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Analyzing Ergonomic Factors Influencing Productivity in Bangladeshi Garment Industry Using Fuzzy ANP Method

Rotan Kumar Saha[1], Md. Mamun[2], Safayet Hossain[1], Md. Tareque Hasan[1], Sujoy kundu[1] Tuhin Hosen[1], Md. Nazmul Hasan[1]

[1]Department of Industrial and Production Engineering,
Dhaka University of Engineering & Technology,
Gazipur, Gazipur-1707, Bangladesh
[2] Department of Mechanical Engineering,
Dhaka University of Engineering & Technology,
Gazipur, Gazipur-1707, Bangladesh

rotansaha@duet.ac.bd, mamun193016@gmail.com, safayetridu@gmail.com , tareque.me2019@gmail.com,sujoykundu246@gmail.com, tuhinhosenipe@gmail.com, nazmulhasan207015@gmail.com

Abstract

This research explores the impact of ergonomic factors on productivity in the Bangladeshi garment industry, a vital sector for the nation's economy, but characterized by challenging working conditions. The study highlights how ergonomic practices aimed at improving worker health, comfort, and efficiency can enhance productivity while reducing health issues such as musculoskeletal disorders and fatigue. Despite growing awareness of ergonomics in developing countries, the application of these principles in the Bangladeshi garment sector remains limited due to constraints in cost-effective worker solutions. The study identifies critical ergonomic factors influencing productivity, categorizing them into personal variables, workplace environment, and health issues. The fuzzy analytical network process (ANP) is employed to prioritize these factors and pinpoint areas requiring urgent intervention, such as poorly maintained equipment. The reliability analysis, with a Cronbach's Alpha value of 0.913, confirms the high reliability of the findings. Results from the analytical hierarchy process show that the work environment (0.68 weight) has the most significant impact on productivity, followed by individual characteristics (0.24 weight) and health-related issues (0.08 weight). Sensitivity analysis reveals that the industrial environment (E3) is the most influential factor, with its impact increasing as its dimensions are gradually adjusted. The findings emphasize the importance of ergonomic improvements to boost productivity and enhance worker well-being, with broader implications for other sectors.

Keywords
Ergonomics, Productivity Optimization, Bangladeshi garment industry, Fuzzy ANP analysis, Musculoskeletal disorders

1. Introduction
Bangladesh's garment industry is the backbone of economic growth, providing employment opportunities to millions of people and contributing to the country's export earnings (Dickinson et al.2016), (Monira et al., 2020). Despite its economic importance, the sector is often criticized for being difficult to work in, which can hinder productivity and employee satisfaction (Van Rensburg, Nkomo, & Mkhize 2020). These conditions may include inadequate machinery,

poor working conditions, and high job demands, which affect workers' physical and mental health (Amin et al., 2019). Ergonomics aims to improve the workplace in terms of productivity, comfort, and safety by reducing occupational risk (Karwowski 2012). Therefore, addressing ergonomic factors in the Bangladesh garment industry is essential to create a healthy and productive environment and promote economic growth (W. Ahmed, Ahmed, & Najmi 2018). Studies show that ergonomic interventions such as improved technology and better work arrangements can improve employee performance, thereby increasing productivity and job satisfaction. However, current ergonomic practices in the garment industry in Bangladesh are often hampered by cost constraints, limited knowledge, and lack of management (Reig 2013). In this study, the Fuzzy Analysis Network Process (FANP), a multi-deterministic method that is effective in evaluating the complex, interdependent impact, was used to quantify and evaluate the importance of these ergonomic issues (Kulak, Stańczykiewicz, & Szewczyk 2017).

The application of FANP in ergonomics is new, especially in the Bangladeshi garment industry, and many methods are rarely used in the process. This study classifies ergonomic features into three groups according to their specific effects on workers' productivity and health: occupational diseases, personal characteristics, and work environment characteristics. Occupational diseases, including musculoskeletal and respiratory problems, are caused mainly by repetitive work and prolonged inadequate rest (Hossain et al. 2017). Personal factors such as age, fitness, and previous health also play a role in determining how they affect the well-being of people working in stressful environments such as the garment industry. Finally, the work environment (including workspace, lighting, and temperature) directly affects the comfort and safety of workers, making it essential for development (Jahan et al. 2020). The study aims to provide insight to managers in the industry by showing the essential ergonomic points that increase the productivity and health of employees. This study provides a benchmark for similar industries in Bangladesh to measure and solve ergonomic problems in heavy work (Rahman, Rahman, Akter, & Pinky 2023).

More importantly, ergonomic practices have been shown to reduce workplace injuries, improve employee morale, and increase productivity and product accuracy (Tappin, Pennycook, & Rand 2020). By adopting ergonomic principles, the apparel industry can support its growth and provide health and satisfaction to its employees. The novel approach of this study is to apply FANP to monitor the importance of ergonomics in the garment industry in Bangladesh and fill the existing gap in ergonomics research in the trade, mainly in developing countries. Due to the lack of ergonomic knowledge, research in this area has not yet used advanced decision-making methods such as FANP, making this study an effort toward systematic ergonomic assessment. By revealing the importance of ergonomics in terms of productivity and health in the garment industry, this study also lays the foundation for the broader use of FANPs in the industry, thereby promoting sustainability and competitive advantage.

