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# A Fuzzy-AHP Analysis to the Determination of Weights of the Main Obstacles of RMG in Industry 4.0 Application for Bangladesh

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#### Article Information

#### ABSTRACT

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#### Keywords

Fuzzy-AHP, Industry 4.0, Main Obstacles, Pair Wise Comparisons, Ready Made Garments (RMG) The movement of the Fourth Industrial Revolution is touching the manufacturing and processing industries in Bangladesh. The research uses the Fuzzy Analytical Hierarchy Process (Fuzzy-AHP) geometric mean technique, a Multi Criteria Decision Making (MCDM) methodology, to identify, analyze, and prioritize the key obstacles to Industry 4.0 implementation in Bangladesh's Ready Made Garments (RMG) industries. Another triangular type Fuzzy-AHP extent analysis approach is applied to evaluate the minimum degree of possibilities by using fuzzy appropriateness indices and to determine the weights of assessment criteria. Pairwise comparisons are used to collect 11 experts' preferences in verbal and numerical terms from different industries. The four main obstacles identified from related review studies are used as input variables in the Fuzzy-AHP methods to measure the intensity level of obstacles. The results have shown that the main four obstacles for Industry 4.0 are "Lack of Top Management Commitment and Owners' Willingness" (40.6%), "Lack of Ability to Meetup Initial Investment" (30.8%), "Lack of Technical Knowledge and Education" (17.8%), and "Availability of Cheaper Labor" (10.8%). In order to avoid a null weight criterion using Fuzzy-AHP possibility extent, the weight values evaluated using Fuzzy-AHP geometric mean method are considered for decision making. The opinions or ratio scales collected from industry experts are verified with the consistency ratio checking technique.

#### INTRODUCTION

The application of sustainable technology constantly opens the door to economic progress. If at least one or two high-quality products can thrive in the global market, the country's economy will be more open to the development of other sectors in Bangladesh. As a result, there is no choice but to continue with pleasant quality products that have already occupied a portion of the global market. Bangladesh's RMG industry produces high-quality garments using advanced technologies and is eager to transition to Industry 4.0 as soon as possible. Clearly, the organization must build a business atmosphere by removing existing obstacles.

According to Dr. Reinhard et al.'s research (Geissbauer et al., 2014), Industry 4.0 prepares the door for new technology, primarily the digitization of products and business models. The unique feature of digital transformation is the rapid acceleration of the velocity of change. The product division is increasingly shifting toward software, which includes outstanding sensor technology, digital networking, and data creation. The core intelligences of integrated solutions and massive data exercise invite new companies to enter existing markets, and the benefit of new technology is the reduction of traditional market entry restrictions. Industry 4.0 technological elements include big data and analytics, the internet of things, cyber physical systems, smart factories, artificial intelligence, cloud computing, and block chain (Dalenogare et al., 2018).

According to Ângelo *et al.* (Ângelo *et al.* 2017), the fourth industrial revolution decreases time for delivering quality

products all over the world, provides adequate adaptable product lines, enhances productivity, makes efficient use of finances, and integrates the virtual global industry into global value chains. As per Fettig et al. (Fettig K. et al., 2018), while the impact of new technology may not be immediate, it will represent an example of transformation in the production system, work, business, livelihood, and interaction in both emerging and established countries. According to M. A. Islam et al. in (Islam et al., 2018), it is a good time for the Bangladesh Government, policymakers, industry experts, and industry owners to take the necessary steps so that Industry 4.0 can be initiated in the manufacturing and service industries to capitalize on the opportunities provided by Industry 4.0. Moktadir used (Moktadir et al., 2018) the Best-Worst-Method (BWM) and concluded in favor of the application of Industry 4.0 technologies in Bangladesh that provide massive facilities for industries with large investments. According to (Hossain, 2016, Humphrey, 2021), Bangladesh has constructed approximately 8000 digital centers throughout the country to train science-based young people in various digital categories. According to the study (Bhuiyan et al., 2020), Bangladesh has a lot of potential for adopting Industry 4.0, but there are also a lot of roadblocks. As a result, the government, policymakers, and industrial groups must collaborate to overcome these obstacles.

#### Objectives of the Study

This study was directed towards achieving the following objectives:

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1) To evaluate the main obstacles of Ready Made Garments (RMG) in an Industry 4.0 application from the related review studies for Bangladesh.

2) To develop a questionnaire for pair-wise comparisons among the main obstacles and to collect experiences on both a linguistic and numeric scale from the RMG industry experts.

3) To create a Fuzzy-AHP analysis mathematical model based on pair-wise data collected from RMG experts and prioritization of major obstacles, as well as to discuss strategies to overcome the intensity of hurdles of RMG for Industry 4.0 initiation in Bangladesh.

#### LITERATURE REVIEW

With decades of experience, the RMG industries, one of the most prosperous export-oriented businesses, have formed their roots, evolved into the primary and core, and are now the generational businesses of the Bangladeshi people. Despite the fact that Bangladesh's industries are rapidly expanding, the ready-made garment (RMG) sector faces significant challenges in implementing Industry 4.0, and the government is motivated to address these issues and implement an enormous change in industrial production through the use of digital technology. According to the focus groups, there are various barriers and levels of complexity to implementing Industry 4.0 in SMEs (Orzes et al., 2020). They classified the difficulties as financial, cultural, competencies, legal, technological, and implementation process-related. The research (Islam et al., 2018) used a phenomenology design to evaluate the experts' judgments and identified various barriers to implementing Industry 4.0 in Bangladesh, such as poor infrastructure, a lack of cheaper labour, expensive technology installation, a lack of government support, and a lack of knowledge. In similar study (Jabbour et al, 2017), discussed the benefits of implementing Industry 4.0 in Bangladesh, but they were also concerned about the problems, such as a lack of awareness, labour skills, factory infrastructure, insufficient investment, technology applications in production, and so on. Hasan and Mahmud also studied about the risks of RMG in Bangladesh (Hasan & Mahmud, 2017) and considered several risks in their research, including finance/capital risk, insufficient employee qualifications, employee turnover risk, standards, regulations, militancy risk, building collapse risk, fire incident risk, labour unrest risk, political unrest risk, climate change risk, health and safety risk, sexual harassment risk, local politics risk, and administration risk.

The study (Geissbauer *et al.*, 2014) defined that, the Industrial Internet, also known as Industry 4.0, is regarded as having some challenges but also offering a number of crucial qualities. Due to the report, the two main topics of interest are high investment levels and usually confusing business justifications for new technology applications. The research also assessed "lack of support by top management" as one of the biggest problems and it is advised that each organization review its current Industry 4.0 competencies and establish its digitization goals. Therefore, policymakers and business organizations can assist efforts to accelerate the system as a whole.

