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An Investigation of Challenges and Opportunities of Implementing Industry 4.0 in the Garments Industry: A Case Study of Bangladesh

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Abstract

The main purpose of this study is to investigate the challenges and opportunities of implementing Industry 4.0 in the Bangladeshi garments industry. Through the literature reviews, 10 challenges and 10 opportunities were identified, which were then presented in a questionnaire to industry experts to determine which factors were the most and least important. Afterward, the relative importance of each statistically significant challenge and opportunity was assessed using the Relative Importance Index (RII) method. Several factors act as barriers to implementing Industry 4.0. These include high investment, lack of skilled workers for Industry 4.0, lack of advance technology, lack of manufacturing system integration, necessity of new management skills, difficulty in hiring/training specialized staff, and threat of data/system security. There are also several potential opportunities associated with implementing Industry 4.0, such as increase productivity, improve communication efficiency, allow mass customization, provide products with superior performance, increase global competitiveness, increase product variety, reduce delivery time, and more flexible production systems. Overall, this study aims to help the Bangladeshi garments industry better understand the challenges and opportunities involved in adopting Industry 4.0.

Keywords
Industry 4.0, Garments Industry, Challenges, Opportunities.

1. Introduction

Bangladesh has the fastest-growing garments sector and ranks second only to China. The country has been producing RMG products for almost four decades. It has earned a position as one of the most promising hubs for the global apparel industry. This is mainly due to the availability of manpower, strong communication, and transportation facilities. In the current global digital transformation era, the garments industry in Bangladesh stands at a pivotal point within the broader deployment phase of digital technologies. This phase is crucial as industries worldwide progressively integrate advanced digital solutions to foster growth and innovation. A combination of manual and automated processes is used daily to meet the continuous market demand. On average, it takes about seven months to introduce a new item to the market, from product conceptualization to the end of the production process.

Significant advancements in technology, communication, digitization, automation, artificial intelligence, 3D printing, and high-performance computing now enable engineering, management, and production to modernize and innovate the RMG sector with state-of-the-art machinery and skilled talent. The government is actively working to implement this transformation in order to better serve customer demands at lower costs and with shorter lead times. This transition is necessary for sustained growth and to meet rising demand. Applying these methods and technologies can reduce new product introduction time from seven months to only a few days, while also standardizing processes, ensuring quality, and minimizing waste. To realize these benefits, the apparel industry must adopt the core principles of the Fourth Industrial Revolution, known as Industry 4.0.

Most garment factories in Bangladesh are at the second stage, or early third stage, of the industrial revolution scale. They rely heavily on manual labor (second stage) and use electrically powered machines for some tasks. Only a small fraction of tasks uses automated machines (third stage). To align current industrial operations with Industry 4.0, factories must first advance fully into the third stage, aiming to complete this transition by 2028. This progression will provide a foundation for gradually moving into the fourth industrial revolution. This planned transition phase will enable factory leaders to visualize the journey more effectively. Yet, many barriers must be overcome to achieve and sustain this transformation. As a result, extensive groundwork and wide organizational changes are required to support these transformations.

Consequently, the rest of the study focuses on addressing the challenges of implementing Industry 4.0 with respect to the garment sector of Bangladesh and the opportunities it might bring if implemented successfully. These issues are explored in detail in the subsequent sections.

1.1 Problem Statement

Industry 4.0 is an emerging technology, and many industries around the world are trying to adopt it for their advancement. To implement this technology in any sector, sufficient study and preparation are essential. The garment industry acts as a catalyst for the development of Bangladesh. Sooner or later, the Bangladeshi garments industry will need to adopt Industry 4.0 to keep pace with the modern world. Therefore, this study aims to investigate the challenges and opportunities related to the implementation of Industry 4.0 in the Bangladeshi garments industry.

1.2 Objectives

- To investigate the challenges of implementing Industry 4.0 in the Bangladeshi garments industry.
- To investigate the opportunities of implementing Industry 4.0 in the Bangladeshi garments industry.

