

# Supplier Selection and Evaluation by Fuzzy-AHP Extent Analysis: A Case Study RMG Sector of Bangladesh

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## ABSTRACT

The ready-made garments (RMG) is a rapid growing industry in Bangladesh and contributing significantly in the country's economy. Effective supplier selection policy has significant strategic importance in the performance of such fast moving consumer goods industry. The supplier selection process is essentially a multi-criterion decision making problem which, therefore, must be developed systematically. Many models have been developed and proposed to find optimum solutions of this complex decision-making problem. Fuzzy Analytic Hierarchy Process (Fuzzy-AHP), which is a derived extension of classical Analytical Hierarchy Process (AHP), is an excellent method for deciding among the complex structure at different levels. In this paper an extent analysis of Fuzzy-AHP has been applied to evaluate and select the best supplier agency providing most satisfaction. The evaluation criteria are developed particularly for an RMG manufacturer in Bangladesh context and used successfully in the proposed model. A detailed implementation process is presented in this paper and finally the best supplier agency has been proposed from the outcome of the model.

**Keywords--** AHP, RMG, Fuzzy, Selection Criteria, Supplier Selection

## I. INTRODUCTION

The success of any manufacturing industry significantly depends on effective supply chain management and it is a pivotal issue in the dynamically changing business environment such as ready-made garments industry. The performance of a supplier is attributed to many factors relating to need of the business. The selection of a supplier includes both qualitative and quantitative factors and the decision becomes complicated by lots of criteria and sub-criteria. A great number of research has been conducted in the past to select the most effective supplier for various businesses and industries. A significant query of all these works is to identify appropriate factor in the supplier selection process. For example, Dickson [1], one of the early researchers in the supplier selection process, identified over twenty supplier's attributes. Managers, however, often need to make tradeoffs on these attributes. Degraeve, Labro and Roodhooft [2] categorized various supplier evaluation methods into four major types:

rating/linear weighting, total cost approaches, mathematical programming and statistical approaches.

The most common method that has been practiced in the past is Linear weighing method in which assigns different weights to a number of criteria and the supplier with the best weighted total score is selected [3]. Mathematical programming models are proved more effective than the linear weighting method because they can optimize the explicitly stated objective [4]. A combination of two methodologies to select suppliers is also seen in recent literature. Ghodsypour and O'Brien [5] was one of the first works, and an integrated method that used AHP and linear programming was proposed to choose the best supplier and to assign the optimum order quantity among selected suppliers. Wang, Huang and Dismukes [6] developed an integrated AHP and preemptive goal programming based multi-criteria decision-making (MCDM) methodology to select the best set of multiple suppliers to satisfy capacity constraint.

Extent analysis of fuzzy AHP was performed by Chang [12] has been applied for supplier selection in a large white good manufacturing organization by Kahrman Cebeci, and Ulukan [14]. Particular application of these methods has been done such as, Yahya and Kingsman [7] on wooden furniture industry; Narasimhan, Talluri, and Mendez [8] on Telecommunication industry and Rahman and Ahsan in Apparel industry [13]. But not too many works have been done on apparel industry. This is a different track where consumers' tastes change dynamically. The same t-shirt rotates almost no times. So each time the manufacturer need to change the layout and requires new sourcing. So, supplier selection and evaluation and to keep the relationship intact is an important part to deliver the product on time.

In the flow of rest of this paper, Fuzzy concept and extent analysis of Fuzzy AHP are introduced in section II from past literatures and section III explains the step wise proposed method of Fuzzy AHP by applying it to the example case and prove its validity. Section IV and V concludes the article with useful insights and describes the ongoing work.

## II. LITERATURE REVIEW

**A. Fuzzy set and fuzzy number**

Zadeh introduced the fuzzy set theory to deal with the uncertainty due to imprecision and vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain [11]. Generally, a fuzzy set is defined by a membership function, which represents the grade of any element  $x$  of  $X$  that have the partial membership to  $M$ . The

degree to which an element belongs to a set is defined by the value between zero and one. If an element  $x$  really belongs to  $M$ ,  $\mu_M(x) = 1$  and clearly not,  $\mu_M(x) = 0$ .

