



Assessment of Health, Safety and Environmental Risk Factors in Garments Industries of Bangladesh

S. M. Tazim Ahmed*, Chitra Lekha Karmaker, Md. Emon Ahmed

Department of Industrial and Production Engineering, Jashore University of Science and Technology, Jashore, Bangladesh.

PAPER INFO	ABSTRACT
<p>Chronicle: Received: 21 June 2019 Revised: 20 August 2019 Accepted: 22 September 2019</p> <p>Keywords: Occupational risks. OSHA Guidelines. AHP. QFD. Garments Industry. Sustainability.</p>	<p>The Ready-Made Garment (RMG) sector, the highest earning foreign currency segment, has had a great influence on GDP (gross domestic product) since 1980. With new technology adaption as well as cheap labor force, this sector has placed the second position of exporting after China. To capture the market position, the management has to give more attention on maintaining Safety, Health, and Environment (SHE) guideline properly. This paper proposes a structured framework for occupational risk assessment by means of quantitative way and also provided remedies of those risks in garments industry in the context of Bangladesh. Here, the Analytic Hierarchy Process (AHP) method is applied for measuring the severity of safety, healthy, and environmental risk factors and QFD to prioritize the possible solutions. Through the literature review and extracting opinions from experts, a total of four evaluation criteria and sixteen risk factors under SHE categories are recognized and examined via AHP approach to measure their importance. The results demonstrate that ‘Fire’ ‘Contagious diseases’, and ‘Noise’ take high priority in safety, health, and environment related risk factors. The findings of this paper may help the garment industry effectively through the proper identification of the most influential risk factors and generating solutions to mitigate this issue.</p>

1. Introduction

Recently, the occupational risk assessment (safety, health, and environment related risks), a strong health and safety policy have gained popularity among researchers and industrialists due to government regulations, unexpected incidents, customer expectations, and foreign pressures imposed on manufacturers for exporting cloths. A health and safety program of any industrial establishment has many salient opportunities like increasing public perception, reducing frequent incidents, minimizing legal liabilities, etc. When workers work in an unsafe environment, their mental stress is raised. Moreover, safe and health working environment helps to increase productivity as well as quality of the product. Therefore, researchers and stakeholders are trying to identify the factors related to the risk and hazards of occupational health and safety [1].

The Ready-Made Garments (RMG) industry, a promoter of the prosperity of Bangladesh, has brought a revolutionary change in our economy. It is the highest earning foreign currency segment in

* Corresponding author
E-mail address: tazim_ipe@just.edu.bd
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Bangladesh and day by day it is capturing the global market. This lucrative multibillion dollar industry has brought a fortune for rural communities especially for women. Although this segment has rapid growth and luminous expectations, there are many affluent challenges that need to be overcome. It is a matter of great sorrow that the overall environment of this sector is not satisfactory. Major Dhaka incidents like Tazreen fire in November 2012 and the Rana Plaza collapse in 2013, etc were some examples of it [2]. Now, the RMG industry in Bangladesh is facing tremendous global pressure for ensuring occupational health, safety, and environment program. To stay in the competitive market as well as preserve the flow of socio-economic advancement, it is crucial for the improvement of its workplace health, safety, and environment.

1.1. Importance of the Study

Few studies were conducted to examine the current scenario of occupational health, safety, and environment management in RMG industry of Bangladesh. But all works are theoretical not quantitative. Hence, this study adopts RMG industry as an example application of occupational risk factors (safety, health and environment) identification and finding possible solutions to ensure good working condition. This study may help garment manufacturers and industrial managers to improve the workplace conditions for their workers. It may also help to improve the business efficiency as workplace condition is closely related to workers' productivity.

1.2. Objectives of the Study

The proposed approach has the following objectives:

- To identify workplace health, safety, and environmental risk factors in garment industry of Bangladesh.
- To analyze these risk factors in a quantitative way.
- To identify some solutions and prioritize those.

To fulfill these objectives, the authors have adopted a two-phased methodology which includes 1) identification of risk factors and their relative impacts based on feedback from different industry experts using AHP approach, and 2) developing possible solutions for mitigating those risks and their severity with the help of QFD method.

2. Related Works

2.1. Workplace Health, Safety and Environment (HSE)

Industrial work has become very risky in many economic sectors like construction industry [3], apparel and garments industry [4], and manufacturing industry [5]. Many safety, health, and environment related problems can arise from any of several combinations of causes, which vary from one industry to another. Workplace safety, health, and environment in garments industry are major issues of concern in Bangladesh because a significant amount of people work here. The most effective way to improve safety, health, and environment of workplace is to identify the risk factors and reduce them. Therefore, the occupational risk assessment has become an obligatory process for garments industry [6].

