EVALUATION AND SELECTION OF SUPPLIERS IN ELECTRONICS INDUSTRY OF PAKISTAN USING ANALYTICAL HIERARCHY PROCESS

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ABSTRACT

Suppliers are always the business drivers of any manufacturing organization. Their evaluation has assumed a strategic role in deciding the future of an organization. Supplier selection is a difficult process for the management. An organization usually has to select a supplier among several available choices on the basis of different criteria. A number of researches have been devoted to cope with this problem in different industries but less work has been done in electronic industry of Pakistan. There is a need to find an effective and precise method for suppliers' selection in electronics industry. The specific objectives of research study are to select suppliers in electronic industry, to explore factors affecting supplier's evaluation and selection and to apply Multi Criteria Decision Making (MCDM) technique for supplier selection. In this paper a model based on Analytic Hierarchy Process (AHP) is used to address the problem of supplier selection in electronics industry of Pakistan. In this study six suppliers have been evaluated on given criteria. Through the study it has been identified that "Quality" is most important criteria followed by "Cost" and "Reciprocal Arrangements" in supplier evaluation in this specific scenario. In addition to that sensitivity of criteria is also discussed. This study will help the decision makers of electronics industry in selecting best supplier for their organization.

KEYWORDS: AHP, Multi Criteria Decision Making, Supplier Selection, Electronics Industry

1. INTRODUCTION

Usually industries are integrated with different segments through their supply chain systems. These segments play important role in success of industry. Every industry requires resources and raw material. Management has to select suppliers for the supply of raw material. Supplier selection process is sensitive, ambiguous and complex. It is more sensitive when the finished products solely depend on quality of raw materials provided by supplier. Sometimes it is ambiguous and complex when there is very less margin in quality, cost, delivery and other features required by an organization. Therefore deciding about appropriate supplier is very crucial and difficult for decision makers because inappropriate selection can lead to a loss not only terms of money but quality, time and sometimes perception of organization also.

Operations of production line of most of the electronics industries essentially depend on several minor and major components being provided by the different suppliers. So the selection of supplier is considered important while making decisions about them. It has been a proven fact that the quality of equipment provided by supplier will be reflected in the original equipment being manufactured by an organization. Several factors have been identified which play an important role in deciding the best possible alternative depending on quality, reliability, delivery, performance background, guaranties, price, technical capability and financial worth of the supplier. Dikson (1966) recognized twenty three different criteria for supplier selection. According to him supplier selection is categorized in two aspects. In one way, only a single supplier meets all requirements of buyers (Single Sourcing) while in other way, a single supplier cannot meet all of the requirements of an organization (Multi Sourcing) [1]. Several techniques have been developed to cater single and multiple sourcing issues in the literature [1]. In the literature, few researchers have considered this issues as an optimization problem, and suggestions have been made to formulate an objective function to solve this issue effectively [2]. From the surveyed literature, it is evident that there different researcher has applied various techniques for supplier selection. These included mathematical modeling , cluster analysis, statistical models, case based reasoning systems, decision support systems, analytic hierarchy process, data envelopment analysis, artificial intelligence and mathematical modeling [3-5]. These methods exhibit several similarities and dissimilarities. Efforts have been made to identify the easy and least complex method in evaluating the suppliers in electronics industry [6]. This has been achieved by

comparing similarities between the methods and secondly contradiction rate between the alternatives [7]. Tangible and intangible factors for supplier selection have been examined using ANP and MOMILP which revealed the relationship of maximizing the total value of purchasing and minimizing the budget [5]. Using benefits, opportunity, cost and risks, AHP model has been utilized to evaluate the suppliers which is found to be a good choice as this method focuses on these factors from buyer perspective [4]. Selection of supplier for electronic industry is done by using FPP which resulted in minimization of uncertainty [8]. In German electronic industry an AHP decision model has been employed to evaluate the suppliers [9]. Neural network model proposed to be a new method of data collection which has been applied for wide range of multi-attribute decision making problems [10]. Due to globalization challenges and the need for fast development of the products new criteria and sub criteria have been evolved and identified by the researchers which have to be considered as the most important for supplier selection. The major factors are quality, service, cost, delivery, flexibility, reputation, technical strengths, facility and responsiveness. These criteria are employed through fuzzy Delphi, fuzzy AHP, SIR.VIKOR in the available literature [11]. Heuristic approach has also been identified as for optimized selection of supplier in MCDM [12]. These MCDM techniques have also been employed for purchasing of computers and printers by using AHP [12].