A triangular fuzzy number is defined as  $(l, m, u)$ , where  $l \leq m \leq u$ . The parameters  $l, m$  and  $u$  respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event.  $(l, m, u)$  has the following triangular type membership function.

$$\mu_M(x) = \begin{cases} \frac{x-l}{m-l} & l \leq x \leq m \\ \frac{u-x}{u-m} & m \leq x \leq u \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

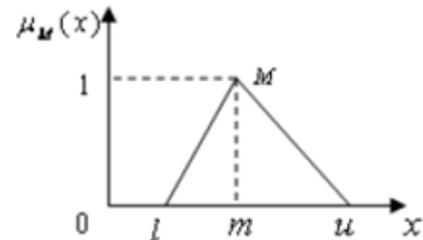


Figure 1: A triangular fuzzy number

A triangular fuzzy number can be shown in Figure. 1

**B. Chang's extent analysis method[9]**

Chang's extent analysis method is one of fuzzy AHP methods, the steps of which are as follows:

Let  $X = \{x_1, x_2, \dots, x_n\}$  be an object set, and  $G = \{g_1, g_2, \dots, g_n\}$  be a goal set. According to the method of Chang's

extent analysis, each object is taken and extent analysis for each goal,  $g_i$ , is performed respectively.

Therefore,  $m$  extent analysis values for each object can be obtained, with the following signs:

$$M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m, i = 1, 2, \dots, n$$

where all the  $M_{g_i}^j (j=1, 2, \dots, m)$  are triangular fuzzy numbers.

Steps of Chang's extent analysis can be given as follows:

a: The value of fuzzy synthetic extent with respect to the  $i$  th object is defined as:

$$S_i = \sum_{j=1}^m M_{g_i}^j \otimes \left[ \sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1} \quad (4)$$

Where

$$\sum_{j=1}^m M_{g_i}^j = (\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j) \quad (5)$$

$$\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j = (\sum_{i=1}^n l_i, \sum_{i=1}^n m_i, \sum_{i=1}^n u_i) \quad (6)$$

$$\left[ \sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1} = \left( \frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right) \quad (7)$$

b: The degree of possibility of  $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$  is defined as

$$V(M_2 \geq M_1) = \begin{cases} 1, & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases} \quad (8)$$

c: The degree of possibility for a convex fuzzy number to be greater than  $k$  convex fuzzy number  $M_i (i=1, 2, \dots, k)$  can be defined by

$$V(M \geq M_1, M_2, \dots, M_k) = \min V(M \geq M_i) \quad (9)$$

Assume,  $d'(A_i) = \min V(S_i \geq S_k)$  For  $k=1, 2, \dots, n; k \neq i$  (10)

Then the weight vector is given by

$$W' = ((d'(A_1), (d'(A_2), \dots, (d'(A_n)))^T \quad (11)$$

where  $A_i (i = 1, 2, \dots, n)$  are  $n$  elements.

d: Via normalization, the normalized weight vectors are

$$W = ((d(A_1), (d(A_2), \dots, (d(A_n)))^T \quad (12)$$

where  $W$  is a non fuzzy number

### III. METHODOLOGY

To implement the fuzzy AHP extent analysis on an apparel manufacturing industry the following steps have been followed:

#### A. Studying the existing supplier selection system

A well reputed apparel manufacturer in Bangladesh have considered as a case company where we have implemented our proposed supplier selection model to see the validity of the method. Before defining the problem we first depict a simplified supply chain network of the case organization (as shown in Figure 2). It was

analyzed using Pareto diagram that, poor print and embroidery supplier delivery performance affecting the production of the organization. Therefore, the model is required to be implemented in the supply chain section as shown by dotted line in Figure 2 for maximum profit of the organization. As the immediate operation is sewing in manufacturing plant, due to the low-quality standards as well as inadequate delivery performance, the organization is suffering to maintain a balanced flow of production. Consequently, they cannot able to deliver their goods on time, and it is a common phenomenon to a lot of the apparel manufacturers in Bangladesh.