Several authors have worked on this topic. Mehta identified some occupational health hazards like musculoskeletal pain, headache, eye strain, etc. among workers in garment factories of India [7]. Another study was conducted by Padmini and Venmathi on unsafe working environment of garment

industries [8]. They measured different work environment parameters such lighting, temperature, noise, etc. and found that due to congested work area, poor ergonomic workstations, poor illumination, and improper ventilation, most of the health hazards occur. Most of the workers in garment industry suffer from musculoskeletal disorders. Different personal and environmental factors are responsible for these disorders and health hazards [9]. Many garment factories in developing countries like Bangladesh suffer from these types of health and environment related problems [10-11]. These problems ultimately affect the overall production of garment because there is a strong relationship between the productivity of workers and risk of accidents in workplace [12].

Ahmed [13] conducted a study on Bangladeshi garment industries and identified that lack of ergonomic interventions in workplace results in many health related problems among operators and workers. Lindholm et al. [14] revealed that use of hazardous chemical in garment industry without proper safety initiatives results in dangerous consequences to environment and workers' health. Most of the garment factories in developing countries are not aware of conducting regular risk assessment program for workplace health, safety, and environment. Recently, the several factories have taken initiatives to conduct regular program due to some compliance issues [15]. Apart from these, researchers have conducted many studies to identify the relationships between the modern management practices and occupational health and safety [16-17].

2.2. Quantitative Risk Assessment

Many researchers and industry experts have attempted to adopt different MCDM tools for the assessment of occupational health and safety issues [18-19]. One of the advantages of MCDM methods is that it can be applied when there is a lack of availability of data [20]. Lang and Fu-Bao [21] applied AHP method to identify the influential factors of hazard in coal and mining industry. Ozfirat [22] integrated the fuzzy AHP with FMEA to evaluate occupational risk parameters. Seker and Zavadskas, [23] applied the fuzzy DEMATEL method for assessing relationships between different occupational risk factors on construction sites. Khandan et al. [24] used the fuzzy TOPSIS approach to analyze different musculoskeletal risks among workers for repetitive tasks. Occupational hazards and risks were identified and analyzed by Ramesh et al. [25] in another research. They applied the hybrid MCDM techniques for this assessment. Stefanović et al. [26] applied a different MCDM techniques for assessing occupational risks for female workers. Mohandes and Zhang [27] performed the fuzzy based risk assessment technique integrating MCDM in another study.

By analyzing above literatures, we chose the analytic hierarchy process to assess occupational risk factors due to its simplicity. Solutions from the experts for these risk factors were further analyzed for applying Quality Function Deployment (QFD).

2.3. Research Gap

After reviewing literature, it is obvious that a few theoretical works on occupational risk factors identification and assessment in the context of Bangladeshi garments industry have been conducted. But to improve the workplace conditions for their workers, it is very crucial. Therefore, it is imperative to quantitatively investigate workplace health, safety, and environmental risk factors in Bangladeshi garments industry. As such, this research focuses on the following research questions:

- What are the workplace health, safety, and environmental risk factors in garment industry?
- How can industrial managers can mitigate and reduce the impact of these risk factors?

- Can the results help managers formulate strategies to improve the workplace conditions?

3. Solution Methodology

In this section, the theoretical background of the present research has been discussed. The aim of this research was to identify safety, health, and environmental risk factors in garments industry in the context of Bangladesh. To achieve these objectives, the authors applied Delphi method, AHP, and QFD. Step by step process of current research has been presented in Fig. 2.

3.1. Delphi Method

The Delphi method is a structured communication technique that was originally developed as a systematic, interactive method of forecasting that entrusts to a panel of experts and stakeholders. The group of experts and stakeholders will receive various rounds of questionnaires. Their responses are aggregated and partitioned after each round with the group. In subsequent rounds, the experts are permitted to adjust the answers.

In the Delphi method, there is no hard and fast rule about the number of experts for data collection and analysis. Although, researchers have suggested taking 10 to 18 experts for getting good quality data [28]. In the current research, a total of fifteen occupational health and safety experts and managers were selected. These experts have sufficient knowledge about occupational health, safety, musculoskeletal disorders, and other environmental factors. A three-round Delphi method was conducted to identify the most relevant health, safety, and environmental risk factors of garments industry in the context of Bangladesh.

3.2. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty which is a structured methodology for ranking factors of complex environment [29]. It has been widely used in complex decision making and has large applications in different fields like business, industry, government, health care, etc. [30-31]. AHP has also been applied in occupational health and safety to show the interrelationship between different risk factors and problems and the influence on each other [32-34]. The steps of AHP method are presented below:

Step 1. Developing pair-wise comparison matrix.