2. Literature Review

In Bangladesh, automation has been used sparingly in key manufacturing industries. Industry 4.0 has the potential to reduce unit costs, enhance communication efficiency, minimize accident risks, and contribute to a more sustainable economy. However, poor infrastructure, the availability of cheaper labor, the high cost of technology installation, lack of government support, and insufficient knowledge are major barriers to its implementation. This study was conducted using a qualitative approach; future studies may employ quantitative methods, using obstacles as variables. This study does not address whether the implementation of Industry 4.0 in Bangladesh will result in job loss (Islam at el. 2018).

A study conducted in Brazil proposed a framework of Industry 4.0 technology layers categorized into front-end and base technologies, along with levels of acceptance and implications for manufacturing industries. Front-end technologies include four dimensions: smart manufacturing, smart products, smart supply chain, and smart working, while base technologies consist of the Internet of Things, cloud services, big data, and analytics. This study focused

on an industrial sample operating within business-to-business (B2B) models, which differ greatly from business-to-consumer (B2C) models. It demonstrated a positive relationship between large companies and advanced Industry 4.0 adoption. Future research may investigate how small companies relate to advanced Industry 4.0 adoption (Frank at el. 2019).

Small and medium-sized enterprises (SMEs) must adopt Industry 4.0 to achieve long-term success. Organizational structure and processes must be supportive for the successful implementation of new technologies. Industry 4.0 represents the latest wave of technological advancement; however, due to limited resources, many SMEs struggle to adopt it properly. In this situation, adapting the existing methodology to high-tech SMEs may yield better results (Haseeb at el. 2019). Manufacturers with higher levels of education show a positive correlation with improved performance. Highly educated entrepreneurs contribute significantly to industrial growth in Bangladesh. Findings emphasize the importance of large-scale technology, marketing, procurement, and production technologies in supporting industrial development in developing countries. Future researchers should identify which technologies are most suitable for Bangladesh to sustain this development (Gera & Singh, 2019).

In Pakistan, both the manufacturing and logistics industries face several challenges that result in below-average performance. These industries require a holistic approach that incorporates big data, smart factories, cyber-physical systems (CPS), and IoT to demonstrate the advantages of Industry 4.0. Future researchers may compare the performance of various production and service industries before and after Industry 4.0 implementation (Imran at el. 2018). Traditional manufacturing faces numerous challenges, including lack of modern technology, insufficient financial investment, weak managerial vision, and inexperienced labor as it transitions toward Industry 4.0. Additional surveys may provide stronger generalizations to better understand these challenges (Huang at el. 2019).

Small and medium enterprises serve as the backbone of the European Union's economy. To remain competitive, advanced innovations must be developed. However, although Industry 4.0 technologies are being applied, the roadmap for successful implementation remains unclear for both academia and industry (Alcácer & Machado, 2019). Industry 4.0 introduces labor-saving technologies, increasing profits for entrepreneurs while creating new skill-based work demands. When viewed broadly, it is evident that developing countries like Bangladesh still have a long way to go to achieve Industry 4.0 targets. Each step requires significant effort and improvements (Mottaleb & Sonobe, 2011).

Due to obstacles such as lack of awareness, insufficient funding, poor infrastructure, lack of skilled human capital, and various socio-economic challenges, the adoption of Industry 4.0 remains far behind. The study also found that Industry 4.0 can enhance productivity, resource efficiency, global competitiveness, revenue growth for high-skilled workers, customer satisfaction, and access to new markets, as well as support new supply chain integration in Bangladesh. However, this paper does not present an implementation model for Industry 4.0 (Bhuiyan at el. 2020).

