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

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Abstract

Ready-Made-Garment (RMG) industries, which is the largest industrial sector of Bangladesh, are seeking to gradually adopt the technologies of industry 4.0 to keep up with the rest of the world. However, industry 4.0 has ten established elements and due to the limitation of available resources, it is quite difficult to implement all ten element of industry 4.0 at the same time in the context of Bangladesh. In this situation, it is very important to identify that which of the ten elements are more important in terms of implementation potentials than others, in the context of the RMG industries of Bangladesh. This study, thereby, utilizes a hybrid Multi-Criteria Decision-Making Method (MCDM) approach to rank the elements of industry 4.0 based on their implementation potentials in the RMG sector of Bangladesh. In this research, a Fuzzy Analytical Hierarchy Process (FAHP) has been utilized to determine the weights of the evaluation criteria, and a Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II) has been used to rank the elements of industry 4.0 based on those weighted criteria. The findings of the research shows that the Industrial Internet of Things (IIoT) is the most influential and Additive Manufacturing is the least influential element of industry 4.0 in the context of the RMG industries of Bangladesh. This research is expected to facilitate the decision makers, both in the government and in the industries, to formulate appropriate plans and policies for the proper implementation of industry 4.0 in the RMG and other similar industrial sectors.

Keywords

Industry 4.0, RMG industries, MCDM, FAHP, PROMETHEE II

1 Introduction

Industrial revolutions are very important for the development of the industries and the economy. The first industrial revolution, which began around 1760, involved mechanization using steam power and hydro power (Xu et al., 2018). During second industrial revolution, the mass production and assembly line was introduced with the help of electrical energy. The third industrial revolution involved the invention and extensive use of Programmable Logic Controllers (PLC) in the production process, whereas the fourth industrial revolution or Industry 4.0 involves the adoption of modern technologies for various industrial operations. Industry 4.0 has ten established elements or pillars, which are (Tay et al., 2018): (i) Autonomous Robots, (ii) Simulation, (iii) System Integration- both Horizontal and Vertical, (iv) Industrial Internet of Things (IIoT), (v) Cyber security, (vi) Cyber Physical System, (vii) Additive Manufacturing, (viii) Augmented Reality, (ix) Big Data Analytics, and (x) Cloud Computing.

As a developing country, Bangladesh cannot fall behind too much when it comes to adopting new technologies that comes with this new industrial revolution. Currently, RMG sector is the most profitable industrial sector of Bangladesh, where the customers, now a days, are giving more orders with a higher degree of customizations. This adds more value to finished good, but also drives up the manufacturing cost and the selling price at the same time. If the price rises too high, it impacts the overall sale and the business negatively. Regular and traditional manufacturing system, which are often outdated, has hard time to process these new customized orders, while trying

to keep the manufacturing cost low. In this regard, industry 4.0 offers a new level of customizations and control over the entire value chain of the production process, which allows the industries to meet the increasingly individualized customer requirements, without increasing the manufacturing cost too much.

RMG industries has immense importance in the economy of Bangladesh for several reasons. Firstly, RMG sector earns majority of the country's foreign currencies till date. Secondly, there are many other sectors that depend on the RMG industries like banks, insurances, logistics and shipping, infrastructure etc. Thirdly, RMG industries are the major source of employment in this region as well. However, to stay relevant in the current highly competitive market, RMG industries, like all other industries, need to adopt sustainable modern manufacturing practices like industry 4.0. In this regard, it is a very important to assess the implementation potentials of industry 4.0 elements in this sector. Some previous research has explored the implementation potentials of industry 4.0 in Bangladesh, but none had any in-depth insights particularly for the RMG industries. Thereby, it clearly presents a research gap, which has motivated to carry out this proposed research.

Manufacturing industries' operations and decisions are expected to be highly influenced by industry 4.0 in near future. Deferent elements of industry 4.0, like automation, simulation, big data analysis, internet of things (IoT) etc. tend to facilitate the adoption of new technologies in the industries, which can make their manufacturing systems more automated and flexible, without driving up the manufacturing cost too much (Moktadir et al., 2018). Experts forecast that businesses will be able to increase their productivity by about 30% by using industry 4.0 (Islam et al., 2018). It also shortens the periods for launching new products, makes it possible to offer more flexible product lines, increased productivity, efficient use of available resources, etc. (Ângelo et al., 2017, Huckle et al., 2016). For example, Lectra is a French equipment manufacturing company, who has successfully implemented industry 4.0 and has seen 85% increase in the forecast accuracy, 20-50% reduction in the inventory cost, 20-50% increase in the speed to market, 10-20% decrease in the cost to market, and 3-2% increase in the overall productivity (Rahman, 2019).

Industries in Bangladesh, specially the RMG industries often do not have too much capital money lying around which they can easily use to implement industry 4.0 elements, which in fact can be very expensive. Hence, RMG industries from a developing country like Bangladesh, have to try to implement the elements of industry 4.0 gradually, instead of trying to implement all the elements at the same time. To do that, industries need to prioritize or rank the elements of industry 4.0 based on their importance and try to implement the elements that comes up on the top of that list first and then gradually work their way to the bottom of that list. This research, thereby, intends to achieve the following objectives :

- Assess the implementation potential of the industry 4.0 elements in RMG sector of Bangladesh and find the relevant evaluation criteria from the previous literatures.
- Calculate the weights of the identified evaluation criteria from the expert feedbacks by using FAHP method.
- Using the obtained criteria weight, rank for the elements of industry 4.0 based on their implementation potential, by using PROMETHEE II method.
- Finally, discuss the research implications of the study and future research directions.

The rest of the paper is organized into the following sections: Section 2 presents a literature review and identifies the evaluation criteria. Section 3 discusses the relevant research methodologies, and calculations. Section 4 presents the obtained results and discussions. Section 5 discusses the managerial Implications of the research. Section 6 concludes the paper and discusses the future research directions.