In this step, a pair-wise comparison matrix A is developed for different evaluation criteria with the help of experts and using Saaty's scale (Table 1).

Table 1. Fundamental scale of Saaty [35].

Relative importance	Description
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2,4,6,8	Intermediate values

In the matrix A , each element a_{ij} represents the relative importance of i th factor over j th factor. If the number of factors is m , then the pairwise comparison matrix will be as follows:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1m} \\ a_{21} & 1 & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & 1 \end{bmatrix} \quad (1)$$

Step 2. Calculation of the relative weight of each criteria.

Relative weight of each criteria is calculated using the following equations:

$$C_{ij} = \frac{a_{ij}}{\sum_{j=1}^m a_{ij}}; j = 1, 2, \dots, m \quad (2)$$

$$w_i = \frac{\sum_{j=1}^m C_{ij}}{n}; i = 1, 2, \dots, n \quad (3)$$

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_n \end{bmatrix} \quad (4)$$

Step 3. Weight calculations of alternatives against each criteria.

In this step, the pair-wise comparison matrix of alternatives is developed for each criteria using experts' opinions. Relative weights are calculated using Eqs. (2-4).

Step 4. Composite weight calculation of alternatives.

Finally, the composite weights of alternatives can be calculated combining all the weights for different criteria.

3.3. Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a customer-oriented quality assurance and improvement tool that deals with the customers' problems and requirements systematically. The original introducer of QFD approach, Yoji Akao, has defined the QFD [36] as "a method for developing a design quality

aimed at satisfying the customer and then translating the customers' demands into design targets and major quality assurance points to be used throughout the design phase". The main purpose of this approach is to increase the customer satisfaction by identifying the most significant problems and their solutions through a quantitative analysis. In this research, QFD tool was used to identify and quantify the significant solutions of health, safety, and environment related problems in garments industry of Bangladesh.

The first step of QFD is precise identification and collection of problems. For the proper identification of problems, the questionnaire surveys are suggested [37]. Afterwards, the House of Quality (HOQ) can be constructed. The general structure of house of quality is presented in Fig. 1.

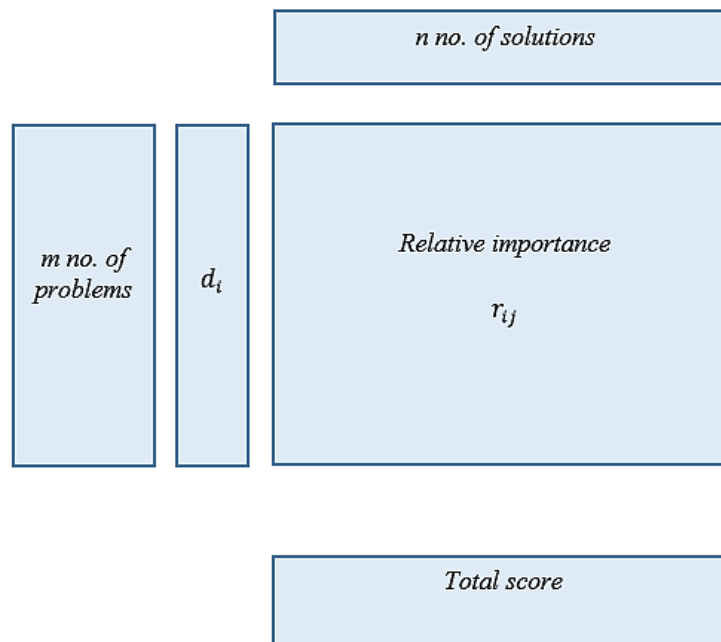


Fig. 1. Articulation among the components of basic HOQ.

Fig. 1 represents a HOQ, where m number of customer problems are represented in the left part. The importance of each problem is d_i , where $i = 1, 2, \dots, m$. So, the customer problems' importance matrix will be $(d_i)_{m \times 1}$. If there are n number of potential solutions against the problems then the affinity relationship matrix will be $(r_{ij})_{m \times n}$, where r_{ij} represents the influence of j th solution on i th problem and $j = 1, 2, \dots, n$ and the rating ranges from 0 to 10 where 0 indicates no relationship and 10 indicates a very high relationship.

Total score of each solution can be calculated as:

$$\text{Total score } T_i = d_i \times r_{ij}. \tag{5}$$

Relative score of each solution is calculated as follows:

$$RS_i = (T_i / \sum_{i=1}^m T_i) \times 100\%, i = 1, 2, \dots, m. \tag{6}$$

Ranking of solutions is developed according to relative score of solutions.

