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Fire Safety in the Readymade Garment Sector in Bangladesh: Structural Inadequacy vs. Management Deficiency

Abstract

The readymade garment (RMG) industry plays a vital role in the socio-economic development of Bangladesh, yet the sector suffers from poor fire safety records. Given the lack of fire risk assessment in the industry, this paper develops a Fire Risk Index (FRI) for individual RMG factories and surveys 60 such factories to develop an understanding of the fire safety conditions in the sector. The paper differentiates the risk factors into structural (hard) and management related (soft) parameters and develops FRIs for the structural factors. The FRI for structural parameters is then compared with the FRI for management factors, published earlier. While an overall mean FRI of 2.12 on a 4 point scale indicates that fire safety condition is quite poor, the FRI for soft parameters (1.80) are even lower than the FRI for hard parameters (2.58), indicating the critical importance of the soft parameters in fire safety assessment of the RMG factories. Within the hard parameters, there appears to be more reliance on firefighting and means for escape than on precautionary measures to contain the fire, which could explain the higher frequency of fire occurrences in the industry. FRI for both hard and soft parameters appear to follow a U shaped relationship with factory size, possibly indicating a Kuznet's effect in fire safety in the garment sector. The poor FRI for hard factors indicates large deviations from safety requirements set in this work and asks for a stricter monitoring and enforcement regime. Improving the performance in the soft parameters, however, would require changes in the safety culture and practices.

Keywords

risk assessment, fire risk index, fire safety, garment factories, developing countries

Fire Safety in the Readymade Garment Sector in Bangladesh: Structural Inadequacy vs. Management Deficiency

1. Introduction

The readymade garment (RMG) industry plays a vital role in the socio-economic development of Bangladesh. At present, this sector consists of around 4,200 factories [5] and generates 80% of the country's total foreign earnings amounting to US $24.49 billion in the last financial year [7]. More than 4 million people are employed in the garment industry, of which 80% are women [6, 1]. Besides, being a large source of female employment, the RMG sector also influences other industries like fabrics, packaging, banking, transportation, real estate, hotel and tourism, etc [8]. Despite the benefits, workplace safety in this highly labor intensive industry is not satisfactory. Numerous accidents in factory floors have affected the reputation of the industry in both home and abroad poorly. Although the Rana plaza accident in 2013, where a factory building collapsed to leave more than a thousand workers dead [3], attracted large attention and action from the Western world, fire related accidents are more frequent and as such more fatal when aggregated over time. Although detail statistics are unavailable, short circuit of electric cables and explosions of chemicals on factory floor are deemed to be the major causes of these fire accidents. Fire accidents cost hundreds of workers' lives and livelihoods along with huge equipment and material loss. However, there is a dearth of studies that attempt to understand the fire risks associated with the industry.

Set in this context, Wadud et al. [19] developed a quantitative Fire Risk Index (FRI) for the factories in the RMG sector and systematically assessed fire risk of 60 randomly selected garment factories in Dhaka, the capital of Bangladesh. This research complements and extends the earlier work of Wadud et al. in several ways. Firstly, this paper focuses on the structural factors affecting fire safety, which we call the 'hard' factors, as opposed to Wadud et al.'s focus on management practices or 'soft' factors. Secondly, we compare the fire safety performance of different types of RMG factories with respect to the 'hard' parameters. Finally and most importantly, we compare the safety performances of the sample factories with respect to structural (hard) and management oriented (soft) factors and investigate whether there is any relationship between the two. In order to compare the safety performances, we develop a Fire Risk Index (FRI) similar to Wadud et al. [19] for the 'hard' parameters. Although the study focuses on the RMG sector in Bangladesh, it is relevant for a wide range of labour intensive industries in the developing and emerging countries, where occupational hazards and safety can often be neglected. The recent fire accidents in an RMG factory in Pakistan (314 fatalities, [16]) or a shoe factory in Philippines (72 fatalities, [9]) highlight the importance and wider appeal of this research.

The paper is organized as follows. Section 2 discusses the current state of fire safety measures in the garment sector of Bangladesh. Section 3 presents the research methodology, describing the development of fire safety assessment method, selection of parameters, their relative importance and grading of the parameters. Section 4 presents the results of 'hard' side while section 5 compares the results of 'hard' side to 'soft' side. Section 6 concludes.

2. Current State of Fire Safety Measures in the RMG Sector of Bangladesh

All factories including those in the RMG sector in Bangladesh, have to obtain certification from Bangladesh Fire Service and Civil Defense Authority (BFSCDA) for their compliance with fire regulations. Newly constructed purpose-built factories have to comply with Bangladesh National Building Code of 1993 (BNBC-93) and have to obtain the certification of local authorities assigned from the Ministry of Housing and Public Works, Government of the People's Republic of Bangladesh. Factories operating in old buildings (buildings those were built before the code was formulated but was in practice), have to collect another fitness certificate from the BFSCDA, which allows them to get a second certificate from the Ministry of Housing and Public Works. According to BFSCDA regulations, garment factories have to take an operational certificate at the very beginning of operation from them and this certificate have to be renewed in every month by the respective zone officials. BFSCDA officials check a total of 61 parameters of which 41 parameters are structural or 'hard' in nature [4]. We define the 'hard' factors as those whose conditions cannot be changed very quickly. These parameters are often structural in the sense that building construction and architectural codes often dictate these factors, although there can be other factors which cannot be changed overnight such as purchase of an equipment. An excellent example of 'hard' parameters is the number and specification of fire exit requirements in the building codes, while the relevant 'soft' factor can be whether the exits are locked or blocked or fully operational at the time of survey. Similarly, the number of fire extinguishers is checked by the BFSCDA officials during their survey of the factories, yet whether the extinguishers are in working condition is not. The number and presence of fire extinguishers is a hard parameter because they may not be procured overnight, while the workability at a specific period of time is a soft parameter as it reflects the management practices of inspection and maintenance. Since the buildings are expected to have been built following the building code, our initial expectation is that the 'hard' parameters would be in a better condition as compared to the 'soft' parameters, the performance in which can change from day-to-day due to management practices. Figs. 1-2 show examples of hard parameters, where the safety regulations have not been met.

Figure-1: Hard factors: Stairway does not meet regulation.

Figure-2: Hard factors: Exit door does not meet regulations.