2 Literature review

Several recent literatures have been studied to understand the background, implication, and application of industry 4.0 and the related technologies. Moktadir et al. (2018) have identified several challenges to implement of industry 4.0 in the leather industries of Bangladesh using Best-Worst method (BWM), where the lack of technological infrastructure has been identified as the biggest challenge. Rumi et al. (2020) has examined the opportunities and problems created by the adoption of industry 4.0 in Bangladesh. Findings of that study showed that the adaptation of industry 4.0 can become difficult if not properly managed. However, it comes with many new opportunities like

sustainable ICT development, higher productivity, women, and citizen empowerment, etc., which have positive effects on the economy and the society in long run. Imran et al. (2018) investigated the role of industry 4.0 in the textile industries in Pakistan using PLS-SEM technique. The research findings suggest that the production can be influenced negatively in absence of proper technological adaptation, which can eventually lead to a decrease in the overall performance. Shabur et al. (2021) investigated the barriers to implement industry 4.0 in Bangladesh. Weak infrastructure, higher cost of installation technologies, lack of government policies and support, lack of knowledge on industry 4.0, etc. have been identified as the key barriers in that research. The research has also proposed some possible solutions for overcoming the identified barriers.

In this research, several important criteria have been identified to evaluate the elements of industry 4.0 for implementation, by studying previous relevant literatures. Then a survey has been conducted to collect opinions and quantitative feedbacks from the subject matter experts on the identified criteria. Later, FAHP has been used to calculate the weight of the identified criteria based on the collected expert feedbacks and PROMETHEE II method has been used to determine the final ranking of the industry 4.0 elements, utilizing the criteria weights obtained from the FAHP calculation.

Analytic hierarchy process (AHP) is a popular MCDM tool based on pairwise comparison technique. However, the pure AHP method has some shortcomings associated with the uncertainty and vagueness of human judgment (Yang and Chen, 2004). Fuzzy sets theory is often incorporated with the pure AHP to overcome those shortcomings. Since then, various researchers have used Fuzzy AHP or FAHP for various decision analysis problems. Rana et al. (2019) used FAHP to analyze the key barriers of smart city development in India. Calabrese et al. (2019) used FAHP method for selecting sustainability issues that are most relevant for creating shared value for both business and society, from strategic planning and management perspective. Sirisawat and Kiatcharoenpol (2018) utilized a hybrid FAHP-FTOPSIS method to explore the barriers of reverse logistics for the electronics industries of Thailand.

PROMETHEE II is the second version of PROMETHEE method, which is a ranking method that can determine the dominance among alternatives. PROMETHEE II is capable of providing a complete ranking of the alternatives, compared to its' first version, which was only suitable for the partial ranking of the alternatives (Anojkumar et al., 2014). PROMETHEE II is often coupled with methods like AHP or FAHP to obtain improved performance in analysis (Isa et al., 2021). Irnanda et al. (2019) used PROMETHEE II method for selecting calcium milk products that are appropriate for elderly people. Tong et al. (2020) proposed an extended fuzzy PROMETHEE II method to develop a performance evaluation framework for the maintenance suppliers in the petrochemical industries. Isa et al. (2021) used a hybrid AHP-PROMETHEE II method for the selection and prioritization of suppliers for a railroad construction project, while Samanlioglu et al. (2017) used AHP-PROMETHEE II method for the evaluation of solar power plant location alternatives.

Thereby, in this study, FAHP has been used to determine the criteria weights, which has then been given as inputs to the PROMETHEE II method to obtain the final ranking of the elements of industry 4.0. Several related research papers have been studied to identify ten important evaluation criteria for the elements of industry 4.0, which is showed in Table 1 below. A brief description of the significance of those ten criteria is given in the *Table 1A* of the *Supplementary materials*.

Table 1: Criteria identified from the previous literatures

No.	Criteria	Reference
1	Computer and IT Knowledge	Moktadir et al., 2018; Bhuiyan et al., 2020; Rumi et al., 2020
2	Proper Integration among different systems	Tareque et al., 2020; Hozdić, 2015
3	Self-regulating mechanism	Sony, 2018
4	Quality of the automated decision making	Sabur et al., 2021; Moktadir et al., 2018; Hozdić, 2015; Krupitzer et al., 2020
5	Application of Embedded Technologies	Tareque et al., 2020
6	Digital communication	Imran et al., 2018; Moktadir et al., 2018; Kumar et al., 2019
7	Magnitude of human-machine interfacing	Krupitzer et al., 2020
8	Energy management system	Tareque et al., 2020; Moktadir et al., 2018
9	Training of Technology (ToT)	Rumi et al., 2020
10	Mindset for technology adoption	Bhuiyan et al., 2020

3 Research Methodologies and Calculations

This study investigates the ranking of industry 4.0 elements to help the decision makers to decide which element they need to implement first, when the available resource is constrained. After identification of the evaluation criteria, two MCDM tools, FAHP and PROMETHEE II, have been used to obtain the final ranking of the elements. Hence, FAHP and PROMETHEE II methods are being briefly discussed below in the next two subsections. After that the data collection and the calculations performed in this research have been discussed.

3.1.1 Fuzzy Analytical Hierarchy Process (FAHP)

Traditional AHP uses crisp numbers for pairwise comparison, which is often considered insufficient and imprecise, since in the decision-makers' judgment, there is always some degree of vagueness and uncertainty (Kumar et al., 2017). Fuzzy logic or fuzzy set theory is often coupled with the traditional AHP to overcome this limitation. The new method is hence called Fuzzy AHP or FAHP. Fuzzy set theory is based on the idea that the elements have a degree of membership in a fuzzy set (Zimmermann, 1985). Fuzzy membership functions that are most commonly used, include monotonic, triangular, and trapezoidal functions (Taha and Rostam, 2011). This study has utilized the triangular-type membership function or the Triangular fuzzy number (TFN), which is the most popular in the Fuzzy MCDM studies, due to its' easy adaptability to the experts' linguistic evaluations (Patil and Kant, 2014).

A TFN is denoted as ã = (l, m, u) where, l, m, and u are the lower bound, most likely value and upper bound of the fuzzy number ã respectively and $l \leq m \leq u$. A TFN is shown in Eq. 1:

$$\mu_{\tilde{a}}(x) = \begin{cases} 0, \ x < 1 \ or \ x > u \\ \frac{x-l}{m-l}, \ l \leq x \leq m \\ \frac{u-x}{u-m}, \ m \leq x \leq u \end{cases} \tag{1}$$

The procedure of FAHP is as below:

Step 1. The problem is structured in a hierarchical way.