1.1 Objectives

This study aims to assess the current state of ergonomic practices in Bangladesh's garment industry and identify key ergonomic factors affecting productivity, worker satisfaction, and well-being. It seeks to explore the challenges and barriers to implementing ergonomic practices, provide recommendations for improving their integration into production processes, and address uncertainties in ergonomic assessments through fuzzy judgments from workers and experts. Additionally, the study aims to capture the interrelationships between ergonomic factors such as adjustability, and workload, and prioritize ergonomic improvements using imprecise data to enhance workplace safety, efficiency, and overall worker comfort. The ultimate goal is to contribute to a deeper understanding of ergonomics' role in boosting productivity and worker well-being in the garment sector.

2. Literature Review

The garment industry of Bangladesh is one of the most critical industries in the country, contributing to employment and exports. However, there are increasing concerns about the impact of ergonomic factors on the productivity and health of workers. This literature review examines the existing research on ergonomics in the garment industry, identifies research gaps, and highlights the importance of ergonomic practices in improving productivity. Further analysis discusses the use of Fuzzy Analytical Network Process (ANP) methods in assessing ergonomic factors in manufacturing, particularly in the garment industry. Although ergonomics plays a vital role in the garment industry, there are still some gaps in the current body of research, especially in Bangladesh. While previous studies have focused on international trends, less research has been devoted to how ergonomic practices are implemented in the garment industry in Bangladesh. Studies conducted in other developing countries often fail to address the specific health and cultural issues Bangladesh faces (F. Ahmed 2017). Sports injuries are associated with long working hours and poorly designed workplaces, affecting employees' overall productivity and health (Koirala & Nepal 2022). The basic concepts of ergonomics in clothing are related to creating a workplace that suits employees' bodies, emotions, and needs. According to Jahan and Rahman (das Neves, Brigatto, & Paschoarelli 2015), ergonomic interventions in the clothing industry include adjusting the workplace, reducing repetitions, and providing appropriate seating arrangements. These interventions are designed to increase comfort, reduce fatigue, and prevent injuries, which are essential factors affecting production workers.

Improved ergonomics can reduce absenteeism and turnover while improving clothing quality. Ergonomic design also includes analyzing tools, materials, and technology, which is the goal of many studies. Many studies have focused on the relationship between ergonomic factors and productivity in the apparel industry. A study by Islam and Hossain showed that employees in an ergonomically sound environment tend to work faster and more accurately. Ergonomic improvements such as adjustable seats, improved lighting, and improved lighting can reduce fatigue and stress from working too hard, thereby increasing productivity and reducing adverse effects (Sidanti & Istikhomah 2021). Not only does productivity increase, but the potential for costly injuries that can affect productivity also decreases. For example, adapting workplaces to the physical characteristics of employees can prevent long-term injuries such as musculoskeletal disorders (MSDs) that are common in the apparel industry (Abebe & Hasegawa 2018). Fuzzy Analytical Network Process (ANP) methods have become famous for evaluating complex processes such as ergonomics in manufacturing. This approach allows for the inclusion of caution, uncertainty, and ambiguity inherent in ergonomic measurements. Using Fuzzy ANP, ergonomic factors can be calculated and prioritized based on their impact on productivity and worker health. Help create a comprehensive view of these issues.

According to Noor and Rahman (som & singh 2023), Fuzzy ANP can evaluate the impact of ergonomic interventions and allow managers to prioritize improvements based on their results. Ergonomics includes workplace design and the relationships that affect work. In the garment industry in Bangladesh, where the workforce is large and primarily female, ergonomics must address gender needs (som & singh 2023) and demonstrate increased employee participation in ergonomic interventions. Worker health is a significant concern in the garment industry because workers work backward and are physically demanding. Ergonomic interventions such as lifting equipment, workplace arrangements, and job rotation have been linked to improved worker health and reduced injuries. Proper ergonomics can improve mental health by reducing stress and discomfort and increasing job satisfaction (F. Ahmed 2018). Bone disease affects garment workers due to prolonged standing or sitting in uncomfortable positions (Bhattacharyya & Rahman 2019)Interventions to reduce these health risks are beneficial not only for workers but also enhance the long-term sustainability of the garment industry. Study Evidence suggests that ergonomic factors affect worker health and productivity. Based on these insights, this study focuses on assessing the ergonomic conditions of the garment industry in Bangladesh using the fuzzy ANP method. This framework will help identify and monitor the most critical ergonomic improvements required by the industry and will form the basis for further research in this area.

3. Methodology

The methodology of this study systematically investigates the ergonomic challenges influencing production within Bangladesh's garment industry. The research began with an extensive literature review to identify the critical ergonomic factors impacting worker performance and production efficiency. Data collection involved distributing carefully designed questionnaires to experienced garment workers from various companies to capture insights on the ergonomic factors they encounter daily. The survey targeted both male and female workers with a minimum of five years of experience, ensuring that the sample was representative of diverse roles within the industry. The responses were then aggregated to derive weighted importance scores for each ergonomic factor influencing productivity, as summarized in Table 1.

To evaluate the relative importance of the identified ergonomic factors, an Analytical Network Process (ANP) combined with a fuzzy methodology was employed. This mixed approach allowed for the inclusion of expert judgments and the quantification of uncertainty in the data, providing a more robust assessment of ergonomic priorities. The expert panel comparisons and consistency checks were carried out to validate the results, ensuring that the findings were reliable and reflective of industry realities. Despite the comprehensive nature of this study, certain limitations are acknowledged, including the sample size and the general applicability of the findings across different sectors within the garment industry. These limitations are noted to offer transparency and guide future research efforts. Overall, this study aims to offer valuable insights into the ergonomic challenges in the Bangladeshi garment sector and their direct impact on productivity.

