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Evaluation of Factors Affecting the Productivity of RMG in Bangladesh: A Fuzzy AHP Approach

P. K. Halder[2*], C. L. Karmaker[1], B. Kundu[1], T. Daniel[1]

[1] Department of Industrial and Production Engineering, Jessore University of Science and Technology, Jessore-7408, Bangladesh.

[2] Department of Chemical and Environmental Engineering, School of Engineering, RMIT University, Melbourne, Victoria 3001, Australia.

A B S T R A C T

Recently, the competitiveness and awareness of productivity have increased rapidly among different industries. Hence, the performance evaluation of the criteria affecting the productivity is needed to improve productivity and strengthen the management of the organization. In Bangladesh, Ready Made Garments (RMGs) is one of the most probable and profitable sectors which is considered as the main economic strength of the country. In this study, a two-phased research method has been projected to find out some governing factors affecting industry's output. In the first phase, six criteria associated with the productivity have been identified based on literature, inputs from experts, opinions from the officials and managers of six garments industries in Bangladesh. In the second phase, among different MCDM tools, Fuzzy Analytic Hierarchy Process (FAHP) has been used for evaluating criteria weights and ranking the criteria. Among several criteria**,** line-balancing criterion has been found as the most important factor to improve the RMG's productivity.

Keywords: Productivity, FAHP, RMG, Bangladesh.

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1. Introduction

In every production related company, productivity improvement is a prime objective. Productivity is the typical dimension of the production efficiency. All over the world, businesses are now facing ferocious competition because of liberalization of trade and globalization. External competition has spread across almost all industries both in production and service areas. Suitable production management system is required for the significant improvements in managerial and other work force levels [1]. The labor quality is considered as a significant contributing factor for explaining Taiwanese industrial sector's changes in productivity [2]. On the other hand, size and specific

* Corresponding author

E-mail address: pobitra.halder@gmail.com

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interest rate on long-term loans of the firm are also significantly affecting its growth [3]. Besides, the growth factors in China's manufacturing industries are affected by technical improvements [4]. Productivity in Ready Made Garments (RMGs) industry can also be increased through conducting motion study and correcting faulty motions, using best possible layout, reducing line setting time, improving line balancing, improving policy and legislation, setting individual operator target, eliminating loss time and off-standard time, installing better equipment, improving skill and training of workers, operator motivation, etc. The main attitudinal factors, such as lack of absenteeism, job satisfaction and organizational obligation affect job performance and productivity [5]. These factors change over the time and location, and interrelate to each other, which make analysis and measurement more complex. However, it is very important to identify the key factors responsible for company's productivity so that the most suitable performance measures could be taken [6]. Multi-Criteria Decision Making (MCDM) refers to the screening, prioritizing and ranking or selecting the best alternative from all of the feasibility alternatives while these alternatives are evaluated according to a number of criteria or attributes [7, 8]. Among the multi-criteria decision making processes, most commonly used methods are Analytical Hierarchy Process (AHP) and Fuzzy Analytical Hierarchy Process (FAHP), TOPSIS, etc. [9–14].

A recent trend is toward applying fuzzy sets, taking into account the uncertainties [14] and also integrating it with AHP [13]. As a consequence, Ordoobadi [15] recommended Fuzzy logic whereas Labib [16] preferred AHP for selecting a supplier. One of the first applications of fuzzy AHP method was to use the triangular membership functions for the pairwise comparisons [17]. Afterwards, Buckley [18] determined the fuzzy priorities of comparison ratios having triangular membership functions. Besides, Chang [19] employed a new method related to the usage of triangular numbers in pairwise comparisons. Kutlu and Ekmekçioğlu [20] introduced new approach based on fuzzy TOPSIS and fuzzy AHP to rank the failure modes. Chang et al. [21] proposed fuzzy Decision Making Trial And Evaluation Laboratory (DEMATEL) method to identify effective factors in chain management supplier selection. Often, the evaluation process requires a numeric scale for the decision maker to express his/her preferences. Several authors [22–25] found the main problem in this elicitation as the perceptions associated with the subjectivity and uncertainty which is lost by forcing the decision maker into a numeric scale. Therefore, Ordoobadi [15] proposed to use Fuzzy logic in order to express preferences in linguistic terms. The FAHP method can be applied in numerous sectors such as renewable energy, supply chain management**,** banking sector, etc. to find the best option from the alternatives [26–32]. The main objective of this paper as mentioned above is to identify the criteria that are much more effective in the productivity of RMG sector. In the assessment procedure, MCDM method (FAHP) has been applied to calculate the weights of the criteria and to determine crucial criteria or factor that has strong effect on productivity improvement of garment sector in Bangladesh.