Step 2. A square (n x n) dimensional comparison matrix is formed between the criteria. Components on the diagonal of the matrix take the value 1, where row number = column number (i=j). The linguistic pairwise comparison of criteria is then transformed into TFNs, ã = (l, m, u). The linguistic scale used in this research, along with the corresponding TFNs and reciprocal of TFNs is shown in Table 2 (Anojkumar et al., 2014).

Table 2: Conversion scale of fuzzy triangular number

Scale of Relative Importance			
Importance Intensity	Linguistic scale for importance	TFN (l, m, u)	Reciprocal of TFN (1/u, 1/m, 1/l)
1	Equal Importance	(1,1,1)	(1,1,1)
3	Moderate Importance	(2,3,4)	(1/4, 1/3, 1/2)
5	Strong Importance	(4,5,6)	(1/6, 1/5, 1/4)
7	Very Strong Importance	(6,7,8)	(1/8, 1/7, 1/6)
9	Extreme Importance	(9,9,9)	(1/9, 1/9, 1/9)
2	Intermediate Values	(1,2,3)	(1/3, 1/2, 1)
4		(3,4,5)	(1/5, 1/4, 1/3)
6		(5,6,7)	(1/7, 1/6, 1/5)
8		(7,8,9)	(1/9, 1/8, 1/7)

Step 3. Based on the information of pairwise comparison as in Eq. 2, fuzzy positive reciprocal matrix can be formed as:

$$\tilde{A}_{nxn}=\begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & \tilde{a}_{nn} \end{bmatrix}, \quad a_{ii} = 1, a_{ji} = \frac{1}{a_{ij}}, a_{ij} \neq 0 \tag{2}$$

Eq. 2 indicates, if ith row jth column component (a_{ij}) of the comparison matrix takes x value, then jth row ith column (a_{ji}) component of the matrix will take 1/x value.

Step 4. Fuzzy weights of each criterion are obtained using Eq. 3.

$$\tilde{w}_i = \tilde{r}_i \times (\tilde{r}_1 + \tilde{r}_2 + \cdots + \tilde{r}_n)^{-1} \tag{3}$$

Fuzzy geometric mean value of each criterion can be obtained from Eq. 4.

$$\tilde{r}_i = (\tilde{a}_{i1} \times \tilde{a}_{i2} \times \cdots \times \tilde{a}_{in})^{\frac{1}{n}} \tag{4}$$

Where $\tilde{w}_i$ denotes the fuzzy weight and $\tilde{r}_i$ denotes the fuzzy geometric mean value of a criterion.

Step 5. Weights of each criterion are defuzzified. Center of Area, COA (Eq. 5) is used for the purpose of weights defuzzification. Weights are normalized to get more precise output.

$$COA, w_i = \frac{l_i + m_i + u_i}{3} \tag{5}$$

Where w_i denotes the defuzzified fuzzy weight of a criterion.

3.1.2 Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II)

To implement PROMETHEE II, two types of information are required on each criterion: the weight and the preference function. Weight determines the importance of each criterion, which done by using FAHP in this research. The preference function translates the evaluations obtained for the alternatives into a preference value, ranging from zero to one. There are six different types of preference functions that are commonly used in PROMETHEE II. However, significant differences have not been found among the performances of these functions in the previous literature (Abdullah et al., 2019). This study has utilized a preference function named 'V-shape criterion', since a large number of literatures on PROMETHEE II have picked it over others (Ozsahin et al., 2017, Wu et al., 2020).

The procedure of PROMETHEE II method is as below (Brans, 1982):

Step 1. Preference function is determined for each criterion to translate the difference between the evaluations obtained by two alternatives into a preference degree ranging from 0 to 1.

Step 2. Deviations are determined based on pairwise comparisons as shown in Eq. 6.

$$d_j(a, b) = g_j(a) - g_j(b) \tag{6}$$

Where $d_j(a, b)$ denotes the difference between the evaluations of a and b on each criterion.

Step 3. Preference function is applied as shown in Eq. 7.

$$P_j(a, b) = F_j[d_j(a, b)] \; ; \qquad j = 1, \ldots, k \tag{7}$$

Where $P_j(a, b)$ denotes the preference of alternative a with respect to the alternative b on each criterion, as a function of $d_j(a, b)$.

Step 4. Overall or global preference index is calculated using Eq. 8.

$$\pi\ (a,b) = \sum_{j=1}^{k} P_j(a,b) * w_j\ ; \qquad \forall\ a,b \in A \tag{8}$$

where π (a, b) is defined as a weighted sum of $P_j(a,b)$, w_j is the weight according to the decision maker's preference as the relative importance of the jth criterion, and A is the set of all available alternatives.

Step 5. Outranking flows are calculated using Eq. 9 and Eq. 10.

$$\phi^+(a) = \frac{1}{n-1}\sum_{x\in A}\pi\ (a,x) \tag{9}$$

$$\phi^-(a) = \frac{1}{n-1}\sum_{x\in A}\pi\ (x,a) \tag{10}$$

Where $\phi^+(a)$ and $\phi^-(a)$ represent the positive and negative outranking flow for each alternative, respectively, and n is the total number of all available alternatives.

Step 6. Net outranking flow ϕ(a) is then determined using Eq. 11.

$$\phi(a) = \phi^+(a) - \phi^-(a) \tag{11}$$

Step 7. Ranking of all considered alternatives is obtained depending on the values of ϕ(a). Higher value of ϕ(a) implies better ranking of the alternative.

3.2 Data collection and calculation

Since this research focuses on the implementation of industry 4.0 in the RMG industries of Bangladesh, all the related information and feedbacks were collected from the relevant domain experts. 25 experienced industrial engineers and managers working in different RMG industries of Bangladesh were contacted to collect their expert opinions and quantitative feedbacks on the criteria identified from the previous literatures. Expert opinions and feedbacks were collected through an extensive online survey or questionnaire using Google forms. The profiles of the experts who participated in the study, is provided in the Table 3 bellow. A sample of the questionnaire that has been sent to the distinguished experts through email (as Google Forms) is given in the *Table 2A and 3A* of the *Supplementary materials*.