Table 1. Collection of expert values

SL NO.	EXPERTS	(E11)	(E12)	(E13)	(E14)	(E21)	(E22)	(E23)	(E24)	(E31)	(E32)	(E33)	(E34)
1	E1	1	2	1	2	1	3	1	2	3	1	3	1
2	E2	2	3	2	4	3	3	2	3	3	4	2	3
3	E3	1	2	1	1	1	1	2	1	3	2	2	1
4	E4	1	4	5	4	2	4	3	4	4	2	3	5
5	E5	3	4	4	5	2	5	2	4	4	4	3	5
6	E6	1	2	1	2	2	2	2	1	1	1	2	1
7	E7	5	4	5	3	5	4	4	3	4	5	5	5
8	E8	1	2	1	1	1	2	1	1	3	1	1	1
9	E9	2	3	5	4	5	3	5	4	5	4	3	5
10	E10	2	3	4	5	4	3	3	1	5	5	3	3
11	E11	2	4	4	5	3	5	4	4	5	3	3	4
12	E12	5	3	4	2	3	4	2	4	5	3	3	3
13	E13	1	2	1	1	2	2	2	2	1	1	1	5
14	E14	5	1	5	3	3	4	2	3	4	3	3	4
15	E15	4	4	3	2	2	3	3	4	2	2	3	3
16	E16	2	4	4	5	3	2	4	3	4	2	3	4
17	E17	2	4	5	4	2	4	4	3	5	3	2	4
18	E18	2	3	3	2	3	3	2	3	3	2	3	3
19	E19	2	2	5	2	2	2	1	2	2	3	3	2
20	E20	4	3	4	2	1	3	3	4	4	3	4	3
21	E21	5	4	3	2	2	4	5	5	4	5	5	3
22	E22	1	2	1	2	2	2	2	2	1	1	2	3
23	E23	3	4	3	2	4	2	3	4	2	3	4	2
24	E24	5	4	3	2	1	5	5	5	4	4	4	3
25	E25	1	2	3	1	2	2	2	2	1	5	1	1
26	E26	4	3	4	3	1	3	4	2	3	4	2	3
27	E27	3	3	2	2	2	3	3	3	2	2	2	3
28	E28	4	4	1	3	4	3	4	3	4	5	3	4
29	E29	2	3	1	2	1	2	1	2	1	2	2	2
30	E30	1	2	1	2	1	3	1	2	3	1	3	1
31	E31	2	3	2	4	3	3	2	3	3	4	2	3
32	E32	1	2	1	2	2	2	2	2	1	1	2	3
33	E33	3	4	3	2	4	2	3	4	2	3	4	2
34	E34	1	2	1	1	1	2	1	1	3	1	1	1
35	E35	2	3	5	4	5	3	5	4	5	4	3	5
36	E36	2	3	4	5	4	3	3	1	5	5	3	3
37	E37	4	3	4	2	1	3	3	4	4	3	4	3
38	E38	5	4	3	2	2	4	5	5	4	5	5	3
39	E39	2	3	4	5	4	3	3	1	5	5	3	3
40	E40	1	2	1	1	1	2	1	1	3	1	1	1

The methodology of this study adopted a method to identify, verify, and evaluate the ergonomic factors affecting productivity in the Bangladeshi garment industry. This process is carried out using the Fuzzy Analysis Network

Process (FANP), a multi-factor decision-making method that allows the analysis of relationships among various factors. The methodology consists of several critical stages, from initial data analysis and data processing to final analysis and sensitivity analysis. Figure 1 shows the flow chart of the proposed Methodology

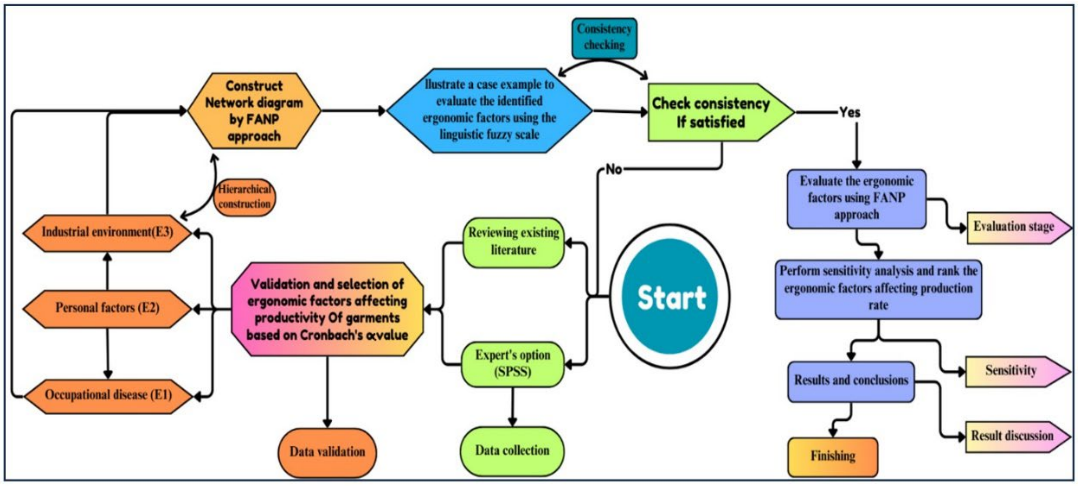

Figure 1. Flow chart of the proposed methodology

3.1 Determination of Ergonomic Factors

This study first investigated the existing literature on ergonomic factors affecting productivity in the garment industry.