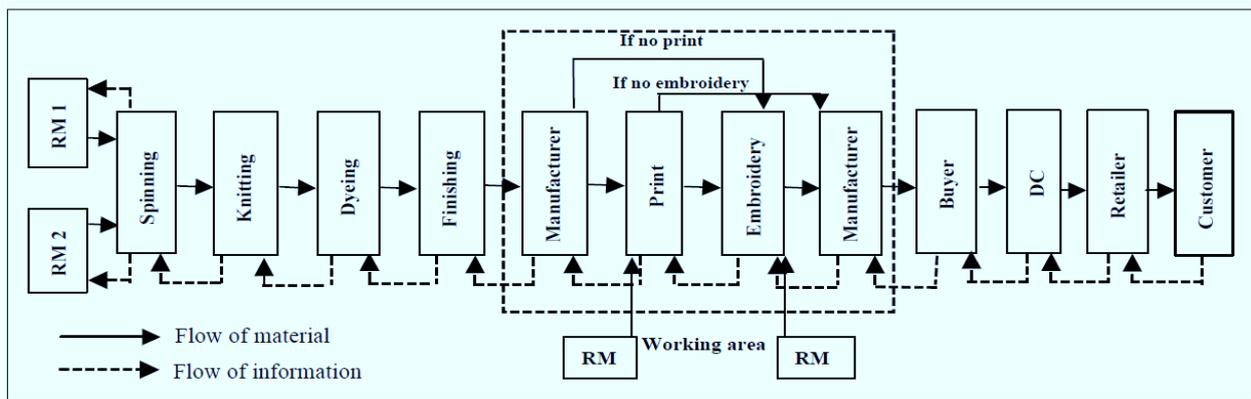


Figure 2 Simplified supply chain network of the apparel manufacturer

To overcome this problem we reviewed their current supplier selection mechanism the following drawbacks are come out [12]:

- It does not consider multiple objectives. Only a few criteria are observed.
- There is no specific proportion of the criteria so that criteria importance is understood. As a result there may have a fair chance to omit a potential supplier.

- There is no subdivision of the criteria and so mutual comparisons among the subdivisions are absent here which may help the evaluation process to become more precise.
- There is no set of indicators which help to evaluate and determine the best supplier.

So, ratings of suppliers are made intuitively in actual practice.

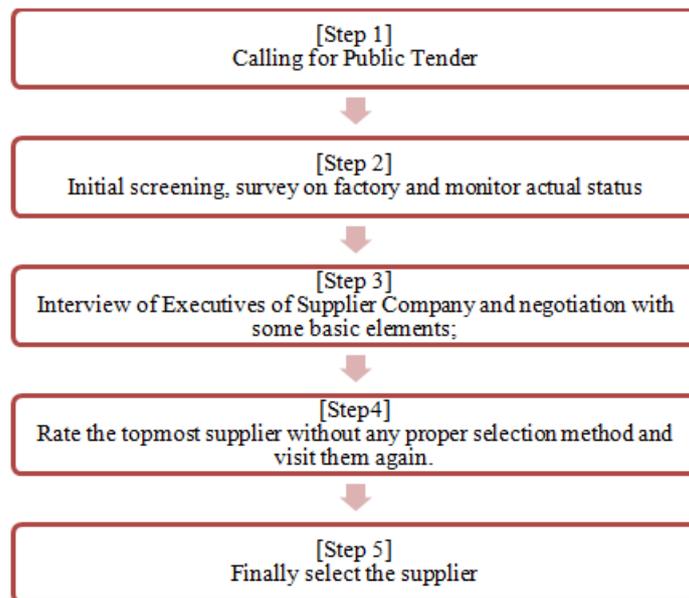


Figure 3 Conventional supplier selection process

But the proposed supplier selection model as shown in Figure 4 eradicates the drawbacks of the

conventional supplier selection process.

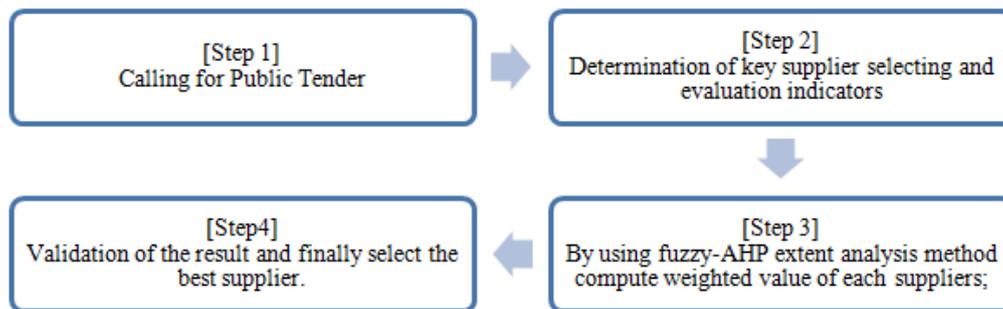


Figure 4 Proposed supplier selection process

**B. Implementation steps of proposed methodology**

**Step 1: Calling for public tender**

In this step, firms are invited publicly to tender against the requirements of the company as in a process which is open for all. The demands of the company should be clearly stated in the advertisement so that the supplier may understand everything easily without any confusion. As the main target is to select the best supplier among different alternatives, the calling approach should be in such a way that only the better suppliers are encouraged to apply. Consequently, the initial screening will not be that much time-consuming and cumbersome. To ensure the fairness of the selection process, the applicants may also know the selection procedures and the steps included. They should conceive that if they want to compete, they have to be fit for the job. Every supplier will be given equal priority without being biased.