As a new technological adaptation, it is evident from the aforementioned talks and literature analysis that the implementation of Industry 4.0 in the RMG sector may encounter some significant variable hurdles. In the context of Bangladesh, difficulties can mount as seen below:

(1) Lack of Top Management Commitment and Owners' Willingness, (Criteria B1)

(2) Lack of Technical Knowledge and Education regarding Industry 4.0, (Criteria B2)

(3) Lack of Ability to Meet up Initial Investments, (Criteria B3) and

(4) Availability of Cheaper labour, (Criteria B4)

The majority of the studies in the aforementioned literature are focused on various environmental challenges and are mainly based on review studies. In this research, the researcher developed a fuzzy-based mathematical model to measure the level of intensity of obstacles for the challenges of RMG in Bangladesh, where the above mentioned four main obstacles are considered input variables in the methodology.

#### MATERIALS AND METHODS

Fuzzy refers to uncertain or foggy situations. Fuzzy logic enables flexibility when researchers can't tell if a viewpoint is real or fake. So, researchers might consider inaccuracies and ambiguities while making a conclusion (Chang, 1996). In this research, two fuzzy based MCDM approaches are considered on the basis of collected pairwise comparisons data from the industry experts. A pairwise comparison matrix is denoted by the n by n matrix  $A = [a_n]$ , where  $a_n > 0$ .  $a_n$  is commonly used to denote an expert's comparative evaluation of one criterion versus another. Every pairwise comparison is graded using the relative scale (from 1 to 9). As stated in (Saaty, 2008), a scale of 1 denotes the lowest score or equal weight of the pairwise comparison, while a scale of 9 shows the greatest score of the pairwise comparison. A pairwise comparison is designed to collect industry expert assessments in verbal and numerical terms. According to the pair-wise comparison format, experts' opinions/ ratio scales were collected from 11 executives of three ready-made garment manufacturers in Bangladesh who took part in physical interviews. The specialists came from a variety of backgrounds, including operation and production management, quality control, business development executives, engineering and design, and so on. Everyone on the team had extensive experience in their respective fields. When gathering data, ethical standards and research procedures were followed. The collected vocal phrases (opinions) and their relative scales among the considered variable obstacles are used to create pairwise comparison single-value matrices for 11 experts.



Aside from research methodology, four major environmental issues of Industry 4.0 are highlighted from related review studies for the Ready-Made Garments (RMG) industry in Bangladesh. Second, the research used the triangular type Fuzzy-AHP geometric mean and Fuzzy-AHP possibility extent methodologies for the evaluation (intensity level) and prioritizing of Industry 4.0's four primary variable issues, namely

(1) Lack of Top Management Commitment and Owners' Willingness, (Criteria B1)



Figure 1: Flow Chart of the research methodology

#### Mathematical Expressions and Symbols Fuzzy Set Theory

First, Lotfi A. Zadeh proposed fuzzy set to describe imprecision mathematically in the year of 1965. A fuzzy number is defined as a fuzzy set whose membership function satisfies the normality and convexity conditions. It depicts an object's belonging to a crisp numeric set using membership functions ranging from zero to one.

#### Fuzzy Set

A fuzzy set  $\tilde{A}$  in adjscrete and finite universe of discourse X is defined by the Eq. (1) as

$$\begin{split} \tilde{A} &= (\ \mu_{\tilde{A}}\ (x_1))/(x_1 \ +)\ (\mu_{\tilde{A}}\ (x_2 \ ))/(x_2 \ + \dots =)\ (\sum_X \ \mu_{\tilde{A}}(x_i \ )) \\ /(x_i) &= \{(xi, \ \mu_{\tilde{A}}\ (x_i))|\ xi \in X\}) \end{split} (1) \\ where, \ x_1, x_2, x_3, -, -, -, -, are the elements of X and \ \mu_{\tilde{A}} : X \rightarrow \\ [0, 1] \ is called membership function \ \mu_{\tilde{A}}\ (x_i)\ /x_i \ is termed \\ as the grade of membership of an element x in X with \\ respect to \ \tilde{A}. \end{split}$$

The complement of a fuzzy set A is a fuzzy set  $\tilde{A}$  in the universe of discourse X whose membership function is defined as in Eq. (2):  $\mu_{\tilde{A}}(x)=1-\mu_{A}(x) \forall x \in X$  (2)

## Convex Fuzzy Set

A fuzzy set  $\tilde{A}$  on R is convex if and only if for any  $x_1 x_2 \in X$  and any parameter lambda,  $\lambda \in [0,1]$  the following condition as shown in Eq. (3) of the membership

(2) Lack of Technical Knowledge and Education regarding Industry 4.0, (Criteria B2)

(3) Lack of Ability to Meet up Initial Investments, (Criteria B3) and

(4) Availability of Cheaper labour, (Criteria B4)

The aforementioned methodology is shown as a flowchart in Fig. 1 to depict all of the components of the research process model sequentially so that the methodology's attributes can be identified, computed, analyzed, improved, and achieved.



function of A satisfies the inequality:

 $\lambda_{\tilde{\Lambda}} \{\lambda x_1 + (1-\lambda)x_2\} \ge \min\{\mu_{\tilde{\Lambda}}(x_1), \mu_{\tilde{\Lambda}}(x_2)\}; 0 \ge \lambda \le 1$  (3) where, min denotes the minimum operator. The intersection of two convex fuzzy sets is also convex as shown in Figure 3.

#### Height of a Fuzzy Set

The height of a fuzzy set  $\tilde{A}$  is the maximum value of the membership function. If  $\tilde{A}$  is a fuzzy set then the statement shown in Eqn. (4) represents the height of a fuzzy set  $\tilde{A}$ :

$$\operatorname{ngt}(\tilde{A}) := \sup_{x \in X_{H}\tilde{A}}(x) \tag{4}$$

#### Normal Fuzzy Set

A fuzzy set  $\tilde{A}$  of the universe of discourse X is called a normal fuzzy set implying that there at least one x in X such that  $\mu_{\tilde{x}}(x)=1$ .

Fuzzy set  $\tilde{A}$  of which the basic set is nonempty with a height strictly between zero and one, i. e.  $0 \le hgt(\tilde{A}) \le 1$ , are called un-normal.

