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Ensuring Occupational Health and Safety by Assessing Risks Embedded in the RMG Sector of Bangladesh through an Integrated Approach

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Abstract:- The ready-made garment sector in Bangladesh holds significant importance as the highest foreign currency earning sector. However, ensuring occupational health and safety within this industry has become a global priority due to past accidents and incidents. While several theoretical studies have identified occupational risk factors in the garment industry, most of these have solely focused on listing these factors without a comprehensive analysis. In reality, each risk factor must be individually assessed within the specific industry, necessitating close collaboration with employees working in that environment. Addressing these concerns, our research proposes a systematic process to quantitatively evaluate occupational risks and offer solutions for existing risks in the garment industry. To achieve this, we employed the AHP approach to estimate the impact of risk factors and adopted the GRA method to identify critical alternatives associated with these risks. By selecting and assessing five evaluation criteria and twelve risk factors, our research aims to effectively support the garment industry by identifying the most influential risk factors and proposing initiatives to address these challenges appropriately.

Keywords:- *AHP, GRA, Garment Industry, Quantitative Evaluation, "Occupational Risk."*

I. INTRODUCTION

The ready-made garment sector is one of the biggest industries in the world and employs millions of people. It consists of many processes, such as marking, lay planning, cutting, printing, sewing, washing, and finishing. There are several types of hazards found in garments industries, such as physical, electrical, fire, ergonomically caused, and physiological [1]. In a competitive market, the garment industry in Bangladesh is on the right track, but it still needs to ensure the proper rights of the workers effectively [2]. Unsound working conditions, low levels of safety in the workplace, low wages, and excessive workload are critical elements that can decrease the total production efficiency of the RMG factory. A healthy and safe working environment leads to higher productivity and quality of products. Besides, it ensures the proper workplace regulation of occupational health and safety rules. Statistically, about 6,300 individuals die daily due to occupational work-related problems worldwide [3].

The management must have a reliable technique to enrich productivity and deal with those criteria that can reduce productivity. Risk analysis is a process for evaluating potential risks associated with particular activities. Moreover, Risk assessment is a systematic way of analyzing and assessing hazards related to the project and creating a risk level for each hazard. Analysts and business experts have implemented different MCDM (Multi-Criteria Decision Making) methods to monitor occupational health and safety concerns. This study will integrate the AHP and GRA methods to find the best alternatives to eliminate the possible risk factors.

The research aims to examine the factors that pose risks, identify effective alternatives, and prioritize the critical alternatives for elimination through a quantitative ranking. Risk assessment is essential and will be done using the Delphi method, analytic hierarchy process, and grey relational analysis.

II. LITERATURE REVIEW

The garment industry in Bangladesh is facing significant challenges due to unsafe working conditions, lack of workplace safety, low wages, and excessive workload. To improve workplace conditions, it is important to identify and reduce risk factors. Risk analysis is a method used to identify potential hazards associated with specific activities, while risk assessment is essential in determining the level of risk for each hazard. Researchers and industry analysts have adopted different MCDM methods to assess occupational health and safety concerns. For example, Lang and Fu. Bao used AHP to identify key hazard factors in the coal and mining industries [4]. Esra Ilbahar and Kahraman integrated Pythagorean fuzzy AHP & fuzzy inference system to evaluate occupational risk parameters [5]. These challenges can reduce overall productivity but have not been fully resolved.