Table 2. List of identified ergonomic factors affecting production

Factor	Sub- Factor	Description
Occupational disease (E1)	Spinal cord problem (E11)	Prevalent among workers working in a static position for a long duration
	Shoulder pain (E12)	Occurs in persons working with inappropriate height tables
	Low Back Pain (E13)	Common among workers engaged in lifting heavy weights
	Knee joint pain (E14)	Predominant among workers involved in movement of raw materials within the workplace
Personal factors (E2)	Fatigue (E21)	Repeated, monotonous work without sufficient break intervals causes fatigue
	Job satisfaction (E22)	Appraisal, rewards and salary hike for the work executed
	Self-motivation (E23)	Internal force motivating the worker to move towards the goal
	Conscientiousness (E24)	Being hardworking, dutiful, and reliable
Industrial environment (E3)	Outdated machinery (E31)	Old, traditional machines which are not ergonomically designed
	Vibration (E32)	Old and repaired machine often cause vibration
	Operational setup (E33)	Adequate spacing must be provided between machines and machines must be arranged on the basis of work sequence
	Poor ventilation and lighting (E34)	Adequate light and air circulation must be ensured

This review aims to establish a basic understanding of ergonomic problems that may affect employee performance and productivity. In addition to data analysis, a statistical package (SPSS) is used for statistical analysis to collect meaningful comments and primarily to observe the definitive results. Experts' feedback helped improve and optimize the unique content of the readymade garments sector in Bangladesh. Table 2 shows the List of identified ergonomic factors affecting production.

3.2 Analysis and Selection of Ergonomic Systems

Once the basic ergonomic principles are identified, they will become practical guidelines. Cronbach alpha was used to measure internal consistency and reliability at this stage. This assessment ensures that the identified ergonomic factors are consistent and relevant to the learning objectives. Only factors with high Cronbach's α values were retained for further analysis, increasing the power of the research process.
The selected ergonomic factors are divided into three broad categories according to their nature and impact:

a. Occupational Diseases (E1) - Characteristics related to occupational health problems.
b. Personal Factors (E2) - Characteristics related to the physical and emotional aspects of the person.
c. Industrial Environment (E3) - Characteristics related to workplaces and environments.

These categories form a process hierarchy that provides the basis for further analysis using the FANP approach.

3.3 Creation of the Artwork

After the ergonomic features were verified, the diagram was created using the FANP method. The FANP method allows the modeling of the shared nature of events, unlike the Analytical Analysis Process (AHP), which assumes the independence of events. This network model is essential in reflecting the interaction of ergonomic factors that affect productivity. FANP-based hierarchies facilitate relational analysis, where the effects of each factor can be related to other factors.

3.4 Assessment with the Fuzzy Language Scale

A case was defined and assessed using the Linguistic Ambiguity Scale to assess the importance of each ergonomic factor. This step converts the quality judgments of ergonomic factors into values, making them suitable for FANP analysis. Fuzzy logic is instrumental here because it considers the uncertainty and ambiguity inherent in human judgment, thus increasing the accuracy of the measurements.

3.5 Social Analysis

Regular checks are made after the initial assessment to ensure the reliability of FANP decisions. Correlation is essential to avoid bias and verify that ergonomic factors are important in professional assessment. If the consistency requirement is not met, corrections are made until a high level of consistency is achieved to ensure the validity of the results.

3.6 Analysis and Evaluation

After verifying consistency, the FANP method assesses the ergonomic factors overall. This level of analysis results in a competitive analysis of various factors based on their relative impact on productivity in the garment industry. Sensitivity analysis is then conducted to assess the stability and robustness of these categories. Sensitivity analysis helps identify changes in rankings in different situations, thereby highlighting valid ergonomic points.

3.7 Results of FANP

The results of the FANP test and sensitivity analyses are presented in the Summary and Conclusions section. This stage discusses the ergonomic factors affecting production in the garment industry. The study's results highlight the possibilities for ergonomic improvements and their desired impact on productivity.

3.8 Collect and Analysis

Finally, the study concludes with a discussion of the implications of the findings, which demonstrate how the importance of ergonomic factors can inform intervention strategies to improve products in the Bangladesh garment industry. By identifying and analyzing these factors, this study provides a basis for implementing ergonomic improvement plans.

Table 3. Data analysis of Cronbach's alpha

Cronbach's Alpha	Number of Items
0.913	12

Table 4. Data analysis of KMO and Barlett's test

KMO and Barlett's Test		
Kaiser–Meyer–Olkin measure of sampling adequacy		0.813
Barlett's Test of Sphericity	Approx. X^2	312.830
	Degrees of Freedom	66
	Significance Level	0.000

In the data analysis stage, reliability and validity, including Cronbach Alpha, KMO, and Bartlett tests, are evaluated to determine the consistency and adequacy of the data. Cronbach Alpha value of 0.913 indicates high reliability. Table 3 presents the Cronbach's Alpha analysis, measuring internal consistency for reliability. Table 4 shows the results of KMO and Bartlett's tests, assessing sampling adequacy and sphericity for data suitability.