**Step 2: Determination of key supplier selecting and evaluating indicators**

As supplier selection is a vital process for every organization, it is very much important to define clearly the basis on which this selection process will be performed. To select a suitable supplier we have to first evaluate and then to decide which supplier will be selected. To perform this, we defined some evaluation criteria, which are termed here as key indicators and also their subdivisions, termed as sub-indicators. In fact, the key indicators reflect the objective functions and the sub-indicators are the main elements of these key indicators.

Print and embroidery suppliers play a significant role to run the production system of an apparel manufacturing company smoothly. Surveying and analyzing different companies, we proposed seven key indicators, listed in Table 3, which are the basis for selecting a print and embroidery supplier. The first key indicator, which comprises three sub-indicators, mainly focuses on the geographical location of the factory, their experiences in this field and also the medium of communication they are availing. The second key indicator represents the competency of the supplier to meet the goal considering the organizational structure, manpower and also their background. The fourth and fifth key indicators are very important as they are concerned with the manufacturing capability and the quality systems. Among the different sub-indicators of the fourth key indicator, multi-item production capacity and capability indicates their ability to manufacture variety of products. Every sub-indicator of the quality system also influences the total quality of the supplier. Service facility is another important key indicator which includes four sub-indicators. Last but not least is upstream supplier name, *i.e.*, the names of the suppliers from which the concerned supplier acquires raw materials. If these suppliers have good reputation and experience, and also maintain proper quality and service levels in delivering the necessary inputs, consequently the ultimate output of the concerned supplier will be more likely of high quality.

**Table 3: Key indicators of proposed selection model**

Indicator	Weight	Sub Indicator	Weight
1 Quality System of the Supplier (QS)	0.365	1 Quality System Certificate of the Supplier (QSCS)	0.451
		2 Quality System Documentation of the Supplier (QSDS)	0.221
		3 Archive of Quality Records (AQR)	0.113
		4 Process Control Capability (PCC)	0.056
		5 Corrective & Preventive Action System (CPAS)	0.15
		6 Audit Mechanism (AM)	0.01
		7 Non-Conforming Material Control System (NCMCS)	0
		8 Receiving Inspection (RI)	0
		9 Quality System of the Supplier (QSS)	0
		10 Training (Tr)	0

2	Service Facility (SF)	0.306	1	Lead Time (LT)	0.08
			2	On Time Delivery (OTD)	0.768
			3	Mode of Transportation (MT)	0.007
			4	Green Purchasing (GP)	0.146
3	Manufacturing Capability & Inventory System of the Supplier (MC)	0.254	1	Machine Capacity and Capability (MCC)	0.723
			2	Manufacturing Technology (MT)	0.235
			3	Manufacturing Planning Capability (MPC)	0.014
			4	Multi-item Production Capacity and Capability (MIPCC)	0.028
4	General Information of the Supplier(GI)	0.075	5	Handling and Packaging Capability (HPC)	0
			1	Facility Location (FL)	0.861
			2	Working Experience (WE)	0.139
5	Organizational Profile of the Supplier (OP)	0	3	Communication Capability (CC)	0
			1	Organizational Structure (OS)	-
			2	Number of Personnel (NP)	-
6	Financial Status of the Supplier (FS)	0	3	Educational Status (ES)	-
			1	Last Year Turnover (LYT)	-
			2	Exporting Status (ExS)	-
7	Supplier Name (SN)	0	3	Appropriateness of the Material Price to Market (AMPM)	-
			1	First Alternative Supplier (FAS)	-
			2	Second Alternative Supplier (SAS)	-
			3	Supplier Name (SN)	-

The proposed decision model of supplier selection was constructed for 31 sub-indicators under seven key indicators which are shown in Table 3.

**Step 3: By using fuzzy-AHP method compute weighted value of each suppliers**

In this step, first by using fuzzy- AHP the weighted values of each indicator are computed to measure the relative weight put the manufacturer against each sub-indicator, Then, it is necessary to collect

detailed data against each sub-indicator among available suppliers.

