



ASSESSING THE READINESS LEVEL OF RMG SECTOR OF BANGLADESH TOWARDS IMPLEMENTING INDUSTRY 4.0

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Abstract

Industry 4.0 is considered as the fourth industrial revolution (4IR) and involves virtual and physical systems that are interconnected and collaborative in an autonomous way. The ready-made garments (RMG) sectors in Bangladesh have been undergoing a transition that encompasses the digitization of garment production processes. This research work provides the readiness assessment of the RMG sector of Bangladesh regarding industry 4.0 deployment. Industry 4.0 is a relatively advanced theory within the RMG factories, and it promotes the interest on how to make utilization of technologies included in the idea and take benefit from them as well. The study dilemma is that there is a limited amount of readiness assessments available that cover problems of interest. The research question has been created to assess the readiness level of the RMG sector in Bangladesh with regard to the application of Industry 4.0. The data collection and analysis techniques were adopted from the IMPULS model which is a foundation of the German Engineering Federation, VDMA (Verband Deutscher Maschinen- und Anlagenbau). The quantitative method of the IMPULS model was modified to address the study issue accordingly. The findings demonstrate that RMG factories are rated no higher than level two out of six levels (0-5). It indicates that they are in the emerging state of implementing Industry 4.0 and facing significant challenges, particularly in strategy formation and facility infrastructure to fulfill the demands of Industry 4.0. The conclusion is that a great portion of RMG factories of Bangladesh is at the beginner level. The beginner level is comparable to level 1, which indicates a low level of readiness. Lack of knowledge, limited government help, poor infrastructure, cheap labor availability, and high initial investment costs could all be the contributing factors toward a lower level of readiness.

Keywords: Industry 4.0, Physical system, Ready-made garments, Digitization, Readiness assessment, Investment cost

Introduction

The impression of the industrial establishment was greatly changed by the global recession over the early years of 21st century. Organizations that followed the traditional approach of relocating facility by considering cheap labor, are now devoted to recuperate their competitiveness. The strategy taken by the German manufacturing industry played a pivotal role on this transformation. They took various initiatives to sustain and stimulate its significance as a predecessor in the manufacturing sectors (Hofmann, et al., 2017). The term Industry 4.0 was introduced and with its big assurances raised to tackle the latest issues in production environment. It facilitates and strengthens digital transformation by means of altering the lifestyles, building new models for corporate, using sophisticated know-hows and new means of manufacturing (Alcacer & Cruz-Machado, 2019). Industry 4.0, well known as the fourth industrial revolution (4IR) includes three technological trends: connectivity, intelligence and flexible automation. Industry 4.0 can be considered as the combination of Cyber-Physical Systems (CPS) production based on IT (information technology) and OT (operational technology), Big Data and smart technologies such as the Industrial Internet of Things (IIoT). It eventually makes machines capable of taking decisions with nominal human interference.

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Industry 4.0 is about more than just technology-focused change, which is a scope to support everybody, including policy makers, business owners, and persons from different income groups and countries, to utilize transforming technologies for creating an inclusive, human-centered future. This revolution embedded in a new phenomenon known as digitalization other than appearance of new form of energy. The first industrial revolution was initiated with the invention of steam engine and the mechanization of industrial activities (mechanization of spinning and weaving mills) in the 18th century. The second industrial revolution was happened in the late 19th century by the application of electrical energy and mass production techniques in manufacturing. New electricity driven machines were developed. Apparel industry grew at a fast pace with rising demand across the world. Clothing industry shifted from small-sized to industrial scale by the introduction of assembly lines. Third revolution took place in late 20th century with the applications of electronic systems and computer technologies for manufacturing system. Apparel equipment became more advanced and automated. China was evolved as a giant in apparel sectors, and western companies became bankrupts or relocated their manufacturing to Asian countries.

Bangladesh is the second largest RMG producer after China. Manufacturing is the leading industrial settlements in Bangladesh of which 86% of them dedicated for apparel products. There are about 5000 garment factories operational in Bangladesh in which almost 4.4 million people are employed. Bangladesh is evolving into an extraordinary contender in RMG due to its substantial capability and comparatively lower labor cost. However, there is a criticism of Bangladesh for not having proper infrastructure and poor technological application. The country also has bad reputation of lower labor productivity, unskilled workers and lower rate of unit output when compared with other RMG producing countries like Sri Lanka and Indonesia (Hossain, et al., 2019). Several authors proposed that a nation with technological amalgamation and its practice in manufacturing can greatly improve production efficiency by keeping high quality standards (Lasi, et al., 2014; Berawi, 2018). Industry 4.0 revolution is already ongoing. Industries that do not implement it are at a great risk of being hampered. If Bangladesh RMG industry fails to integrate the digital technological revolution, there is a possibility to decline competitiveness and soon will be replaced by the competitors from the global RMG markets. Thus, this research work is designed to assess the readiness level of RMG sectors in the context of Industry 4.0 perspective.

Literature Review

Numerous studies were conducted to explore the ins and outs of Industry 4.0. In this section the relevance of this study to the outcomes of the previous research works on this field will be addressed. Industry 4.0 has some elements that are crucial for the successful integration to a specific industry. Simulation is considered as very significant part of the 'Industry 4.0'. It uses information of products or elements, equipment and personnel to create virtual copies of real world (Gilchrist, 2016). Simulation technology is extending its applications in the design of virtual garments production, equipment settings for new apparel products design and development, and virtual plant operations. Another element of Industry 4.0 is the autonomous or self-governing Robots also known as collaborative robots ("Cobots"), developed to handle delicate and difficult task and so freeing workforces from boring and hazardous tasks (Bahrin, et al., 2016; Iyer, 2018). The use of autonomous Robots is yet to be noticeable in apparel manufacturing. However, they may play some roles in apparel manufacturing where 'health and safety' is a concern. Beside robotics, Additive Manufacturing is a key element of this revolution as it supports for the 3D sample garment printing which enables sample making within short time.

Information and materials flow as well as smooth running of finance from fiber producers to the clothing producers to the retailers will be more productive through 'Vertical and Horizontal System Integration'. IoT will be used for developing an interactive network amongst the controlling areas of a production system which will empower simplification of supply chain variables, merchandising tasks and business decision strategies. Augmented Reality may be a functional tool for training-up the operative employees and engineers employed in garment manufacturing machines and systems design. Perhaps, it will assist in decision making with more practical physical environmental conditions. However, as secure and reliable communication is a big issue in RMG global supply chain, this revolution will assure Cyber security with the help of advanced identity recognition and machine access management systems (Drath & Horch, 2014). Technologies like RFID (Radio Frequency Identification) will be an effective tool to identify the product location, specification and vital facts of which the stake holders should become aware.