Table 3. Profile of the experts

Experts participated in the study to provide feedback on the evaluation criteria			
	Experience	N	Percentage
Total number of experts (N=25)	< 10 years	13	52%
	From 10 to 15 years	7	23%
	> 15 years	5	20%

Experts weighed each criterion based on the following point system:

10 Point – Very Strong
7 point – Strong
4 Point – Moderate
1 Point- Very Poor

As there were total 25 responses from 25 experts for each criterion against each industry 4.0 elements, the averages of those point responses have been used in this study. For example, if the average of the responses for a certain criterion against a certain element is 7.70, which is closest to ranking point-7 (Strong), the particular criterion then receives a point equal to 7 for that element. This way all the criteria have been rated, which is shown in the Table 4.

Table 4: Criteria rating values obtained from expert feedbacks

Industry 4.0 elements / Criteria	Computer and IT Knowledge	Proper integration among different systems	Self-regulating mechanism	Quality of the automated decision making	Application of embedded technologies	Digital communication	Magnitude of human-machine interfacing	Energy management system	Training of Technology	Mindset for technology adoption
Autonomous robots	10	10	7	7	4	10	10	4	7	7
Simulation	10	10	4	4	10	7	7	1	4	7
System integration (horizontal and vertical)	10	10	7	10	7	10	7	1	4	4
Industrial Internet of Things (iiot)	10	10	7	10	10	10	10	7	7	7
Cyber security	10	10	10	7	7	7	7	1	10	7
Cyber physical system	10	10	7	7	7	7	7	4	7	7
Additive manufacturing	7	4	10	10	10	4	7	7	7	10
Augmented reality	7	10	7	4	7	10	7	10	4	10
Big data analytics	10	10	7	4	4	10	4	1	7	7
Cloud computing	10	10	7	4	10	10	4	1	10	7

The experts' opinions and judgments have also been used to construct the pairwise comparison matrix for the criteria, which is shown in Table 5.

Table 5: Pairwise comparison of criterion using expert feedbacks

Criteria / Criteria	Computer and IT Knowledge	Proper integration among different systems	Self-regulating mechanism	Quality of the automated decision making	Application of embedded technologies	Digital communication	Magnitude of human-machine interfacing	Energy management system	Training of Technology	Mindset for technology adoption
Computer and IT Knowledge	1	½	5	6	3	4	3	7	2	5
Proper Integration among different Systems	2	1	6	8	4	5	4	9	3	7
Self-regulating Mechanism	1/5	1/6	1	3	¼	1/3	¼	5	2	5
Quality of the automated Decision Making	1/6	1/8	1/3	1	1/5	1/4	1/5	3	4	5
Application of Embedded Technologies	1/3	1/4	4	5	1	2	2	7	3	6
Digital Communication	1/4	1/5	3	4	1/2	1	2	6	2	4
Magnitude of Human-Machine Interfacing	1/3	1/4	4	5	1/2	1/2	1	7	1/3	3
Energy Management System	1/7	1/9	1/5	1/3	1/7	1/6	1/7	1	1/4	2
Training of Technology	1/2	1/3	1/2	1/4	1/3	1/2	3	4	1	4
Mindset for Technology Adoption	1/5	1/7	1/5	1/5	1/6	1/4	1/3	1/2	1/4	1

Values shown in Table 5 have been transformed into TFN following the conversion scale given in Table 2, which is shown in *Table 4A* of the *Supplementary materials*. Afterwards, the geometric mean of each criterion has been calculated using the fuzzy pairwise comparison matrix. Table 6 shows the fuzzy geometric mean, fuzzy weights, and defuzzified weights of the criteria. If the sum of the defuzzified weights has been found greater than 1, they have been normalized for better accuracy.

Table 6: Fuzzy Geometric mean, Fuzzy weights, defuzzified weights and normalized defuzzified weights of the criteria by using FAHP

Criteria	Fuzzy Geometric Mean Value, $\tilde{r}_i$	Fuzzy Weights, $\tilde{w}_i$	Defuzzified Weights, w_i	Normalized Defuzzified Weights
Computer and IT Knowledge	(2.16, 2.80, 3.58)	(0.145, 0.236, 0.388)	0.209	0.197
Proper Integration among different Systems	(3.21, 4.03, 4.74)	(0.215, 0.339, 0.514)	0.272	0.258
Self-regulating Mechanism	(0.46, 0.57, 0.71)	(0.031, 0.048, 0.077)	0.058	0.055
Quality of the automated Decision Making	(0.29, 0.35, 0.43)	(0.019, 0.029, 0.047)	0.039	0.037
Application of Embedded Technologies	(1.17, 1.62, 2.09)	(0.079, 0.136, 0.226)	0.134	0.126
Digital communication	(0.87, 1.17, 1.56)	(0.058, 0.099, 0.169)	0.105	0.099
Magnitude of Human-Machine Interfacing	(0.89, 1.14, 1.59)	(0.060, 0.096, 0.172)	0.105	0.100
Energy management system	(0.18, 0.21, 0.24)	(0.012, 0.018, 0.027)	0.026	0.025
Training of Technology	(0.62, 0.84, 1.24)	(0.044, 0.073, 0.132)	0.083	0.078
Mindset for technology adoption	(0.22, 0.27, 0.35)	(0.016, 0.023, 0.038)	0.026	0.024
		Sum	1.057	1.000

Defuzzified Criteria weights obtained using FAHP, as shown Table 6, are then used as inputs to the PROMETHEE II method, to obtain the ranking of the industry 4.0 elements. All the required information for the evaluation of industry 4.0 elements is given in Table 7.