A nonempty/subnormal fuzzy set  $\tilde{A}$  can always be normalized by division of  $\mu_{\tilde{A}}\left(x\right)$  by

 $\sup_{x \in X\mu\lambda}(x)$  for all  $x \in X$ . Therefore, the Eq. (5) of normalized fuzzy set A<sup>^</sup> is shown as:

 $A' = Norm(\tilde{A}) = \sum (\mu_{\tilde{A}}(x)) / hgt(\tilde{A}) / x$ 

(5)



## Support of a Fuzzy Set

The support of a fuzzy set  $\tilde{A}$  is the set of all points x in the universe of discourse X for any associated membership function such that  $\mu_{\tilde{A}}$  (x)>0. The crisp set can be represented by the Eq. (6) as:

 $supp(\tilde{A}) := \{ x \in X \mid \mu_{\tilde{A}}(x) > 0 \}.$ (6) It is called support of  $\tilde{A}$ .

#### Triangular Fuzzy Number (TFNs)



**Figure 2:** Membership functions of Fuzzy Triangular Number

A Triangular fuzzy number is denoted by M  $\tilde{M}^{=}(l,m,u)$  as shown in Figure 2, where l,m,u are real numbers and  $l \le m \le u$ . The membership function  $\mu_M \tilde{M}(x)$  can be described by the following Eq. (7):

$$\mu_{M_{\widetilde{M}}}(\mathbf{x}) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, & x \in [l,m], \\ \frac{x}{m-u} - \frac{u}{m-u}, & x \in [m,u] \end{cases}$$
(7)

0, otherwise

#### Defuzzification

A crisp output y is desirable in many applications. The output fuzzy set must be defuzzified to achieve a crisp value. The Mamdani inference approach employs the centre of gravity (COG) defuzzification method. This method computes the y coordinate of the area's centre of gravity under the fuzzy set B' as shown in Eq. (8):  $y' = cog(B') = (\sum_{(j=1)}^{F} \mu_B) (y_j) y_j) / (\sum_{(j=1)}^{F} \mu_B) (y_j))$  (8) Where, F is the number of elements y\_jin Y. The domain is continuous. In order to compute the canter of gravity, Y must be converted to discrete.

#### Fuzzy Analytical Hierarchy Process (Fuzzy-AHP)

Classical AHP method is identical to human judgment and a good solution for multi-criteria decision-making process. Independent judgments are converted into ratio scale weights using the AHP approach for successful paired comparison and ranking of decision criteria. The hierarchical structure of the problem, pairwise comparisons, uncertain judgments, an eigenvector method for determining weights, and consistency There are many different kinds of fuzzy numbers. Chang introduced the triangular fuzzy membership function for the pairwise comparison judgment matrix in (Chang, 1996). The researchers selected triangular fuzzy numbers in this study because they are more accessible and easier to use. TFNs are represented by [l m u] (as shown in Figs. 2 and 3) and the membership function  $\mu$ M is defined as follows. A Triangular Fuzzy Number is a special case of a fuzzy number.



**Figure 3:** Intersection between TFNs (Ahmed & Kilic 2015)

requirements are the essential bestowals of AHP. But the AHP technique is insufficient for considering cognitive aspects of human experiences. The Fuzzy-AHP technique is a participation and data-oriented analytic system in the MCDM approach, and it is a development of RW Saaty's theory (Saaty, 1987), that overcomes the AHP approach's ambiguity/uncertainty. In (Kilincci & Onal, 2011), the authors concluded that the Fuzzy-AHP technique deals with more uncertain opinions, both in linguistic terms and on a relative scale, and that it takes into account a set of values (TFNs) to cover the ambiguity where the prioritization of criteria will be more assured.

According to Saaty T. L.'s paper (Saaty, 2008), the Fuzzy-AHP geometric mean method using triangular fuzzy numbers and the input of experts produces better results. To improve decision making, a hierarchy containing the problem's main goal or objective, criteria, sub-criteria, and alternate levels must be constructed. The authors (Sharma & Yu 2014) decided that all components would be compared in pairs to determine their relative relevance at both this level and the level above. The system computes eigenvectors until the composite final vector is produced. The Fuzzy AHP methodology is based on Chang's Extent Analysis method (Chang, 1996)., each object xi set is designed as  $X = (x_1, ..., x_i, ..., x_n)$ , is taken and extent analysis is performed for each goal, gi where  $G = (g1, ..., g_i, ..., g_m)$ , similar to m criteria in traditional AHP.

In this research, only the goal, criteria, and outcomes of hierarchy are considered.

### Fuzzy Conversion Weight Scaling

Fuzzy-AHP is a more reliable methodology for dealing with uncertainty for decision makers by covering a wide range of values. Fuzzy fundamental scaling refers to the



link in Table 1 between a linguistic term, a crisp numeric value, and TFNs. With the help of Table 1 (Lane & Dirk, 2016), this method is carried out by carrying out

a comparison in pairs by assigning a full number to the criterion that is superior and a reciprocal assessment for the criterion of least importance.

Table 1:	Fuzzy	Convers	sion	Scale
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Linguistic variable	Crisp numeric	Triangular	Reciprocal Triangular
	value	fuzzy number	fuzzy number
Equally important	1	(1, 1, 1)	(1/1, 1/1, 1/1)
Judgment value between equally and moderately	2	(1, 2, 3)	(1/3, 1/2, 1/1)
Moderately more important	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Judgment value between moderately and strongly	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strongly more important	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Judgment value between strongly and very strongly	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strongly more important	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Judgment value between very strongly and extremely	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely more important	9	(9, 9, 9)	(1/9, 1/9, 1/9)

TFN may mathematically express the fuzzy judgment matrix  $\tilde{A}(a_{ij})$  by pairwise comparison. For the same criterion, various experts may present divergent views. The several provided judgments are combined into one fuzzy figure for each criterion using the Fuzzy-AHP geometric mean method. The user can use the following formula as shown in Eq. (9) to determine the geometric mean:

Geometric mean =  $\{(x_1) (x_2) (x_3) \dots (x_n)\}^{1/n}$  (9) Where, x = individual paired weight value of individual expert

n =Sample size (number of judgment)

Assume a triangular fuzzy number  $A = a_{ij}$  is written as  $[l_{ij}, m_{ij}, u_{ij}]$ , i and j = 1, 2, -, -, -, n, where  $l_{ij}, m_{ij}, u_{ij}$  are the lower bound, mean bound and upper bound of the triangular fuzzy set. In addition, assume that  $l_{ij} < m_{ij} < u_{ij}$ , when  $i \neq j$ .