The execution of Industry 4.0 requires vast amount of information dissemination across corporations (Coronado, et al., 2018). The application of Cloud computing will augment reaction times substantially (Liu & Xu, 2017). With the help of Cloud computing, information stored in the Cloud, can be accessed distantly through the internet. It will also cultivate the advancement of Computer-Aided Engineering and Manufacturing Execution Systems (AMFG, 2019). There are enormous collections of untapped data in the business world and to get information from this data, Big Data analytics is crucial. Experts suggest that Big Data can be used to discover unseen patterns, trends, correlations, consumer habits and other valuable insights (Witkowski, 2017; Lotti, et al., 2018). With Big Data and business analytics solutions, apparel retailer market decision making will be more practical and productive.

Germany introduced first the terminology “Industry 4.0” in order to improve its competitiveness in manufacturing industry (BDI, 2016). Germany is developing more rapidly than any other countries and reached at level 3.8. It may take a few more years to obtain Industry 4.0 completely. Though Industry 4.0 is acquainted and partially functioning in some developed countries, the phenomenon is not known to many industry people or policy makers of rest of the countries (Cleverism, 2018). However, this technology is crucial for the manufacturing dominated growing economy. RMG industry did not quite grab the opportunities that came with Industry 3.0 because of cheap labor and access to limited software. As a result, it experiences a lower production efficiency.

Fuzzy logic is a method of variable processing based on the observation or degrees of truth that people make decisions in conformity with imprecise and non-numerical information. Fuzzy logic approach could be used for assessment of Industry 4.0 (I4.0) readiness index of various manufacturing organizations. Wankhede and Vinodh (2023) proposed a fuzzy logic based I4.0 readiness model which assessed the readiness level of an automotive component manufacturing organization. The proposed assessment model has successfully applied fuzzy logic and multi-grade fuzzy approach for assessment of I4.0 readiness index and it could be utilized to further develop multi-level assessment module for Industry 4.0 readiness in an organization.

Saha et al., (2023) empirically examined the combined effect of the correlation between the I4.0 technologies and lean production (LP) practices on the degree of organizational sustainability performance (SP) enhancement of the ready-made garment (RMG) sectors of Bangladesh. The research findings indicated that the implementation of I4.0 technologies along with the application of LP tools can assist in delivering the lean objectives more efficiently which in fact helped explain the organizational SP through the combination of common resources, and technologies and management.

Sharmin (2022) explored the various dimensions of a readiness model that could be best suited for assessing the readiness index of the RMG sectors of Bangladesh regarding the adoption of I4.0 technologies. This exploratory research work utilized a mixed-method strategy (a hybrid method consisted of qualitative and quantitative approaches) to evaluate the preparedness of apparel sectors in various categories and focused on how factories do use technological tools and methodologies in order to adopt the massive changes brought forward by IR 4.0. The apparel companies should use technologies such as ERP, Big data analytics, Cloud computing, machine-to-machine communication /IoT to boost Bangladesh's global competitiveness and the findings revealed that Bangladesh's RMG sectors face significant difficulties in IR 4.0 strategy design and equipment organization to meet IR 4.0 expectations.

A hybrid Multi-Criteria Decision-Making Method (MCDM) approach has been proposed to rank the elements of industry 4.0 on the basis of their implementation potentials in the RMG sectors of Bangladesh (Bari et al., 2021). A combined Fuzzy Analytical Hierarchy Process (FAHP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II) approach has been used in the study to assess the weights of the evaluation criteria as well as to rank the elements of industry 4.0 based on those weighted criteria, in order to assist the decision makers in deciding which element needs to be adopted first, when the available resource is constrained. The research findings identified that the Industrial Internet of Things (IIoT) is the most dominant and Additive Manufacturing is the least significant element in regard to the adoption of I4.0 in the RMG industries of Bangladesh.

Bangladesh has set the RMG export target of US\$50 billion (Saber et al., 2019) and this ambitious goal comes with certain challenges. The assumption is such that if I4.0 is not absorbed, the growth of the industry might be hampered. There is also a vision of transforming Bangladesh into a digital economy. Bangladesh expects to be the 24th largest economy by 2030. To achieve those goals, systematic development is essential, for which digital

manufacturing will be one of the major drivers. This research work will contribute to a greater perception of how the technologies of Industry 4.0 can enhance competitiveness of RMG sectors. Moreover, it will contribute to the literature by finding the opportunities and challenges of implementing such sophisticated technology in labor intensive industry of RMG.

Methodology

This research work has been conducted for RMG sectors of Bangladesh in particular. As these sectors play the leading role of foreign income source in Bangladesh economy and contribute a major portion of the GDP growth, the management has to prioritize as well as focus on different types of innovation practices and technologies. In this concern, the methodology of the research was designed using a hybrid-method (combination of quantitative and qualitative methods) strategy to measure the readiness level of apparel sectors in Bangladesh from the perspective of Industry 4.0 implementation. The quantitative information of the IMPULS model, which is a foundation of the association of Germany's engineering industry study (VDMA), was revised to address the problem of interest - readiness assessment of the RMG sector of Bangladesh with regard to the adoption of I4.0. This research investigates the various dimensions of a readiness model, regarding this the questionnaire instrument used was modified from the VDMA study (Lightblau, K. et al., 2015.), with some questions amended and adjusted to match Bangladesh RMG factory's perspective.

Questionnaire Preparation: The research strategy in this study was a questionnaire instrument considering quantitative criteria. Following the important modifications, the questionnaire instrument comprised of a single qualitative question to examine respondents' knowledge of Industry 4.0 and 24 quantitative questions. The questions were divided into the following categories:

Category 1: General queries aimed at collecting information from respondents, such as respondent name, organizational size.

Category 2: Questions about organizational strategy that evaluated the status of strategy execution, organizational adaptability with Industry 4.0, and amount of investment in Industry 4.0 activities. The section was continued to identify the technologies which the organization was using during the survey period.

Category 3: Infrastructure inquiries targeted to collect information on the level of machinery infrastructure adaptability to Industry 4.0 operational requirements that facilitate a relation between the physical and virtual worlds.