2. Research Methodology

To complete the study, six Ready Made Garments (RMGs) industries in Bangladesh have been visited. Numbers of criteria have been found that affect productivity in garments. The study has been done by taking into consideration the most frequently used six criteria collected from reviewing literature and opinions from experts in relevant fields. A set of questionnaires were completed; expert's views were integrated by using group decision process. Therefore, a group decision has been conducted to improve the pairwise comparison in the evaluation process. To measure the weights of criteria by FAHP method, pairwise comparison matrix, an input of the method has been developed. The evaluation process consists of three main steps as follows:

First step. Identification of the evaluation criteria considered as the most important performance parameters for the RMG industry.
Second step. Construction of the hierarchy of the evaluation criteria and calculation of the weights of these criteria using FAHP method.
Third step. Implementation of the FAHP method to attain the final ranking results.

3. Details of FAHP

The most decisions made in the real world take place in an environment in which the goals constraint because their complexity are not known precisely. In addition, a decision maker's requirements on evaluating criteria and alternatives always contain vagueness and diversity of meaning. Furthermore, it is also recognized that human assessment on qualitative attributes is always idiosyncratic and thus imprecise. In order to model this kind of uncertainty in human preference fuzzy AHP, an extension of AHP integrated fuzzy set provides a more accurate result.

3.1. Fuzzy Set Theory

Fuzzy sets theory is a multi-valued theory where intermediate values are defined in a range, such as high, moderate or low, instead of yes or no, true or false as in the classical crisp logic theory. The fuzzy sets symbolize the grade of any element x of space X that has partial membership in A (where A is a fuzzy set). The degree to which an element belongs to the set μ_A is defined by the value between 0 and 1 [33]. A Triangle Fuzzy Number (TFN) is described as a special class of fuzzy numbers whose membership defined by three real numbers and expressed as (l, m, u) [34], where m is the most possible value of a fuzzy number A; l and u are the lower and upper bound, respectively. Note that, $\mu\big(A(x)\big) = 0$, if $x < 1$ and $x > u$ will have no membership in the fuzzy number $A = (l, m, u)$ [7].

Let, A and B are two triangular fuzzy numbers, where $A = (l_a, m_a, u_a)$ and $B = (l_b, m_b, u_b)$.

Addition: $A + B = (l_a + l_b,\ m_a + m_b,\ u_a + u_b)$.

Subtraction: $A - B = (l_a - l_b,\ m_a - m_b,\ u_a - u_b)$.

Multiplication: $A.B = (l_a.l_b,\ m_a.m_b,\ u_a.u_b)$.

$$Inverse\text{: } A^{-1} = \left(\frac{1}{u_a}, \frac{1}{m_a}, \frac{1}{l_a}\right).$$

4. Model Estimation

The aim of this study is to evaluate the effectiveness of the criteria influencing the productivity in RMG by using fuzzy AHP method. A comparison of six criteria of the six famous garments industry in Bangladesh is used to validate the model by testing the propositions that are developed. The industry intends to decide which criteria emphasize more on their productivity. First, the evaluation criteria for selecting decision are identified through surveying six industries as well as reviewing previous literature. The study is done depending on different reiterate criteria and the model is developed by six criteria, such as C1: Skill and Training of the worker, C2: Less Absenteeism, C3: Policy and Legislation, C4: Better Equipment, C5: Line Balancing, and C6: Work Study. At the highest level of the hierarchy, the goal of the problem is labeled as productivity. In the second level, six aspects or main criteria are situated which are to be ranked.