Supplier selection is a challenge for decision makers and electronics industry of Pakistan is also facing such problems. It has been discovered thorough review of literature that there is little work done in this field in Pakistan and there is a need to provide some easy and logical understanding about this problem. AHP is least complex technique; it is being used for decades for decision making. The applications of AHP are numerous in the field of CAD/CAM engineering, simulation software selection and in academia [13-14]. In all cases AHP proved to be one of the best candidates for MCDM and can easily be used to resolve such problems.

In this article a case of an electronics industry of Pakistan has been considered to derive the multi-criteria decision making model. The company designs and fabricates different electronic circuits on a large scale. The famous products of the organization are Radio Jammers, Radio Wireless Sets and Electronic Control System of Locomotives. This company requires various parts such as Printed Circuit Boards, Transistors, Resistors, Capacitors, and Inductors on a large scale. Any interruption in the supply of the parts can lead to inefficiency in the organization.

2. RESEARCH METHODOLOGY

The research methodology adopted involves the following steps;

First step involves the identification of criteria (literature review and experts' interview). In the second step questionnaire was prepared on the basis of identified criteria. In the third step questionnaires were floated to relevant audience and data was collected. In the fourth step AHP was applied on the collected data. Fifth step relates the discussion and results obtained after implementation of AHP. In the lasts step conclusion and recommendation are made.

3. MODEL FORMULATION BY AHP METHODOLOGY

In Analytical Hierarchy Process (AHP), overall hierarchy is formulated for decision problem. The hierarchy is structured from the top to the bottom level of the problem. In the highest hierarchy the overall goal of the problem is determined, then in the intermediate level, criteria and sub criteria are identified and at the end (bottom) several available alternatives are evaluated. Each criterion in the lower level of hierarchy is compared with respect to the criteria in the upper level of hierarchy. The criteria in the same level are compared using pair wise comparison. Figure-1 describes the hierarchy of a general decision making problem.

The hierarchy is constructed taking all the criteria, sub-criteria and alternatives specific to the research problem. The hierarchy is structured from the top (performance evaluation of suppliers) through the intermediate levels (main and sub-criteria on which subsequent levels depend) to the bottom level (the list of suppliers).

To determine important criteria and their relationship with the decision variables is a crucial step. This step is crucial because the selected criteria and sub-criteria can influence the final choice. Here in this study, the criteria and sub-criteria are selected based on the literature review and through expert's opinion.

The construction of pairwise comparison matrix for each level in hierarchy is the next logical step in AHP. A nominal evaluation scale is used during pairwise comparison. The scale used is a discrete scale from 1 to 9 [15]. The value 1 for equally important, 3 for moderately more important, 5 for strongly more important, 7 for very strongly more important, 9 for extremely more important and 2,4,6,8 are used for intermediate responses.

Matrix X is a pairwise comparison matrix constructed after comparing criteria pairwise. The element x_{ij} of matrix X is importance of ith criterion relative to the jth criterion at the same level of hierarchy. As the relation $x_{ij} = \frac{1}{x_{ji}}$ exists so X is a positive reciprocal matrix. Refer to" (1)".

$$X = (x_{ij})_{m\times n} = \begin{bmatrix} 1 & x_{12} & \cdots & x_{1m} \\ \frac{1}{x_{12}} & 1 & \cdots & \vdots \\ \vdots & \vdots & \cdots & \vdots \\ \frac{1}{x_{1m}} & \frac{1}{x_{2m}} & \cdots & 1 \end{bmatrix} \quad (1)$$

A prioritization technique such as the Fuzzy Programming method, the Goal Programming method, Eigenvector analysis and the Logarithmic Least Squares method, [18] may be applied on pairwise comparison matrix to get the values of weights w_i of the criteria.

At the last step, relative weights are calculated by normalizing each matrix. The relative weights are given by the right eigenvector (U) corresponding to the largest eigenvalue (λ_{max}) as:

$$X_U = \lambda_{max} U \quad (0)$$

If the pairwise comparisons are completely consistent, the matrix X has rank 1 and λ_max= m. In this case, weights can be obtained by normalizing any of rows or columns of X.