Category 4: Operations-related questions evaluated the views of vertical and horizontal integration that is the company-level and cross-enterprise integration of the physical and virtual worlds.

Category 5: Product questions judged the capacity to gather data on products, navigate the manufacturing process, and interact with higher-level systems. Respondents were questioned to identify the product information and communication add-on attributes provided by their firms.

Category 6: Data-driven questions attempted to evaluate how organizations reviewed and analyzed data collected for company-level integration. Respondents were advised whether they gathered and analyzed data during the production and consumption stages for constant improvement.

Category 7: Employee-related questions rated the availability of employee capabilities for digital transformation. Respondents were questioned to rate the talents obtainable in their organization for prospective Industry 4.0 requirements.

A sample of the questionnaire regarding the readiness dimension of 'Strategy and organization' that has been sent to the notable experts through email is given below.

Q1.1 How would you describe the implementation status of your Industry 4.0 strategy? (Tick the appropriate answer)

- (a) No existing strategy (b) Pilot initiatives launched (c) Strategy in development
(d) Strategy formulated (e) Strategy in implementation (f) Strategy implemented.

Q1.2 How compatible is Industry 4.0 with your organizational strategies? (Tick the appropriate answer)

- (a) Not compatible (b) Not sure (c) Compatible.

Q1.3 Has your organization invested or have any plans to invest in the implementation of Industry 4.0 in of the following divisions? (Tick all that apply)

- (a) Research and development (R&D) (b) Production /Manufacturing (c) Purchasing

- (d) Logistics (e) Sales (f) Service (g) IT (h) Other: _____.
- Q1.4 In which areas does your company have systematic technology and innovation management? (Tick all that apply)
- (a) IT (b) Production technology (c) Product development (d) Services
 (e) Centralized, integrative management (f) Do not have (g) Other: _____.
- Q1.5 Indicate the technologies you do use in your organization. (Tick all that apply)
- (a) Sensor technology (b) Mobile end devices (c) Radio-frequency identification (RFID)
 (d) Real-time location systems (RTLS) (e) Cyber security (f) Machine to Machine (M2M) communications (g) Big data Analytics (h) Simulations (i) Virtualization technologies
 (j) Cloud computing (k) Additive manufacturing (l) Embedded IT systems
 (m) Adaptive robotics (n) Augmented reality (o) Digital twin technology (p) Other: _____.

Data Collection

Previous studies like Bari et al., (2021) conducted their study of hybrid MCDM approach to 25 experienced industrial engineers and managers working in different RMG industries of Bangladesh. In this connection, a total of 40 factories were contacted randomly from a distinct list of leading export-oriented RMG factories through email (the participants were randomly selected on condition that they held a management role in order to share their expert opinions), from which 35 responses were addressed. And for ethical and confidential reasons, the name of the RMG factories was not mentioned here. The recruits of participant were based on their availability as per convenience sampling method. All the related information and responses were received from the relevant domain experts. However, during the data screening process, 5 responses could not be accepted for analysis purpose due to a lack of adequate knowledge and information.

When all the necessary data (primary and secondary) were collected, they were analyzed by using several tools and techniques. Collected data from questionnaire were mainly qualitative data and this data had been converted to quantitative format using Likert scale. These converted data were then analyzed using Microsoft excel 2019. Different statistical tools like ANOVA analysis, and t-test were used to get final result. Opportunities and challenges of adopting Industry 4.0, will be extracted from the responses of structured and unstructured interviews. Based on the current situation, some recommendations on how to proceed to implementing Industry 4.0 will be provided.

Analysis and Results

Analysis of the data using different equation and statistical tools are presented here. Results of different dimension were presented by pie chart. Finally, ANOVA and t-test were performed to observe the significant difference in different dimensions.

Data Analysis

The survey questionnaire's first three questions were open-ended and could only be evaluated qualitatively. The answers to these questions counted for 0 points when calculating the readiness score for each dimension. Questions 1.1 to 6.2 were quantitative type, and compiled in order to evaluate the possible total score of each readiness assessment dimension. Table 1 shows the highest possible total score for each readiness dimension, which was determined by observing the possible total score for each question and summing up these scores for the questions belonging to that specific readiness dimension.

Table 1. Maximum possible total score for each readiness dimension

Readiness dimension	Max.m possible total score
Organizational strategy	36
Smart factory/Infrastructure	39
Operations	45
Products	9
Data-driven services	4
Employees	27

The total score for each question was calculated in two steps: (a) assigning a value of 1 to all the positive replies, as required by the question, and summing up all the possible total scores; and (b) assuming the Likert scales to be interval data, converting the verbal Likert rating scale to a numerical Likert rating scale, and summing up all the possible total scores for the question. The maximum possible total score was applied to evaluate the percentage score for each readiness assessment dimension. The overall readiness score for each dimension was determined using the standard VDMA percentages (%) of weighted score shown in Table 2.

In the context of the VDMA, the dimension 'organizational strategy' featured a secondary criterion that stated that if question 1.2 received zero points, an organization would automatically attain level 0. As a result, the dimension 'organizational strategy' would have no bearing on the company's total readiness. Furthermore, if respondents believe that Industry 4.0 is incompatible with their organization, the overall readiness level is considered to be zero. If respondents elect not to provide any feedback, indicators in any questions were valueless (zero score).

Table 2. Dimensions' weighted scores

Dimensions	Weighted score
Organizational strategy	25%
Smart factory/Infrastructure	14%
Smart operations	10%
Smart products	19%
Data-driven service	14%
Employees	18%

Calculation: Level percentage of any dimension is measured by the following equation.

$$\frac{\text{Gained score in any dimension}}{\text{Total score on that dimension}} \times 100 = \text{level percentage}$$

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For e.g., level percentage of organizational strategy is = $\frac{36}{160} \times 100 = 22.2\%$.

From this percentage, dimension readiness level is determined from Table 3.

Overall level of any dimension is assessed by the following equation, (Lichtblau, K. et al., 2015).

$$\sum \text{Dimension level} \times \text{dimension weight} = \text{Overall level}$$

So, overall level of Organizational strategy is

$$= (1 \times 0.25) + (1 \times 0.14) + (2 \times 0.1) + (2 \times 0.19) + (5 \times 0.14) + (3 \times 0.18) = 2.21, \text{ which is equivalent to level 2 or learner.}$$

There are six readiness levels (level 0: outsider – level 5: top performer) in the VDMA 'Industry 4.0 Readiness' model. Table 3 below presents the criteria that were applied to find out the preparedness level for each of the six dimensions categorized into four maturity levels.