 $a_{ij} = [l_{ij}, m_{ij}, u_{ij}]$  $a_{ij}^{-1} = [1/u_{ij}, 1/m_{ij}, 1/l_{ij}]$ 

If i = j, then  $a_{ij} = a_{ii} = (1,1,1)$ . As a result, the judgment matrix produces an accurate priority vector  $w = (w_1, w_2, \dots, \dots, \dots, w_n)$  that must meet the inequalities. Chang *et al.* (1996) provided the following formula to calculate the synthetic value by using the Eq. (10):

$$a_{ii}^{t} = [a_{ii}^{t}, a_{ii}^{t}, a_{ii}^{t}], i, j = 1, 2, ..., n_{k}; t = 1, 2$$
 (10)

T' is a TFN given by the *tth* expert, by the formula *kth*:  
$$M_{ii}^{k} = 1/\tau \bigotimes (a_{ii}^{-1} + a_{ii}^{-2} + \dots + a_{ii}^{-\tau})$$
(11)

The following formula as shown in Eq. (12) can be used to get the value of fuzzy synthetic extent with regard to the ith item using the fuzzy comparison matrix theory:

 $S_j^k = \sum_{j=1}^n M_{ij}^k \bigotimes \sum_{i=1}^{nk} \sum_{j=1}^{nk} M_{ij}^{k}^{ij}^{-1}$ , i, j = 1, 2, --, (12)Now, compute the degree of possibility [13] between two fuzzy synthetic extents is defined as

$$S_1 = (l_1, m_1, u_1) \ge S_2 = (l_2, m_2, u_2)$$

where  $S_1$  and  $S_2$  are calculated based on Eq. (13)

Once synthetic value is determined, the degree of possibility on one fuzzy number/synthetic value obtained to be greater than other is determined by the application of Extent Fuzzy-AHP approach shown in Eq. (13),

which is equivalently expressed as in Eqs. (14) and (15) as follows:

$$V(S_{1} \ge S_{2}) = \sup_{x \ge y} [\min(\mu_{S1}(x), \mu_{S2}(y))$$
(13)

When a pair (x, y) exists such that  $x \ge y$  and  $\mu_{S1}(x) = \mu_{S2}(x)$ , then we have  $V(S_1 \ge S_2) = 1$ . Since  $S_1$  and  $S_2$  are convex fuzzy numbers, we have that

$$V(S_1 \ge S_2) = 1 \text{ iff } m_1 \ge m_2$$

V(S<sub>1</sub>≥S<sub>2</sub>)=hgt(S<sub>1</sub>∩ S<sub>2</sub>)=  $\mu_{S1}$  (d) (14) where, 'd' is the ordinate of highest intersection point D (in Figure 3) between  $\mu_{S1}$  and  $\mu_{S2}$ .

Also, the above equation (as shown in Eq. 14) can be equivalently expressed for  $V(S_1 \ge S_2)$  by the Eq. (15):

$$V(S_1 \ge S_2) = hgt(S_1 \cap S_2) = \mu_{S_1}(d) = \begin{cases} 1, & \text{if } m_1 \ge m_2 \\ 0, & \text{if } l_2 \ge u_1 \\ \\ \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)}, & \text{otherwise} \end{cases}$$
(15)

To compare  $S_1$  and  $S_2$ , it is required both the values of  $V(S_1 \ge S_2)$  and  $V(S_2 \ge S_1)$ 

Let compute the vector W

d' (S<sub>1</sub>)=min V(S<sub>1</sub> $\ge$ S<sub>k</sub>), k= 1, 2, 3, ..... n; k $\neq$ i

Then the weight vector is given by the Eq. (16)

$$W' = (d'(S_1), d'(S_2), \dots, \dots, d'(S_n))^{\tau}$$
(16)

$$W = (d(S_1), d(S_2), ---, d(S_n)) T,$$
(17)

Where W is a non-fuzzy number calculated for each comparison matrix.

# **RESULTS AND DISCUSSION**

The study created a Fuzzy-AHP geometric mean approach for computing the criteria weight value for obstacles to Ready Made Garments in Bangladesh's Industry 4.0 application. The review study and expert perspectives reveal the main four challenges/obstacles confronting the RMG sector in implementing Industry 4.0. The single-value pair-wise comparison matrices (PCMs) for the four key RMG hurdles are generated utilizing industry executives' verbal judgments based on the pairwise comparisons and its relative relevance crisp numeric value. In the Fuzzy-AHP geometric mean method, these numbers are turned into triangular fuzzy numbers (TFNs).

Table 2 combines the 11 experts' judgments on each pair of comparisons into a single matrix, along with the

number of experts who made that set of observations. Then the geometric mean approach is used to combine all decision-makers' viewpoints to develop the fuzzy positive reciprocal matrices. All the 11 experts' judgments are illustrated in single value pairwise comparison matrixes as given below in Table 2.

Relative scale Comparing Criteria	Extremely Strong 9	Very Very Strong 8	Very Strong 7	Strong Plus 6	Strong 5	Moderate plus 4	Moderate 3	Weak Advan- tage 2	Equal 1
Obstacle B1	0	0	0	0	0	0	9	2	0
Obstacle B1	0	0	0	0	0	0	0	5	6
Obstacle B1	0	0	0	0	1	6	4	0	0
Obstacle B2	0	0	0	0	0	0	0	11	0
Obstacle B3	0	0	0	0	0	0	1	9	1
Obstacle B3	0	0	0	0	0	2	7	2	0
Reciprocal Re. Scale	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1/1
The remaining	portion of t	he Table 2 (C	Continuatio	on) with ree	ciprocal rel	lative scale	is shown		
Weak Advantage 1/2	Moderate 1/3	Moderate plus 1/4	Strong 1/5	Strong Plus 1/6	Very Strong 1/7	Very Very Strong 1/8	Extremely Strong 1/9	With respect to	Total No. of Experts
0	0	0	0	0	0	0	0	B2	11
0	0	0	0	0	0	0	0	B3	11
0	0	0	0	0	0	0	0	B4	11
0	0	0	0	0	0	0	0	B4	11
0	0	0	0	0	0	0	0	B2	11
0	0	0	0	0	0	0	0	B4	11
2	3	4	5	6	7	8	9		

Table 2: Experts'	opinions on the	e basis of linguistic term	ns and its relative impor	rtance scale
		()	I	

Based on the four main criteria for obstacles and the experts' judgments, there are six paired comparisons created, such as Criteria B1 over Criteria B2, B1 over B3, B1 over B4, B2 over B4, B3 over B2, and B3 over B4. These measures are counted from left criteria with respect to right criteria, that is, right side criteria are comparing criteria in these judgments. When the same paired comparisons are considered in opposite directions, the measures are counted from the right criteria of the same Table 2 (right over left), and six new paired comparisons are obtained, with the values having to be the reciprocal of the previous six paired comparisons.