Table 7: Evaluation matrix to be used for analysis by PROMETHEE II

	Weightage →	0.197	0.258	0.055	0.037	0.126	0.099	0.100	0.025	0.078	0.024
	Criteria →	Computer and IT Knowledge	Proper integration among different systems	Self-regulating mechanism	Quality of the automated decision making	Application of embedded technologies	Digital communication	Magnitude of human-machine interfacing	Energy management system	Training of Technology	Mindset for technology adoption
Industry 4.0 Elements	Autonomous robots	10	10	7	7	4	10	10	4	7	7
	Simulation	10	10	4	4	10	7	7	1	4	7
	System Integration (Horizontal and Vertical)	10	10	7	10	7	10	7	1	4	4
	Industrial Internet of Things (iiot)	10	10	7	10	10	10	10	7	7	7
	Cyber security	10	10	10	7	7	7	7	1	10	7
	Cyber physical system	10	10	7	7	7	7	7	4	7	7
	Additive manufacturing	7	4	10	10	10	4	7	7	7	10
	Augmented reality	7	10	7	4	7	10	7	10	4	10
	Big data analytics	10	10	7	4	4	10	4	1	7	7
	Cloud computing	10	10	7	4	10	10	4	1	10	7
	Max(Xij), Min(Xij)	10, 7	10, 4	10, 4	10, 4	10, 4	10, 4	10, 4	10, 1	10, 4	10, 4

Finally, the complete final ranking of the industry 4.0 elements is obtained by using PROMETHEE II method is presented in Table 8. The final ranking of the elements is based on the obtained value of the Net Outranking Flow $\phi(a)$.

Table 8: Final ranking of the industry 4.0 elements using PROMETHEE II

Aggregated Preference Function (Industry 4.0 Elements)	Leaving Flow, ϕ^+	Entering Flow, ϕ^-	Net Outranking Flow, $\phi(a)$	Rank
Industrial Internet of Things (iiot)	0.262791806	0.018432715	0.244359091	1
Cloud computing	0.208672035	0.090951224	0.117720811	2
Cyber security	0.188248004	0.089349865	0.098898139	3
Autonomous robots	0.185779202	0.111656685	0.074122517	4
System Integration (Horizontal and Vertical)	0.150997851	0.107491966	0.043505885	5
Cyber physical system	0.133439703	0.099644945	0.033794759	6
Simulation	0.146654293	0.146519822	0.000134471	7
Big data analytics	0.117586547	0.183977592	-0.06639105	8
Augmented reality	0.115572788	0.278668245	-0.16309546	9
Additive manufacturing	0.153588173	0.536637343	-0.38304917	10

4 Results and Discussions

In this study, based on an extensive literature review, ten evaluation criteria have been identified. Then FAHP has been used to determine the criteria weights and those weights has been used as inputs to the PROMETHEE II method, to rank the elements of industry 4.0 for the implementation in the RMG Sector of Bangladesh. It is evident from Table 6, which shows the result obtained from FAHP, that among all the criteria, 'Proper integration among different systems' has been found to be the most significant, bearing 25.80% of the total weight. Therefore, 'Proper integration among different systems' is the most important evaluation criteria, on which the RMG industries of Bangladesh need to be focusing more to facilitate proper implementation of the industry 4.0 elements. This criterion is then followed by 'Computer and IT Knowledge' and 'Application of embedded technologies' with 19.70% and 12.60% of the total weight respectively. On the other hand, 'Mindset for technology adoption' with 2.40% weight has been found to be the criteria with the least importance.

Later, the complete ranking of industry 4.0 elements, obtained from the PROMETHEE II method, has been presented in Table 8. It is evident from the Table 9 that 'Industrial Internet of Things (IIoT)' is the most important and 'Cloud computing' is the second most important element of industry 4.0, which need to be implemented in RMG industries of Bangladesh on a priority basis. On the other hand, 'Additive manufacturing' has been identified to be the least important element of industry 4.0 from implementation priority perspective.

It is undeniable that the RMG industries of Bangladesh must adopt industry 4.0 in their operations, in order to stay relevant in the competitive economy of the twenty-first century. To do that the management team must take the right decision at right moment, while maintaining company's financial solvency, since a complete implementation of all the elements of industry 4.0 can be very expensive. For a developing country like Bangladesh, where industries usually have limited resources, it is not practical to implement all the elements of industry 4.0 simultaneously. Thereby, implementing the elements one by one following the ranking presented in Table 9 of this study can help the RMG industries of Bangladesh to implement industry 4.0 more efficiently and effectively, without losing too much of their financial solvency.

5 Research Implications

The proposed research can help the managers and decision makers of the RMG industries as well as other similar industrial sectors in the developing countries to formulate necessary framework for the implementation of industry 4.0. This research will also provide industrial technologists and experts with means to evaluate the impact of the identified criteria for implementing industry 4.0 in emerging economic context. In addition, this study can help industrial decision makers to realize the importance of assessing and ranking the industry 4.0 elements before proceeding to implementation, especially when their resources are constrained. The research may guide the government and other industrial stakeholders as well. Policy makers can acquire knowledge about the significant of the evaluation criteria and priority ranking of the elements of industry 4.0 from this research, which can help them to

put together strategies to facilitate the implementation of industry 4.0 in the RMG industries as well as other similar industries.

6 Conclusions and Future Research

The impact of modern manufacturing technologies on industrial sector is very exigent, as they can improve the production system by optimizing the process, reducing the process loss, and manufacturing cost, while increasing the product quality at the same time. Industry 4.0 entails the implementation of modern technologies like advanced robotics, artificial intelligence, automation, sensor technologies etc. Therefore, adoption of industry 4.0 in the RMG sector of Bangladesh is an imperative need. This research has been conducted with a view to help the managers and the decision makers to efficiently implement industry 4.0, without putting too much financial strain on their respective organizations.

In this study, a hybrid FAHP-PROMETHEE II method has been used for the analysis. From the result of FAHP, it is evident that the 'Proper integration among different systems' is the most important evaluation criteria, while the 'Mindset for technology adoption' is the criteria with the least importance, for the implementation of industry 4.0 in the RMG industries of the developing countries like Bangladesh. The findings demonstrate the weightage of each criterion and thus gives the decision makers insights about which criteria they should emphasize on more for the efficient implementation of industry 4.0 in their industries. Again, from the final ranking obtained from the PROMETHEE II result, it is evident that the 'Industrial Internet of Things (IIoT)' is the most important element, while the 'Additive manufacturing' is the least important element of industry 4.0 from implementation priority perspective. These findings suggest the decision makers about which element of industry 4.0 they should implement first, when their resources are constrained. For an industry situated in a developing country, implementing all the elements of industry 4.0 can create immense financial burden, which might even lead to bankruptcy if not managed properly and carefully. Hence, for such industries, this research can provide insights of immense value.