After the criteria are determined as given in Table 3, pair wise comparisons have been made to determine the importance levels of these criteria. To compare, people only select the related linguistic variable, then for calculations they are converted into the following scale including triangular fuzzy numbers developed by (Chang, 1996 [9]) and generalized for such analysis as given in Table 4 below:

**Table 4: TFN values**

Triangular Fuzzy Numbers (TFN)			Statements (row to column)	Statements (column to row)	Triangular Fuzzy Numbers (TFN)		
l	m	u			l	m	u
7/2	4	9/2	Absolute	Weak	2/3	1	3/2
5/2	3	7/2	Very Strong	Fairly Strong	2/5	1/2	2/3
3/2	2	5/2	Fairly Strong	Very Strong	2/7	1/3	2/5
2/3	1	3/2	Weak	Absolute	2/9	1/4	2/7
1	1	1	Equal	Equal	1	1	1

**Table 5: Pairwise comparison of the criteria**

	QS	SF	MC	GI	OP	FS	SN
QS	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)	(5/2,3,7/2)	(5/2,3,7/2)	(5/2,3,7/2)	(7/2,4,9/2)
SF	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)	(5/2,3,7/2)	(5/2,3,7/2)	(7/2,4,9/2)
MC	(2/5,1/2,2/3)	(2/3,1,3/2)	(1,1,1)	(3/2,2,5/2)	(5/2,3,7/2)	(5/2,3,7/2)	(5/2,3,7/2)
GI	(2/7,1/3,2/5)	(2/5,1/2,1/2)	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)	(5/2,3,7/2)
OP	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)
FS	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
SN	(2/9,1/4,2/7)	(2/9,1/4,2/7)	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(2/3,1,3/2)	(1,1,1)

After performing the calculations according to equations (4) to (12) the following weights of each criteria has been found.

$$W_{QS}=0.365; W_{SF}=0.306; W_{MC}=0.254; W_{GI}=0.075; W_{OP}=0; W_{FS}=0; W_{SN}=0;$$

We have checked the degree of consistency and found that the pair wise comparison matrix does not exhibit any serious inconsistencies. It is seen that the weight of the criteria which are less important becomes zero. Now, we will find out the scores of each objective

by making proper comparisons among the suppliers against each sub criteria of the objective functions. For example, in SF the weighted values for the sub criteria OTD can be calculated as:

**Table 6:** Pairwise comparison of the alternatives against On Time Delivery (OTD) sub criteria

	Supplier A			Supplier B			Supplier C		
Supplier A	1	1	1	2/3	1	3/2	2/5	1/2	3/2
Supplier B	2/3	1	3/2	1	1	1	2/3	1	3/2
Supplier C	3/2	2	5/2	2/3	1	3/2	1	1	1

By following same equations the weights of each supplier for On Time Delivery (OTD) sub-indicator is found as:

$$(Supplier A)_{SF}=0.292, (Supplier B)_{SF}= 0.3252, (Supplier C)_{SF}= 0.383.$$

Similarly the other calculations are made. Since the weight of OP, FS and SN were found to be zero in the goal vector therefore these criteria have been omitted during relative performance calculation of the suppliers against each sub-indicator.

By the same procedure the pairwise comparison of the sub indicator of the dominating indicators to the goal

function have calculated and the relative performance of the suppliers against each of these sub indicator have evaluated. For example the relative weight of the sub indicators of Service Facility (SF) are:

$$W_{OTD}=0.77, W_{LT}=0.01, W_{MT}=0.08, W_{GP}=0.14$$

And the relative performances of the suppliers against each of these sub indicators are shown in the Table 7.

**Table 7:** Calculation of final score against ‘Service Facility’ indicator

	OTD	LT	MT	GP	Alternative priority weight
Weight	0.770	0.010	0.080	0.140	
(S <sub>A</sub> ) <sub>SF</sub>	0.292	0.333	0.333	1	0.395
(S <sub>B</sub> ) <sub>SF</sub>	0.325	0.333	0.333	0	0.280
(S <sub>C</sub> ) <sub>SF</sub>	0.383	0.333	0.333	0	0.325

**Step 4: Validation of the result and finally select the best supplier**

Finally the overall score for each alternative supplier is calculated by multiplying each weight of key

indicators and supplier performance to that indicator, and then summing them to get the final score.