The given judgments of 11 experts for the comparison of "Criteria B1 with respect to Criteria B3" in Table 2 are explained in such a way that:

• Criteria B1 is equally important to Criteria B3 according to six experts, and its weight value/ratio scale is 1.

• Five experts agreed that a criterion B1 has a weak advantage over criteria B3, and its relative weight scale is 2. Similarly, other pairwise comparisons can be explained for 11 experts in a single-value matrix.

The arrangements in Table 2 are converted then into a Fuzzy Triangular Number value (l m u) with the help of the conversion scale in Table 1 for applying Fuzzy-AHP geometric mean method in another table, which is not shown here due to a long table in an Excel sheet. The pairwise fuzzy triangular matrix for 11 experts is then converted to a non-normalized fuzzy triangular 4×4 pairwise matrix as stated in Table 3 using the geometric mean approach with geometric mean Eq. (9), where "n" represents the number of industry specialists.

For four criteria for obstacles,  $4 \times 4$  matrix is created, and there are 16 elements in the matrix. Four diagonal elements' scale value is 1 because one criterion is compared

with the same criterion. The scale values of 6 pairwise comparisons are obtained from experts' judgments, and the rest of the 6 pairwise comparisons' weight values are accordingly reciprocal to those six pair-wise comparison values. For example, in Table 3, the fuzzy pair-wise comparison values of B1 w. r. t. B2 (1.76318, 2.78679, 3.79615) and B2 w. r. t. B1 (0.26342, 0.35884, 0.56716)

are calculated for each element individually from Fuzzy-AHP geometric mean method, but according to the judgment, these two sets of fuzzy values are reciprocal with each other. After calculation, it is observed that the fuzzy value B2 w. r. t. B1 is the reciprocal of B1 w. r. t. B2. So, undoubtedly, it can be said that the methodology of calculation is done accordingly.

Criteria for Obstacles	Obst	Obstacle B1		Obsta	Obstacle B2		Obstacle B3		Obstacle B4			
Obstacle B1	1	-		1.76318	2.78679	3.79615		1.37035	1.64768	2.65733	3.67653	4.68736
Obstacle B2	0.26342	0.35884	0.56716	1	1	1	0.35884	0.51325	0.93893	1	0	3
Obstacle B3	0.60691	0.72974		1.06504	1.94837	2.78679		<del></del>	-	1.89808	2.93644	3.95334
Obstacle B4	0.21334	0.272	0.37632	0.33333	0.5	1	0.25295	0.34055	0.52685	1	1	1
TFNs	1	m	1	m	u	u	1	m	u	1	m	u

Table 3: Fuzzy triangular pairwise matrix obtained by Fuzzy-AHP geometric mean method

The remainder of the mathematical techniques for determining the percentage weight values of obstacles at RMG in the Industry 4.0 application is given below in Table 4. The row-wise Fuzzy geometric mean values are calculated from Table 3 which are illustrated in Table 4 as matrix A1, and each element from the aforementioned fuzzy triangular matrix is assessed using Eq. (9), where 'n' represents the number of criteria. Matrix A2 is the column-wise sum of matrix A1, and the fuzzy synthetic weight of each criterion is calculated using fuzzy synthetic Eq. (12). In the defuzzification procedure, the Centre of the area of a fuzzy triangular matrix, which is the arithmetic mean of TFNs, is employed. As a result, the defuzzified weight  $W'_i(0.447771, 0.196267, 0.338769, 0.118684)$  is calculated using the average value of TFNs. Now, dividing each defuzzified weight vector by the sum, the non-fuzzy numeric weight vectors are normalized. The ranks of challenges and their normalized weights  $W'_i(0.406514, 0.178183, 0.307555, 0.107748)$  are derived in Table 4.

**Table 4:** Calculation of Fuzzy synthetic weightings, de-fuzzification, normalization through Fuzzy-AHP geometric mean method

Row wise Mean r <sup>~</sup> <sub>i</sub>	e Fuzzy Ge = Matrix A	eometric A1	Fuzzy Weight of each Cri- teria $W_i^{\sim} = (A1^*(1/A2))$			De-fuzzified Crisp Numeric Weights Wi	Normalized Weight for Criteria	Ranking
1.47125	1.93572	2.32695	0.24767	0.42007	0.67557	0.447771	0.406514	1
0.55448	0.77905	1.12425	0.09334	0.16906	0.3264	0.196267	0.178183	3
1.05245	1.42944	1.82187	0.17717	0.3102	0.52894	0.338769	0.307555	2
0.36622	0.4639	0.66728	0.06165	0.10067	0.19373	0.118684	0.107748	4
Column Wise Sum (A2) =		1	m	u	Sum =	Sum = 1		
3.4444	4.60811	5.94035				1.101490		

The traditional Fuzzy-AHP only provides a partial preorder on each fuzzy value of each criterion. The number generated by the arithmetic mean of the defuzzification operation is also positive because the acquired values of the fuzzy synthetic weight are always positive. Therefore, the Fuzzy-AHP geometric approach will never produce null weights. These Normalized weights which indicate the intensity of obstacles are used in further calculation, results and discussions.

Now, the paired triangular fuzzy matrix obtained through geometric mean computations, represented in Table 3, is used to calculate the fuzzy appropriateness/suitability indices, degree of possibility values, minimum degree of possibility (de-fuzzified), as well as normalized values of all criteria using the Fuzzy-AHP possibility extent approach, as shown in Tables 5 and 6.

Row wise TFM in T	We wise Summation of $^{3}M$ in Table 3 = Matrix A1 (A1*(1/A2))			Minimum Degree bility min $V(B \ge I)$	e of Possi- B <sub>i</sub> ),	Normalized Weight for Criteria		
6.42052	8.83367	11.1312	0.22703	0.41216	0.72222	$V(B_1 \ge B_2, B_3, B_4) =$	1	0.470236786
2.62226	3.87208	5.50609	0.09272	0.18066	0.35725	$V(B_2 \ge B_1, B_3, B_4) =$	0.3600022	0.169286277
4.57003	6.61455	8.74013	0.1616	0.30862	0.56708	$V(B_3 \ge B_1, B_2, B_4) =$	0.766586	0.36047697
1.79962	2.11254	2.90317	0.06363	0.09857	0.18837	$V(B_4 \ge B_1, B_2, B_3) =$	0	0
15.41243	21.43285	28.28058	1	m	u	Column Sum =	2.1265882	Sum = 1
=Sum = N	=Sum = Matrix A2							

Table 5: Calculations of Normalized Weightings of Criteria using Fuzzy-AHP Possibility Extent method

Following Eq. (15), the degree of possibility calculation is completed and presented as shown in Table 6.