Another paper investigates several challenges of implementing Industry 4.0 in developing countries and proposes solutions to overcome these barriers. The study was conducted using qualitative methods; future studies may use quantitative approaches (Rashidian, 2021). Technoware was identified as the most significant factor, while humanware was the least significant for the advancement of Industry 4.0 technologies in the new product development process of the apparel industry. The study used a small sample from the Sri Lankan apparel sector; therefore, future studies should focus on specific industries and different country settings to examine the external validity of the findings (Wijewardhana at el. 2020).

2.1 Research Gap

Most studies on the implementation of Industry 4.0 have been conducted in various parts of the world. The garment industry serves as a catalyst for the economic development of Bangladesh. As a developing country, Bangladesh is not yet fully aware of or prepared for Industry 4.0. However, sooner or later, the country will need to adopt Industry 4.0 to keep pace with the modern world. The challenges and opportunities related to implementing Industry 4.0 in the Bangladeshi garments industry have not been thoroughly studied. Therefore, this study aims to investigate these challenges and opportunities. The factors most relevant to the context of Bangladesh were considered to obtain accurate and meaningful insights.

3. Methodology

This case study followed a structured methodological approach to identify and evaluate the key challenges and opportunities associated with implementing Industry 4.0 in the Bangladeshi garments industry. The methodology consisted of four major phases: literature review, data collection, data analysis, and ranking of factors (See Figure 1).

A comprehensive review of existing literature was conducted to understand global perspectives on Industry 4.0 and its implications for developing economies. From this review, 10 potential challenges and 10 potential opportunities relevant to Industry 4.0 implementation were identified for further investigation.

To validate and assess the relevance of these factors within the context of Bangladesh, expert opinions were collected through a structured questionnaire. Industry professionals with experience in the garments sector were selected to ensure reliable and context-specific insights.

Expert responses were first converted into a five-point Likert scale to standardize the data. Hypothesis testing was then performed using SPSS to determine the statistical significance of each factor. This step ensured that the identified challenges and opportunities were supported by empirical evidence rather than subjective assumptions.

Following statistical validation, the Relative Importance Index (RII) method was applied to rank the challenges and opportunities in order of their perceived importance. This ranking provided a clear hierarchy of factors, highlighting the most critical issues and the most promising opportunities for Industry 4.0 adoption in the garments sector of Bangladesh.

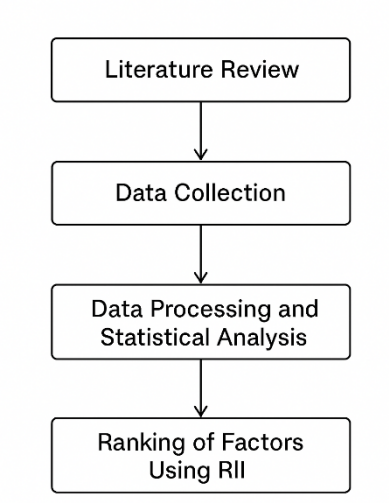

Figure 1. Methodology Flowchart.

3.1 Proposed Solution

In this study, our main aim is to investigate the challenges and opportunities associated with implementing Industry 4.0 in the Bangladeshi garments industry. We also sought to identify the relative importance of these challenges and opportunities. To achieve these objectives, we designed a structured questionnaire based on ten potential challenges (listed in Table 1) and ten potential opportunities (listed in Table 2), which were systematically derived from an extensive review of existing literature. The use of a questionnaire enabled us to collect standardized responses from industry experts, thus ensuring the comparability and reliability of the data. This approach also facilitated the quantitative assessment of each factor's significance within the specific context of the Bangladeshi garments sector.

Table 1. Potential Challenges.

Serial No.	Challenges	References
1	High investment	(Dalenogare at el. 2018)
2	Poor infrastructure	(Islam at el. 2018)
3	Lack of skilled workers for Industry 4.0	(Fettermann at el. 2018)
4	Difficulty in hiring/training specialized staff	(Horváth & Szabo, 2019)
5	Lack of manufacturing system integration	(Ghobakhloo, 2018)
6	Lack of advance technology	(Islam at el. 2018)
7	Threat of data/system security	(Ojra, 2019)
8	Necessity of new management skills	(Alok Raj, 2019).
9	Resistance of the organizational culture	(Raj at el. 2019).
10	Lack of govt. policy and support	(Islam at el. 2018)

Table 2. Potential Opportunities.