A. Related Study

Karmaker and Ahmed presented a paper on the analysis of health, safety, and environmental risk factors in the garments industries of Bangladesh. This paper proposed a systematic approach for the quantitative assessment of occupational risks and also provided remedies for these dangers in the garments industry from Bangladesh's perspective [6]. Hamja & Hasle assessed the effects of lean on occupational health and safety in the ready-made garment industry. The purpose of this study was to add to the existing knowledge on the relationship between lean and OHS in RMG Industry. Negative health impact on workers was found, like short-term muscle discomfort and a statistically significant increase in a negative impact on workers' health was found in the long term [7]. Polat & Kalayci used Rapid Entire Body Assessment (REBA) method to assess the ergonomic risk of garment industry workers. This paper investigated workers' working environments and physical workloads in a factory that produced baby towels, bathrobes, and sleeping bags. According to the study, workers could feel minor pain at first, but it could turn into incapacitating disorders over time. Repetitive body postures during forceful exertions negatively affect workers by causing musculoskeletal disorders [8]. Sharma presented a paper on poor work conditions in the RMG sector of Bangladesh. This paper reflected on the efficiency of labor legislation in Bangladesh and provided an overview of the objective impact of labor law in Bangladesh. The analysis revealed the shocking situation of the ready-made garment industry, where factory managers were likely to break the law and abuse the workers [9]. Lindholm and Ruden stated the impact of chemical exposure in the garment industry. This paper elaborated on the chemical risk factors in the garments industry. Solvents commonly used in spot removal operations involve perchloroethylene, methylene, chloride, and trichloroethylene. This paper suggested implementing the ILO project in the garments Industries. ILO project includes promoting decent working conditions, proper training for workers, correct utilization of Personal Protective Equipment (PPE), minimizing exposure through ventilation, and ensuring safe chemical storage [10]. Karmaker & Saha presented a case study report on constraints affecting the productivity of the ready-made garment industry in Bangladesh. In this paper, prospects, and constraints affecting the RMG sector's productivity were analyzed using the most commonly used multi-criteria decision-making method i.e. Analytic Hierarchy Process (AHP). Data were collected through a question-answer session and individual interviews with managers from the garment industry. Then data were aggregated and analyzed with the help of the AHP model. This paper found that unsafe working conditions, lack of security strategy, and financial reasons, among several challenges, affected the capability of workers and productivity severely [11]. Padmini and Venmathi studied the unsafe working environment of garment industries. It stated that a safe and inspired workforce is the secret to growth and economic development. There were some important parameters like lightning, noise, temperature, and humidity to which humans are exposed regarding the environment in which they live and work. This study measured the value of different parameters and showed the difference between the standard and measured values. Additionally, this study assessed the safety measures practiced in garments industries by using a checklist, and finally, it detected unsafe working environments in garments industries. This study revealed that noise level in the garment industry was relatively above the permitted level, and other metrics, such as humidity and temperature, were not at the acceptable limit [1]. Bakhtavar and Yousefi assessed occupational risk factors in underground collieries by integrating a multi-purpose cause-and-effect design methodology with an MCDM sensitivity analysis. This paper introduced a multi-goal fuzzy cognitive map (FCM) and multi-criteria decision-making method based on a sensitivity method for determining potential risks with work-related accidents in underground collieries [12].

These research works have discussed the identification and evaluation of occupational risk factors in the context of the Bangladeshi garment industry. It is observed that risk factors are identified only in some of the papers and are categorized and then assessed through different MCDM methods. It is also noted that different risk factors have different significance in different industries, so it is important to analyze the significance of the risk factors using expert opinion. The text also discusses the research questions that need to be answered, such as what are the significant risks involved with developing an accident and a vital alternative in the ready-made garment industry, which risk has the most impact on accidents, which alternative is vital to the success of the industry, is it possible to implement all alternatives at once in a Garment Industry, and what preventive measures are needed by industrial analysts to measure the frequency of accidents.

III. EXPERIMENTAL SECTION

A. Proposed Approach

The Delphi method, AHP, and GRA have been chosen to assess the critical alternatives and risk factors. The Delphi method involves preparing research questions, selecting experts related to the field of investigation, collecting data and methods for analyzing it, and finalizing the data [12]. It requires several rounds of questioning, and it requires two rounds of questioning. The experts are from HR and compliance departments, which are responsible for monitoring and ensuring occupational health and safety. The Delphi method is a better technique for the systematic communication of experts than carrying out a traditional survey.