**Table 8:** Calculation the overall score from assesment of sub indicators

	QS	SF	MC	GI	Final Score
Weight	0.365	0.306	0.254	0.075	
Supplier A	1.000	0.395	0.176	0.576	<b>0.574</b>
Supplier B	0.000	0.280	0.726	0.019	<b>0.272</b>
Supplier C	0.000	0.325	0.098	0.405	<b>0.155</b>

**IV. DISCUSSION**

From the above calculations it is clear that *supplier A* should be selected as it has the highest score. It was a tough decision to pick a supplier from the available three strong candidates. And, it is reflected in their overall scores. In the case organization, they ranked QS top compared to other key indicators. From Table 8 we can see that supplier A’s quality service score is 1 whereas supplier B’s and C’s are 0. It is also reflected in the overall score. So, the proposed supplier selection model using fuzzy-AHP is a valid model.

To select a supplier through fuzzy-AHP requires extensive analysis and to do so we need to consider a good number of factors. Basically, the selection process varies

as per the evaluation criteria selected by the manufacturer. As for example, the manufacturer wish to select a supplier who accentuate more on quality, proximity to the firm, has a well raw supplier reputation of the supplier rather than its manufacturing capability and which is usually seen in selecting supplier A. Supplier B has equal good manufacturing capability (0.726) as compared to supplier A (0.176). But the manufacturer wishes to choose the factory which is the best quality provider supported by the environments to maintain it.

Moreover the proposed model has done by only AHP previously which increase the number of calculation as there is no chance of reducing indicators by calculation. But fuzzy AHP gives the opportunity of ignoring one or more indicators or sub indicators due to their zero weight

in the goal function in the intermittent step. This reduces the number of calculation and gives a quick result. By using AHP it was also found that supplier A is the best alternative but the comparison was too close and was difficult to take decision in that competitive scoring (*Supplier A = 0.341, supplier B = 0.316 and supplier C = 0.339*) [12]. But in this model there is no confusion about selection of supplier A as the difference in final score is large enough. This results due to taking fuzzy comparison instead of crisp value, which gives more vagueness to take the decision and makes the decision more accurate and justified.

Another matter should be considered that we have made the final score based on the performance of the supplier against sub indicators and the pair wise comparison of the sub indicators rather than indicator. This optimizes the decision by considering the hierarchy level of the indicators.

## V. CONCLUSION

In this paper, we have proposed a supplier selection model using a multi criteria decision-making method which includes identifying key indicators, sub-indicators and detailed step-by-step analysis. We have used fuzzy-AHP method for the purpose of multi attribute characteristics of supplier selection problems. The proposed model of supplier selection was implemented in an apparel manufacturing firm. There were 1706 employees in the company; 42 of them are engineers, 122 of them are officers and executives and remaining 1542 are operators, technicians and helpers. The activities like supplier selection, evaluating the supplier performance and selecting the best supplier among alternatives are performed by the merchandising department. They review the candidate suppliers according to the evaluation criteria and after this evaluation; they select the best supplier as per the method mentioned in this paper. It was proved right for the company considering their previous supplier selection process.

This selection process helps the manager to select a supplier from a dynamic environment. Basically, a fashion market is totally different considering other markets, because consumer tastes changes from time to time. Then it makes changes in the construction of garments as well. So, the manufacturer needs to select a supplier with diversified production facility while meeting the quality standards too. And, this is best can be done by using this proposed supplier selection process.

The paired comparisons were made by taking the experts' opinions in the company's merchandising team. Also all the calculations were performed by using MS Excel.

Evaluating the supplier from both objective and subjective criteria will gain flexibility to the design process. If we consider all the functional departments of a supplier, we will get close relationships among the departments with one another. And hence we can easily

say that the success of a supplier to get selected by a company is fully dependant on the combined effort of all the departments as they can influence the selection criteria as well as the key indicators.

Another important finding is that the proposed model is more reflecting the relation of how the selection criteria affect the selected suppliers and at the same time what is more important for the suppliers among the selection criteria.

The proposed system has some limitations. One of the major drawbacks of using fuzzy-AHP in selecting a supplier is the number of objective functions and their relevant evaluation factors. It requires sufficient time for a manager to collect necessary data. Sometimes, the comparison differs from one manager to another and hence the overall scores will be affected by that. So, to circumvent the drawbacks we are now developing a computer program for the proposed model instead of excel sheet which can be used by the organization to take their decision in a user friendly environment.

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