The alternatives' rating scores Rij are obtained from the comparison matrix for each ith criterion relative to alternative in lower level.

Relative priorities of alternatives and criteria implied by comparison matrix are found in the last step. Relative priorities are obtained by Eigen vector theory. Consistency index is checked at selection stage. Consistency index (CI) and Random consistency Index (RI) are required to evaluate consistency. For determining CI and RI values a Matrix size M×M approach is used. Weights are calculated from the comparison matrices. The first step is placing the values in each cell of the matrix and summing columns' value. Then the result of summations would be equated, and then the weights of the criteria/ factors are found by dividing the each column summation by the total sum of the columns.

$$CI = \frac{\lambda_{max}-1}{n-1} \quad (3)$$

Where "λ_{max}" is the maximum eigenvalue and "n" is the size of the pairwise comparison matrix. The random consistency index (RI) is computed as,

$$RI = 1.98\frac{n-2}{n} \quad (4)$$

Thus the consistency ratio (CR) is obtained using,

$$CR = \frac{CI}{RI} \quad (5)$$

The computed result of CR is recommended to be consistent if CR value is less than or equal to 0.1 or 10%. In the final step, weights are multiplied with criteria to get preference matrix and addition of results gives composite score of criteria.

4. APPLICATION OF AHP FOR SUPPLIER SELECTION

In this study, electronic industry of Pakistan has been chosen as a case study. Data for six suppliers have been collected from the case company for specific demand of LM324 (general purpose transistor). On the basis of collected data and expert opinion, AHP technique has been selected for resolving this problem. In the current study, the "Goal" is evaluation and selection of suppliers in electronic industry of Pakistan. Goal is placed at zero level of hierarchy. Main Criteria are placed at the first level below the goal. Sub-Criteria are placed below main-criteria at level two. At the last and third level alternatives have been placed which are supplier 1 to supplier 6 in this specific case. The alternatives taken are suppliers dealing in electronic components internationally.

After the construction of hierarchy the main and sub criteria have been determined. The main and sub criteria are defined through expert opinion of decision makers dealing in procurement of electronic components. These criteria were also validated through review of research survey as explained in table-1

Quality of products to be supplied, delivery of orders, cost of components and handling cost, financial stability and worth of a supplier are the key criteria mentioned in literature [15-20]. While purchasing electronics components, the pre-shipment inspection and testing is not easy as compared to mechanical components therefore the issues of reliability, warranty and after sale services are very important. Therefore researchers have considered services as a major factor for consideration of supplier. Similarly, perception and customer relationship management has also been selected as one of the important criteria for selection of the vendor [20]. Last three criteria in above table-1 have been included from expert opinion of practitioners associated with this area.

The next step is pair wise comparison of criteria and sub-criteria. At this stage level of importance of each main and sub criteria is defined. Relative judgments of criteria have been tabulated in table-2 . The judgments are based on expert opinion of practitioners of this specific area.

To minimize the computational efforts Excel Sheets® and Expert Choice® software have been incorporated. After pairwise comparison weights of criteria have been calculated by right eigenvector analysis method. In the next step, rating score of suppliers have been calculated

from pairwise comparison matrix for each criterion. In the last step, decision has been made on the basis of priorities of criteria and alternatives.

5. RESULTS AND DISCUSSIONS

In this paper three aspects have been studied by using AHP. First of all, Priorities of alternatives have been assessed, second it has revealed performance of criteria by decision maker and at the last best from all of available supplier is selected. In this study, AHP has been used to evaluate importance and priorities of factor for supplier selection in electronic industry. The case has been evaluated by considering ten main criteria and seventeen sub-criteria as shown in Table 1. In the each of six suppliers has also been assessed by considering the same criteria Fig 3 presents the evaluation of each supplier against specific criteria. Comparison matrix every xij position corresponds to geometric mean of experts opinions' involved in decision making processes. In this case, to access the judgment of decision makers, each of them has been inquired about the importance of criteria over other. Assessment of judgment of decision makers resulted "Quality" as the highest importance with a weight of 0.120. "Cost" is lagging "Quality" with a weight of 0.118. "Reciprocal Arrangements" was rated at number third with a weight of 1.11. Figure 2 presents the graphical representation of criteria according to the level of importance and weights.