Serial No.	Opportunities	References
1	Increase productivity	(Islam at el. 2018)
2	Reduce production cost	(Long at el. 2017)
3	Improve communication efficiency	(Islam at el. 2018)
4	Increase product variety	(Santos at el. 2017)
5	Allow mass customization	(Birkel at el. 2019)
6	Lessen the waste materials	(Islam at el. 2018)
7	More flexible production systems	(Szalavetz, 2017)
8	Reduce delivery time	(Kurniawan at el. 2019)
9	Provide products with superior performance	(Santos at el. 2017)
10	Increase global competitiveness	(Gružauskas at el. 2018)

Each factor (challenge or opportunity) included five levels of agreement: strongly agree, agree, neutral, disagree, and strongly disagree. On the five-point Likert scale, “strongly agree” was assigned a value of 5, while “strongly disagree” was assigned a value of 1. Respondents were asked to rate their level of agreement with each statement accordingly. A t-test was used to identify the statistically significant factors. After filtering the significant factors, the Relative Importance Index (RII) method was used to rank them. The RII method was selected because of its effectiveness in ranking variables to support the decision-making process. Details of the RII method are provided below. The Relative Importance Index (RII) is used to determine the relative importance of each factor, and its equation is presented in Equation 1.

$$\mathbf{RII = \Sigma W / (A \times N)} \quad \textit{(Equation 1)}$$

Where:

- **W** = Weight given to each factor by the respondents, ranging from 1 to 5 on the five-point Likert scale.
- **A** = The highest weight on the Likert scale.
- **N** = Total number of respondents.

4. Result and Discussion

Results and associated discussion are presented in this section.

4.1 Data Collection

People who had adequate knowledge about Bangladesh, the garments industry, and Industry 4.0 were encouraged to participate in the survey. A total of 40 participants took part in the study. Most of the respondents were engineers, teachers, industry experts, and university students. The demographic characteristics of the respondents are presented in Table 3.

Table 3. Demographic characteristics of the respondents.

Age				**Gender**		**Working Experience (years)**		
20-29	30-39	40-49	50 or above	Male	Female	0-2	2-5	More than 5
50%	25%	17.5%	7.5%	82.5%	17.5%	35%	27.5%	37.5%

Participants in the study were provided with a questionnaire along with sufficient information. The questionnaire included 10 potential challenges and 10 potential opportunities related to implementing Industry 4.0 in the Bangladeshi garments industry. Respondents were asked to rate each item on a Likert scale ranging from strongly disagree (1) to strongly agree (5). They were also encouraged to provide additional suggestions related to the study.

4.1 Result Analysis

After completing data collection, the responses were converted into a five-point Likert scale. A one-sample t-test was then performed using SPSS on the selected challenges and opportunities to identify statistically significant factors. The confidence level was set at 90%, corresponding to a significance level (α) of 0.10. A factor was considered statistically significant if the p-value (Sig. 2-tailed) was less than 0.10.

The hypotheses were formulated as follows:

- **Null Hypothesis (H_{on}):** The nth factor is not statistically significant.
- **Alternative Hypothesis (H_{an}):** The nth factor is statistically significant.

where *n* represents the serial number of each factor listed in Table 4 and Table 5.

Table 4. One-sample t-test results for Challenges.