5. Initial Data for FAHP Evaluation

FAHP approach is used to capture subjective preference of the decision makers and handle the uncertainty. FAHP uses a scale about relative importance to determine the relative weights [34]. Based on the linguistic scales for preferences, necessary data are collected and presented in Table 1.

Table 1. Data for FAHP calculation.

Factors	Skill & Training	Less Absenteeism	Policy & Legislation	Better Equipment	Line Balancing	Work Study
Skill & Training	(1,1,1)	(1/2,1,3/2)	(3/2,2,5/2)	(1,1,1)	(1,3/2,2)	(2,5/2,3)
Less Absenteeism	(2/3,1,2)	(1,1,1)	(1,3/2,2)	(1/2,2/3,1)	(2/3,1,2)	(1/2,2/3,1)
Policy & Legislation	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,1,1)	(2/3,1,2)	(1/2,2/3,1)	(2/3,1,2)
Better Equipment	(1,1,1)	(1,3/2,2)	(1/2,1,3/2)	(1,1,1)	(1,3/2,2)	(2,5/2,3)
Line Balancing	(1/2,2/3,1)	(1/2,1,3/2)	(1,3/2,2)	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)
Work Study	(1/3,2/5,1/2)	(1,3/2,2)	(1/2,1,3/2)	(1/3,2/5,1/2)	(1/2,2/3,1)	(1,1,1)

6. Determination of Criteria Weights by FAHP

In FAHP, the linguistic variables are used for the pairwise comparisons of both criteria and the alternatives. Although there are various techniques, which are integrated in FAHP, considering the objectives of this study, Buckley's methods [18] are implemented to determine the relative significance for both the criteria and the alternatives. The steps of the procedure are as follows:

Step 1: *Aggregated fuzzy pairwise matrix*

According to the corresponding triangular fuzzy numbers of the linguistic terms, if the criterion 1 (C_1) is declared less important than criterion 2 (C_2), then the fuzzy triangular scale is expressed as (2, 3, 4). On the other hand, in the pairwise contribution matrices of the criteria, comparison of C_2 to C_1 takes the fuzzy triangular scale as (1/4, 1/3, 1/2). The pairwise contribution matric is shown in Eq. (1), where $\widetilde{d_{ij}^{k}}$ indicates the k_{th} decision maker's preference of i_{th} criterion over j_{th} criterion via fuzzy triangular numbers.

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{d_{11}^{k}} & \widetilde{d_{11}^{k}} & \cdots & \widetilde{d_{1n}^{k}} \\ \widetilde{d_{21}^{k}} & \widetilde{d_{22}^{k}} & \cdots & \widetilde{d_{2n}^{k}} \\ \cdots & \cdots & \cdots & \cdots \\ \widetilde{d_{n1}^{k}} & \widetilde{d_{n2}^{k}} & \cdots & \widetilde{d_{nn}^{k}} \end{bmatrix}. \tag{1}$$

In this case study, the pairwise evaluation of both criteria and the alternatives are accomplished through the linguistic variables, which are exemplified by triangular numbers. The fuzzy pairwise comparison matrices are constructed to estimate the aggregated fuzzy pairwise comparison matrix as shown in Table 2.

Table 2. Aggregated fuzzy pairwise comparison matrix.

Factors	C_1	C_2	C_3	C_4	C_5	C_6
C_1	(1,1,1)	(0.58,1.0, 1.58)	(1.42,1.92,2.42)	(1,1,1)	(0.88,1.8, 1.5)	(1,1.5,2)
C_2	(0.63,0.93, 1.7)	(1,1,1)	(0.92,1.42,1.92)	(0.63,0.94,1.83)	(0.58,0.3, 1.5)	(0.83,1.02, 1.25)
C_3	(0.41,0.52, 0.7)	(0.52,0.7, 1.08)	(1,1,1)	(0.48,0.64,1.02)	(0.36,0.5, 0.59)	(0.63,0.94, 1.83)
C_4	(1,1,1)	(0.54,1.06, 1.58)	(0.98,1.56,2.08)	(1,1,1)	(0.75,1.08, 1.75)	(1.16,1.66, 2.16)
C_5	(0.66,0.92, 1.2)	(0.66,1.2, 1.72)	(1.69,2.22,0.77)	(0.57,0.92,1.33)	(1,1,1)	(1,1.5,2)
C_6	(0.5,0.66, 1)	(0.8,0.98, 1.2)	(0.54,1.06,1.59)	(0.46,0.6,0.86)	(0.5,0.66, 1)	(1,1,1)