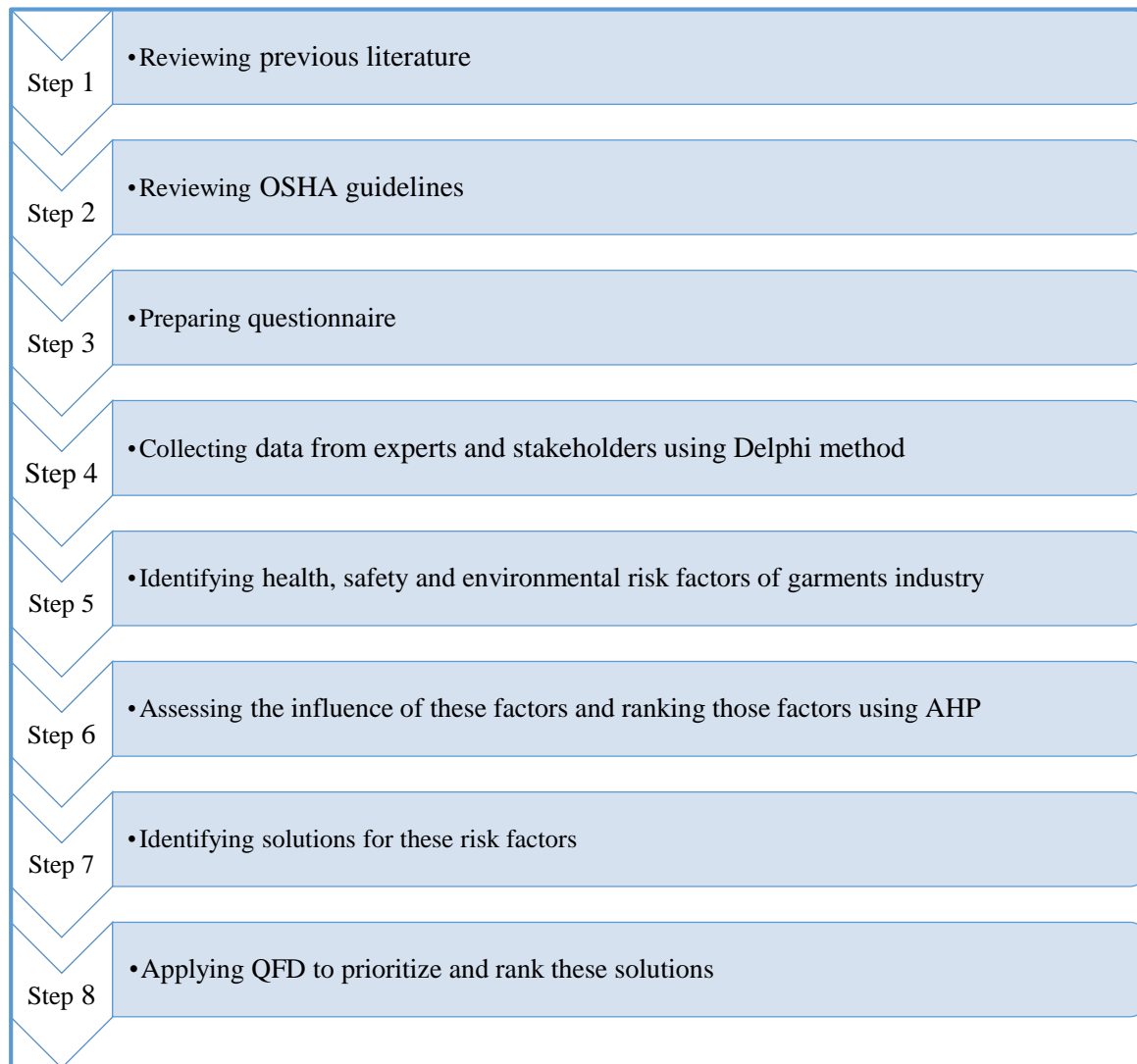


Fig. 2. Step by step methodology for the present research.

4. Results and Discussion

In this part of the research, the collected data from experts were analyzed to reveal the most significant risk factors and their solutions in health, safety, and environmental condition of garments industries of Bangladesh.

4.1. Evaluation Criteria Selection

In this research, four evaluation criteria have been selected by experts and stakeholders. These evaluation criteria are: (a) probability of occurrence, (b) associated cost, (c) severity, and (d) ease of mitigation. Health, safety and environment related risk factors were evaluated against these four criteria separately. Relative weight of each criterion was calculated using Eqs. (1-4). Fig. 3 shows the relative weight of each criterion. Severity has got the highest priority among all criteria with relative weight of 0.392. Relative weights of probability of occurrence and associated cost were 0.302 and 0.207, respectively. Ease of mitigation has got the least priority from the experts.