Serial No.	**Challenges**	**Test Value = 3.75**					
		t	**df**	**P-value (Sig. 2-tailed)**	**Mean Difference**	**90% Confidence Interval of the Difference**	
						Lower	**Upper**
1	High investment	8.275	39	0.000	0.725	0.58	0.87
2	Poor infrastructure	0.842	39	0.405	0.125	-0.13	0.38
3	Lack of skilled workers for Industry 4.0	5.725	39	0.000	0.550	0.39	0.71
4	Difficulty in hiring/training specialized staff	2.656	39	0.011	0.300	0.11	0.49
5	Lack of manufacturing system integration	3.500	39	0.001	0.350	0.18	0.52
6	Lack of advance technology	3.660	39	0.001	0.375	0.20	0.55
7	Threat of data/system security	1.746	39	0.089	0.250	0.01	0.49

8	Necessity of new management skills	3.749	39	0.001	0.350	0.19	0.51
9	Resistance of the organizational culture	1.516	39	0.137	0.175	-0.02	0.37
10	Lack of govt. policy and support	-1.283	39	0.207	-0.200	-0.46	0.06

Table 4 presents the results of the one-sample t-test for challenges associated with Industry 4.0 implementation. The results indicate that most of the challenges have p-values less than 0.10, leading to the rejection of the null hypothesis and confirming their statistical significance. Specifically, high investment, lack of skilled workers for Industry 4.0, difficulty in hiring/training specialized staff, lack of manufacturing system integration, lack of advance technology, Threat of data/system security, and necessity of new management skills were found to be statistically significant challenges. However, poor infrastructure (2nd), resistance of organizational culture (9th), and lack of govt. policy and support (10th) exhibit p-values greater than 0.10. Hence, the null hypothesis fails to be rejected for these factors, indicating that they are not statistically significant challenges within the scope of this study.

Table 5. One-sample t-test results for opportunities.

Serial No.	**Opportunities**	**Test Value = 3.75**					
		t	**df**	**P-value (Sig. 2-tailed)**	**Mean Difference**	**90% Confidence Interval of the Difference**	
						Lower	**Upper**
1	Increase productivity	11.13	39	0.000	0.925	0.78	1.07
2	Reduce production cost	-0.534	39	0.596	-0.075	-0.31	0.16
3	Improve communication efficiency	8.286	39	0.000	0.650	0.52	0.78
4	Increase product variety	2.328	39	0.025	0.300	0.08	0.52
5	Allow mass customization	6.354	39	0.000	0.575	0.42	0.73
6	Lessen the waste materials	-0.944	39	0.351	-0.125	-0.35	0.10
7	More flexible production systems	1.688	39	0.099	0.200	0.00	0.40
8	Reduce delivery time	1.940	39	0.060	0.225	0.03	0.42
9	Provide products with superior performance	3.455	39	0.001	0.375	0.19	0.56
10	Increase global competitiveness	2.962	39	0.005	0.325	0.14	0.51

Table 5 summarizes the one-sample t-test results for opportunities related to Industry 4.0 adoption. The findings reveal that several opportunities are statistically significant at the 90% confidence level. These include increase productivity, improve communication efficiency, increase product variety, allow mass customization, more flexible production systems, reduce delivery time, provide products with superior performance, and increase global competitiveness. For these factors, the null hypothesis is rejected due to p-values less than 0.10. In contrast, reduce production cost (2nd) and lessen the waste materials (6th) have p-values greater than 0.10. Therefore, the null hypothesis fails to be rejected for these opportunities, suggesting that they are not statistically significant in this study.

Then, the Relative Importance Index (RII) method was applied to rank the statistically significant challenges and opportunities. The corresponding ranks of the significant challenges are presented in Table 6. Here, the factor ranked

first has the greatest impact, and the intensity of the impact decreases as the rank increases. As shown in Table 6, high investment is identified as the most significant challenge, whereas threat of data/system security is ranked as the least significant among the statistically significant challenges.

Table 6. Relative Importance Index (RII) of statistically significant challenges.