B. Purpose of AHP and GRA Integration

The Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA) are two decision-making techniques used in different contexts, but their integration can provide a more comprehensive and robust decision-making framework. AHP is a structured method that helps in multi-criteria decision-making, while GRA evaluates the correlation between different variables and identifies the relative importance of each variable in relation to the decision criteria. The integration of AHP and GRA can provide several benefits, such as enhanced decision-making, improved accuracy, increased transparency, robustness, and flexibility. This integration enhances the accuracy, transparency, and overall quality of the decision-making process, particularly in complex and uncertain situations.

C. Methodology

Multi-criteria decision making (MCDM) approaches are statistical methods that help to make decisions in situations where potential solutions are weighed over several overlapping criteria. The Analytical Hierarchy Process (AHP) is a method for conducting and evaluating critical decisions, using math and psychology. It was developed by Thomas L. Saaty in the 1970s and has been developed since then [13]. It contains three parts: the ultimate goal or problem that needs to be solved, all of the possible solutions, and the criteria upon which the alternative will be judged. The procedure of carrying out AHP method is described as follows.

- *Step 1: Building Matrix of Pairwise Comparison (M) and Given the Ratings based on the Expert's Opinions using Linguistic Scale.*

$$M = \begin{bmatrix} M_{11} & M_{12} & \cdots & M_{1n} \\ M_{21} & M_{22} & \cdots & M_{2n} \\ \vdots & \vdots & & \vdots \\ M_{31} & M_{32} & \cdots & M_{3n} \end{bmatrix} \quad (1)$$

Where n is the matrix order.

- *Step 2: Developing Normalizing Matrix*

$$M_1 = \begin{bmatrix} M'_{11} & M'_{12} & \cdots & M'_{1n} \\ M'_{21} & M'_{22} & \cdots & M'_{2n} \\ \vdots & \vdots & & \vdots \\ M'_{31} & M'_{32} & \cdots & M'_{3n} \end{bmatrix} \quad (2)$$

Where $M'_{ji} = \frac{M_{Ij}}{\sum_{j=1}^{N} M_{Ij}}$ For j, i = 1,2,3,…, n

- *Step 3: Computation of Weight for Risk Factor*

$$W = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_N \end{bmatrix}$$

$$W_j = \frac{\sum_{j=1}^{N} W'_{ji}}{N} \quad (3)$$

Grey Relational Analysis is another MCDM method. Julong Deng was the first to introduce the Grey method, which has become widely used to address the complex issues associated with missing knowledge and discrete data [14]. The procedures include grey relational generating, grey relational coefficient calculation, and grey relational grade calculation. The equations involved in this process are summarized below.

$$X_{ij} = \frac{\mathrm{Max}\{Y_{Ij}, i=1,2,\ldots,m\} - Y_{Ij}}{\mathrm{Max}\{Y_{Ij}, i=1,2,\ldots,m\} - \mathrm{Min}\{Y_{Ij}, i=1,2,\ldots,m\}} \quad (4)$$

For i = 1,2,…,m and j = 1,2,…,n

$$\gamma\,(x_{0j}, x_{ij}) = \frac{\Delta_{Min} + \zeta\Delta_{Max}}{\Delta_{Ij} + \zeta\Delta_{Max}} \quad (5)$$

For i = 1,2, …, m and j = 1,2, …, n

In Eq. 4.7, $\gamma\,(x_{0j}, x_{ij})$ is the grey relational coefficient between x_{ij} and x_{0j}, and

$\Delta_{ij} = |\, x_{oj} - x_{ij} \,|$,

$\Delta_{min} = \mathrm{Min}\{\Delta_{ij}, i = 1,2,\ldots,m; j = 1,2,\ldots,n\}$,

$\Delta_{max} = \mathrm{Max}\{\Delta_{ij}, i = 1,2,\ldots,m{:}\ j = 1,2,\ldots,n\}$,

ζ is the distinguishing coefficient, $\zeta\ \varepsilon\ [0,1]$

$$\Gamma(X_0,X_i)=\frac{1}{N}\sum_{J=1}^{N} W_J\,\gamma\left(X_{0j},X_{Ij}\right) \qquad (6)$$