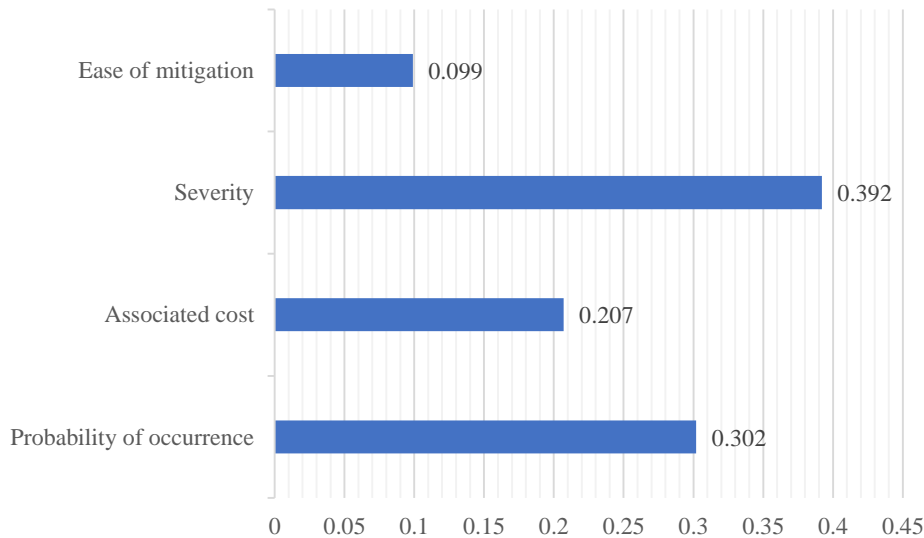


Fig. 3. Relative weights of evaluation criteria.

All the health, safety, and environment related risk factors have been identified by experts based on the frequency and occurrence of harm. Assessment of these risk factors have been performed based on the weights of the above criteria simultaneously through AHP. Some risk factors have severe impact on human and environment but their probability of occurrence is somewhat low. Whereas some of these risk factors have low severity but the probability of occurrence is so high. Again, ease of mitigation and associated cost with the occurrence vary from risk factor to risk factor. Although all of these risk factors have negative impact, the probability of occurrence is not the same. Therefore, all this considerations have been incorporated into AHP for risk factor assessment in the next step of this research.

4.2. Health Related Risk Factors and Their Solutions

There exists a significant amount of health related risk factors among the workers and employee in garments industry. Among these risk factors, the experts and stakeholders have selected four most common health related risks that prevail among the workers. These five risk factors are: (a) musculoskeletal disorders, (b) contagious diseases, (c) vision fatigue, (d) hearing loss, and (e) mental stress. Table 2 shows the final weights and ranking of health related risk factors.

Table 2. Final weights and ranking of health related risk factors.

	Probability of occurrence (0.302)	Associated cost (0.207)	Severity (0.392)	Ease of mitigation (0.099)	Final weight	Rank
<i>Musculoskeletal disorders</i>	0.372	0.089	0.172	0.239	0.218	2
<i>Contagious diseases</i>	0.085	0.344	0.343	0.153	0.251	1
<i>Vision fatigue</i>	0.143	0.315	0.223	0.133	0.211	3
<i>Hearing loss</i>	0.091	0.181	0.201	0.102	0.156	5
<i>Mental stress</i>	0.309	0.071	0.061	0.373	0.164	4

Contagious diseases were ranked as the most significant risk in health related problems in garments industry with final weight of 0.251. Most of the workers of garments industry in Bangladesh are not aware of contagious diseases. They have lack of awareness about these type of diseases. As significant amount of workers work together in a single floor, this risk factor (contagious diseases) may cause great harm to them. Musculoskeletal disorder is another significant risk factors in health related problems. Nowadays, it has become a common problem among most of the workers. Therefore, it was ranked second with relative weight of 0.218, next was ranked vision fatigue. Vision fatigue occurs to workers due to low light work environment. Mental stress is another common risk factor among workers. In Bangladesh, the average working hour for workers is about 10 to 12 hours. Therefore, most of the workers suffer from mental stress. Mental stress was ranked fourth in this study. Finally, hearing loss was ranked last. However, it has also significant and long term impact to the workers. Noise level in garments floor remains high during working time and workers are not aware of using ear protectors during work.