Step 2: *Computation of geometric mean*

The geometric mean of fuzzy comparison values of each criterion are calculated using the Eq. (2), where $\widetilde{r_i}$ still represents triangular values.

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)^{1/n}. \tag{2}$$

The sample calculation of geometric mean of fuzzy comparison values of "C_1" criterion is presented as follows. Other geometric values of each criterion are calculated in similar way and illustrated in Table 3.

$$\left[(1 \times 0.58 \times 1.42 \times 1 \times 0.88 \times 1)^{1/6}; (1 \times 1.08 \times 1.92 \times 1 \times 1.08 \times 1.5)^{1/6}; (1 \times 1.58 \times 2.42 \times 1 \times 1.5 \times 2)^{1/6}\right] = [0.95, 1.22, 1.5].$$

Table 3. Calculation of geometric mean.

Criteria	Geometric Mean (GM)		
C_1	0.95	1.22	1.5
C_2	0.75	1	1.5
C_3	0.53	0.68	0.97
C_4	0.88	1.2	1.52
C_5	0.87	1.22	1.56
C_6	0.6	0.8	1.08
$\sum r_i$	4.58	6.12	8.13
Reverse of GM	0.2183	0.1633	0.1230
Increasing Order	0.1230	0.1633	0.2183

Step 3: *Computation of relative fuzzy weights*

The fuzzy weight of each criterion is calculated according to the Eq. (3). This includes the replacement of existing fuzzy triangular number with (-1) power of summation vector of each $\widetilde{r}_1$.

$$\widetilde{w_i} = \widetilde{r_i} \oplus (\widetilde{r_i} \oplus \widetilde{r_2} \oplus \dots \dots \dots \oplus \widetilde{r_n})^{-1}. \quad (3)$$

The fuzzy weight of criterion 'C_1' is obtained through three calculation Steps. The first Step is to find the summation of geometric mean of each $\widetilde{r_i}$ while the second Step is to make the inverse of summation and to replace the fuzzy triangular number to make it in an increasing order. Finally, the third Step is to find the fuzzy weight of criterion 'C_1' ($\widetilde{w_1}$), multiply each $\widetilde{r_1}$ with this reverse vector. Hence, the fuzzy weight of criteria C_1 is obtained as follows. The fuzzy weight of other criteria are calculated in similar procedure and shown in Table 4.

$$\widetilde{w_i} = [(0.95 \times 0.123), (1.22 \times 0.1633), (1.5 \times 0.2183)] = [0.1168, 0.1993, 0.3275].$$

Table 4. Relative fuzzy weight of each criterion.

Criteria	Fuzzy weight of criterion ($\widetilde{w_i}$)		
Skill & Training	0.1168	0.1993	0.3275
Less Absenteeism	0.0922	0.1633	0.3275
Policy & Legislation	0.0651	0.1111	0.2117
Better Equipment	0.1082	0.1960	0.3318
Line Balancing	0.1070	0.1993	0.3406
Work Study	0.0738	0.1307	0.2358

Step 4: *Determination of non-fuzzy weight*

The fuzzy triangular numbers $\widetilde{w_i}$ are defuzzified based on the Centre of area method using the Eq. (4).

$$M_1 = \frac{lw_i + mw_i + uw_i}{3}. \tag{4}$$

To compute the normalized weight, the relative non-fuzzy weight of each criterion is calculated by taking the average of fuzzy numbers for each criterion. The average weight of criteria Skill and Training (C_1) is calculated as follows. The average value of other criteria are estimated in similar fashion and listed in Table 5.

$$M_1 = \frac{0.1168 + 0.1993 + 0.3275}{3} = 0.2145.$$

Table 5. Relative non-fuzzy weight of each criterion.