Table 3. Readiness levels criteria by percentages (Lichtblau, K. et al., 2015.; Sabine Dall'Omo, 2017)

Category	Readiness level	Description	Criteria
Emerging	Level 0	Outsider	0
	Level 1	Beginner	$0 < X \leq 30$
Developing	Level 2	Learner	$30 < X \leq 65$
Established	Level 3	Experienced	$65 < X \leq 80$
	Level 4	Expert	$80 < X \leq 90$
Advanced	Level 5	Top performer	$90 < X \leq 100$

Table 4 shows the dimensions' level calculation for a single respondent, in which first column represents the obtained score for each dimension, second column represents possible total score on each dimension, third column represents level percentages on that dimension and fourth column represents their relative level determined using Table 3.

Table 4. Dimensions’ level calculation for respondent 1

Dimension	Obtained Score	Possible total score	Percentage (%)	Level
Org. Strategy	8	36	22.2	1
Infrastructure	8	39	20.5	1
Smart Operation	16	45	35.6	2
Smart Product	4	9	44.4	2
Data Driven service	4	4	100	5
Employees	18	27	66.7	3

Survey Results

Industry 4.0 readiness level by the dimension ‘organizational strategy’ is shown in the Figure 1 below, which was based on the response of questions 1.1-1.5 where 80% respondent were at level 1 (Beginner) in the organizational strategy category, while 7% responded as at level 0 (Outsider) and the rest 13% responded at level 2 (Learner). In the infrastructure category, 14 % of respondents considered their organization was at level 0 (Outsider), 83 % responded at level 1 (Beginner) and the remaining 3% responded at level 2 (Learner), as shown in Figure 2.

According to Figure 3, in the category of Smart Operations, 93 percent of respondents remarked their organizations as at level 1 (Beginner), while the remaining 7% were at level 0 (Outsider). In the category of data-driven services, 7 percent of organizations were at level 0 (Outsider), 10 percent were at level 1 (Beginner), 17 percent were at level 2 (Learner), 36 percent were at level 3 (Experienced) and 30 percent were at level 5 (Top performer), the readiness level chart of which is shown in the Figure 4 below.