Table 5. The scale of significance used in the pair-wise comparison of fuzzy AHP

Linguistic Variables	Scale of Significance	Triangular Fuzzy Numbers	Triangular Fuzzy Reciprocal Numbers
Equally significant (E)	1	(1,1,1)	(1,1,1)
Weakly significant (W)	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Really significant (R)	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Very strongly significant (VS)	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Absolutely significant (A)	9	(8, 17/2, 9)	(1/9, 2/17, 1/8)

Next, the fuzzy analytical hierarchy process (FAHP) and fuzzy ANP method were used to evaluate ergonomic factors. Triangular fuzzy numbers represent different words together comparatively, researching to resolve ambiguous or incorrect information. Table 5 presents the scale of significance for pair-wise comparisons in fuzzy AHP using linguistic variables mapped to triangular fuzzy numbers. Figure 2 illustrates a triangular fuzzy number, showing its membership function across three points (a1, a2, a3). Critical vectors in the region are generated

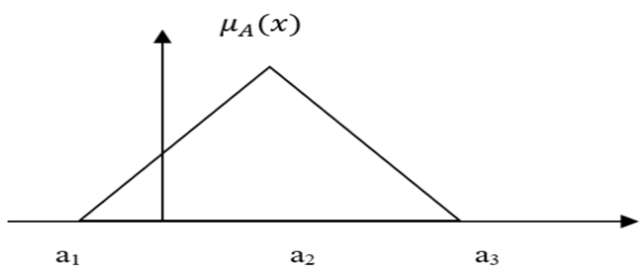

Figure 2. Triangular fuzzy number

from the comparative analysis in constructing the super matrix. The weighted super matrix assigns Specific weights to individual factors (PF) and environmental factors (IE). This approach allows the research to consider the differences between different cases, providing an overview of all ergonomic factors affecting production in the clothing industry.

$$
\text{Super matrix}=\begin{bmatrix}
0.0385 & 0.0556 & 0.0270 & 0.0526 & 0.0313 & 0.0769 & 0.0323 & 0.0625 & 0.0667 & 0.0286 & 0.0909 & 0.0270 \\
0.0769 & 0.0833 & 0.0541 & 0.1053 & 0.0938 & 0.0769 & 0.0645 & 0.0938 & 0.0667 & 0.1143 & 0.0606 & 0.0811 \\
0.0385 & 0.0556 & 0.0270 & 0.0263 & 0.0313 & 0.0256 & 0.0645 & 0.0313 & 0.0667 & 0.0571 & 0.0606 & 0.0270 \\
0.0385 & 0.1111 & 0.1351 & 0.1053 & 0.0625 & 0.1026 & 0.0968 & 0.1250 & 0.0889 & 0.0571 & 0.0909 & 0.1351 \\
0.1154 & 0.1111 & 0.1081 & 0.1316 & 0.0625 & 0.1282 & 0.0645 & 0.1250 & 0.0222 & 0.1143 & 0.0909 & 0.1351 \\
0.0385 & 0.0556 & 0.0270 & 0.0526 & 0.0625 & 0.0513 & 0.0645 & 0.0313 & 0.0286 & 0.0286 & 0.0606 & 0.0270 \\
0.1923 & 0.1111 & 0.1351 & 0.0789 & 0.1563 & 0.1026 & 0.1290 & 0.0938 & 0.0889 & 0.1429 & 0.1515 & 0.1351 \\
0.0385 & 0.0556 & 0.0270 & 0.0263 & 0.0313 & 0.0513 & 0.0323 & 0.0313 & 0.0667 & 0.0286 & 0.0303 & 0.0270 \\
0.0769 & 0.0833 & 0.1351 & 0.1053 & 0.1563 & 0.0769 & 0.1613 & 0.1250 & 0.1111 & 0.1143 & 0.0909 & 0.1351 \\
0.0769 & 0.0833 & 0.1081 & 0.1316 & 0.1250 & 0.0769 & 0.0968 & 0.0313 & 0.1111 & 0.1429 & 0.0909 & 0.0811 \\
0.0769 & 0.1111 & 0.1081 & 0.1316 & 0.0938 & 0.1282 & 0.1290 & 0.1250 & 0.1111 & 0.0857 & 0.0909 & 0.1080 \\
0.1923 & 0.0833 & 0.1081 & 0.0526 & 0.0938 & 0.1026 & 0.0645 & 0.1250 & 0.1111 & 0.0857 & 0.0909 & 0.0811
\end{bmatrix}
$$

4. Results and Discussion

Analyzing data, including qualitative and quantitative analysis, is crucial for achieving meaningful results and insights in research. In the context of studying ergonomic problems in the garment industry in Bangladesh, data evaluation should be done based on multiple methods to ensure the benefits' validity, reliability, and relevance. Steps. It should check the stability and consistency of data collection. The consistency of the data can be analyzed by methods such as calculating Cronbach's α coefficient. A high value of Cronbach's alpha indicates the consistency and reliability of the data. Confidence was assessed. Experts were presented with a questionnaire containing a fuzzy scale and ergonomic concepts (Table 5). Ergonomic factors were analyzed using the fuzzy analytical hierarchy process (FAHP) based on expert opinions. We compare everything together to evaluate the factors affecting the clothing design. Table 6 shows the comparison matrix of the results. All triangular fuzzy numbers are converted to intelligent numbers. Equations are used to determine the maximum eigenvalue and eigenvector as shown in Table 7. The calculated consistency CR ratio was 0.048, which aligned with the recommended consistency ratio in below Table 8.