For i = 1,2,…,m

Table 1 List of Risk Factors

Risks	**Notation**	**Author of the literature**	**Risks**
Poor lighting and ventilation	A1	[1]	Poor lighting and ventilation
Lifting heavy weight	A2	[8]	Lifting heavy weight
Electrical short circuit happens	A3	[11]	Electrical short circuit happens
Improper guarding	A4	[9]	Improper guarding
Worker using chemicals without PPE	A5	[10]	Worker using chemicals without PPE
Repetitive strain injuries	A6	[7]	Repetitive strain injuries
Uncomfortable workstation and height	A7	[6]	Uncomfortable workstation and height
Poor electrical maintenance	A8	[1]	Poor electrical maintenance
High noise	A9	[11]	High noise
Temperature and humidity	A10	[1]	Temperature and humidity
Congested work area	A11	[9]	Congested work area
Contagious disease	A12	[6]	Contagious disease

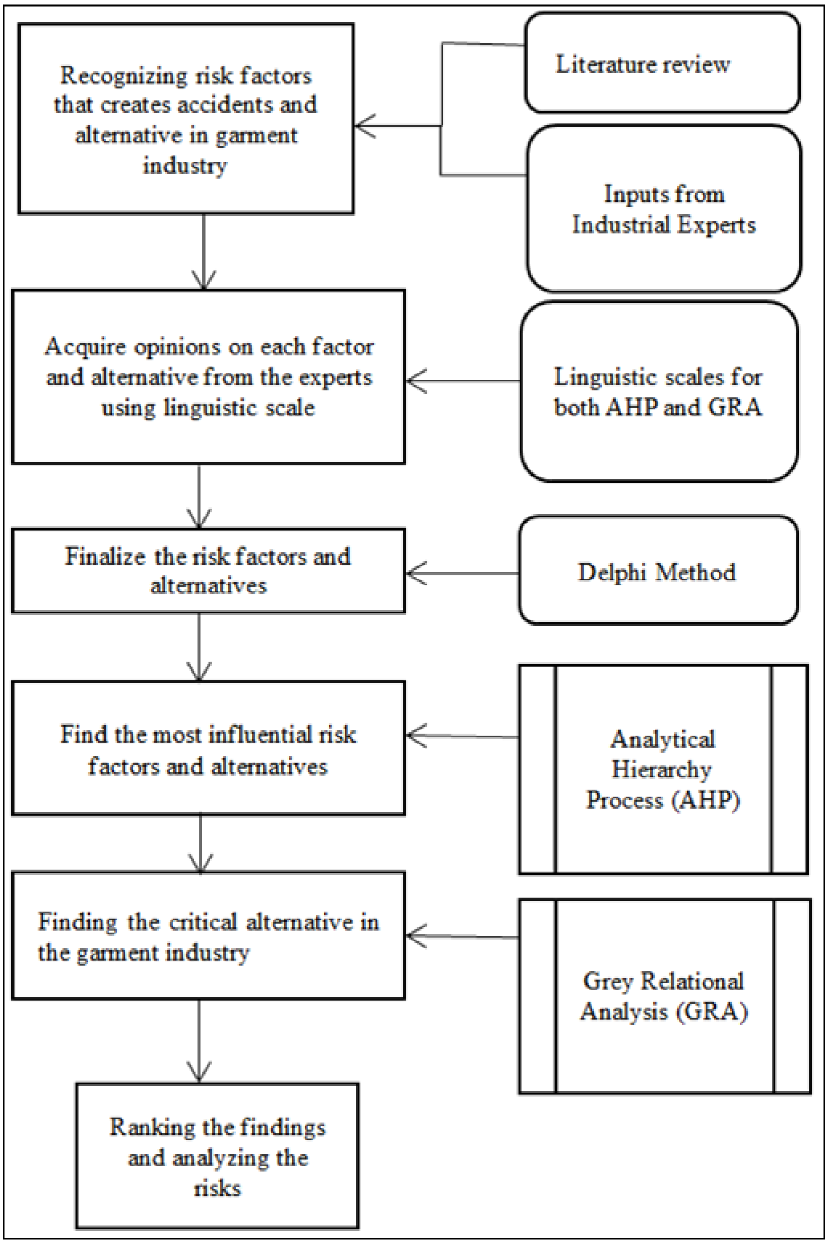

Fig 1 Proposed Framework of Current Research

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D. Result Analysis

➢ *Linguistics Scale*

In my research, I employed a linguistic scale, also known as a qualitative or ordinal scale, as a valuable tool for measuring certain attributes and phenomena. The linguistic scale allowed me to capture the intensity and magnitude of variables in a subjective and descriptive manner, which was particularly beneficial when dealing with complex or abstract concepts that lacked numerical quantification. Table 2 represents the linguistics scale value. Table 3 and Table 5 represent the listed risks factor pariwise comparison matrix and the value of the critical alternatives obtained with this linguistics scale.

Table 2 Linguistics Scale

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

➢ *Risk Factor Weight Assessment*

The result analysis reveals that the most critical and influential risk factor among the identified hazards is "Electrical short circuit happens," with a weight of 0.2149. This risk factor poses the highest level of threat to the safety and well-being of the workforce. Following closely behind is the risk associated with "Worker using chemicals without PPE," with a weight of 0.1363, making it the second most significant concern. In the third position is "Poor electrical maintenance," with a weight of 0.1348. The analysis continues with "High noise" ranked fourth, having a weight of 0.1107, followed by "Temperature and humidity" in the fifth position, with a weight of 0.0814. The remaining risk factors are then arranged in descending order of their weights and ascending order of their priority. This analysis enables a focused approach in allocating resources and attention to address the most critical hazards first, ultimately enhancing workplace safety and risk management strategies.

Final value is shown in Table 4. Fig. 2 illustrates the priority graphically.