This research can be extended in several directions in future. This study analyzed the criteria only related to the RMG industries of the developing countries like Bangladesh. Hence, in future, this study can be extended to include other industries of different natures and different economic capabilities. Moreover, this study has not analyzed the challenges and the drivers of industry 4.0 implementation either, which can be another important research scope worth exploring in future.

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Supplementary Materials

Table 1A: Description of the significance of the identified criteria

No.	Criteria	Brief Description of Significance
1	Computer and IT Knowledge	Use of computer and IT in every industrial operation reduces the chance of error and improves job efficiency. Computer records all activity data through IT, which allows subsequent activity review and thus paves the way for further process improvement.
2	Proper Integration among different systems	Proper horizontal and vertical integration among different systems involved in production process promotes the data flow among all stakeholders like industrial and financial partners, suppliers, customers and employees, which is necessary overall all process improvement.
3	Self-regulating mechanism	Adjustment, calibration and operation of machines or devices by themselves, without too much human control, reduces room for human error and necessity of middlemen. It can be achieved through smart algorithm integration with the end-to-end product engineering, which also promotes continuous improvement.
4	Quality of the automated decision making	Sensor based automated machines, which can operate without human assistance , can facilitate improved productivity in industry 4.0 platform. It increases the speed and precision of work. Big data, cloud computing also facilitates in precision autonomous decision making.
5	Application of Embedded Technologies	Avoiding too outdated machineries and adopting more microprocessor-based production systems, that can perform particular functions over and over with high repeatability and precision can make the process error free and efficient
6	Digital communication	Communicating wirelessly with other machines and interfaces allows the system to be more responsive and agile. This also reduces the need for human intervention and thus allows human to focus more on monitoring and decision-making activities.
7	Magnitude of human-machine interfacing	Seamless interaction between human and machine is necessary for proper integration among different parts of the modern manufacturing system. Touch interfaces, gesture interfaces, voice recognition and command interfaces etc. can help in this regard.
8	Energy management system	Optimum energy consumption would make the system longer lasting, more profitable and sustainable. Modern automated chip-based machineries are more energy conserving than the machineries with older technology.
9	Training of Technology (ToT)	Industry 4.0 elements are often very complex. Scheduled and proper ToT will make it easier to adopt and embrace this technology for continuous improvement of the production system.
10	Mindset for technology adoption	Industry 4.0 is involved technological revolution and costly investment. This revolution requires installation of modern machine, technology and it exclude too much human intervention. Since the RMG sector of Bangladesh is still cheap human labor oriented, it is very important to foster a positive mindset about the adoption of new technologies to rip the full benefit of industry 4.0.

Table 2A: Questionnaire for Criteria rating values obtained from expert feedbacks (to be used in Table 4)

S/L	Questionnaire	10 Point-Very Strong	7 point-Strong	4 Point-Moderate	1 Point-Very Poor
1	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Autonomous Robots'	○	○	○	○
2	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Autonomous Robots'	○	○	○	○
3	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Autonomous Robots'	○	○	○	○
4	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Autonomous Robots'	○	○	○	○
5	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Autonomous Robots'	○	○	○	○
6	How would you like to rate the criteria 'Digital Communication' to implement the element 'Autonomous Robots'	○	○	○	○

7	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Autonomous Robots'	○	○	○	○
8	How would you like to rate the criteria 'Energy Management System' to implement the element 'Autonomous Robots'	○	○	○	○
9	How would you like to rate the criteria 'Training of Technology' to implement the element 'Autonomous Robots'	○	○	○	○
10	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Autonomous Robots'	○	○	○	○
11	How would you like to rate the criteria 'Computer and IT' Knowledge to implement the element 'Simulation'	○	○	○	○
12	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Simulation'	○	○	○	○
13	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Simulation'	○	○	○	○
14	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Simulation'	○	○	○	○
15	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Simulation'	○	○	○	○
16	How would you like to rate the criteria 'Digital Communication' to implement the element 'Simulation'	○	○	○	○
17	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Simulation'	○	○	○	○
18	How would you like to rate the criteria 'Energy Management System' to implement the element 'Simulation'	○	○	○	○
19	How would you like to rate the criteria 'Training of Technology' to implement the element 'Simulation'	○	○	○	○
20	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Simulation'	○	○	○	○
21	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
22	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
23	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
24	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
25	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
26	How would you like to rate the criteria 'Digital Communication' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
27	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
28	How would you like to rate the criteria 'Energy Management System' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
29	How would you like to rate the criteria 'Training of Technology' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○
30	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'System Integration (Horizontal and Vertical)'	○	○	○	○

31	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Industrial Internet of Things'	○	○	○	○
32	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Industrial Internet of Things'	○	○	○	○
33	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Industrial Internet of Things'	○	○	○	○
34	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Industrial Internet of Things'	○	○	○	○
35	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Industrial Internet of Things'	○	○	○	○
36	How would you like to rate the criteria 'Digital Communication' to implement the element 'Industrial Internet of Things'	○	○	○	○
37	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Industrial Internet of Things'	○	○	○	○
38	How would you like to rate the criteria ' Management System' to implement the element 'Industrial Internet of Things'	○	○	○	○
39	How would you like to rate the criteria 'Training of Technology' to implement the element 'Industrial Internet of Things'	○	○	○	○
40	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Industrial Internet of Things'	○	○	○	○
41	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Cyber Security'	○	○	○	○
42	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Cyber Security'	○	○	○	○
43	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Cyber Security'	○	○	○	○
44	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Cyber Security'	○	○	○	○
45	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Cyber Security'	○	○	○	○
46	How would you like to rate the criteria 'Digital Communication' to implement the element 'Cyber Security'	○	○	○	○
47	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Cyber Security'	○	○	○	○
48	How would you like to rate the criteria 'Energy Management System' to implement the element 'Cyber Security'	○	○	○	○
49	How would you like to rate the criteria 'Training of Technology' to implement the element 'Cyber Security'	○	○	○	○
50	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Cyber Security'	○	○	○	○
51	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Cyber Physical System'	○	○	○	○
52	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Cyber Physical System'	○	○	○	○
53	How would you like to rate the criteria 'Self-regulating mechanism to implement' the element 'Cyber Physical System'	○	○	○	○
54	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Cyber Physical System'	○	○	○	○