Criteria	Non-fuzzy weights
Skill & Training	0.2145
Less Absenteeism	0.1943
Policy & Legislation	0.1293
Better Equipment	0.2120
Line Balancing	0.2156
Work Study	0.1467
Sum	1.1128

Step 5: *Computation normalized weight*

The non-fuzzy number M_i is normalized by following Eq. (5). The final score of each alternative is calculated by multiplying the weight of each alternative with related criteria.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}. \tag{5}$$

Using these non-fuzzy weights, the normalized weights of each criterion are calculated through dividing weights of criteria by total summation of weights. For skill and training (C_1), normalized relative weights, $N_1 = \frac{0.2145}{1.1128} = 0.1928$. The weight of other criteria are computed through a similar way and displayed in Table 6. Different criteria emphasize different aspects of productivity. The intensity of the criteria can be ranked based on the normalized weights.

Table 6. Normalized weight of each criterion by FAHP.

Criteria	Non-fuzzy weights	Normalized weights	Ranking
Skill and Training	0.2145	0.1928	2
Less Absenteeism	0.1943	0.1746	4
Policy & Legislation	0.1293	0.1162	6
Better Equipment	0.2120	0.1905	3
Line Balancing	0.2156	0.1937	1
Work Study	0.1467	0.1318	5

The normalized weight of each criterion obtained from FAHP analysis is depicted in Figure 1**.** From Figure 1, it is obvious that the criterion "line balancing" has the highest weight followed by the criterion "skill and training." Therefore, managers should put more focus on this factor for improving productivity.

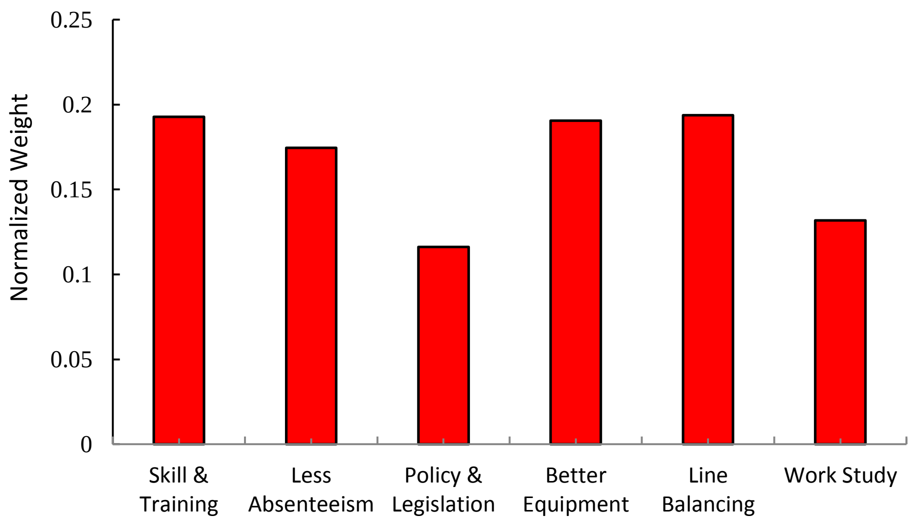

Figure 1. Normalized weight of each criterion.

6. Conclusions

This paper identified different effective factors in productivity, which was studied in Ready Made Garments (RMGs) sector in Bangladesh. In any production related organization, enhancement of productivity is of great importance. Through this study, it is possible to mark the major factors of productivity. Then, necessary steps can be taken for adjustment if necessary. However, the working environment that affects the workers' working capability has not been satisfactory yet. This factor directly influences the productivity. Here, multi-criteria decision- making tool such as FAHP was used for evaluating the best criterion among several criteria. The result of FAHP emphasized more on line balancing factor. Besides, regular training should be arranged for employee, and better equipment should be implemented. Although, this research carried out in RMG sector, this technique can be applied for any production-related organizations, such as beverage industry, steel manufacturing industry, furniture, etc. This study provided a better solution for Bangladeshi garments industries to increase their productivity at a significant level.

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