Figure 1. Readiness level chart of Org. strategy

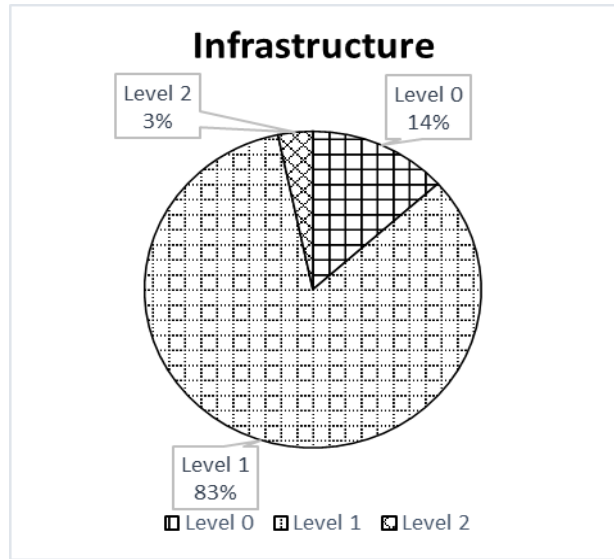


Figure 2. Readiness level chart of Smartfactory/Infrastructure

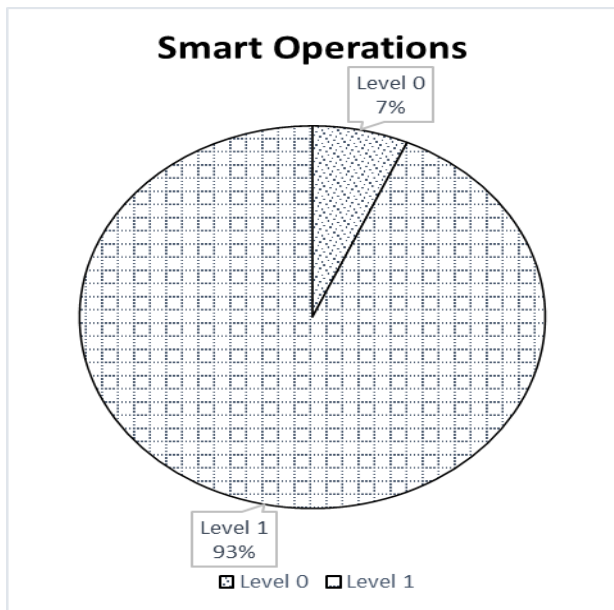


Figure 3. Readiness level chart of smart operation

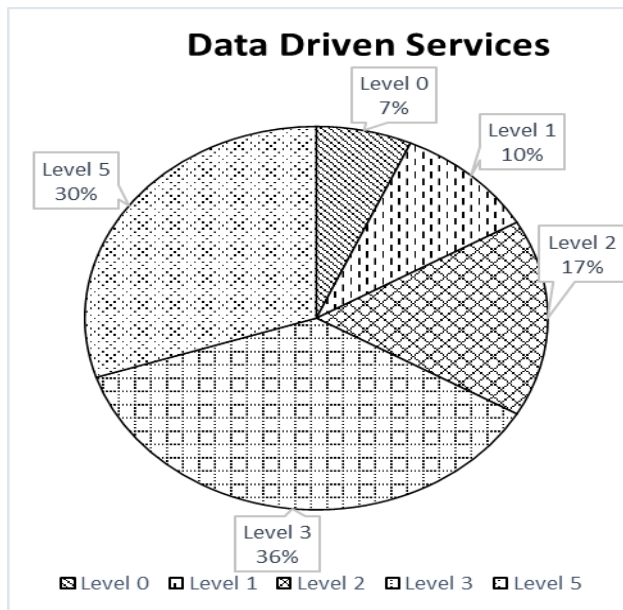


Figure 4. Readiness level chart of data driven service

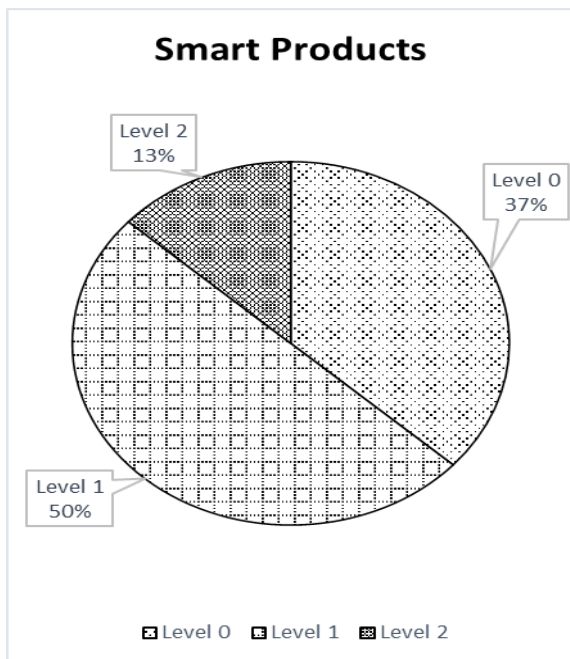


Figure 5. Readiness level chart of Smart Products category.

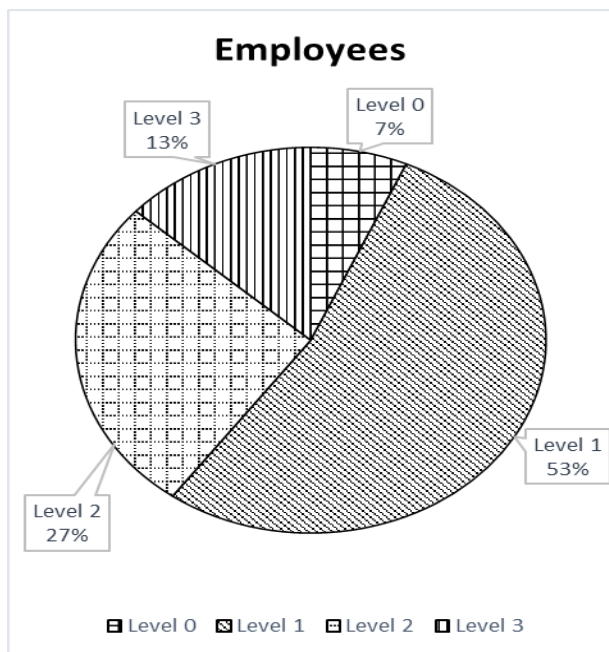


Figure 6. Readiness level chart of Employees category

Figure 5 shows the readiness level chart in the smart Product category which ranges from level 0 to level 2, with 37 percent of responses falling into level 0 (Outsider), 50 percent falling into level 1 (Beginner) and the remaining 13 percent falling into level 2 (Learner). In the employee category, 7 percent of respondents were in level 0 (Outsider)

where 53 percent were in level 1 (Beginner), 27 percent were in level 2 (Learner) and 13 percent were in level 3 (Experienced) as shown in Figure 6.

Overall Readiness Level: The outcomes of the organizations' total Industry 4.0 readiness level are shown in Figure 7. All of the organizations evaluated in this study's Industry 4.0 readiness levels varied from level 0 to level 2 where 50 percent of the organizations were eligible for readiness level 1 (beginner), 43% for level 2 (learner), and 7% for level 0 (Outsider).

Overall Readiness Score Means Graph: The overall readiness score means graph versus readiness dimensions is illustrated in the Figure 8. The error bars in the means graph were not overlapped, showing a substantial difference between the contributions of a particular readiness dimension to the overall readiness level score (within a 95 % Confidence level).

ANOVA and t-test results: In order to verify the means graph results of Figure 8, a null hypothesis (H₀) as well as an alternative hypothesis (H_A) were constructed and an analysis of variance (ANOVA) and the respective 't-test' have been performed.

H₀: There is no significant statistical difference between the contribution of six readiness dimensions to the Industry 4.0 overall readiness level.

H_A: There is a significant statistical difference in contribution to the Industry 4.0 overall readiness level between the six readiness dimensions.