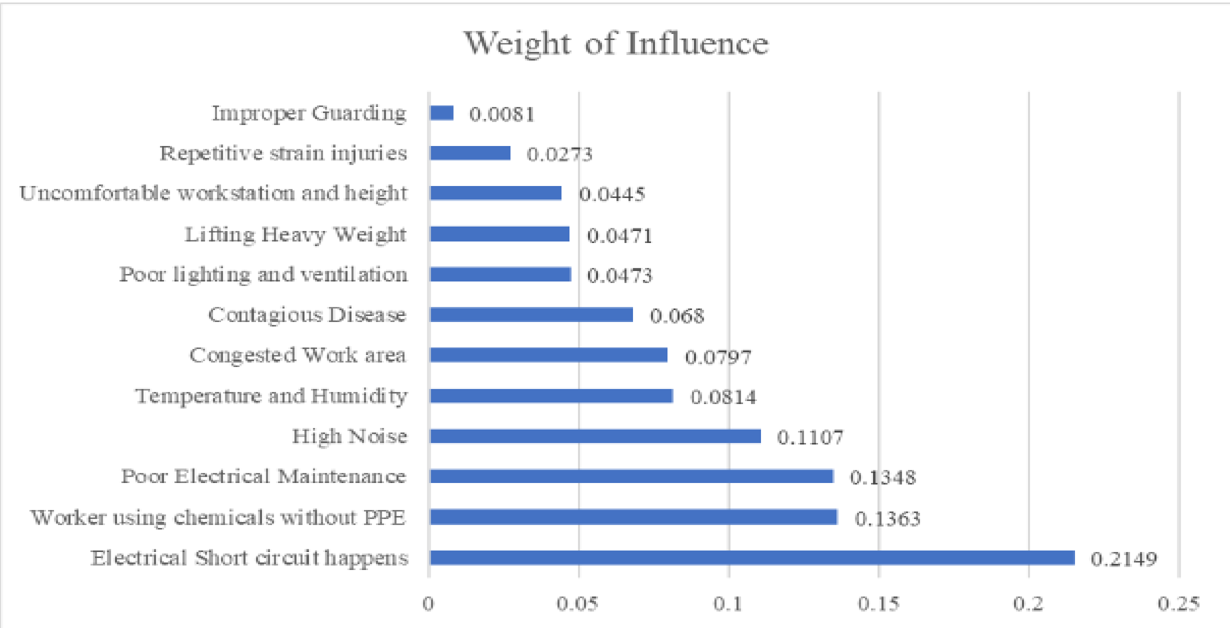

Fig. 2. Risk Factors Prioritized According To Their Influence

Table 3 Pairwise Comparison Matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
A1	1	6	1/6	7	1/4	4	1/5	1/3	1/6	1/5	6	1/9
A2	1/6	1	1/8	6	1/3	6	5	1/7	1/4	1/5	7	1/6
A3	6	8	1	8	6	5	7	6	6	5	1/5	5
A4	1/7	1/6	1/8	1	1/7	1/6	1/7	1/8	1/6	1/5	1/5	1/4
A5	4	3	1/6	7	1	8	6	4	6	4	3	5
A6	¼	1/6	1/5	6	1/8	1	6	1/4	1/8	1/6	1/7	1/4
A7	5	1/5	1/7	7	1/6	1/6	1	1/8	1/5	1/7	4	4
A8	3	7	1/6	8	1/4	4	8	1	9	7	5	4
A9	6	4	1/6	6	1/6	8	5	1/9	1	9	7	5
A10	4	5	1/5	5	1/4	6	7	1/7	1/9	1	7	5
A11	1/6	1/7	5	5	1/3	7	1/4	1/5	1/7	1/7	1	1/9
A12	9	6	1/5	4	1/5	4	1/4	1/4	1/5	1/5	9	1

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- *Finding the Critical Alternative/Solutions*

Table 6 reveals essential insights into the prioritization of risk factors and critical alternatives for increasing productivity. The highest-weighted risk factor, "Electrical short circuit happens," with a weight of 0.2149, demands immediate attention and resource allocation to prevent potential accidents and ensure the safety of employees. Following closely are "Worker using chemicals without PPE" and "Poor electrical maintenance," which rank second and third, respectively, warranting proactive measures to address these hazards. Meanwhile, "Proper housekeeping" emerges as the most effective solution to enhance productivity, ranking first with a substantial GRG score of 0.07223. Coupled with addressing worker awareness of OHS and implementing financial incentives, organizations can drive positive changes