Table 6. Factor to Factor (F–F) pair-wise comparison matrix

Main factor	E1	E2	E3
E1	(1,1,1)	(1/4,1/3,1/2)	(1/9,2/17,1/8)
E2	(2,3,4)	(1,1,1)	(1/4,1/3,1/2)
E3	(8,17/2,9)	(2,3,4)	(1,1,1)

Table 7. Largest eigenvalue and eigenvector

Main factors	W	W'	λ_{max}	CR Value
Occupational disease (E1)	0.08	3.083	3.056	$CI = \frac{3.056 - 3.00}{2} = 0.028$ $CR = \frac{0.028}{0.58} = 0.048$
Personal factors (E2)	0.24	3.028		
Industrial environment (E3)	0.68	3.058		

Table 8. Random index and recommended consistency ratio (CR) values

Size (n)	3	4	5	6	7	8	9	10
CI	.58	.90	1.12	1.24	1.32	1.41	1.45	1.49
Recommended CR value	<0.05	<0.08	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

The ranking of the main factors is presented in Table 9 Similarly, a pairwise comparison matrix was constructed for the sub-factors, specifically for E1, E2, and E3. However, in this paper, only the pairwise comparison of the main factors is displayed.

Table 9. Ranking of main factors influencing garments production

Main Factors	Preference Weight	Ranking
Occupational disease(E1)	0.08	3
Personal factors (E2)	0.24	2
Industrial Environment (E3)	0.68	1

The consistency ratio for all sub-factors within each main factor was calculated, satisfying the required condition. Once the individual weight of the sub-factors in each main factor was determined, the global priority weight of the sub-factors was calculated. The global weights of the sub-factors were obtained using Equation, and their priority ranks are shown in Table 10.

Table 10. Local and global weights of main and sub-factors of the garments industry

Factors	Weight	Rank	Sub-Factor	Local Weight	Rank	Global Weight	Rank
E1	0.08	3	E11	0.591	1	0.04728	7
			E12	0.065	4	0.0052	12
			E13	0.22	2	0.0176	9
			E14	0.12	3	0.0096	11
E2	0.24	2	E21	0.646	1	0.15504	2
			E22	0.215	2	0.0516	6
			E23	0.092	3	0.02208	8
			E24	0.047	4	0.01128	10
E3	0.68	1	E31	0.621	1	0.42228	1
			E32	0.111	4	0.07548	5
			E33	0.131	3	0.08908	4
			E34	0.137	2	0.09316	3

4.1 Reliability and Validity of Analysis
Cronbach's α was computed to evaluate the data's dependability; the results are shown in Table 3. The total factor Cronbach's α value was 0.913, which is an adequate degree of reliability. Furthermore, when deleting each element separately, Cronbach's α values persisted above 0.8, indicating that all 12 factors considered are dependable and appropriate for further investigation. When the KMO measure was used to assess the sample adequacy, a value of 0.806 was obtained (Table 4). This number suggests that the sample size was appropriate and that the amount of data gathered was sufficient for analysis. Based on these assessments, the ergonomic elements that impede the production rate of SMEs in the clothing industry were determined. Additionally, the variables and sub-factors that lead to ergonomic production loss were assessed after the factors were finalized using the FAHP approach.

4.2 Weight of Ergonomic Factors
Following the assessment of validity and reliability, the factors were evaluated by experts using fuzzy AHP. Each element's consistency was examined before its weight was determined, and the resultant consistency ratio (CR) is shown in Table 7. The computed CR value of 0.048 is inside Table 8 acceptable range. Next, the preference weight of the main factors was calculated and presented in Table 9, Similarly, the local weights of the sub-factors were calculated and displayed in Table 9. The global weight of the sub-factors was then obtained by multiplying the local weight of each sub-factor with the preference weight of the corresponding main factor. The calculated global weights of the sub-factors are also provided in Table 10.

4.3 Comparison of AHP & ANP results
The results of the analytical hierarchy process show that the work environment has the greatest impact on the productivity of the garment industry with a weight of 0.68. Individual characteristics followed with a weight of 0.24, indicating a moderate impact. Functional diseases have the least impact, with a weight of 0.08. These results show the differences in the impact of ergonomic factors on productivity results. The economic environment (IE) plays a vital role in this analysis. The AHP result for IE is 0.68, while the last four rows represent the ANP result. The last four columns show more values than the first eight, confirming the high IE values in ANP, allowing the same value to be obtained. However, AHP is more efficient than ANP. ANP result comes:

$$
\text{W.S.M} = \begin{bmatrix}
0.0030 & 0.0044 & 0.0022 & 0.0042 & 0.0075 & 0.0185 & 0.0078 & 0.0150 & 0.0454 & 0.0194 & 0.0618 & 0.0184 \\
0.0061 & 0.0067 & 0.0043 & 0.0084 & 0.0225 & 0.0185 & 0.0155 & 0.0225 & 0.0454 & 0.0778 & 0.0412 & 0.0551 \\
0.0030 & 0.0044 & 0.0022 & 0.0021 & 0.0075 & 0.0061 & 0.0155 & 0.0075 & 0.0454 & 0.0388 & 0.0412 & 0.0184 \\
0.0030 & 0.0089 & 0.0108 & 0.0084 & 0.0150 & 0.0246 & 0.0232 & 0.0300 & 0.0605 & 0.0388 & 0.0618 & 0.0919 \\
0.0092 & 0.0089 & 0.0086 & 0.0105 & 0.0150 & 0.0308 & 0.0155 & 0.0300 & 0.0605 & 0.0778 & 0.0618 & 0.0919 \\
0.0030 & 0.0044 & 0.0022 & 0.0042 & 0.0150 & 0.0123 & 0.0155 & 0.0075 & 0.0151 & 0.0194 & 0.0412 & 0.0184 \\
0.0153 & 0.0089 & 0.0108 & 0.0063 & 0.0375 & 0.0246 & 0.0309 & 0.0023 & 0.0605 & 0.0972 & 0.1030 & 0.0919 \\
0.0030 & 0.0044 & 0.0022 & 0.0021 & 0.0075 & 0.0123 & 0.0078 & 0.0075 & 0.0454 & 0.0194 & 0.0206 & 0.0184 \\
0.0061 & 0.0067 & 0.0108 & 0.0084 & 0.0375 & 0.0185 & 0.0387 & 0.0300 & 0.0756 & 0.0778 & 0.0618 & 0.0919 \\
0.0061 & 0.0067 & 0.0086 & 0.0105 & 0.0300 & 0.0185 & 0.0232 & 0.0075 & 0.0756 & 0.0972 & 0.0618 & 0.0551 \\
0.0061 & 0.0089 & 0.0086 & 0.0105 & 0.0225 & 0.0308 & 0.0309 & 0.0300 & 0.0756 & 0.0583 & 0.0618 & 0.0735 \\
0.0154 & 0.0067 & 0.0086 & 0.0042 & 0.0225 & 0.0246 & 0.0155 & 0.0300 & 0.0756 & 0.0583 & 0.0618 & 0.0551
\end{bmatrix}
$$

4.4 Sensitivity Analysis

Due to the inherent subjectivity in human judgment, collecting responses through questionnaires can introduce imprecision and ambiguity into the analysis process. Even minor variations in the relative weights assigned to different factors can substantially alter the final ranking of variables, potentially leading to inaccurate or misleading conclusions. This is particularly true when the inputs are based on arbitrary language assessments, such as those derived from fuzzy logic or expert opinions, where slight differences in interpretation can cause fluctuations in the results. To ensure the validity and reliability of the findings, it is crucial to perform a final rank check to validate the outcomes of fuzzy Analytical Hierarchy Process (AHP). By incorporating a sensitivity analysis to assess the global weights for sub-factors, researchers can better understand how changes in input values influence the overall ranking and ensure that the conclusions drawn are robust and reliable. Sensitivity analysis provides an additional layer of confidence, allowing for the identification of the most critical factors that impact the final ranking and ensuring that the decision-making process reflects the true priorities and relationships between the variables.

Table 11. Global weights for sub-factors by sensitivity analysis

Sub-Factors	0.1	0.2	0.3	0.4	0.5	0.6	0.68 (Normal)	0.7	0.8	0.9
E11	0.133	0.118	0.103	0.089	0.074	0.059	0.047	0.044	0.030	0.015
E12	0.015	0.013	0.011	0.010	0.008	0.007	0.005	0.005	0.003	0.002
E13	0.050	0.044	0.039	0.033	0.028	0.022	0.018	0.017	0.011	0.006
E14	0.027	0.024	0.021	0.018	0.015	0.012	0.010	0.009	0.006	0.003
E21	0.436	0.388	0.339	0.291	0.242	0.194	0.155	0.145	0.097	0.048
E22	0.145	0.129	0.113	0.097	0.081	0.065	0.052	0.048	0.032	0.016
E23	0.062	0.055	0.048	0.041	0.035	0.028	0.022	0.021	0.014	0.007
E24	0.032	0.028	0.025	0.021	0.018	0.014	0.011	0.011	0.007	0.004
E31	0.062	0.124	0.186	0.248	0.311	0.373	0.422	0.435	0.497	0.559
E32	0.011	0.022	0.033	0.044	0.056	0.067	0.075	0.078	0.089	0.100
E33	0.013	0.026	0.039	0.052	0.066	0.079	0.089	0.092	0.105	0.118
E34	0.014	0.027	0.041	0.055	0.069	0.082	0.093	0.096	0.110	0.123

Figure 3 illustrates a sensitivity analysis graph showing the impact of variable changes on the system's performance. This study performed a sensitivity analysis to examine the priority ranking of ergonomic factors in garment production. Specifically, the analysis focused on the most influential factor, "Industrial environment (E3)," by incrementally increasing its dimensions from 0.1 to 0.9 in steps of 0.1. As the weights of the main factors change, the ranking of the sub-factors also changes. Table 11 presents the corresponding changes in the global weights of the sub-factors resulting from the sensitivity analysis.