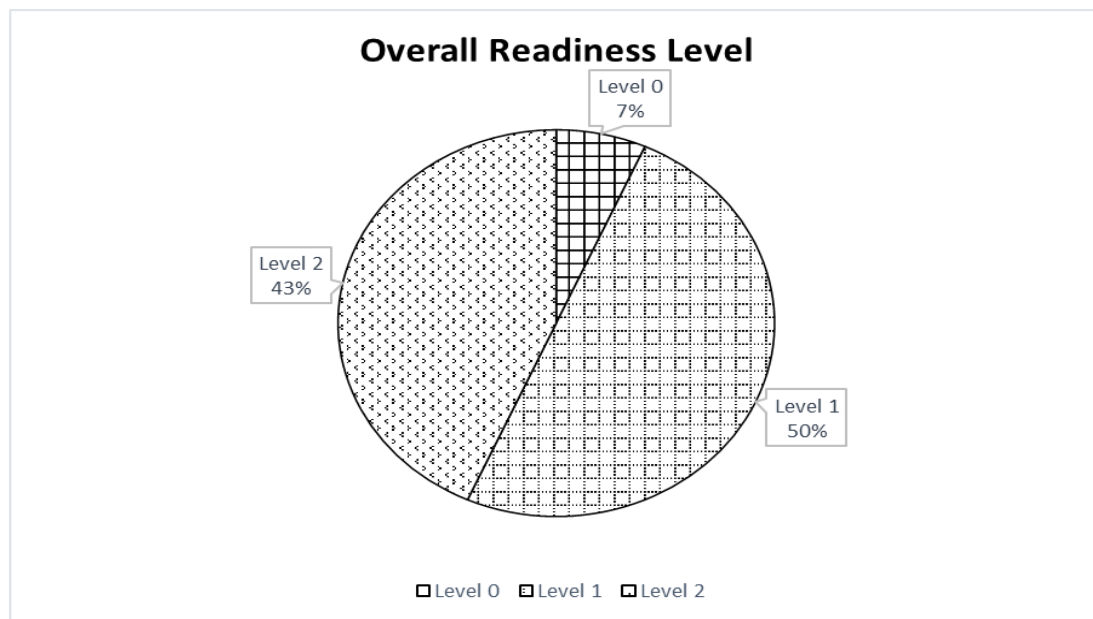


Figure 7. Chart of Organizations' overall readiness level

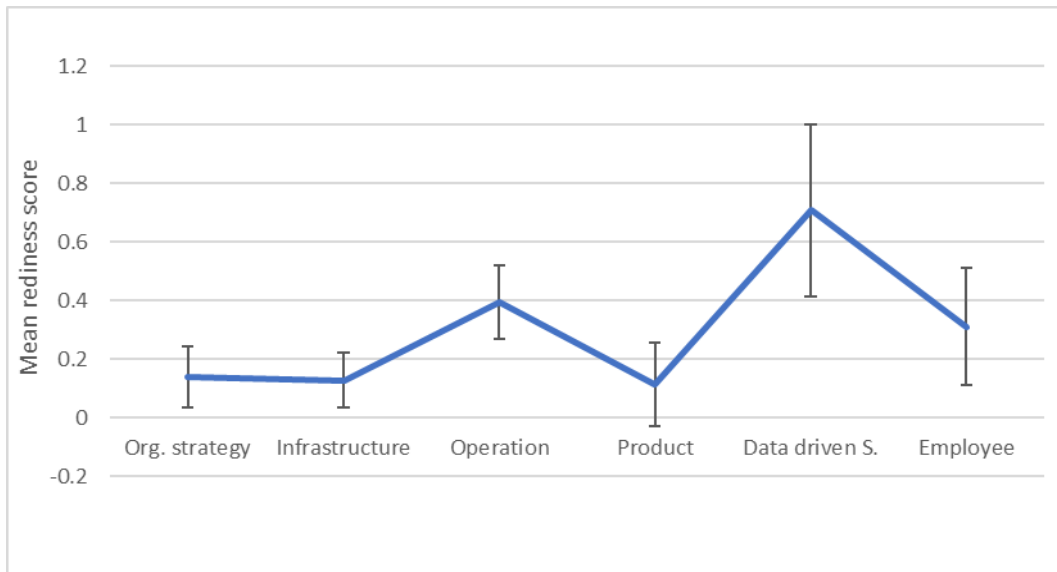


Figure 8. Readiness dimension means graph

Table 5 provides the results of the ANOVA test conducted on the readiness dimensions' contribution to the overall readiness level score. The results of the ANOVA test justify a requirement to do a t-test between each set of the dimensions.

Table 6 below provides the t-test findings. The number in each cell reflects the p-value. The results demonstrate the fact that there is no significant statistical difference in contributing to the overall readiness level among organizational strategy, infrastructure, and smart products category. On the other hand, there is a considerable statistical difference among data-driven services, smart operations and employees category in contributing to the total readiness level.

Table 5. Analysis of Variance test results

Test	P-value	Conclusion / Remarks
ANOVA results	7.32×10^{-33}	There is a statistical difference between at least two dimensions in contribution to the overall readiness level

Table 6. t-test analysis results (p-value)

	Infrastructure	Operation	Product	Employee	Data-Driven services
Strategy	0.381602	2.75×10^{-11}	0.084226	7.61×10^{-7}	5.72×10^{-13}
Infrastructure		1.94×10^{-13}	0.206487	7.15×10^{-7}	1.52×10^{-12}
Operation			2.57×10^{-10}	0.007718	6.54×10^{-8}
Product				2.72×10^{-11}	2.48×10^{-13}
Employees					6.99×10^{-10}

Discussion

The organization's overall Industry 4.0 readiness level varied from level 0 to level 2 where 50 percent of the organizations were eligible for readiness level 1 (beginner), 43 percent for level 2 (learner) and 7 percent for a level 0 (Outsider). The core reasons for poorer levels of readiness can be lack of knowledge, limited government assistance, poor infrastructure, availability of cheap labor, costly initial investment based on several research done on Bangladesh.

In terms of Industry 4.0 organizational strategy, 87 percent of respondents indicated their organizations were at level 1 (Beginner) while 7 percent responded as at level 0 (Outsider) and the rest 13% at level 2 (Learner). This could indicate that a significant number of RMGs in Bangladesh do not have an Industry 4.0 based strategic plan or have begun pilot initiatives. Lack of enthusiasm for driving Industry 4.0 efforts forward could be the reason for lagging in Organizational Strategy. The firms should develop awareness for Industry 4.0 and define strategies for advancing higher levels.

In areas of equipment infrastructure total 14 percent of respondents considered their organization was at level 0 (Outsider), 83 percent at level 1 (Beginner) where only 3 percent at level 2 (Learner). These outcomes reveal the scenario that a considerable proportion of RMG sectors' equipment infrastructure in Bangladesh hasn't been well connected to higher-level IT systems, their equipment functionality is somewhat not upgraded to Industry 4.0 criteria. For achieving higher level, they should constantly connect equipment infrastructure to higher-level IT systems, design and install IT integrated equipment infrastructure.

In the Smart Operations category, 93 percent of respondents remarked their organizations as at level 1 (Beginner), while the remaining 7% were at level 0 (Outsider). This could indicate that a significant fraction of organizations is ill-equipped to merge the physical and virtual worlds vertically and horizontally, with no early moves toward system-integrated information sharing with external partners. Their action plan should include the expansion of system-integrated information sharing both in-company and externally.

When it comes to readiness of the smart product dimension of Industry 4.0, 37 percent of responses falling into level 0 (Outsider), 50 percent falling into level 1 (Beginner) and the remaining 13 percent falling into level 2 (Learner). The results could be interpreted as existing products from organizations do have little or no ICT add-on functionality and acquired data haven't been properly analyzed or used to improve goods or processes (product development, sales support, after-sales). Emerging businesses should look into the possibility of ICT add-on features. Developing organizations should examine the potential uses of obtained data and the breadth of ICT add-on functionality in a systematic manner.

Among all, 7 percent of organizations were at level 0 (Outsider), 10 percent were at level 1 (Beginner), 17 percent were at level 2 (Learner), 36 percent were at level 3 (Experienced) and 30 percent were at level 5 (Top performer) in the dimension of data-driven services. Although some segments are still suffering with collecting and analyzing digital data, this might be taken as a significant percentage of RMG factories gathering digital data and assessing it for continuous improvement goals. Product portfolios should be realigned, and data-driven services should be defined for emerging enterprises. Developing organizations should use data more extensively and provide more data-driven services. Established and advanced organizations should diversify their service portfolios to incorporate digitally connected client offers.