Serial No.	Challenges	Relative Importance Index	Rank
1	High investment	0.895	1
3	Lack of skilled workers for Industry 4.0	0.86	2
4	Difficulty in hiring/training specialized staff	0.81	6
5	Lack of manufacturing system integration	0.82	4
6	Lack of advance technology	0.825	3
7	Threat of data/system security	0.8	7
8	Necessity of new management skills	0.82	5

The Pareto chart of potential challenges with RII values is shown in Figure 2. It shows the frequency of potential challenges related to implementing Industry 4.0 in the Bangladeshi garments industry.

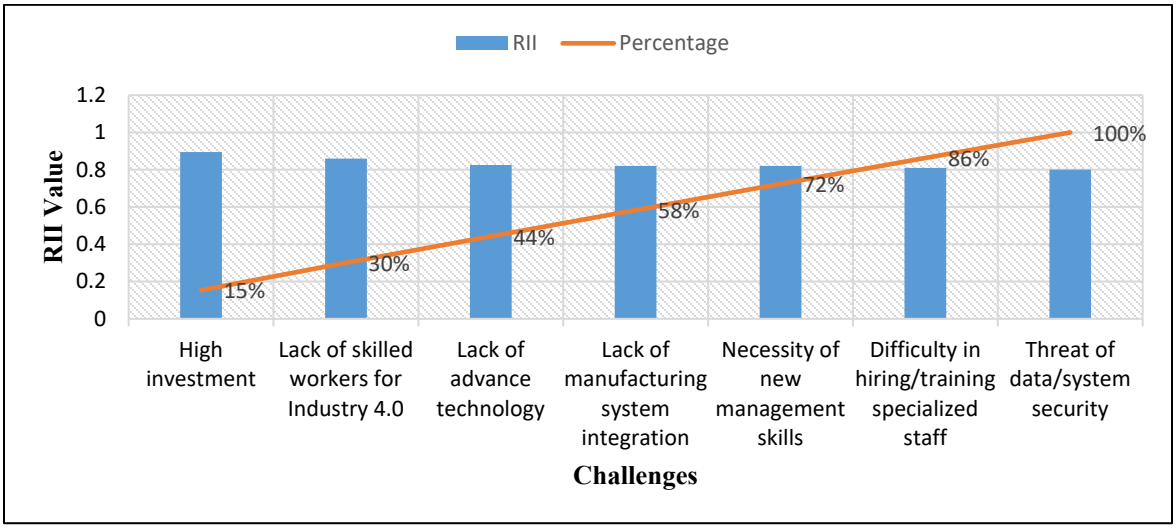

Figure 2. Pareto chart of statistically significant Challenges.

The resultant ranks of the opportunities are shown in Table 7. The factor ranked first has the greatest impact, and the intensity of the impact decreases as the rank increases. From Table 7, it is seen that “increase productivity” is the most significant opportunity, while “more flexible production systems” is the least significant opportunity. Greater attention should be given to the factors ranked at the top.

Table 7. Relative Importance Index (RII) of statistically significant opportunities.

Serial No.	Opportunities	Relative Importance Index	Rank
1	Increase productivity	0.935	1
3	Improve communication efficiency	0.88	2
4	Increase product variety	0.81	6
5	Allow mass customization	0.865	3
7	More flexible production systems	0.79	8
8	Reduce delivery time	0.795	7
9	Provide products with superior performance	0.825	4
10	Increase global competitiveness	0.815	5

The Pareto chart of potential opportunities with RII values is shown in Figure 3. It shows the frequency of potential opportunities related to implementing Industry 4.0 in the Bangladeshi garments industry.