In Table 6, there are 12 degrees of possibilities are obtained by using possibility extent Eq. (15) for four criteria with four situations. In the last situation of Table 6, for the case of V ( $B_4 \ge B_1$ ), the obtained possibility value is zero. Intersection procedure is used while analysing comparison findings in Chang's fuzzy AHP extent approach. When the fuzzy intersection yields a

value of zero, the related criterion is considered to be irrelevant. According to fuzzy pair-wise comparisons, a criterion has no importance and has a weight of zero if it is comparatively less essential than all of the others. Extent Fuzzy-AHP ignores the unimportant criterion that is less significant than the others, but traditional Fuzzy-AHP gives this criterion very little weight. It is critical to note that the null weight occurs when the values of the obtained fuzzy weights are scattered and

Table 6: Degree of possibility values for four criteria with four situations

V(B1≥ B2,B3,B4)	V(B2≥ B1,B3,B4)	V(B3≥ B1,B2,B4)	V(B4≥ B1,B2,B3)
V(B_1≥B_2)=1	$V (B2 \ge B1) = 0.3600022$	$V (B3 \ge B1) = 0.766586$	$V (B4 \ge B1) = 0.0$
$V (B1 \ge B3) = 1$	$V (B2 \ge B3) = 0.6045858$	$V (B3 \ge B2 = 1$	$V (B4 \ge B2) = 0.5381456$
$V(B1 \ge B4) = 1$	$V (B2 \ge B4) = 1$	$V (B3 \ge B4) = 1$	$V (B4 \ge B3) = 0.1130394$

without intersections, as illustrated in Table 5. For this reason, the possibility case V ( $B_4 \ge B_1$ ) in which there is no intersection between the fuzzy weights of criteria ( $B_4$ ,  $B_1$ ), where the fuzzy weights of the criteria are different. In this situation, the possibility condition  $l_1 \ge u_4$  according to Eq. (15), is satisfied which results the possibility value V ( $B_4 \ge B_1$ ) become zero and calculated weight value also zero. But other cases, there is intersection between the triangular fuzzy numbers, where possible weight values are obtained by satisfying the condition. The minimum degree of possibility values or de-fuzzified values are identified from Table 6 as (1, 0.3600022, 0.766586, 0.0). By normalizing the de-fuzzified values, normalized weight vector (0.470236786, 0.169286277, 0.36047697, 0.0) is obtained in Table 5.

The normalized weightings show that the obstacle

'Availability of Cheaper Labour' is the least important of all the criteria and has a weight value of zero in the Fuzzy-AHP extent technique. To tackle the multi-criteria decision problem in a fuzzy decision environment, two different approaches are provided. While possibility extent Fuzzy-AHP delivers a complete preorder on the set of the degree of possibility, traditional Fuzzy-AHP only provides a partial preorder on each fuzzy value of each criterion.

# Consistency Index (CI) and Consistency Ratio (CR) Calculation

The matrix shown in Table 7 is the pairwise single value matrix form, obtained from the center of area of the above fuzzy triangular non-normalized matrix, which is shown in Table 3.

Criteria Weight	0.4080568	0.1773383	0.3071133	0.10749154
Criteria	Obstacle B1	Obstacle B2	Obstacle B3	Obstacle B4
Obstacle B1	1	2.782043	1.339344	3.673740
Obstacle B2	0.396472	1	0.603672	2.000000
Obstacle B3	0.778884	1.933402	1	2.929284
Obstacle B4	0.287218	0.611111	0.373450	1
Column Sum	2.462574	6.326556	3.316465	9.603024

Table 7: Non-normalized pair-wise matrix (obtained from Fuzzy Triangular paired matrix)



The normalizing technique is completed by dividing each column value in Table 7 by the total of the individual columns, just like it is done with the traditional AHP method. As indicated in Table 8, the row-wise values of the normalized matrix are averaged to get the weights of the criteria.

Criteria	B1	B2	B3	B4	Criteria Weights
Obstacle B1	0.406079	0.439741	0.403847	0.382561	0.408057
Obstacle B2	0.160999	0.158064	0.182023	0.208268	0.177338
Obstacle B3	0.316289	0.305601	0.301526	0.305038	0.307113
Obstacle B4	0.116633	0.096595	0.112605	0.104134	0.107492
					Sum = 1

Table 8: Normalized pairwise matrix and criteria weights for verification of experts' judgments

The same pairwise comparison matrix from Table 7 (Arithmetic mean of FTNs), which is not normalized, is used to calculate the normalized matrix (Eigen Vector) by multiplying each value in the column by the Criteria

weight value (obtained in Table 8). Table 9 displays the obtained Eigen Vectors, their row-by-row weighted total, the matrix's highest Eigen value ( $\lambda_{max}$ ), Consistency Index (CI), and Consistency Ratio (CR) as a whole.

Table 9: Normalized pair wise comparison matrix (Eigen Vector) & CR

Criteria	B1	B2	B3	B4	Criteria Weight	Weighted Sum Value	(Weighted Sum/ Weight)
Obstacle B1	0.408057	0.493363	0.411330	0.394896	0.408057	1.70765	4.1848241
Obstacle B2	0.161783	0.177338	0.185396	0.214983	0.177338	0.7395	4.16999637
Obstacle B3	0.317829	0.342866	0.307113	0.314873	0.307113	1.28268	4.17657538
Obstacle B4	0.117201	0.108373	0.114691	0.107492	0.107492	0.44776	4.16551211
							$\lambda_{max} = 4.17422699$

The largest Eigen value ( $\lambda$ max) of matrix of order n = 4.17422699

Consistency Index (CI) =  $(\lambda_{max} - n)/(n-1) = 0.058075696$ Consistency Ratio (CR) = (Consistency Index)/(Random Index (RI)) = 0.064528551< 0.1

Number of criteria 'n' equal to 4 and the corresponding Random Index (RI) value is 0.90.

CR < 0.1 that is the weights are acceptable i. e. some small inconsistency is present in judgments.