In contrast to the other four Industry 4.0 readiness dimensions, 7 percent of participants were at level 0 (Outsider), 53 percent were at level 1 (Beginner), 27 percent were at level 2 (Learner) and 13 percent were at level 3 (Experienced) when it comes to employee dimension of Industry 4.0. This could indicate a lack of Industry 4.0-specific skill sets or insufficient Industry 4.0-specific skill sets in critical areas. Emerging and developing companies need to perform systematic needs assessments, adapting training and professional-skill development programs.

The ANOVA and t-test results demonstrated that the dimensions of smart operations, employees, and data-driven services vary considerably from the other three categories in terms of their contributory score to overall Industry 4.0 readiness. This revelation is consistent with the previous study conducted by W. Maisiri et al., (2019) on South African industries in which employee skill demands and data-driven services vary significantly from the other four dimensions.

Suggestions on Implementation of Industry 4.0: As an emerging developing nation, Bangladesh is embracing revolutionary technologies considerably in RMG companies for socio-economic development in spite of facing lots of challenges. In recent years, private to semi-government to public authorities have been undertaking significant steps towards the development of infrastructure and human, technical, and financial capacity to upgrade the education and training systems in order to gain the benefits from 4th Industrial revolution. To implement Industry 4.0 in RMG sectors, dimension wise suggestions are provided below:

In case of organizational strategy, most of the RMG factories do not have any existing indicators to evaluate Industry 4.0 implementation status. Factories should develop a system to identify implementation status of Industry 4.0. In this analysis it is found that some RMG factories have technology and innovation management system in one

or two areas. To increase Industry 4.0 readiness, these factories should gradually introduce it in other areas with the goal of integrating all areas.

When it comes infrastructure, most of the factories are still producing their products in traditional way. RMG factories should invest more to upgrade their current infrastructure. Perhaps, it may be suggested to explore if current systems can be upgraded. Research projects may provide an incentive here.

In smart operation, inter department information sharing is already taking place in some factories. They can run an analysis to find out where bottlenecks do exist between systems. Autonomous control and Self-reacting processes are already existing in some factories, they can utilize the opportunity to gather experience and execute autonomous control and self-reacting processes in additional areas. Besides cloud-based data analytics, cloud computing should be emphasized.

In the dimension of data-driven services, most of the RMG factories have almost all the skills needed to successfully implement Industry 4.0. The share of data used in RMG factories provides an excellent foundation for successful implementation of Industry 4.0. To further enhance Industry 4.0 readiness, RMG factories should make more use of the data available to develop services with better customer experience.

Products in some company already offer several ICT add-on functionalities. To strengthen company's Industry 4.0 readiness, it is important to gradually expand the add-on functionalities of their products.

Most of the factories are still lacking in employee skill category, employees have limited skills in terms of Industry 4.0 implementation. Consequently, it is very significant to expand and enhance the skills in other areas such as IT infrastructure, automation and advanced technology, data analytics, data and communications security, development and application of assistance systems, collaboration software.

Conclusion

Industry 4.0 supports to manage and optimize all aspects of manufacturing processes and systems. It gives the access to the real-time data and insights that is needed to make smarter, faster decisions about the business, which can eventually increase the efficiency and profitability of the entire operation.

Assessment of the readiness status of Industry 4.0 is essential to the fruitful adoption and selection of Industry 4.0 technology. The findings of this exploratory study revealed major gaps in organizations' Industry 4.0 strategies. While strategy formation is the driver of Industry 4.0 adoption, a significant proportion of organizations lack a strategy or merely in pilot initiatives.

According to the study's observations, there are significant barriers to overcome in case of equipment infrastructure that favors Industry 4.0 and equipment features that can be improved to meet Industry 4.0 criteria.

Though the dimensions of employee, smart product and smart operations are little more consistent than organizational strategy and infrastructure, their readiness for adopting Industry 4.0 is still not up to the mark. On the contrary, from the perspective of data-driven services, Bangladesh's RMG factories are rapidly expanding, which might be regarded as large number of organizations are making use of digital data.

We can summarize the overall readiness of the RMG sectors of Bangladesh as a beginner. We can further conclude that the organizational infrastructure is the least ready dimension, and the data-driven services is the readiest level of dimension. Industry 4.0 implementation would be constrained by lack of appropriate knowledge, limited government aid, insufficient infrastructure, the availability of cheap labor, and a high initial investment. This research work suggests that the top management of RMG sectors needs to re-envision the IR4.0 as a new business model instead of restraining its vision to adopting information and communication technologies and practices.

Scope for Future Research work

There are numerous areas where additional research work could be conducted in future in connection to the adoption of IR 4.0 in the RMG industries of developing countries like Bangladesh. Some areas of research are listed below, which can provide directions for further research –

- (i) This research work was only carried out in context to the implementation of I4.0 in apparel sectors, however similar research might be conducted to other industries of different natures like electronics, chemical, pharmaceuticals industry, and other manufacturing industries of different economic capabilities.

- (ii) There is a growing demand for productivity analysis and efficiency improvement of the apparel sectors comparing the different dimension levels such as outsider, beginner, learner, experienced, and expert levels of I4.0.
- (iii) Realizing appropriate policy measures to help SMEs implement I4.0 would be a significant research extension in the future.
- (iv) Analyzing the challenges and drivers of I4.0 implementation in the RMG sectors and other manufacturing industries can be another important research dimension.
- (v) Identifying the necessary skills and knowledge gaps of the future RMG workers in context to experiencing I4.0 will be worth exploring in near future.
- (vi) An exploratory research work is essential for determining the needs and initiatives for designing and enabling the appropriate environment for I4.0.
- (vii) Further study can be conducted in different category of industries like small, medium, and large-scale industries according to the employee size.

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Conflict of Interests

The authors declare no conflict of interest.