to boost productivity levels. The result analysis provides a clear roadmap for organizations to prioritize safety measures, address critical risks, and implement productivity-enhancing strategies to create a safer and more efficient work environment. Fig. 3 illustrates the priority graphically.

Table 4 Computation of Weight of Risk Factors

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	Weight	Rank
A1	0.0258	0.1475	0.0218	0.1000	0.0271	0.0750	0.0044	0.0263	0.0071	0.0073	0.1211	0.0037	0.0473	8
A2	0.0043	0.0246	0.0163	0.0857	0.0362	0.1125	0.1091	0.0113	0.0107	0.0073	0.1413	0.0056	0.0471	9
A3	0.1549	0.1967	0.1306	0.1143	0.6509	0.0938	0.1527	0.4732	0.2568	0.1835	0.0040	0.1673	0.2149	1
A4	0.0037	0.0041	0.0163	0.0143	0.0155	0.0031	0.0031	0.0099	0.0071	0.0073	0.0040	0.0084	0.0081	12
A5	0.1033	0.0738	0.0218	0.1000	0.1085	0.1500	0.1309	0.3155	0.2568	0.1468	0.0606	0.1673	0.1363	2
A6	0.0065	0.0041	0.0261	0.0857	0.0136	0.0188	0.1309	0.0197	0.0054	0.0061	0.0029	0.0084	0.0273	11
A7	0.1291	0.0049	0.0187	0.1000	0.0181	0.0031	0.0218	0.0099	0.0086	0.0052	0.0807	0.1338	0.0445	10
A8	0.0775	0.1721	0.0218	0.1143	0.0271	0.0750	0.1745	0.0789	0.3852	0.2569	0.1009	0.1338	0.1348	3
A9	0.1549	0.0983	0.0218	0.0857	0.0181	0.1500	0.1091	0.0088	0.0428	0.3302	0.1413	0.1673	0.1107	4
A10	0.1033	0.1229	0.0261	0.0714	0.0271	0.1125	0.1527	0.0113	0.0048	0.0367	0.1413	0.1673	0.0814	5
A11	0.0043	0.0035	0.6528	0.0714	0.0362	0.1313	0.0055	0.0158	0.0061	0.0052	0.0202	0.0037	0.0797	6
A12	0.2324	0.1475	0.0261	0.0571	0.0217	0.0750	0.0055	0.0197	0.0086	0.0073	0.1817	0.0335	0.0680	7