Using the Eigen vector, the consistency ratio (CR) was determined to be 0.064528551, which is less than 0.1.

Therefore, it may be assumed that the matrix is generally consistent and that the research computation has been adequately synthesized for use in the Fuzzy-AHP study of decision-making. A MS Excel sheet is used to perform all of the calculations required for each stage of the Fuzzy-AHP geometric mean as well as Fuzzy-AHP extent possibility methodology, including the calculations for the consistency index (CI) and consistency ratio (CR). In Table 10 below, the middle bound value (m) of each criterion's fuzzy weight and the criteria's normalized weights of both approaches are displayed side by side.

Table 10: Normalized weights of criteria for obstacles,	, Fuzzy middle bound value and ranking of criteria
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	Extent Fuzzy-AHP Method		Fuzzy-AHP Geometric Mean		Ranking
Obstacles of RMG Sector for Industry 4.0 Application	Mid bound value (m) of Fuzzy Weights (W <sub>i</sub> )	Normalized Weights of Criteria for Obstacles	Middle bound value (m) of Fuzzy Weights (W <sub>i</sub> )	Normalized Weights of Criteria for Obstacles	
Lack of Top Management Com- mitment and Owners' Willingness, (Criteria B1)	0.41216	0.470236786	0.42007	0.406514	1
Lack of Technical Knowledge and Education (Criteria B2)	0.18066	0.169286277	0.16906	0.178183	3
Lack of Ability to Meet up Initial Investments, (Criteria B3)	0.30862	0.36047697	0.31020	0.307555	2
Availability of Cheaper Labour (Criteria B4)	0.09857	0.0	0.10067	0.107748	4

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Table 10 presents a summary for comparing with normalized weightings and for subsequent computations of the fuzzy mid-bound value.

Table 10 shows the difference between the normalized weight and the value specified as the middle bound m of the triangular fuzzy weight created for each criterion in each approach. Because the degree of differences (between criteria weights and middle bound value) is expressed lower in the Fuzzy-AHP geometric mean method, the findings for criteria weights are the most consistent using this approach [Rodrigues & Carpinetti, 2019).

The Fuzzy-AHP geometric mean approach offers benefits such as easy computational implementation, canter of area defuzzification operator, and greater understanding by decision makers without compromising consistency of results. In this research, the investigated weight values of criteria utilizing the Fuzzy-AHP geometric mean approach are considered for measuring the intensities of obstacles and discussions in order to avoid null weight criterion using Fuzzy-AHP possibility extent.

Figure 4 depicts a graphical depiction with ranking of the normalized crisp weights and fuzzy middle bound value (m) by Fuzzy-AHP geometric mean for RMG industries' barriers to Industry 4.0 implementation in Bangladesh. The mean bound value (m) of fuzzy synthetic weight for barrier B1 has the greatest lacking value of 0.42007, whereas the normalized weight value has the highest priority but the weighting is 0.406514.

Variations were also seen on the second, third, and fourth hurdles, where the normalized percentage values of criteria B2 and B4 were slightly higher. Because the Fuzzy-AHP approach always captures more vagueness in its appreciations, the normalized weight values of the existing prioritized obstacles can be included for analysis, discussion, and additional decision-making calculations. The fuzzy mean bound value (m), on the other hand, is nearly a crisp decision application weight that overlooks judgment uncertainty.



Figure 4: Criteria weights for Obstacles of RMG sector in Industry 4.0 application using Fuzzy-AHP geometric mean method

The key barriers are the most significant challenges in the RMG sector in Bangladesh, and their weight values as well as ranking are the hopeful outcome for decision makers and industry owners to enter the fourth industrial revolution. According to the findings through Fuzzy-AHP geometric mean method, "Lack of Top Management Commitment and Owners' Willingness" (Criteria B1) is the most relevant and significant issue (40.6%), in the context of Industry 4.0 implementation. However, the government of Bangladesh consistently signals silver linings to entrepreneurs and wealthy members of society in order to unveil Industry 4.0 technology. In order to adapt vocational trades and courses of study for younger learners with a foundation in mathematics to the needs of the digital world in future decades, the government of Bangladesh is working with ICT professionals and Industry 4.0-related university researchers.

Table 10 shows the second-most critical deficiency

(30.8%) is "Lack of Ability to Meet up Initial Investments (Criteria B3)," which is a significant impediment to the country's ability to launch Industry 4.0. It should be noted that six experts out of eleven have stated their realization that Criteria B1 and Criteria B3 are equally relevant. As a result, the investment in small and medium-sized business owners is a significant barrier. The government and senior management can encourage adequate investment and welcome international entrepreneurs to develop innovative technology.

Another significant impediment (17.8%) identified by the experts in this analysis is a lack of technical expertise and education (Criteria B2). People are concerned about their future careers and are attempting to up-skill or reskill themselves in response to new technologies and networks. Technical universities are carefully introducing Fourth Industrial Revolution courses and training in order to adapt to new technology and bridge the



technical gap between education and industry. To meet the need and scarcity of the fourth industrial revolution, large corporations are establishing technical workshops, training courses, conferences, and long-term training.

The fourth and serious barrier to Industry 4.0 adoption in the RMG sector is the availability of cheaper labour (Criteria B4), with a weighted proportion of 10.8%. Traditional physical labour is gradually being replaced in RMG factories due to the introduction of computer, semi-automated and automated machines and other digital technology. In this arrangement, overall employees, particularly technical trained workforces, are paid well. The government is concerned about industry workers' pay, safety, health, and other welfare issues. However, labour in Bangladesh remains inexpensive as compared to Myanmar, Cambodia, and Vietnam.

Analysts in Bangladesh said that the removal of significant barriers will help to mitigate some of the other local and dependent risks in the RMG sector.

# CONCLUSIONS

The challenges for the business environment of the RMG sector in Bangladesh were evaluated in this study based on the existing scenario of Industry 4.0 applications and the preferences of experts in this industry. The main four variables of obstacles were considered in the Fuzzy-AHP methodology to develop the model that produces more precise priorities from all levels of judgment for criteria to achieve the goal of this research. This study determined how these issues affect Ready-Made Garments' transition to Industry 4.0. The study also attempted to determine the interrelationship among environmental barriers and how to eliminate these constraints in order to improve the implementation of new technology.

Obstacles to Industry 4.0 for the RMG sector play a negative influence on the development of new technology adoption, affecting other associated local obstacles. So, in order to adapt to today's technologies and benefit from Industry 4.0 in the RMG sector, experts have made the following recommendations: Top management commitment and owners' willingness as the most lacking criteria, followed by Ability to meetup initial investments, and so on.