References

- Alcácer, V., & Cruz-Machado, V. (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. *Engineering Science and Technology, an International Journal*, 22(3), 899–919. <https://doi.org/10.1016/J.ESTECH.2019.01.006>
- As-Saber, S., Wilson, B., Waheduzzaman, W., & Islam, S., (2016). Bangladesh RMG Roadmap. In BGMEA. ISBN: 978-984-34-0606-4
- Axmann, B., & Harmoko, H. (2020). Industry 4.0 Readiness Assessment: Comparison of Tools and Introduction of New Tool for SME. *Tehnički Glasnik*, 14(2), 212–217. <https://doi.org/10.31803/>
- Bahrin, M. A. K., Othman, M. F., Azli, N. H. N., & Talib, M. F. (2016). Industry 4.0: A Review on Industrial Automation and Robotic. *Journal Teknologi*, 78(6–13), 137–143. <https://doi.org/10.11113/JT.V78.9285>
- Bari, A. B. M. M., Habib, A., & Akash, M. H. (2021). Assessment of the Elements of Industry 4.0 in Terms of their Implementation Potentials: In the Context of the Ready-Made-Garment Industries of Bangladesh. Proceedings of the International Conference on Industrial & Mechanical Engineering and Operations Management (IMEOM), Dhaka, Bangladesh, December 26-27, 2021
- Berawi, M. A. (2018). Utilizing big data in industry 4.0: Managing competitive advantages and business ethics. *International Journal of Technology*, 9(3), 430–433. <https://doi.org/10.14716/IJTECH.V9I3.1948>
- Cleverism. (2018). Industry 4.0: Definition, design principles, challenges and the future of employment. Retrieved November 17, 2020 from <https://www.cleverism.com/industry-4-0/>
- Coronado, P. D. U., Lynn, R., Louhichi, W., Parto, M., Wescoat, E., & Kurfess, T. (2018). Part data integration in the Shop Floor Digital Twin: Mobile and cloud technologies to enable a manufacturing execution system. *Journal of Manufacturing Systems*, 48, 25–33. <https://doi.org/10.1016/j.jmsy.2018.02.002>
- Dr. Karl Lichtblau, Prof. Volker Stich, Dr.-Ing., Dr. Roman Bertenrath, Matthias Blum, Martin Bleider, Agnes Millack, Katharina Schmitt, Edgar Schmitz, M. S. (2015). Industrie 4.0 readiness. Cologne Institute for Economic Research (IW), Frankfurt. <https://doi.org/10.3969/j.issn.1002-6819.2010.02.038>
- Drath, R., & Horch, A. (2014). Industrie 4.0: Hit or hype? [Industry Forum]. *IEEE Industrial Electronics Magazine*, 8(2), 56–58. <https://doi.org/10.1109/MIE.2014.2312079>
- Gilchrist, A., & Gilchrist, A. (2016). Introducing Industry 4.0. *Industry 4.0: The industrial internet of things*, 195-215. DOI: 10.1007/978-1-4842-2047-4_13.

- Hofmann, E., & Rüsçh, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in industry*, 89, 23-34. <https://doi.org/10.1016/J.COMPIND.2017.04.002>
- Hossian, M. S., Kabir, R., & Latifee, E. H. (2019). Export Competitiveness of Bangladesh Readymade Garments Sector. *International Journal of Research in Business and Social Science (2147- 4478)*, 8(3), 45–63. <https://doi.org/10.20525/IJRBS.V8I3.205>
- In book: Industry 4.0 (pp. 195-215), Berkeley, CA.
- Industry 4.0: 7 Real-World Examples of Digital Manufacturing in Action - AMFG. (n.d.). Retrieved November 15, 2020, from <https://amfg.ai/2019/03/28/industry-4-0-7-real-world-examples-of-digital-manufacturing-in-action/>
- Islam, M. A., Jantan, A. H., Hashim, H. B., Chong, C. W., Abdullah, M. M., Rahman, M. A., & Abdul Hamid, A. B. (2018). Fourth industrial revolution in developing countries: A case on Bangladesh. *Journal of Management Information and Decision Sciences*, 21(1), 1–9.
- Iyer, A. (2018). Moving from Industry 2.0 to Industry 4.0: A case study from India on leapfrogging in smart manufacturing. *Procedia Manufacturing*, 21, 663–670. <https://doi.org/10.1016/J.PROMFG.2018.02.169>
- Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business and Information Systems Engineering*, 6(4), 239–242. <https://doi.org/10.1007/S12599-014-0334-4>
- Likert scale questions, survey and examples | QuestionPro. (n.d.). Retrieved July 15, 2020, from <https://www.questionpro.com/article/likert-scale-survey-questions.html>
- Liu, Y., & Xu, X. (2017). Industry 4.0 and cloud manufacturing: A comparative analysis. *Journal of Manufacturing Science and Engineering, Transactions of the ASME*, 139(3), 1–8. <https://doi.org/10.1115/1.4034667>
- Lotti, G., Villani, V., Battilani, N., & Fantuzzi, C. (2018). Towards an integrated approach for supporting the workers in Industry 4.0. *IEEE*, 609–614. <https://doi.org/10.1109/ICPHYS.2018.8390775>
- Maisiri, W., & van Dyk, L. (2019). Industry 4.0 readiness assessment for South African industries. *South African Journal of Industrial Engineering*, 30(3), 134–148. <https://doi.org/10.7166/30-3-2231>
- Rahman, A. (n.d.). Introducing 'Industry 4.0' to Bangladesh. Retrieved June 12, 2020, from <https://www.textiletoday.com.bd/introducing-industry-4-0-bangladesh/>
- Sabine Dall'Omo. (2017). African Digitalization Maturity Report. Siemens Ingenuity for Life.
- Saha, P., Talapatra, S., Belal, H.M., Jackson, V., Mason, A., & Durowoju, O. (2023). Examining the viability of lean production practices in the Industry 4.0 era: an empirical evidence based on B2B garment manufacturing sector. *Journal of Business & Industrial Marketing*, ISSN: 0885-8624. <https://doi.org/10.1108/JBIM-01-2023-0029>
- Sharmin, S. (2022). IR 4.0 Readiness of Apparel Industry in Bangladesh. *Asian Journal of Social Sciences and Legal Studies*, 4(4), 148 – 159. <https://doi.org/10.34104/ajssls.022.01480159>
- Wankhede, V.A. & Vinodh, S. (2023). Benchmarking Industry 4.0 readiness evaluation using fuzzy approaches. *Benchmarking: An International Journal*, Vol. 30(1), 281-306. <https://doi.org/10.1108/BIJ-08-2021-0505>
- Witkowski, K. (2017). Internet of Things, Big Data, Industry 4.0 – Innovative Solutions in Logistics and Supply Chains Management. *Procedia Engineering*, 182, 763–769. <https://doi.org/10.1016/J.PROENG.2017.03.197>