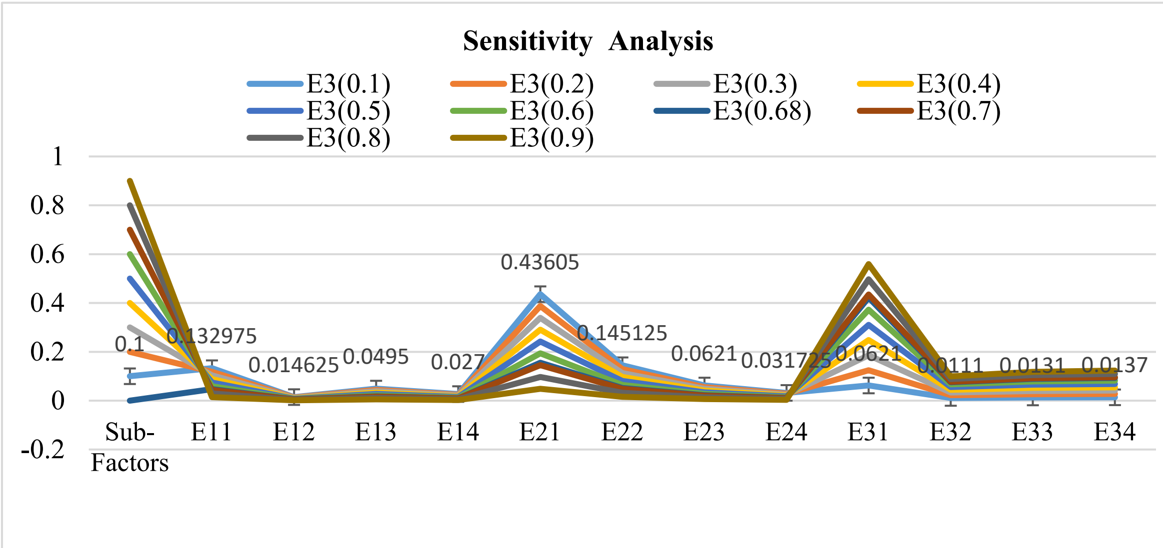

Figure 3. Graph for sensitivity analysis

The ranking of main factors is shown in Table 9 above: "Industrial environment (E3)" has the highest weight and impact is 0.68, followed by "occupational diseases (E1)" and "personal factors (E2)". The results show that the workplace significantly impacts workers' health more than anything else. Poor construction, poorly designed machinery, and inefficient fields reduced Production and increased the risk of musculoskeletal diseases (MSDs) among workers (Govindan, Diabat, & Shankar 2015).

BentProp et al. (Di Valentin, Emrich, Werth, & Loos, 2015) have drawn attention to how economic pressure can affect workers' health and lead to increased absenteeism. "Personal factors (E2)" comes second with 0.24. Studies on call centers, such as that of Vulvic et al. (Bontrup et al., 2019), found a positive relationship between the personal health of workers and the incidence of back pain. Many studies have investigated the link between prolonged sitting and back pain, emphasizing the role of individual characteristics in ergonomic Production. Most ergonomic issues vary from workplace to workplace and according to the nature of the job. Workers in physically demanding industries like construction, driving, and manual labor are more prone to experience ergonomic issues. In addition, workers who work in front of computers for long periods often experience musculoskeletal disorders and back, wrist, and neck pain. These findings support the idea that occupational diseases contribute to many worker-related illnesses. The ranking highlights the need to address these ergonomic issues to increase productivity and improve worker quality.

5. Conclusion

In conclusion, this research highlights the significant role of ergonomic factors in shaping productivity within Bangladesh's garment industry, pinpointing key issues impacting worker health and well-being. Ergonomic deficiencies, such as outdated machinery, poorly designed workspaces, and health concerns, contribute to reduced productivity and increase the risk of musculoskeletal disorders and respiratory issues. Unlike developed nations, where ergonomic practices are prioritized, Bangladesh's garment industry has yet to fully address these challenges due to a reliance on inexpensive labor and limited awareness. Through the application of the Analytical Network Process (ANP), the study reveals that the work environment has the most substantial influence on productivity (0.68), followed by individual characteristics (0.24) and health issues (0.08). The findings stress the need for management to enhance the work environment and allow sufficient rest periods for workers. These improvements are not only critical for the garment sector but also beneficial for other small and medium-sized enterprises. Future research should integrate DEMATEL and ISM methodologies to explore the interrelationships between ergonomic factors, while also examining the psychological and cognitive aspects that can drive technological updates in workplace design.

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Biographies

Rotan Kumar Saha is a dynamic and energetic researcher who completed his M.Sc. in Mechanical Engineering at Dhaka University of Engineering & Technology (DUET), Gazipur. He holds an undergraduate degree from the Department of Industrial and Production Engineering at DUET. His research interests include a broad range of advanced manufacturing topics such as additive manufacturing, 3D printing, lean manufacturing, Lean Six Sigma, Total Quality Management (TQM), and optimization techniques.

Md. Mamun is a motivated researcher and a graduate student in the Department of Mechanical Engineering at Dhaka University of Engineering & Technology, Gazipur. His research interests span a wide range of innovative and sustainable fields, including sustainable energy, renewable energy, and green energy.

Safayet Hossain is a student of the Department of Industrial & Production Engineering at Dhaka University of Engineering and Technology, Gazipur. His research interests include Optimization, Advance Manufacturing, Modeling & simulations, 3D printing. He is very much interested to be a part of IEOM.

Md. Tareque Hasan is a student of the Department of Industrial & Production Engineering at Dhaka University of Engineering and Technology, Gazipur. His research interests include Manufacturing, Modeling & simulations, Data Analytics and Machine Learning, Optimization, Operation research etc. He is very much interested to be a part of IEOM.

Sujoy kundu is a student of the Department of Industrial & Production Engineering at Dhaka University of Engineering and Technology, Gazipur. His research interests include Manufacturing, Optimization, 3D printing and Additive manufacturing.

Tuhin Hosen is a student of the Department of Industrial & Production Engineering at Dhaka University of Engineering and Technology, Gazipur. His research interests include Manufacturing, Modeling & simulations, Optimization, 3D printing and Additive manufacturing. He is very much interested to be a part of IEOM.

Md. Nazmul Hasan is a student of the Department of Industrial & Production Engineering at Dhaka University of Engineering and Technology, Gazipur. His research interests include Manufacturing, Green Supply Chain, Optimization, 3D printing and additive manufacturing.