Local environmental barriers discovered by review studies will be decreased by the perception of major barriers, which would be a matter of senior management commitment and owners' willingness. The results of the criteria weight values and their ranking generated by employing experts' offered opinions in the Fuzzy-AHP geometric mean method are acceptable because the consistency ratio is satisfied and the method avoids the null weights of criteria. The model's execution would have a favorable impact on future decision-making processes in the ready-made garment sector by focusing on the most crucial hurdles in the current context.

This research is especially useful for enterprises and decision-makers interested in analyzing various challenges in the business environment. The study also produced a

mathematical model that discloses a practice method for industry owners and researchers. After addressing the primary problems for the business environment and prior to implementing Industry 4.0 elements, companies and researchers should evaluate another technical difficulty, the "maturity level of required technologies or Degree of Industry 4.0," to assess their contemporary technical position. This is yet another analytical research approach to the primary characteristics of Industry 4.0. Companies cannot tackle these significant difficulties on their own. In the process of implementing Industry 4.0, industrial groups, trade unions, and employers' federations must work together to establish a good business environment that supports new technology.

# REFERENCES

- Ahmed F. & Kilic K. (2015), Modification to Fuzzy Extent Analysis Method and its Performance Analysis. *6th IEMS Conference, Sevile, Spain,* 435-438, https://doi. org/10.1109/IESM.2015.7380193.
- Ângelo, A., Barata, J., da Cunha, P. R., & Almeida, V., (2017). Digital transformation in the pharmaceutical compounds supply chain: Design of a service ecosystem with e-labelling. *European, Mediterranean,* and Middle Eastern conference on information systems. 299, 307-323, Available: https://doi.org/10.1007/978-3-319-65930-5\_26
- Bhuiyan Dr. A. B., Ali, M. J. Zulkifli N. & Muthu M. (2020). Industry 4.0: Challenges, Opportunities, And Strategic Solutions for Bangladesh. *International Journal of Business and Management Future*, 4(2). https:// doi.org/10.46281/ijbmf.v4i2.83
- Chang D. Y., (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research, vol. 95, Issue. 95*, pp. 649–655, Available: https://doi.org/10.1016/0377-2217(95)00300-2 (Journal article)
- Dalenogare, L. S. Benitez, G. B., Ayala, N. F. & Frank, A. G., (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *Int. J. Prod. Econ.* 204, 383-394.
- Fettig K., Gačić T., Köskal A., Kühn A., & Stuber F., (2018). Impact of industry 4.0 on organizational structures. The 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), Stuttgart, Germany, 1-8, https://doi.org/10.1109/ ICE.2018.8436284.2018, Available: https://ieeexplore. ieee.org/document/8436284
- Geissbauer, Dr. R. (PwC), Schrauf, S. (PwC), Koch V.&Kuge S., (2014). Industry 4.0 – Opportunities and Challenges of the Industrial Internet. PricewaterhouseCoopers, AktiengesellschaftWirtschaftsprufungsgesellschaft, Available: http://www.pwc.de/industry4.0
- Hasan M. M. & Mahmud A. (2017). Risks Management of Ready-Made Garments Industry in Bangladesh. *International Research Journal of Business Studies*, 10(1), 1–13, Available: https://doi.org/10.21632/irjbs
- Hossain M. S., & Khan M. A., (2016). Financial

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sustainability of microfinance institutions (MFIs) of Bangladesh. *Developing Country Studies*, 6(6), 69-78, Available: https://core.ac.uk/download/pdf/234682971.pdf

- Humphrey C. E., (2021). Privatization in Bangladesh: economic transition in a poor country. Book, 1st edition, ISBN 9780367299767, Published May 31 2021, by Routledge, 276 Pages, Available: https://www. routledge.com
- Islam, M. A., et al., (2018). Fourth Industrial Revolution in Developing Countries: A Case on Bangladesh. Journal of Management Information and Decision Sciences, (JMIDS), 21(1), Available: https://www.researchgate. net/publication/327954073
- Jabbour, C. J. C., Jabbour, A. B. L. de S., Joseph, S. & Filho, M. G., (2017). Unlocking the circular economy through new business models based on large-scale data: an integrative framework and research agenda. *Technological Forecasting and Social Change*, 144, 546-552. https://doi.org/10.1016/j.techfore.2017.09.010
- Kilincci O. & Onal S. A., (2011). Fuzzy AHP approach for supplier selection in a washing machine company. *Expert Systems with Applications, An International Journal,* 38(8), 9656-9664. https://doi.org/10.1016/j.eswa, 2011.01.159
- Lane T. & Dirk S., (2016). Software-Defined Cloud Manufacturing for Industry 4.0. Procedia CIRP, 52, 12–17, https://doi.org/10.1016/j.procir.2016.07.041
- Moktadir, M. A., Ali, S. M., Rajesh, R., and Paul, S. K., (2018). Modelling the interrelationships among

barriers to sustainable supply chain management in leather industry. *Journal of Cleaner Production, 181*(20), 631-651, Available: https://doi.org/10.1016/j. jclepro.2018.01.245

- Orzes G., Poklemba R. & Towner W. T., (2020). Implementing Industry 4.0 in SMEs: A Focus Group Study on Organizational Requirements. Industry 4.0 for SMEs, 251-277, Cite as, First Online: 2020. https://link. springer.com/chapter/10.1007/978-3-030-25425-4\_9
- Rodrigues F. L.J. & Carpinetti L. C. R., (2019.). Dealing with the problem of null weights and scores in Fuzzy Analytic Hierarchy Process. Springer-Verlag GmbH Germany, part of Springer Nature, Soft Computing, https://doi.org/10.1007/s00500-019-04464-8(012345)
- Saaty RW., (1987). The analytic hierarchy process-what and how it is used. *Mathematical Modelling*, 9(3), 161– 176, https://doi.org/10.1016/0270-0255(87)90473-8.
- Saaty T. L., (2008). Decision Making for Leaders. RWS Publications: Pittsburgh, PA, USA.
- Saaty TL., (2008). Decision making with the analytic hierarchy process. *Int J Serv Sci.*, 1(1), 83–98. Available: https://www.rafikulislam.com/uploads/ resourses/197245512559a37aadea6d.pdf
- Sharma, M. J. & Yu S. J. (2014). Fuzzy analytic hierarchy process-based decision tree in identifying priority attributes for supply chain coordination. *International Journal of Logistics Systems and Management*, 17(1), 46-65.