Table 5 Data for Finding Best Alternative

Notation	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
A1	1	2	1	4	4	4	1	1	2	1	1	1
A2	1	4	3	4	5	4	4	3	2	2	1	4
A3	2	1	2	2	1	2	3	3	3	3	3	1
A4	1	5	2	5	2	7	3	1	1	1	2	4
A5	4	1	4	4	2	3	4	3	4	4	3	5

Table 6 Grey Relational Grade Calculation

Notation	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	GRG	Rank
A1	0.3333	0.4000	0.3333	0.6000	0.6667	0.4545	0.3333	0.3333	0.4286	0.3333	0.3333	0.3333	0.0332	5
A2	0.3333	0.6667	0.6000	0.6000	1.0000	0.4545	1.0000	1.0000	0.4286	0.4286	0.3333	0.6667	0.0553	2
A3	0.4286	0.3333	0.4286	0.3333	0.3333	0.3333	0.6000	1.0000	0.6000	0.6000	1.0000	0.3333	0.0470	3
A4	0.3333	1.0000	0.4286	1.0000	0.4000	1.0000	0.6000	0.3333	0.3333	0.3333	0.5000	0.6667	0.0388	4
A5	1.0000	0.3333	1.0000	0.6000	0.4000	0.3846	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0722	1

Table 7 Critical Alternatives Priority for Different Distinguishing Co-Efficient

	ξ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Proper housekeeping	0.3333	0.4000	0.3333	0.6000	0.6667	0.4545	0.3333	0.3333	0.4286	0.3333
Unaware of OHS	0.3333	0.6667	0.6000	0.6000	1.0000	0.4545	1.0000	1.0000	0.4286	0.4286
Financial Reason	0.4286	0.3333	0.4286	0.3333	0.3333	0.3333	0.6000	1.0000	0.6000	0.6000
Proper Work distribution	0.3333	1.0000	0.4286	1.0000	0.4000	1.0000	0.6000	0.3333	0.3333	0.3333
Unwillingness of worker	1.0000	0.3333	1.0000	0.6000	0.4000	0.3846	1.0000	1.0000	1.0000	1.0000

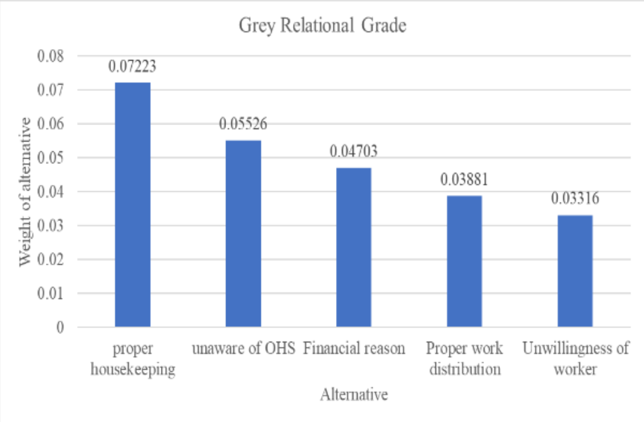

Fig 3 Grey Relational Grade for Critical Alternative

E. Sensitivity Analysis

Grey relational co-efficient determines the closeness relationship between the reference sequence and comparability sequence. So, the impact of distinguishing co-efficient on grey relational co-efficient is not negligible. Mahmoudi (2019) conducted a research on the impact of determining co-efficient where it was clearly demonstrated that the weight of the alternatives can vary for different values of distinguishing co-efficient [15].