As "Quality", "Cost" and "Reciprocal arrangements" are prior of all criteria so their importance is higher than all other factors. Evaluation of suppliers strongly depend on these criteria. Supplier 3 is good in "Quality", "Cost" and "Reciprocal arrangements" than other suppliers. Supplier 3 has been rated marginally higher than 1, 2, 4, 5 and 6. Priorities of criteria directly affect the decision. Change in priorities of criteria changes the final results. Fig 4 and 5 presents the changed results due to variation in priorities of criteria.

Suppliers' evaluation is sensitive to weights of criteria. A minor change in priority of criteria changes the result. Supplier 3 is on top, supplier 4 and 6 are substantially closer when "Quality" is prior to all other criteria as shown in Fig 3. However supplier 3 is replaced by supplier 1, when quality is slightly compromised. The gap between both suppliers 4 and 6 marginally increased when "Delivery" and "Impression" is prior to all other criteria as shown in Fig 4. Similarly the gap between supplier 1 and 3 marginally decreased when "Cost" is prior to all other criteria. There is a difference in stated preferences and revealed preferences of criteria by decision maker. AHP has highlighted this difference. In the stated preference of the decision maker, the more importance has been given to "Quality", "Cost" and "Delivery". In stated preference "Delivery" has third top priority by decision maker but in revealed preference it has not such importance. It is only 8.1% important. The AHP method determined the supplier 3 as the best supplier. The overall inconsistency is 0.06 which is within the boundary 0.1 with tolerance ±10%. Fig 6 presents the final result of the selection of suppliers

The components provided by supplier 3 have good quality relative to other suppliers. It offers comparatively less cost. It is good in reciprocal arrangements and service. It is flexible in lead time and negotiations. It is relatively good in delivering the product on right time and right place. Specifically in this case "quality", "Cost", "reciprocal Arrangements" and "Service" has more weight, supplier 3 is good in these criteria so it is the best choice. Quality of components provided by supplier 1 is slightly lower than the quality of components provided by supplier3. Supplier 2 offers comparatively high cost, it is good in delivering products than all other suppliers, so supplier two is third choice, similarly supplier 4,5 and 6 are ranked on same criteria.

6. CONCLUSIONS

Through literature review and expert opinion, it emerges that selecting a supplier is difficult and complex multi-criteria decision making problem. Decision made on alternatives depends on different criteria. Supplier evaluation is sensitive to priorities of criteria. Frequently, these evaluation criteria support or oppose each other. This specific problem is resolved by using comparable scales of criteria values. This study presents a structure that can be used to formalize the process of evaluating the suppliers in electronic industry. "Quality". Similarly "Delivery" has second highest importance but AHP resulted "Cost" as third highest importance but AHP, resulted "Reciprocal Arrangements" as third high important criterion. Firstly, difference is due to inconsistencies in judgments, made by experts during assigning weights of preferences. Secondly, continuously changing human behavior, human mode, working environment and thoughts affects the human decisions. AHP proved to be the best candidate for multi-criteria decision making and human error can be eliminated or reduced by AHP effectively in decision making

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APPENDIX

TABLES

Table.1 Selection of Criteria and Sub Criteria

Main criteria	Sub-criteria	Reference
Delivery	Lead time	Shyur and Shih [15]; Wang, Huang, and Dismukes [17]; Hua, Gong, and Xu [18]
	Order delays	
Quality	Product quality	Liu and Hai [19]; Shyur and Shih [15]; Jharkharia and Shankar [20];
	Customer complaint rate	
Cost	Price	Shyur and Shih [15]; Jharkharia and Shankar [20]; Wang, Huang, and Dismukes [17];
	Exchange rate	
	Transport cost	
	Unit cost	
Financials	Financial position	Liu and Hai [19], Shyur and Shih [15], Wang, Huang, and Dismukes [17];
	Profitability	
Flexible	Short lead times	Liu and Hai [19], Shyur and Shih [15], Stevenson [16]
	Solve conflict	
Services	Warranties & claim policies	Hua, Gong, and Xu [18].
Relationship	Long-term relational development	Shyur and Shih [15], Liu and Hai [19], Jharkharia and Shankar [20].
	Open communication	
	Reputation	
	Mutual trust	
Impression		Expert Decision Makers
Packaging ability		Expert Decision Makers
Reciprocal arrangements		Expert Decision Makers