With identification of significant health related risk factors, this research also found some solutions for these problems with the help of experts. These solutions were furthered analyzed by applying QFD tool named house of quality. Table 3 shows the ranking of solutions to health related problems in garments industry. Developing awareness among employees and workers as well as top management can solve most of the problems. Therefore this initiative was ranked first. Top management of garments industry can provide regular health check-up to their employees and workers. This was ranked second in this research. There is a strong relationship between musculoskeletal disorders of workers and design of furniture they used. Therefore, ergonomic office furniture must be provided by the management to prevent musculoskeletal disorders. Moreover, awkward postures of workers are responsible for musculoskeletal disorders. Training and awareness about proper postures may help prevent these disorders. Proper work distribution is necessary to reduce the mental stress of workers. This was ranked sixth in this research. Different protective devices like noise reducer and proper light arrangement can reduce the problem of hearing loss and vision fatigue. Finally, provision of full time medical team was ranked last. However, it is very significant for every workplace.

Table 3. Ranking of solutions to health related risk factors.

	Weight	Developing awareness	Proper work distribution	Full time medical team	Ergonomic office furniture and equipment	Training	Providing protective devices	Ensuring hygienic meal	Regular health check-up
<i>Musculoskeletal disorders</i>	0.218	3	6	0	9	3	0	0	0
<i>Contagious diseases</i>	0.251	9	0	3	0	3	0	3	6
<i>Vision fatigue</i>	0.211	0	0	0	0	0	6	0	3
<i>Hearing loss</i>	0.156	0	0	0	0	0	6	0	3
<i>Mental stress</i>	0.164	6	3	0	3	3	0	3	0
<i>Total score</i>		3.90	1.80	0.75	2.45	1.90	2.20	1.25	2.61
<i>Relative score</i>		0.231	0.107	0.045	0.146	0.113	0.131	0.074	0.155
<i>Rank</i>		1	6	8	3	5	4	7	2

4.3. Safety Related Risk Factors and Their Solutions

Workplace safety depends on different factors. In this research, experts selected four significant risk factors for workplace safety in the context of garments industry. These factors are: (a) unsafe machinery, (b) hazardous chemical, (c) fire, and (d) workplace accident. Authors examined these factors applying AHP for better understanding them. Fig. 4 represents the final weight of these risk factors obtained by applying AHP. In safety category, fire is the highest-ranked risk factor with weight of 0.413. It has become a big issue for garments industries in Bangladesh. So, they should prioritize attention on this risk factor. Workplace accident is another significant risk factor and it occurs due to many reasons like slippery floor, etc. This risk factor has taken the second position in the ranking with weight of 0.309. Industrial managers should give proper attention to it. Unsafe machinery was next in the safety related risk category. Unsafe machinery may cause many serious accidents. Lack of proper maintenance is the main reason behind unsafe machinery. Finally, hazardous chemical was ranked last with value of 0.131. In garments industry, many hazardous chemical are used and workers often make contact with this type of chemical.

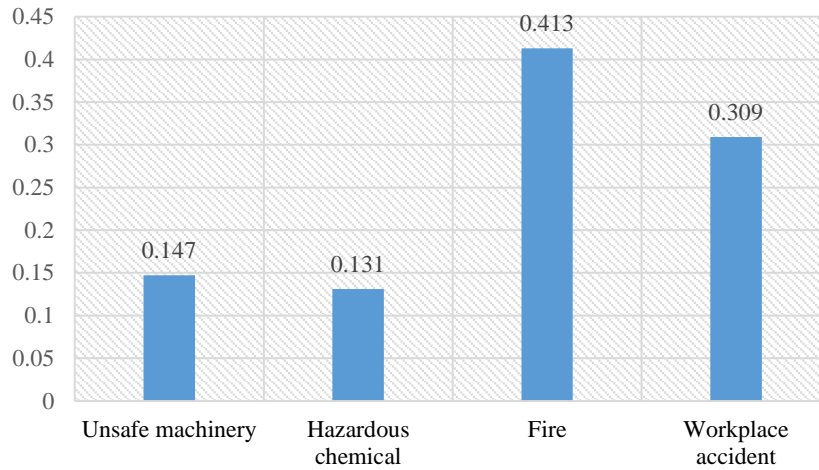


Fig. 4. Ranking of safety related risk factors.

After identifying safety related risk factors, this research identifies some solutions to these risk factors with the assistance of experts. These solutions were further ranked using QFD. Fig. 5 shows the ranking of these solutions to safety related problems. Provision for fire extinguisher in garments industry was ranked first with value of 0.284. Many garments lack fire protection systems and fire extinguishers in Bangladesh. Use of personal protective equipment was next in the solutions to safety related problems. Use of different safety and emergency sign was ranked third. This may reduce most of the safety related problems. Every building should have emergency exit for workers. Work floor should be kept clean to avoid different physical accidents.