Normally distinguishing co-efficient ranges from 0.1 to 0.9. We will analyze our Grey relational grade for different values of distinguishing co-efficient. For different values of distinguishing co-efficient, different values of the alternatives is represented in a Table 5. Fig 3 illustrates the sensitive values.

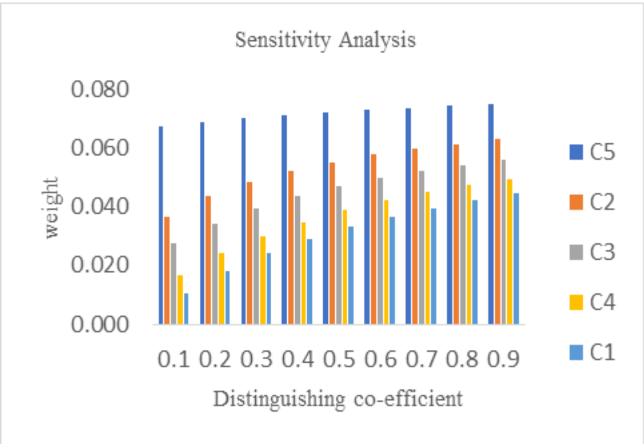

Fig 4 Critical Alternatives for Different Distinguishing Co-Efficient Value

Fig. 3 includes sensitivity analysis for critical alternatives' impact on productivity, represented by the variable ξ ranging from 0.1 to 0.9, Each alternative, labeled with notations C1 to C5, exhibits increasing outcomes as ξ increases. For example, "Proper housekeeping" (C5) ranges from 0.067 to 0.075, and "Unaware of OHS" (C2) varies from 0.037 to 0.063 as ξ changes. This analysis enables decision-makers to assess how sensitive the outcomes are to parameter variations, guiding them in prioritizing alternatives based on their potential impact on productivity improvement. The values of different alternatives have changed, but the order in which those alternatives had presented, is not changed. According to Table 6, Among the five possible alternatives, we recommend to ensure 'proper housekeeping' as a first step to eliminate the most of the risk factors. Proper housekeeping has got the highest priority based on our research. We recommend to sort out the risk factors according to Table 6.

IV. CONCLUSION

The ready-made garments (RMG) industry is a vital contributor to Bangladesh's economy. This research aimed to address the pressing need for a structured framework to analyze safety, health, and environmental risk factors within the context of the RMG industry. Twelve factors encompassing safety, health, and environmental concerns were thoroughly evaluated and the Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA) approach were used to mitigate these risks. The analysis identified several critical alternatives that warrant immediate attention, such as proper housekeeping, awareness of occupational health and safety (OHS), financial considerations, optimal work distribution, and enhancing workers' willingness. To sustain and further enhance this profitable sector, it is imperative to take proactive measures to maintain a secure and healthy working environment. Government involvement is crucial, and the implementation of regulations and educational programs will serve as catalysts for sustainable growth and success in this significant sector.

FUTURE WORK AND LIMITATIONS

In this study, we provide valuable insights into safety, health, and environmental risk factors associated with the ready-made garments industry in Bangladesh and propose a structured framework for analyzing these risks. In the future, longitudinal studies will be required to assess the long-term impact of implemented measures and to compare the practices of different RMG factories worldwide. By involving workers in the risk assessment process and integrating technology for real-time monitoring, risk management and decision-making can be further improved. While the research provides specific insights into the RMG industry in Bangladesh, its generalizability to other industries and regions should be explored. In order to effectively implement risk management measures, it is imperative to address data limitations and overcome implementation challenges. Overall, this study provides a foundation for continued improvements in workplace safety and productivity, however, further investigation is necessary to ensure that the RMG industry is a safe and sustainable one.

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