A comparison of BFSCDA checklist and BNBC-93 shows that some major precautionary steps of 'hard' parameters as per BNBC-93, e.g. existence of central command center, existence of announcement system, presence of fire damper, maximum length of travel distances toward nearest exit, widths of stairways and corridors, etc. are missing from the BFSCDA checklist. Since the objective is to understand the fire safety situation in practice in the RMG factories and not to check regulatory compliance, we develop our own list of parameters to calculate FRI in this work.

Since the Rana Plaza accident, where the collapse of a building housing several garment factories led to more than 1,200 fatalities, there have been concerted efforts from the Government of Bangladesh and the international community to improve the conditions in the RMG factories. Two international groups of stakeholders - Alliance for Bangladesh Worker Safety (Alliance) and Accord on Fire and Building Safety in Bangladesh (Accord) - are currently conducting regulatory checks and suggesting remedies for every RMG factory of Bangladesh.

Although the focus is wider safety environment, fire safety forms a part of their monitoring process as well.

3. Research Method and Data Analysis

3.1. Fire Risk Assessment Method

Fire risk assessment techniques can be broadly classified into four categories: checklists, narratives, probabilistic or indexing method. Checklists and narrative are qualitative, while probabilistic and indexing methods are quantitative. Our approach is to use a quantitative method since we are later interested in comparing safety performances for different factory types and parameter types, for which a numerical interpretation is more useful. Among the quantitative methods, the probabilistic method can involve decision tree analysis, event tree analysis, fault tree analysis and influence line analysis, which are well demonstrated to quantify the fire risk of a building [**20**]. But the main disadvantage of this method is the requirement of an excellent record of past fire incidents to derive accurate probabilities [**14**] which is rare in most developing countries like Bangladesh. Therefore, the indexing method has been chosen for this research due to its practical advantages. Besides, Hultquist and Karlsson [**12**] found that probabilistic and index methods provide exact ranking for four multi-storied buildings in Sweden, and gives confidence that our results will not be widely off the mark.

Fire risk indexing involves assigning values to some preselected fire safety parameters and then combining them by an arithmetic function to reach at a single Fire Risk Index (FRI), which numerically summarizes the fire risk of that specific building. This single risk index value can also be used to compare the performance of different buildings. Out of various types of risk rating systems, the most popular ones are Gretener's index, FRAME index, Dow's Fire and Explosion index, Building Officials and Code Administrators (BOCA) index, Fire Safety Evaluation System (FSES) index and Hierarchical Approach index [**15, 17, 13, 18**]. In these systems 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. Although our method of risk indexing follows similar underlying principle, some of the parameters in those methods are often poorly applicable to a developing country like Bangladesh, or to the readymade garment sector, which is a labour-intensive industry. Therefore we develop our own parameters considering the local context, ease of measurement and usefulness of the parameters to measure safety. In our research, we have categorized the ‘hard’ parameters into three main groups namely, precautionary requirement, means of escape and in-built firefighting facilities which consists of several individual parameters, as per BNBC-93. All of these 'hard' parameters are a subset of BNBC-93 parameters. The ‘soft’ parameters are considered as a single group. Fire Risk Index (FRI) for the ‘hard’ and ‘soft’ parameters has been calculated in a linear additive model of the following form:

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

where, w_i is the weight value which is used to determine the variations in importance of various parameters relative to each other, x_i is the grade point (a dimensionless score) for parameter i and n is the total number of parameters.

3.2. Selection of the Parameters

In Bangladesh, garment factories are required to follow the rules and regulations of fire safety set by the BNBC and BFSCDA. There is no other standard set by any regulating authority to ensure the operational fire safety in the garment factories. In this research, the parameters were initially selected using the BNBC-93, BFSCDA checklist, Bangladesh Gadget of the Ministry of Housing and Public Works, literature review and consultation with fire safety experts. A pilot survey was initially carried out in two garment factories to ensure that whether the parameters are ‘quantitatively’ measurable during survey. After final scrutiny, 22 ‘hard’ parameters have been chosen, under 3 categories namely precautionary requirement, means of escape, and in-built firefighting facilities. Table-1 shows the list of ‘hard’ parameters with their categorization respectively.[1] These categorization follows BNBC-93, although there are some limitations in the membership of the parameters in the specific groups.[2]

Table-1: List of ‘hard’ parameters

Sl.	Category	Parameters

[1] These parameters do not necessarily appear in the BFSCDA checklists, therefore the safety requirements that we discuss here are not BFSCDA regulatory criteria. All of these hard parameters, however, are part of the BNBC-93.
[2] For example, road width, announcement system should be part of means of escape, rather than precautionary requirements to limit fire growth.

Sl.	Category	Parameters
1	Precautionary Requirement	Announcement system
2		Boiler room
3		Command center
4		Emergency light
5		Fire damper
6		Road width
7		Vent area
8		Vent opening
9	Means of Escape	Corridor height
10		Corridor width
11		Door height
12		Door width
13		Exit door rating
14		Exit sign & illumination type
15		Exit sign letter size
16		Fire exit
17		Horizontal exit
18		Stairway width
19		Travel run
20	In-built Firefighting Facilities	Fire extinguisher
21		Fire pump
22		Water tank

3.3. Performance Grading Scheme

During the field inspection of the garment factories, each of the 'hard' parameters is given a grade point, x_i in equation 1, for each factory, ranging from 0 (zero) to 4 depending on the factory's performance, where 0 (zero) depicts the absolute absence and 4 represents a 100% compliance in that specific parameter. For some of these structural parameters, there are prescribed standard values in the BNBC-93 or Bangladesh Gadget, which are directly used as the standard for measuring and comparing the present status of the parameters. The performance in some of the parameters was difficult to measure quantitatively, and grade points are awarded based on qualitative observation in these cases. The scale of grading has been formulated by consultation with the experts, management of the garments factories, workers of the garments and BFSCDA officials. Table-2 presents the grade point used for quantitative and/or qualitative measurement of the ‘hard’ parameters. For parameters where quantification was possible, the grading strategy is based on the measured quantity. For example, according to BNBC-93 width of stairway should be minimum 1.5 meter. If any garment factory possess the stairway width of 1.5 meter it is awarded with a grade point 4, but if the width is 1.05 meter, then it has a 30% deviation from the standard value, and thus assigned a grade point 2 as per Table-2. ‘Soft’ parameters are graded in a range from 1 to 5 and this grading scheme is available in Wadud et al. [19].