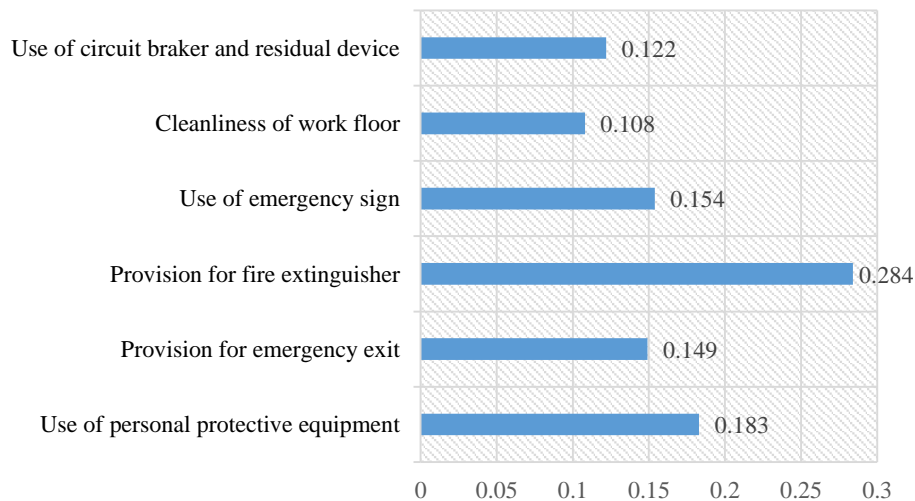


Fig. 5. Ranking of solutions to safety related problems.

4.4. Environment Related Risk Factors and Their Solutions

In the environment related category, seven risk factors were identified by experts in the context of Bangladeshi garments industry. These risk factors are: (a) poor lighting, (b) noise, (c) uncomfortable

temperature, (d) lack of pure drinking water, (e) lack of hygienic sanitary facility, (f) lack of hygienic dining facility, and (g) poor ventilation. Relative weights of these risk factors are presented in Fig. 6. Among these risk factors, noise was ranked first with value of 0.226. Different types of sewing machines make noise and this has a long term impact on workers and operators. Uncomfortable temperature was ranked second in the study. Poor lighting system is another common problem in garments industry. Poor ventilation system was ranked last in this research. However, it has a significant impact on workplace environment. Garments industry should give adequate attention to this problem.

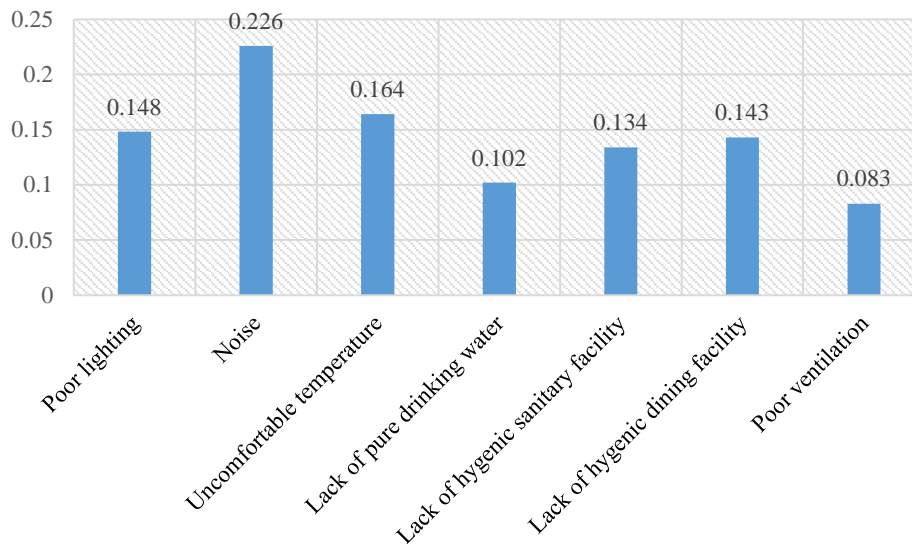


Fig. 6. Ranking of environment related risk factors.

This research found some solutions to environment related problems by consulting with industry experts. Fig. 7 shows different solutions and their ranking for mitigating environment related problems. Proper layout may reduce most of environment related problems. Therefore, this solution was ranked first by experts. Provision for hygienic dining facilities was ranked next. Most of the workers take their lunch in their working place. Therefore, hygienic food and dining facility must be ensured by the company. As workers spend most of their time in workplace, the proper air conditioning system is necessary for them. This initiative was ranked third in this research. Apart from these, awareness must be build up among workers about workplace environment issues. Top management can take initiatives to conduct regular program on this. Provision for pure drinking water is also a significant initiative that must be taken by the top management. Finally, facilitating adequate light was ranked last. However, it has also significant impact on the workplace environment.