55	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Cyber Physical System'	○	○	○	○
56	How would you like to rate the criteria 'Digital Communication' to implement the element 'Cyber Physical System'	○	○	○	○
57	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Cyber Physical System'	○	○	○	○
58	How would you like to rate the criteria 'Energy Management System' to implement the element 'Cyber Physical System'	○	○	○	○
59	How would you like to rate the criteria 'Training of Technology' to implement the element 'Cyber Physical System'	○	○	○	○
60	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Cyber Physical System'	○	○	○	○
61	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Additive Manufacturing'	○	○	○	○
62	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Additive Manufacturing'	○	○	○	○
63	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Additive Manufacturing'	○	○	○	○
64	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Additive Manufacturing'	○	○	○	○
65	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Additive Manufacturing'	○	○	○	○
66	How would you like to rate the criteria 'Digital Communication' to implement the element 'Additive Manufacturing'	○	○	○	○
67	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Additive Manufacturing'	○	○	○	○
68	How would you like to rate the criteria 'Energy Management System' to implement the element 'Additive Manufacturing'	○	○	○	○
69	How would you like to rate the criteria 'Training of Technology' to implement the element 'Additive Manufacturing'	○	○	○	○
70	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Additive Manufacturing'	○	○	○	○
71	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Augmented Reality'	○	○	○	○
72	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Augmented Reality'	○	○	○	○
73	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Augmented Reality'	○	○	○	○
74	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Augmented Reality'	○	○	○	○
75	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Augmented Reality'	○	○	○	○
76	How would you like to rate the criteria 'Digital Communication' to implement the element 'Augmented Reality'	○	○	○	○
77	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Augmented Reality'	○	○	○	○
78	How would you like to rate the criteria 'Energy Management System' to implement the element 'Augmented Reality'	○	○	○	○

79	How would you like to rate the criteria 'Training of Technology' to implement the element 'Augmented Reality'	○	○	○	○
80	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Augmented Reality'	○	○	○	○
81	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Big Data Analytics'	○	○	○	○
82	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Big Data Analytics'	○	○	○	○
83	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Big Data Analytics'	○	○	○	○
84	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Big Data Analytics'	○	○	○	○
85	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Big Data Analytics'	○	○	○	○
86	How would you like to rate the criteria 'Digital Communication' to implement the element 'Big Data Analytics'	○	○	○	○
87	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Big Data Analytics'	○	○	○	○
88	How would you like to rate the criteria 'Energy Management System' to implement the element 'Big Data Analytics'	○	○	○	○
89	How would you like to rate the criteria 'Training of Technology' to implement the element 'Big Data Analytics'	○	○	○	○
90	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Big Data Analytics'	○	○	○	○
91	How would you like to rate the criteria 'Computer and IT Knowledge' to implement the element 'Cloud Computing'	○	○	○	○
92	How would you like to rate the criteria 'Proper Integration among different Systems' to implement the element 'Cloud Computing'	○	○	○	○
93	How would you like to rate the criteria 'Self-regulating mechanism' to implement the element 'Cloud Computing'	○	○	○	○
94	How would you like to rate the criteria 'Quality of the automated Decision Making' to implement the element 'Cloud Computing'	○	○	○	○
95	How would you like to rate the criteria 'Application of Embedded Technologies' to implement the element 'Cloud Computing'	○	○	○	○
96	How would you like to rate the criteria 'Digital Communication' to implement the element 'Cloud Computing'	○	○	○	○
97	How would you like to rate the criteria 'Magnitude of Human-Machine Interfacing' to implement the element 'Cloud Computing'	○	○	○	○
98	How would you like to rate the criteria 'Energy Management System' to implement the element 'Cloud Computing'	○	○	○	○
99	How would you like to rate the criteria 'Training of Technology' to implement the element 'Cloud Computing'	○	○	○	○
100	How would you like to rate the criteria 'Mindset for technology adoption' to implement the element 'Cloud Computing'	○	○	○	○

Table 3A: Questionnaire for Pairwise comparison of criterion using expert feedbacks (to be used in Table 5)

S/L	Questionnaire	Importance Type		Importance Intensity								
		More	Less	9 times	8 times	7 times	6 times	5 times	4 times	3 times	2 times	1 time (Equal)
1	How more/less important do you think 'Computer and IT Knowledge' is than 'Proper Integration among different Systems'?	○	○	○	○	○	○	○	○	○	○	○
2	How more/less important do you think 'Computer and IT Knowledge' is than 'Self-regulating Mechanism'?	○	○	○	○	○	○	○	○	○	○	○
3	How more/less important do you think 'Computer and IT Knowledge' is than 'Quality of the automated Decision Making'?	○	○	○	○	○	○	○	○	○	○	○
4	How more/less important do you think 'Computer and IT Knowledge' is than 'Application of Embedded Technologies'?	○	○	○	○	○	○	○	○	○	○	○
5	How more/less important do you think 'Computer and IT Knowledge' is than 'Digital Communication'?	○	○	○	○	○	○	○	○	○	○	○
6	How more/less important do you think 'Computer and IT Knowledge' is than 'Magnitude of Human-Machine Interfacing'?	○	○	○	○	○	○	○	○	○	○	○
7	How more/less important do you think 'Computer and IT Knowledge' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
8	How more/less important do you think 'Computer and IT Knowledge' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○
9	How more/less important do you think 'Computer and IT Knowledge' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
10	How more/less important do you think 'Proper Integration among different Systems' is than 'Self-regulating Mechanism'?	○	○	○	○	○	○	○	○	○	○	○
11	How more/less important do you think 'Proper Integration among different Systems' is than 'Quality of the automated Decision Making'?	○	○	○	○	○	○	○	○	○	○	○