Table-2: Grade point for ‘hard’ parameters

Grade point	Subjective observation	Quantifiable parameters % deviation from ideal case
4	Excellent	0 (zero)
3	Good	Less than 10%
2	Average	From 10% to 30%
1	Poor	More than 30%
0	Very poor	Not present

3.4. Development of Weights

The weight, w_i of equation 1, reflect the relative importance or potential consequences of the parameters in terms of fire safety. This weight values have been collected from the experts’ panel consisting of both academics and professionals who are directly involved with fire safety or disaster management. This panel includes 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 the National Housing Authority (NHA) of Bangladesh, and an urban risk reduction specialist from the Comprehensive Disaster Management Program (CDMP) of Bangladesh. To guide the perception of the experts regarding the relative importance of the parameters [11], a 'weighting scheme' (Table-3) along with the parameters list was explained to the experts. When an expert considered that deficiencies in the specific parameter will cause high damage to both life and goods, he/she awarded the parameter with maximum weight of 5 and when the expected damage is minimal, it was given a minimum weight of 1. Based on their own judgment and experience in fire safety, experts provided the weights of the parameters as in Table 3, independent of the grades as in Table 2.

Table-3: Definition of weights for each parameters

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

In this research, we have taken the arithmetic average for the weights of each parameter. To ensure that the weights are not influenced by one or two extreme values, we remove the maximum and minimum weight for each parameter and then average the weights for remaining eight experts and calculate the FRI. Table-4 provides the weight value of the 'hard' parameters. Our earlier work also shows that the FRIs for soft parameters were not sensitive to the use of 8-expert or 10-expert averaged weights, indicating a good degree of agreement between the experts. Detail description of this procedure and the weight value of the 'soft' parameters can be found in Wadud et al. [19].

Table-4: Weight of 'hard' parameters according to their rank

Rank	Parameters short name	Parameters Description	Weight
1	Road width	Road width in front of the building for free movement of fire fighting vehicle	4.75

Rank	Parameters short name	Parameters Description	Weight
2	Stairway width	Width of stairway	4.63
3	Water tank	Presence of water tank	4.63
4	Fire pump	Availability & function ability of fire pump	4.38
5	Announcement system	Existence of announcement system	4.25
6	Boiler room	Segregation of boiler room	4.13
7	Command center	Existence of command center	4.00
8	Travel run	Length of maximum travel distance towards exit	4.00
9	Door width	Width of doorway	4.00
10	Exit sign & illumination type	Availability of exit sign & illumination type	4.00
11	Fire extinguisher	No of fire extinguisher	4.00
12	Fire exit	No of fire exit	3.88
13	Corridor width	Clear width of the corridor	3.88
14	Fire damper	Installment of fire damper within air-conditioner & ventilation ducts	3.63
15	Emergency light	Presence of emergency light	3.63
16	Exit door rating	Fire rating of exit door	3.63
17	Horizontal exit	Availability of horizontal exit	3.50
18	Vent area	Vent area to floor area ratio	3.38
19	Door height	Height of doorway	3.25
20	Corridor height	Clear height of the corridor	3.13
21	Exit sign letter size	Letter size of exit sign	2.88
22	Vent opening	Vent opening in any direction	2.50

3.5. Data Collection

To determine the risk index of the garment factories, total 60 factories of Dhaka city have been surveyed in 2011 between May and September. These factories are expected to be representative of the current state of the RMG sector substantially. Due to limited resources and lack of time, out of six major regions of Dhaka city where garment factories are clustered, two regions - Mirpur and Tejgaon - were selected for this research. 35 factories from Mirpur area and 25 from Tejgaon area were surveyed, the location of which are presented in Fig. 3. Number of employees of each factory was either directly collected or calculated. Membership status of the factories in trade bodies such as Bangladesh Garment Manufacturers and Exporters Association (BGMEA) was collected from the BGMEA directory.

Note that these are the same 60 factories for which Wadud et al. [**19**] calculated the FRI for 'soft' parameters. Therefore the randomness of the factories is the same as those, while the surprise element of the survey visit was also maintained in order to avoid the announcement bias. However, we recognize that for 'hard' parameters announcement bias may not be as important as the 'soft' parameters, given the conditions of the 'hard' parameters are difficult to change overnight. The same two surveyors (of whom one is a co-author) carried out the surveys at every factory, and agreed on grades in every parameter, potentially removing any bias during inspection.

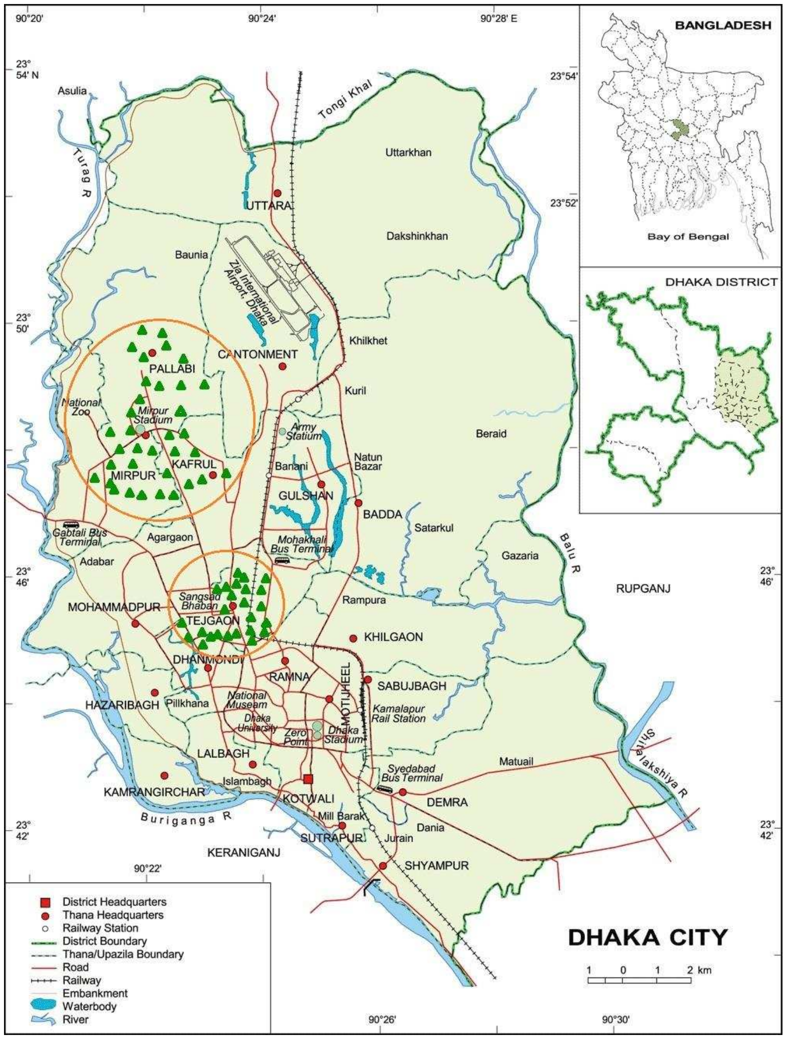

Figure-3: Location of garment factories surveyed in Dhaka city. Orange circles indicate the region and green triangles indicate the factory locations. [source: [2], edited by the authors]