The most influential risk factors for health, safety, and environment were revealed as well as some significant solutions were also identified. Although some uncertainty parameters exists in this whole process. Some of the risk factors have aleatory uncertainty as natural randomness exists in the occurrence of these risks. Some of the risk factors have epistemic uncertainty due to lack of prior knowledge and adequate data.

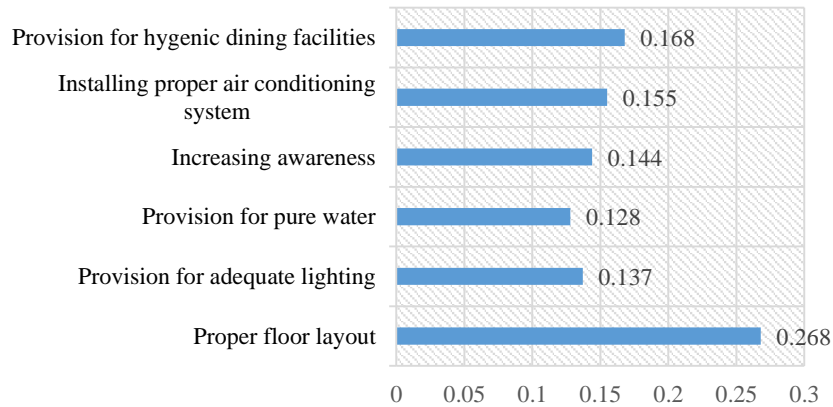


Fig. 7. Ranking of solutions to environment related problems.

5. Conclusions

Readymade Garments (RMG) industry has opened a new chapter to Bangladeshi people especially rural women. With rapid increase of GDP, it has changed the life style of many people through bringing them from four constrained wall. This Aladin lamp has placed second position in exporting cloths after china for its cheap labor and dense population. RMG sector is now facing some challenges and one of them is ensuring proper healthy and safe working environment with environmental issues. Some deadly incidents like Tazreen fashion fire, Rana plaza, ban of GSP facility by USA, etc. has pressurized RMG manufacturers to follow OSHA guidelines properly so that workers feel safe to work. A health and safe environment with environmental concern helps to reduce injuries as well as mental stress of workers which ultimately increase productivity and quality of product. So, to achieve the benefits, RMG industrialists must focus on the identification of the risk factors and formulate possible solutions for pursuing market position. To fulfill these objectives, the current research proposed a structured framework to sort out the safety, health, and environmental risk factors in the context of RMG industry in Bangladesh and developed possible remedies to improve the situation. Here, AHP approach was used to measure the severity of risk factors and QFD for generating remedies of those risks.

A total of 16 influential factors were considered under safety, health, and environment category and evaluated. Under safety category, 'fire incident' was the highest-ranked risk factor among four potential risks whereas hazardous chemical was the last ranked. Potential remedies for safety problems were 'Provision for fire extinguisher', 'Use of personal protective equipment', 'Use of different safety and emergency sign', etc. In this research, five most common health related risk factors were considered which were (a) musculoskeletal disorders, (b) contagious diseases, (c) vision fatigue, (d) hearing loss, and (e) mental stress. Among these risks, 'Contagious diseases' was the most significant risk followed by 'Musculoskeletal disorder'. 'Hearing loss' got the lowest priority. To reduce health related problems, the significant solutions were identified and some of them were 'Developing awareness', 'Regular health check-up', 'ergonomic office furniture and equipment', etc. Finally, under environmental risk category, 'noise' was ranked first with value of 0.226 and 'Poor ventilation system' was ranked last. For mitigating environment related problems, some possible solutions were generated and ranked with the help of QFD approach. 'Proper layout' may reduce most of environment related problems which is followed by 'Provision for hygienic dining facilities'. To protect this lucrative business, it is high time for taking proper measures so that a healthy and safe environment is ensured. Moreover, the government

should enforce laws and arrange different training program to raise awareness which ultimately raises our economy.

5.1. Limitations of the Research

Following are the limitations of the research:

- In this study, only four evaluation criteria and 16 risk factors were considered for evaluation.
- Feedbacks were collected from visiting 10 garments. This might not reveal the real picture of the business.
- The proposed methodology was applied in RMG industry as a case study which may not be applicable to other company.
- Workers couldn't explain their problem in quantitative way.
- AHP approach was used to rank the factors which is dependent on human judgments.

The limitations can provide a new way for future research.

5.2. Direction of Future Research

- In future, more safety, health, and environment related risk factors can be considered.
- The impact and interaction among these factors can be assessed using other MCDM techniques like VIKOR, PROMETHEE, etc.
- In future, the fuzzy environment can be considered.
- They may be assessed considering more RMG industries in Bangladesh.
- Proposed method can be applied in other industrial sectors such as Leather, Electronics, Spinning mills, Ship Building, pharmaceutical industries, and so on.

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