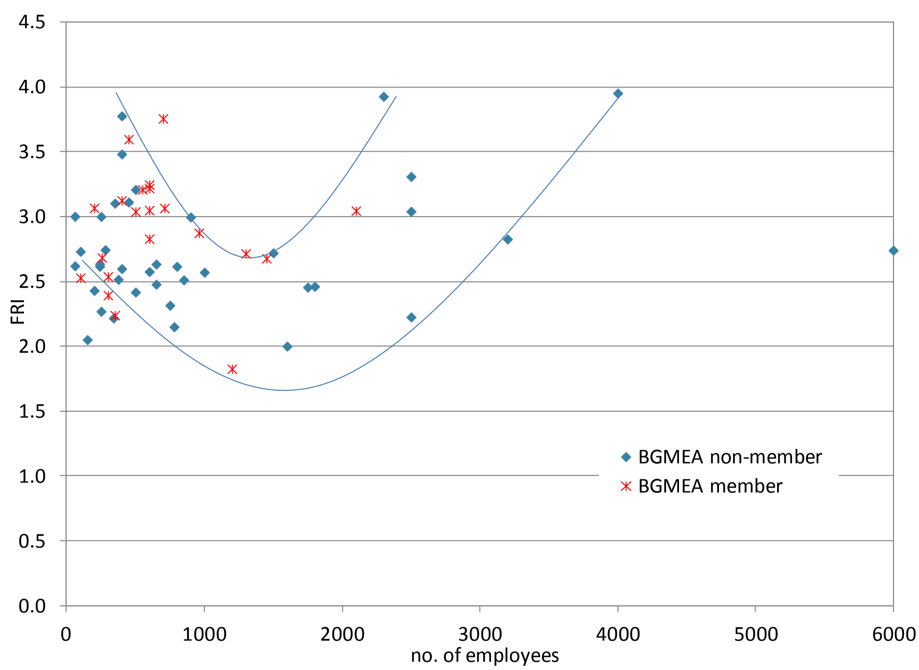

Fig 9: Scatter plot of FRI vs. size of factories, expressed as no of employees.

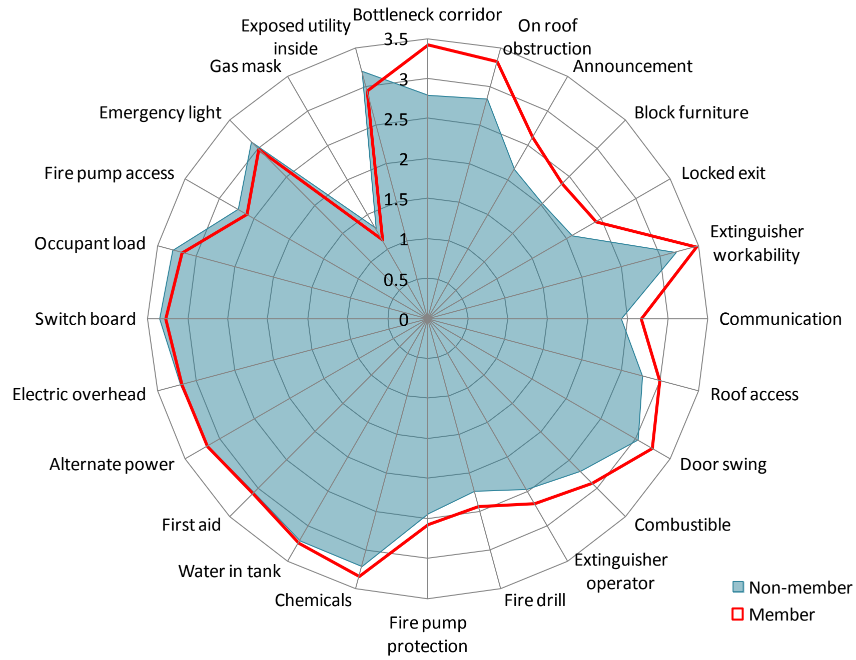

Fig 10: Spider diagram for average scores of the garment factories based on BGMEA membership status.