4. Results

4.1. Fire Safety Status for ‘Hard’ Parameters of the Garment Factories

In our grading strategy, a higher FRI means a lower fire risk. Fig. 4 represents the distribution of FRIs for all the factories. Mean FRI for all the ‘hard’ parameter is 2.58 which is significantly below from the ideal value of 4. Only 10 factories (16.67% of the total sample) are in ‘Good’ condition with a deviation of less than 10% from the standard value.

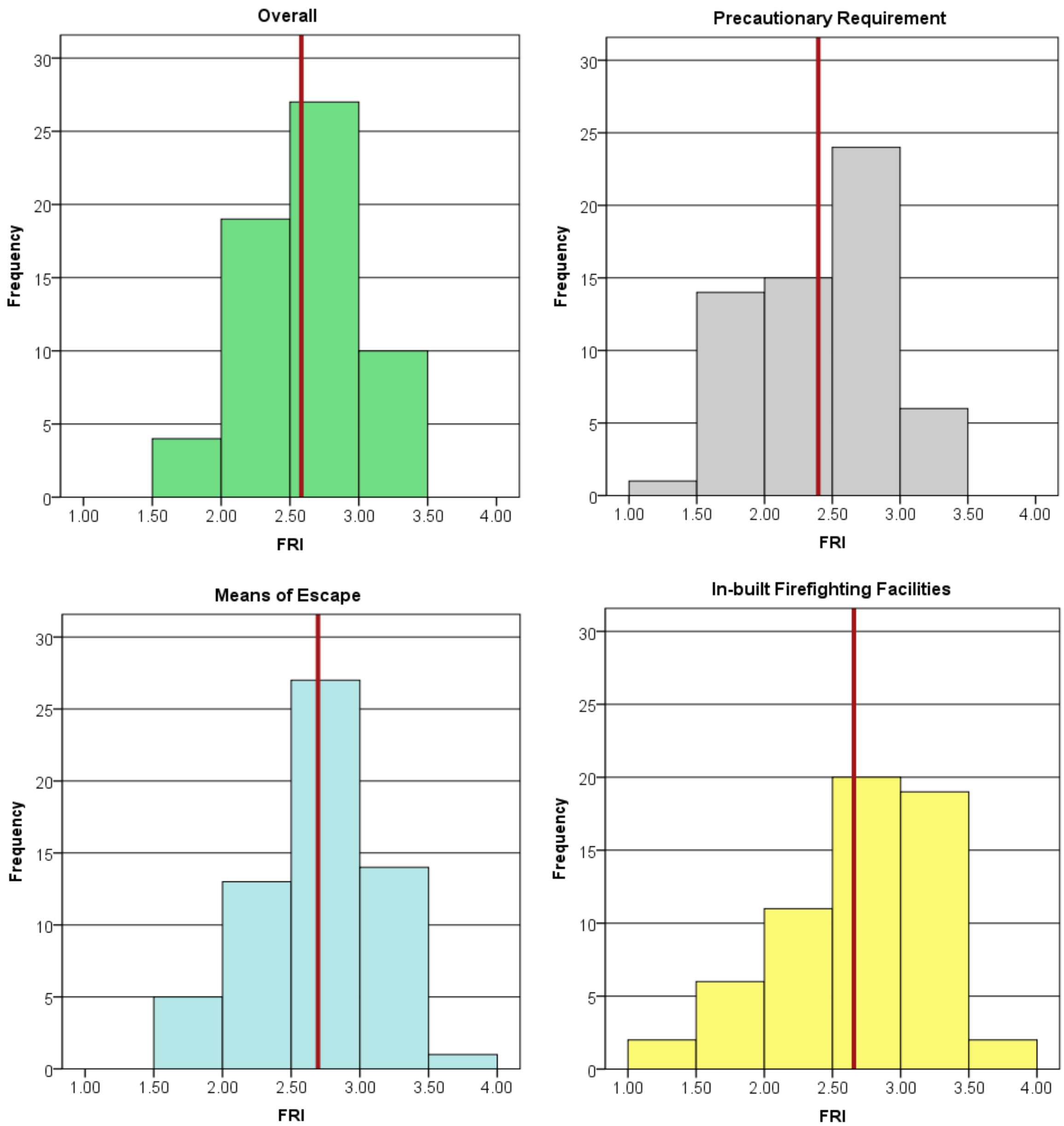

Figure-4: Frequency distribution of FRIs for 60 factories. Dark red vertical lines represent the mean FRI.

FRIs in 46 factories (76.67% of the total sample) lie between 2 to 3, which means that most of the parameters in these factories deviate from 10% to 30% from the standard value. Looking at FRIs of individual groups of parameters, precautionary requirement section shows the worst scenario. The mean FRI for precautionary requirement section is only 2.40 which is much lower than the overall mean FRI of 2.58 and the difference is statistically significant with a paired t test ($t=5.13$, $p<0.01$). 15 factories (25% of total sample) have FRI from 1 to 2 with a deviation of more than 30% from the standard value. Only 6 factories scored FRI above or equal to 3.

Average FRIs for means of escape and in-built firefighting facilities are 2.70 and 2.66 respectively.

It is clear that there is more emphasis on the 'cure' measures than the 'prevention' measures in terms of fire safety in the RMG factories. This is possibly a result of the prevalence of an 'inspection' culture in addressing safety concern. The inspection culture focuses on monitoring and correcting any deviations of the hard parameters from an established set of criteria (e.g. in checklists). While the developed countries moved away from checklist and inspection paradigm to fire prevention and pro-active safety management, in developing and emerging countries inspection is still the dominant practice. The large frequency of fires in the RMG factories is also possibly a result of this lower emphasis in fire prevention in the inspection culture.