12	How more/less important do you think 'Proper Integration among different Systems' is than 'Application of Embedded Technologies'?	○	○	○	○	○	○	○	○	○	○	○
13	How more/less important do you think 'Proper Integration among different Systems' is than 'Digital Communication'?	○	○	○	○	○	○	○	○	○	○	○
14	How more/less important do you think 'Proper Integration among different Systems' is than 'Magnitude of Human-Machine Interfacing'?	○	○	○	○	○	○	○	○	○	○	○
15	How more/less important do you think 'Proper Integration among different Systems' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
16	How more/less important do you think 'Proper Integration among different Systems' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○
17	How more/less important do you think 'Proper Integration among different Systems' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
18	How more/less important do you think 'Self-regulating Mechanism' is than 'Quality of the automated Decision Making'?	○	○	○	○	○	○	○	○	○	○	○
19	How more/less important do you think 'Self-regulating Mechanism' is than 'Application of Embedded Technologies'?	○	○	○	○	○	○	○	○	○	○	○
20	How more/less important do you think 'Self-regulating Mechanism' is than 'Digital Communication'?	○	○	○	○	○	○	○	○	○	○	○
21	How more/less important do you think 'Self-regulating Mechanism' is than 'Magnitude of Human-Machine Interfacing'?	○	○	○	○	○	○	○	○	○	○	○
22	How more/less important do you think 'Self-regulating Mechanism' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
23	How more/less important do you think 'Self-regulating Mechanism' is than 'Training of	○	○	○	○	○	○	○	○	○	○	○

	Technology'?											
24	How more/less important do you think 'Self-regulating Mechanism' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
25	How more/less important do you think 'Quality of the automated Decision Making' is than 'Application of Embedded Technologies'?	○	○	○	○	○	○	○	○	○	○	○
26	How more/less important do you think 'Quality of the automated Decision Making' is than 'Digital Communication'?	○	○	○	○	○	○	○	○	○	○	○
27	How more/less important do you think 'Quality of the automated Decision Making' is than 'Magnitude of Human-Machine Interfacing'?	○	○	○	○	○	○	○	○	○	○	○
28	How more/less important do you think 'Quality of the automated Decision Making' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
29	How more/less important do you think 'Quality of the automated Decision Making' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○
30	How more/less important do you think 'Quality of the automated Decision Making' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
31	How more/less important do you think 'Application of Embedded Technologies' is than 'Digital Communication'?	○	○	○	○	○	○	○	○	○	○	○
32	How more/less important do you think 'Application of Embedded Technologies' is than 'Magnitude of Human-Machine Interfacing'?	○	○	○	○	○	○	○	○	○	○	○
33	How more/less important do you think 'Application of Embedded Technologies' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
34	How more/less important do you think 'Application of Embedded Technologies' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○

35	How more/less important do you think 'Application of Embedded Technologies' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
36	How more/less important do you think 'Digital Communication' is than 'Magnitude of Human-Machine Interfacing'?	○	○	○	○	○	○	○	○	○	○	○
37	How more/less important do you think 'Digital Communication' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
38	How more/less important do you think 'Digital Communication' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○
39	How more/less important do you think 'Digital Communication' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
40	How more/less important do you think 'Magnitude of Human-Machine Interfacing' is than 'Energy Management System'?	○	○	○	○	○	○	○	○	○	○	○
41	How more/less important do you think 'Magnitude of Human-Machine Interfacing' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○
42	How more/less important do you think 'Magnitude of Human-Machine Interfacing' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
43	How more/less important do you think 'Energy Management System' is than 'Training of Technology'?	○	○	○	○	○	○	○	○	○	○	○
44	How more/less important do you think 'Energy Management System' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○
45	How more/less important do you think 'Training of Technology' is than 'Mindset for Technology Adoption'?	○	○	○	○	○	○	○	○	○	○	○

Table 4A: Fuzzy pairwise comparison of criterion for FHP

Criteria	Computer and IT Knowledge	Proper integration among different systems	Self-regulating mechanism	Quality of the automated decision making	Application of embedded technologies	Digital communication	Magnitude of human-machine interfacing	Energy management system	Training of Technology	Mindset for technology adoption
Computer and IT Knowledge	(1,1,1)	(1/3, 1/2, 1)	(4,5,6)	(5,6,7)	(2,3,4)	(3,4,5)	(2,3,4)	(6,7,8)	(1,2,3)	(4,5,6)
Proper Integration among different Systems	(1,2,3)	(1,1,1)	(5,6,7)	(7,8,9)	(3,4,5)	(4,5,6)	(3,4,5)	(9,9,9)	(2,3,4)	(6,7,8)
Self-regulating Mechanism	(1/6, 1/5, 1/4)	(1/7, 1/6, 1/5)	(1,1,1)	(2,3,4)	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(4,5,6)	(1,2,3)	(4,5,6)
Quality of the automated Decision Making	(1/7, 1/6, 1/5)	(1/9, 1/8, 1/7)	(1/4, 1/3, 1/2)	(1,1,1)	(1/6, 1/5, 1/4)	(1/5, 1/4, 1/3)	(1/6, 1/5, 1/4)	(2,3,4)	(3,4,5)	(4,5,6)
Application of Embedded Technologies	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(3,4,5)	(4,5,6)	(1,1,1)	(1,2,3)	(1,2,3)	(6,7,8)	(2,3,4)	(5,6,7)
Digital communication	(1/5, 1/4, 1/3)	(1/6, 1/5, 1/4)	(2,3,4)	(3,4,5)	(1/3, 1/2, 1)	(1,1,1)	(1,2,3)	(5,6,7)	(1,2,3)	(3,4,5)
Magnitude of Human-Machine Interfacing	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(3,4,5)	(4,5,6)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1,1,1)	(6,7,8)	(1/4, 1/3, 1/2)	(2,3,4)
Energy management system	(1/8, 1/7, 1/6)	(1/9, 1/9, 1/9)	(1/6, 1/5, 1/4)	(1/4, 1/3, 1/2)	(1/8, 1/7, 1/6)	(1/7, 1/6, 1/5)	(1/8, 1/7, 1/6)	(1,1,1)	(1/5, 1/4, 1/3)	(1,2,3)
Training of Technology	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(2,3,4)	(3,4,5)	(1,1,1)	(3,4,5)
Mindset for Technology Adoption	(1/6, 1/5, 1/4)	(1/8, 1/7, 1/6)	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)	(1,1,1)