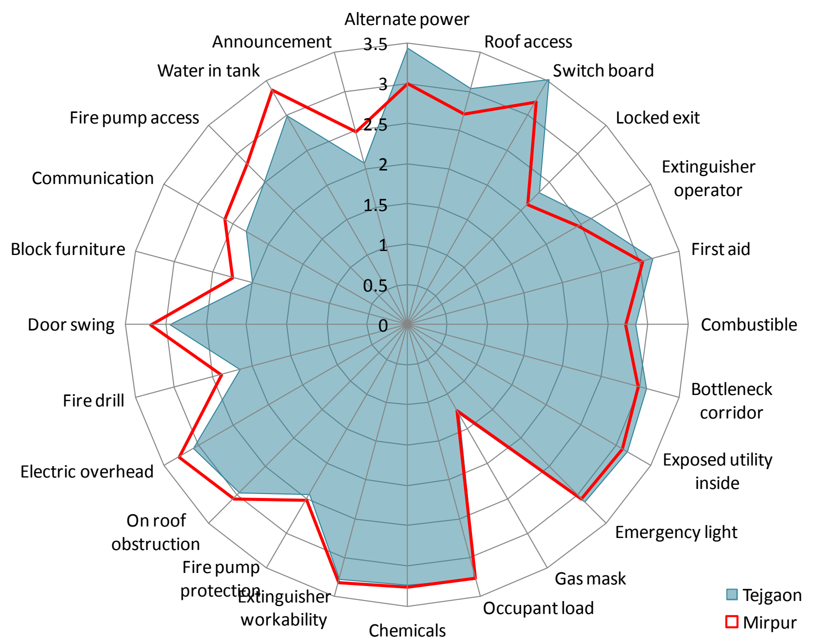

Fig 11: Spider diagram for average scores of the garment factories based on location.

Assessment of Fire Risk in the Readymade Garment Industry in Dhaka, Bangladesh

Tables

Table 1: Definition of weights for each parameter.

Weight	Description of consequences
5	Most important – if not present, very high damage of both life and properties may occur
4	Important – if not present, considerable damage of both life and properties may occur
3	Essential – loss of life may not occur but other losses and injuries are high
2	Essential – loss of properties and injuries are considerable
1	Not essential but preferable

Table 2: Weight of the parameters

Rank	Parameters short name	Parameters description	Weight average
1	Locked exit	Locked/unlocked condition of exit door	5.00
2	Chemicals	Existence of chemical material inside	4.75
3	Block furniture	Blockade of exit corridor by furniture/other material	4.75
4	Fire drill	Practice of fire drill	4.75
5	Extinguisher workability	Serviceability of fire extinguisher	4.63
6	Water in tank	Presence of adequate water in tank	4.63
7	Extinguisher operator	Performance of fire extinguisher operator	4.50
8	Exposed utility inside	Exposed electric or gas line inside factory floor	4.38
9	Bottleneck corridor	Formation of bottleneck between corridor & exit door	4.38
10	Announcement	Workability of announcement system	4.25
11	Fire pump access	Accessibility to fire hydrant	4.25
12	Switch board	Location of main electric switch board	4.13
13	Communication	Communication between command centre to floor	4.13
14	Combustible	Presence of combustible item (cotton, cloth) inside	4.00
15	Fire pump protection	Protection of fire pump against mechanical damage	4.00
16	Occupant load	Number of workers/occupants per unit floor area	3.88
17	Roof access	Unobstructed access to the roof	3.88
18	On roof obstruction	Presence of obstruction on the roof	3.75
19	Emergency light	Serviceability/ working condition of emergency lights	3.75
20	Electric overhead	Existence of electric overhead line in front of the building	3.63
21	Door swing	Outward/inward swinging of door	3.63
22	Alternate power	Presence of alternative power system	3.63
23	First aid	Availability of first aid kits on shop floor	3.50
24	Gas mask	Availability of gas mask for emergencies	3.38

Table 3: Grade Point of Soft Parameter.

Grade Point	Not quantifiable parameters Subjective observations	Quantifiable parameters % deviation from ideal case
5	Excellent	Less than 10%
4	Good	From 10% ~ 30%
3	Average	From 31% ~ 60%
2	Poor	From 61% ~ 80%
1	Very Poor	More than 80%

Table 4: Sensitivity of FRI with respect to different schemes summarizing the experts' opinion

	Mean FRI			Standard deviation of FRI		
	Avg of 8 experts	Avg of 10 experts	Mode	Avg of 8 experts	Avg of 10 experts	Mode
All factories	2.797	2.798	2.799	0.467	0.467	0.470
BGMEA member factories	2.894	2.893	2.894	0.445	0.445	0.453
BGMEA non-member factories	2.745	2.747	2.747	0.475	0.477	0.477
Factories in Mirpur	2.808	2.808	2.813	0.440	0.441	0.446
Factories in Tejgaon	2.783	2.783	2.778	0.510	0.511	0.511