In order to analyze the performance of each 'hard' parameter of the factories, the average grade points of the 60 factories in each parameter (without experts' weight) are plotted as a box and whisker plot in Fig. 5, in decreasing order of importance of 'hard' parameter. The boxes represent inter-quartile ranges; dark red lines indicate medians and whiskers represent 5^{th} and 95^{th} percentiles. It is a matter of concern that out of 22 parameters only 12 have their median grade point 3. Nearly half of the factories of the total sample have scored 3 or less for 18 parameters. Only 2 parameters have median grade point 4, indicating excellent safety performance but these parameters are well down the ladder in terms of importance (weight), e.g. out of the 22 hard parameters door height and corridor height are ranked 19 and 20 respectively. 5 parameters have their median grade point of only 2 and alarmingly, these 5 parameters are among the most important ones in the eyes of the experts. Especially announcement system and command center possess high importance in maintaining a standard precautionary measure during an emergency. Presence of an emergency command center is a vital parameter for maintaining fire safety of garment factories but 75% of the factories scored below 2 in this specific parameter and only 2 factories out of 60 had a dedicated command center. The worst performance among all the parameters is the presence or absence of fire damper which has a median grade point of only 1 and some factories even score a zero, although the parameter is not among the high priority ones.

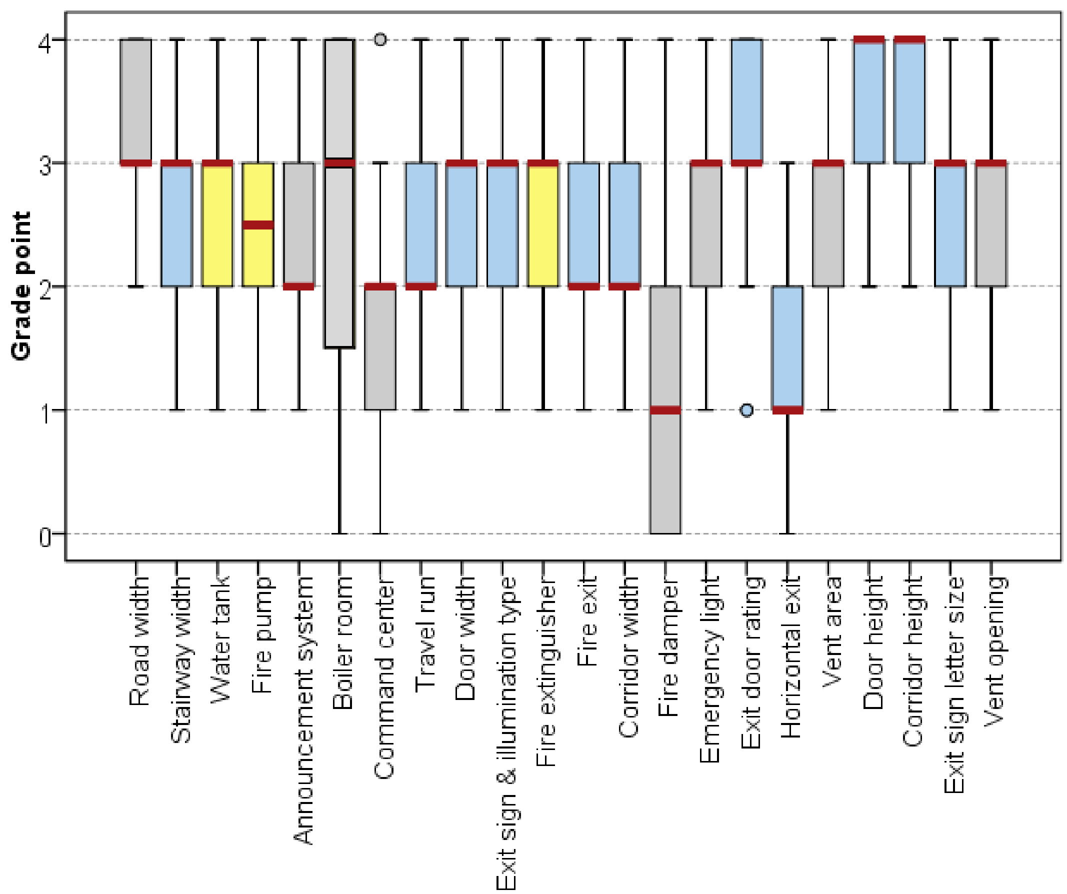

Figure-5: Box-plot distribution of grade point for all the 'hard' parameters in 60 factories. Color code indicates the category of groups (grey = precaution, blue = means of escape, yellow = firefighting facilities).

Our next analysis focuses on the BFSCDA checklist. Comparing the checklist with our parameters, we find 10 common ones. In an ideal scenario, all the garment factories should score a near perfect score for these checklist parameters, given the factories are all in use. However, the modified FRI (FRI_{chklst}) for these common parameters (i.e. when i in equation 1 presents the common parameters, n=10) is still only 2.74 which is well below the ideal value of 4. This indicates that there persists a large deviation between BFSCDA certification and 'on-site' fire safety performances. Considering only the additional 12 parameters in our study, the modified FRI (FRI_{add}) is 2.44, which is statistically smaller than FRI_{chklst} (paired t test, t=9.02, $p<0.01$). Thus the presence of the parameters in the certification checklist improves the performance in those factors, although the absolute performance is still of concern.

4.2. Fire Safety Status and Factory Type

An important objective of this research is to investigate any relationship between fire safety performance and factory characteristics such as the size or location or membership of the trade body, BGEMA. In Fig. 6, the FRI indices for the hard parameters of the 60 factories are plotted against the factory size, where factory size is proxied by the number of employees. Although no statistical test is carried out, it appears the relationship can be represented by a broad-brush U shaped curve. This is similar to Wadud et al.'s [19] earlier finding for soft parameters, and supports the Kuznet's curve hypothesis [10] in fire safety in the RMG industry of Bangladesh.[3] A Pearson's correlation coefficient of 0.01 indicates that no linear relationship exists between factory size and its FRI.