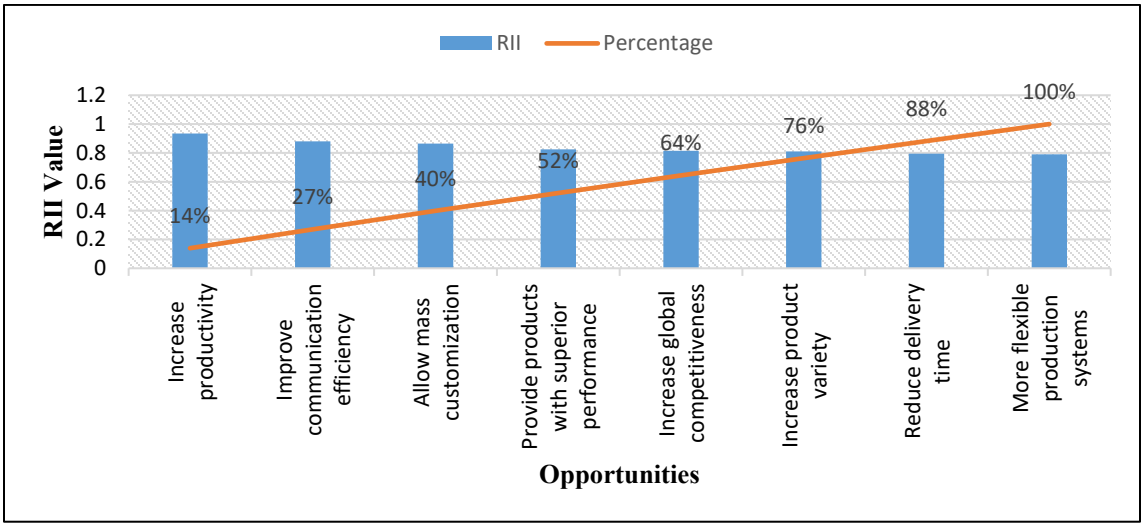

Figure 3. Pareto chart of statistically significant Opportunities.

4.3 Discussion

The analysis generates an organized list of factors, both challenges and opportunities, that affect the decision-making process for implementing Industry 4.0. In Table 6, the factors ranked 1, 2, and 3 represent the most critical challenges in the context of Industry 4.0 implementation. Similarly, the most significant opportunities are ranked 1, 2, and 3 in Table 7.

The RII method, which forms the basis of this study, relies on the ratings provided by the respondents and the number of respondents. The data were primarily collected through interviews with industry experts who possess in-depth knowledge of the field. This approach minimizes the likelihood of apparent errors. However, the number of respondents was limited to 40 participants, so there is a high probability that some unintentional noise in the dataset was carried forward in the ranking process. To address this, we conducted hypothesis testing to further minimize errors. Although we initially collected 10 potential challenges and 10 potential opportunities from the literature review, we were forced to reject three challenges and two opportunities because they were not statistically significant.

The fundamental factors of challenges and opportunities were screened from various literature sources, forming the core of this study. However, the shortlisted factors were selected randomly, which might have some impact on the

generalizability of Industry 4.0 implementation. Yet, no hard evidence suggests that these factors are equally addressable, specific, and logical for the Apparel Industry 4.0.

6. Conclusion

Due to several barriers such as high investment, lack of skilled workers for Industry 4.0, lack of advance technology, lack of manufacturing system integration, necessity of new management skills, Difficulty in hiring/training specialized staff, and Threat of data/system security, Bangladesh has fallen behind in properly implementing Industry 4.0 in the garments industry. However, there are potential opportunities, including increase productivity, improve communication efficiency, allow mass customization, provide products with superior performance, increase global competitiveness, Increase product variety, Reduce delivery time, and more flexible production systems regarding implementing Industry 4.0 in the garments industry. Therefore, the industry should strive to adopt Industry 4.0 as soon as possible to keep pace with the modern world. It is crucial for key decision-makers, from the highest levels of government to industry leaders, to rapidly embrace Industry 4.0 so that the country can fully utilize and maximize the benefits it offers.

7. Future Work

In this study, the analysis was carried out using the Relative Importance Index (RII) method. Future studies can apply multi-criteria decision-making (MCDM) methods, such as the Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), or VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), which may generalize the results more precisely. In our study, only 40 respondents participated in the survey. Future studies can increase the number of expert respondents from various companies, which may yield more reliable results.

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