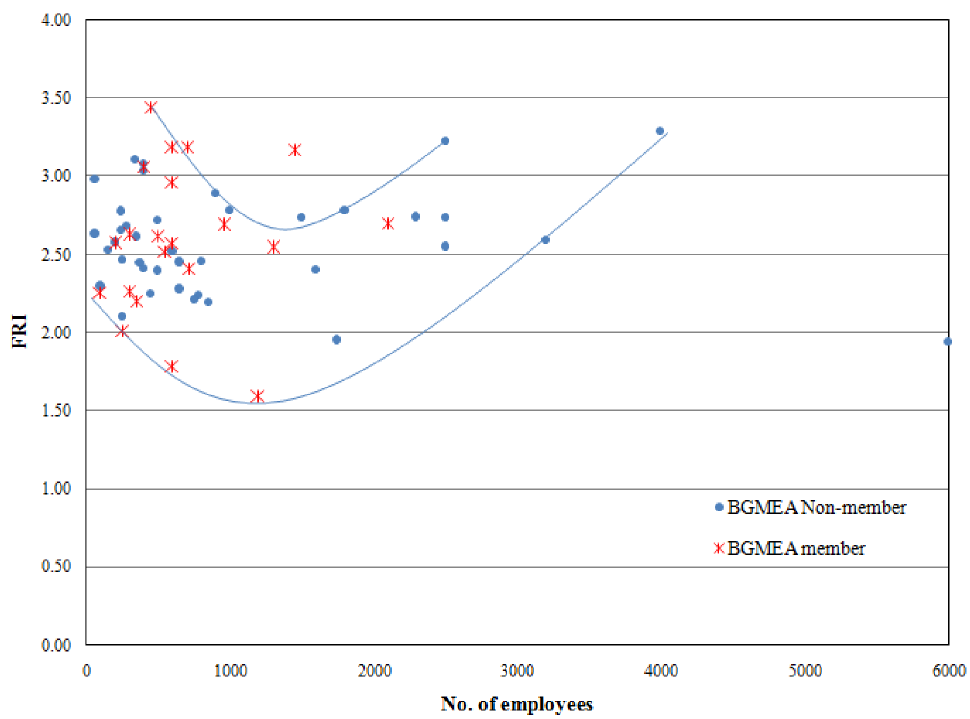

Figure-6: Scatter plot of FRI of 'hard' parameters versus the size of factories.

Next, we investigate the effect of membership of the factories in the trade body, BGMEA, the hypothesis being that the member factories would be better informed about and more willing to

[3] Kuznets hypothesized that as countries grow wealthier environmental pollution increased but then reduces as the wealth reaches a threshold. In fire safety this is possible as concerns for fire safety may not be a priority during the initial phases of growth of a factory, but beyond a threshold size, worker power may become important and management becomes more worker friendly and improves fire safety performance.

ensure worker safety. The spider diagram in Fig. 7 plots the average grade points (non-weighted) for each of the hard parameters for member and non-member factories which reveals that the average FRIs for member and non-member factories are similar (2.59 vs. 2.58). However, comparing the FRI for the 10 most important 'hard' parameters (FRI_{top10}) as per Table 4, we find that BGMEA member factories are marginally better off than non-member factories (2.67 vs. 2.57). A two sample t test (t=4.52, p=0.07) provides statistical justification to this finding.

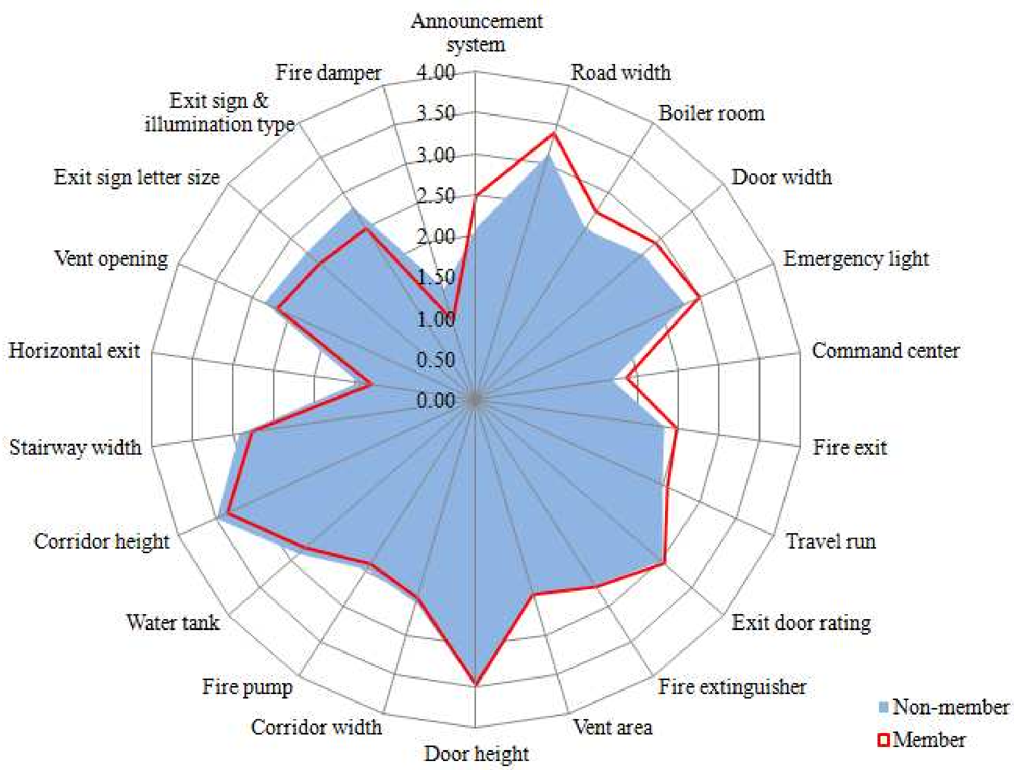

Figure-7: Spider diagram for average scores of 'hard' parameter of the garment factories based on BGMEA membership status.

Our next categorization is based on building usage type. As per BNBC-93, every building is classified into 13 categories according to its occupancy or use type. RMG factories are designated the occupancy type 'G' within the industrial use types. This means that any RMG factory should be located only in buildings which have been designed for occupancy types 'G' (G1 or G2). However, in practice, many of the RMG factories are housed in buildings which do not comply with the 'G1' or 'G2' criteria. Out of the 60 garment factories, 43 factories were correctly operating in buildings are categorized as either 'G1' or 'G2'. The rest 17 (28.3% of the sample) are operating in buildings which were originally designed as offices or markets. Clearly, RMG factories which are housed in proper 'G' type building should have a better fire safety status than other factories. Based on the occupancy type of the factories, the modified FRI (FRI_G) for 'hard' parameters of these 43 factories is 2.73 while for rest 17 factories FRI_{NonG} is only 2.22. The difference is statistically significant through a two sample t-test ($t=5.96$, $p<0.01$). Therefore flouting the regulatory requirements clearly undermines the fire safety condition of the factories. It is vital that such regulatory violations are curbed through establishing appropriate governance and institutional framework.

5. Comparison of Safety Performance between 'Hard' and 'Soft' Parameters

One of our major objectives of this research is to compare the safety performance of the RMG factories with respect to 'hard' and 'soft' parameters. As mentioned earlier, the 'soft' factors are those that can be changed very quickly due to changes in management practices. Table-5 depicts the list of 'soft' parameters. Wadud et al. [19] argued that the 'soft' parameters are crucial in understanding the fire safety performance of the RMG factories in Bangladesh and other developing countries since they can deteriorate very quickly due to incompetent management practices. Figures 8-10 show examples of the importance of the 'soft' parameters, where the 'hard' conditions are met, yet management practices nullify the objectives of the 'hard' parameters.

Table-5: List of 'soft' parameters according to their rank

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

[source: Wadud et al. (**16**)]

Detail description of the FRIs for the 'soft' parameters and their relationship with factory size, location or membership in BGMEA are available in Wadud et al. [19]. Although in Wadud et al. [19] the 'soft' factors were graded from 1 to 5, we recalibrated those from 0 to 4 for ease of comparison in this paper. Fig. 11 presents the distribution of hard and soft FRIs for all 60 factories. The mean FRI for all 'soft' parameter was only 1.80 whereas for 'hard' parameter it is 2.58. A paired t-test indicates the difference to be statistically significant ($t=15.25$, $p<0.01$). Therefore, on average, the factories perform better in the hard parameters. It is also clear that but for two factories, the FRIs for soft parameters are consistently worse than the FRIs for hard parameters. The fire safety performance in the soft parameters is clearly quite alarming in comparison to the hard parameters. The poor FRIs in the soft factors show a clear lack of day-to-day safety culture among the RMG management.

Figure-8: Soft factors: Exit door meets regulation, but blocked.

Figure-9: Soft factors: Exit corridor width meets regulation but reduced in practice.

Figure-10: Soft factors: Stairway width meets regulation but reduced in practice.

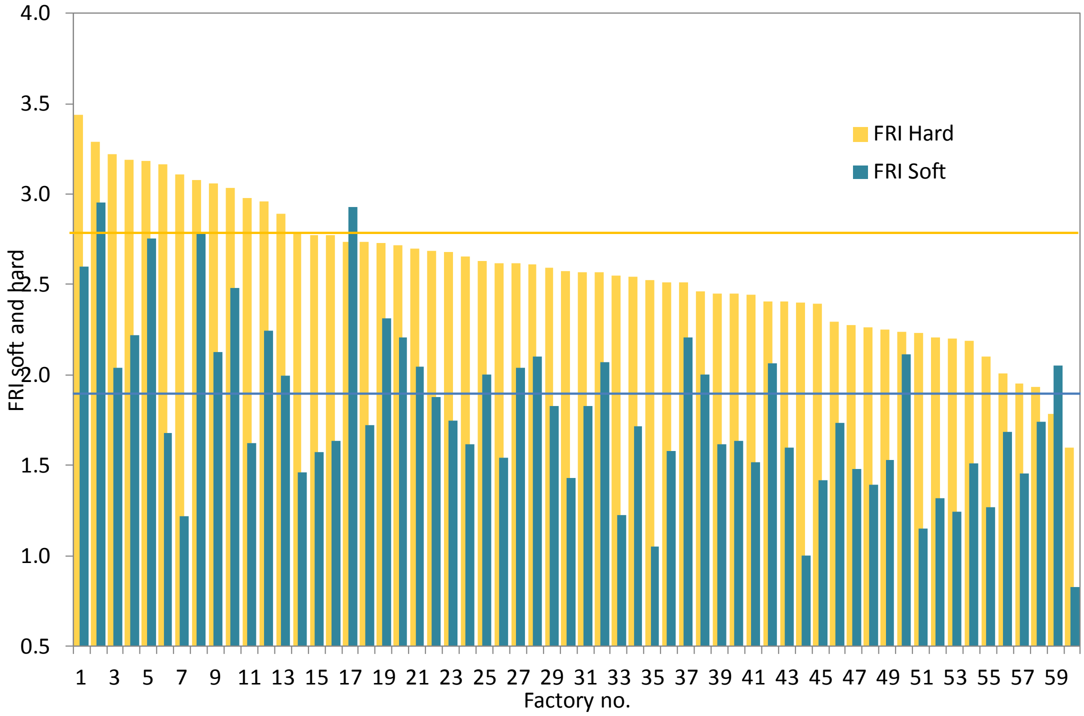

Figure-11: Distribution of FRIs for hard and soft parameters for 60 factories.

Fig. 11, however cannot reveal if the factories consistently perform well in both types of safety factors. It is expected that the fire safety performances with respect to both types of parameters would be correlated since owners and managers who are committed to better working and safety conditions should strive to improve both structural and managerial factors. We therefore plot the FRIs for hard and soft factors of the 60 factories as a scatter plot in Fig. 12. Generally, a broad-brush trend can be observed, i.e. factories which have a larger FRI in the hard parameters, tend to have larger FRI for soft parameters, too. A trend line (dashed in Fig. 12) however shows that the correlation between the two is not high - only 33% of the variations in the FRI for the soft factors can be explained by the variations in the FRI for hard factors. A closer inspection shows two groups of factories. In group one (shaded orange) there appear to be a general agreement between the FRIs for hard and soft parameters, with relatively low dispersion. In group 2, (shaded blue) the FRIs for hard parameters are relatively high, but the FRIs for soft factors are widely dispersed, indicating an apparent breakdown of the correlation between the two.

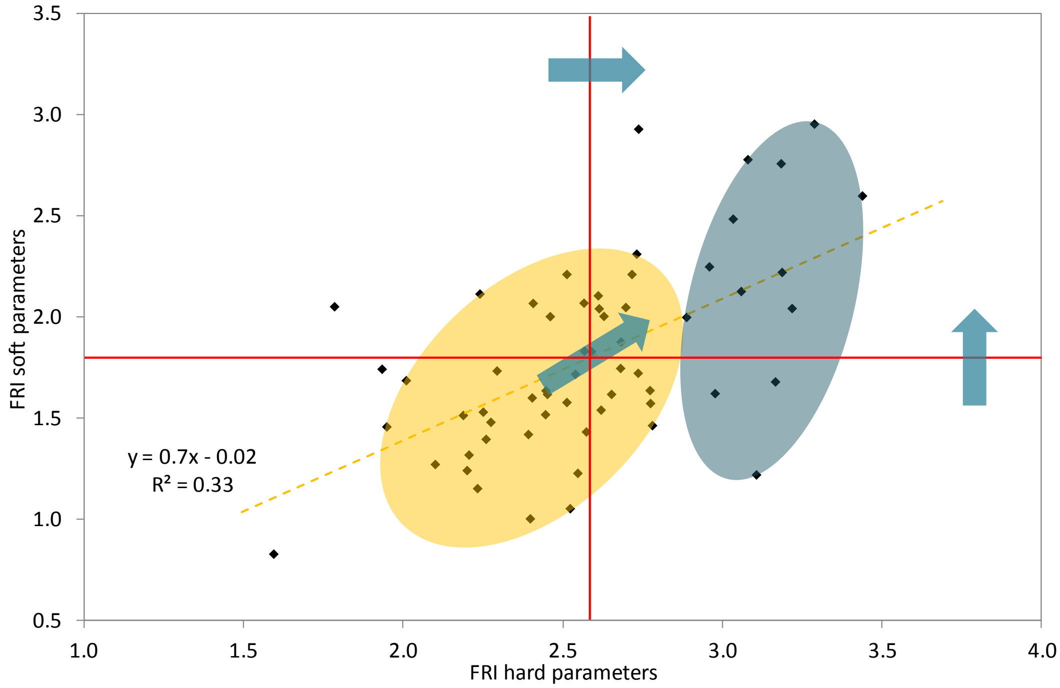

Figure-12: Scatter plot for FRIs for soft and hard parameters.

Fig. 12 also helps understand the measures that need to be taken to improve the fire safety performance in the factories. The two red lines represent the average FRIs with respect to the hard and soft parameters. Assuming the average FRI of this current sample as 'target' FRIs (acknowledging it is a very low target indeed), the 7 factories on the top left quadrant need to improve their structural safety, while the 10 in the bottom right need to improve their day-to-day management practices. The 24 factories in the bottom left need improve both. It would have been useful if the factories in the two groups shaded by colour or those in the four quadrants could have been characterized on the basis of size, ownership, management structure or other characteristics; however this is beyond the scope of current work.

The impact of BGMEA membership on the FRI is more pronounced for the soft parameters than for the hard ones. As mentioned earlier, for average FRI of hard parameters there were no difference between BGMEA members and non-members, but for soft parameters the FRIs differed at 85% confidence level (1.89 vs. 1.75). For the 10 most important parameters, the BGMEA factories are better for both hard and soft parameters.

6. Conclusions

This research had three objectives: developing a FRI for hard or structural parameters affecting fire safety in the readymade garment factories in Bangladesh, unearthing any relationship that may exist between factory characteristics and its fire safety performance, and finally comparing the FRI with respect to structural and management oriented factors. Across the 60 factories surveyed, we find a mean FRI of 2.58 for structural factors in a scale of 4 to be less than satisfactory. This is, however, better than the mean FRI with respect to the soft factors, which is only 1.82 on a similar scale, indicating the poor 'in-use' safety conditions in the factories. Combining them both, an overall mean FRI of 2.12 for the 60 factories also indicates an alarming condition.

The poor FRI in the hard parameters means substantial investment is required to improve the safety performance related to these structural parameters. Regular monitoring and enforcement is important in maintaining the structural parameters in satisfactory condition. Simple measures such as enforcing the regulation that the factories are housed in buildings designed for the appropriate occupancy type could improve the fire safety substantially (from 2.22 to 2.73). Our research shows that there is a larger reliance on firefighting and fire escape measures than on precautionary measures to limit the growth of a fire. This possibly explains the frequent occurrence of fire incidents in the RMG factories in Bangladesh. It is therefore also important to change the fire management culture from 'damage control' to 'incidence avoidance'.

Although we categorized our 'hard' parameters among three categories according to BNBC-93, review of literature on fire safety shows that many of these parameters need to be reassigned to different groups. Especially, most of the parameters in the precautionary measures of BNBC-93 (and as such, here) would most likely fall within the means of escape category in other fire indexing methods. Therefore, the building code should be corrected to resolve these discrepancies.

The even poorer FRI for management-related soft factors can be more crucial. Compared to the hard factors, conditions of the soft parameters can be substantially different between two days, thus affecting on-site the risks rapidly. A good performance in hard factors, which is generally part of compliance checklists could make the management complacent and ignore the importance of the soft parameters. At the same time, the poor performance in the soft factors offers the opportunity for the RMG factories to improve their fire safety conditions rapidly. Improvements in the soft parameters will likely require much less capital investment (compared to hard parameters), especially some of the most important soft parameters, where performances are the poorest require little investments to improve. These soft parameters are: locked exit, partially or fully blocked exits and corridors, workability of announcement system, fire drills and training of fire extinguisher operators. However, maintaining an acceptable level of safety in the soft factors requires continuous monitoring from the management and a change in the safety culture and practices, which is more difficult. Sudden, unannounced monitoring from the regulatory authorities can also help improve these factors.

Attempts to recover any relationship between the deficiencies in management practices and limitations in structural factors in fire safety were moderately successful. In general, factories tend to perform similarly in both the factors (i.e. linear), although the relationship is statistically not very strong - especially at higher end of the FRIs for hard factors, the relationship between the FRIs of hard and soft factors is quite weak. However, FRIs for hard and soft factors both tend to follow a U shape relationship with factory size, which indicates the potential presence of Kuznets curve in fire safety.

Because of the ongoing efforts of the Alliance and the Accord on improving the worker safety conditions in the RMG sector in Bangladesh, it is expected that the fire safety conditions have improved recently, especially in the hard factors, given that is the major focus. However, our work still remains important for at least two reasons. Firstly, along with Wadud et al. [**19**], this study forms the only 'baseline' of the original conditions of fire safety in the RMG sector in Bangladesh against which the recent results can be compared to measure the improvement in the industry and the effectiveness of the recent efforts. Secondly, the checklists used in the recent surveys are still dominated by hard parameters and have limited application in understanding the management-related day-to-day fire safety factors, which can be vitally important in practice.

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