Table 2: Pairwise Comparison of main criteria

	Delivery	Quality	Cost	Financials	Flexible	Service	Relationship	Impression	Packaging	Reciprocal A
Delivery	1	1/4	1/2	2	1	1/2	1	1	1	1
Quality	4	1	1	1/2	1	1	1	1	1	2
Cost	2	1	1	3	1	1	2	1	1	1/2
Financials	1/2	2	1/3	1	1	1	1	1	1	1
Flexible	1	1	1	1	1	1	1	1	1/2	1/3
Service	2	1	1	1	1	1	1	1	2	1
Relationship	1	1	1/2	1	1	1	1	1	1	1
Impression	1	1	1	1	1	1	1	1	2	1
Packaging Ability	1	1	1	1	2	1/2	1	1/2	1	2
Reciprocal Arrangements	1	1/2	2	1	3	1	1	1	1/2	1

FIGURES

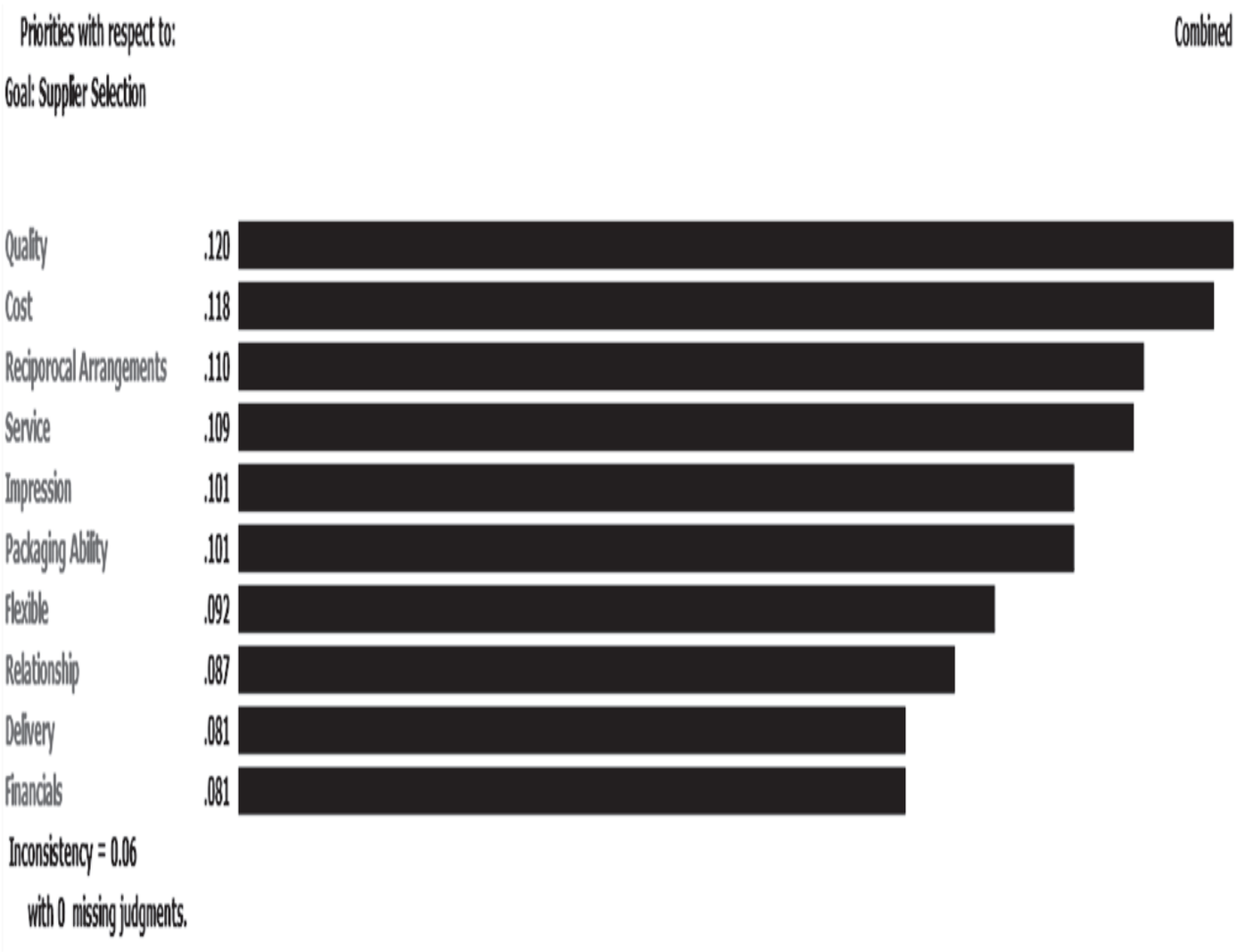


Fig 1-General Hierarchy for evaluation of problem

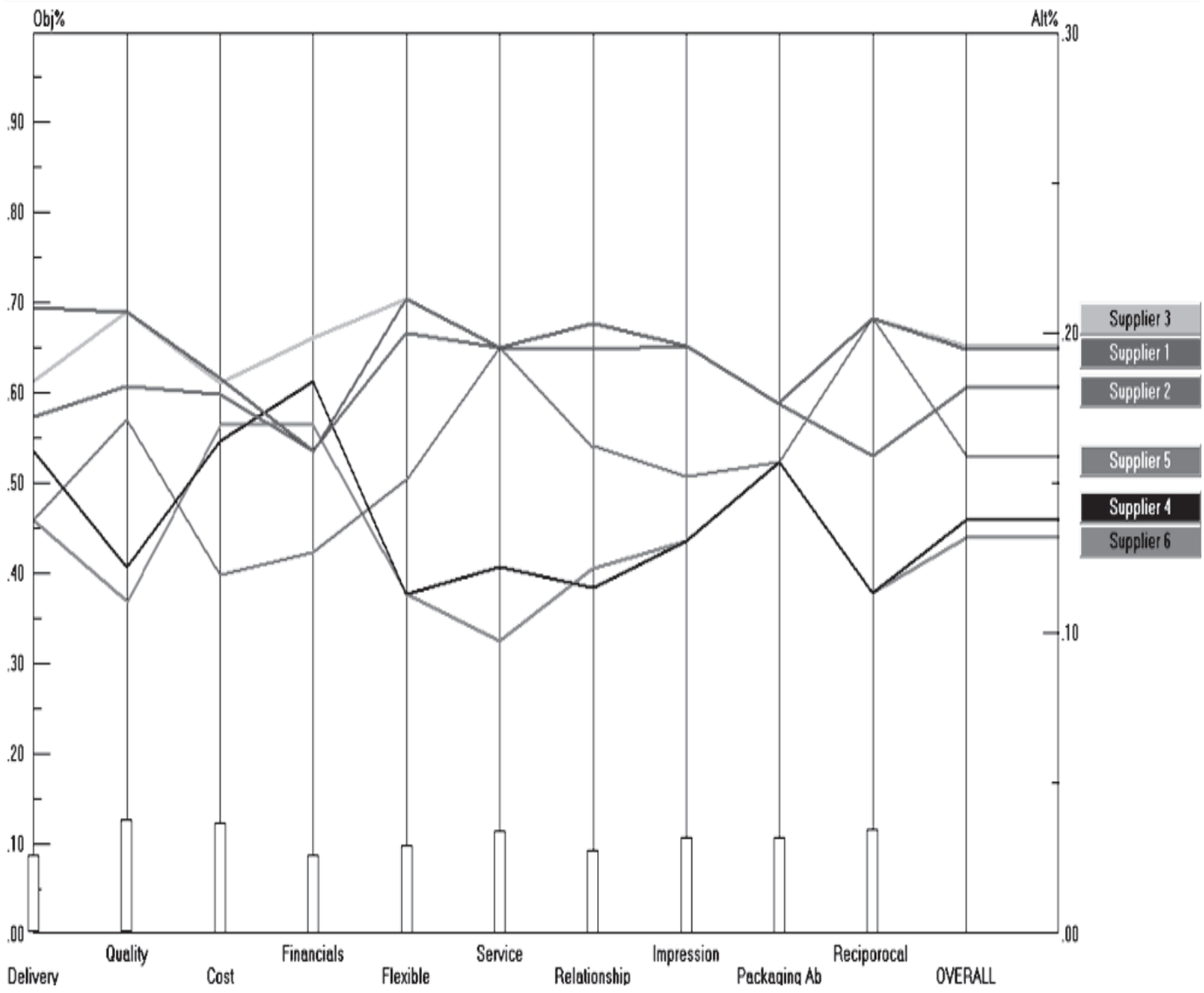


Fig 2 Priorities of criteria with respect to goal

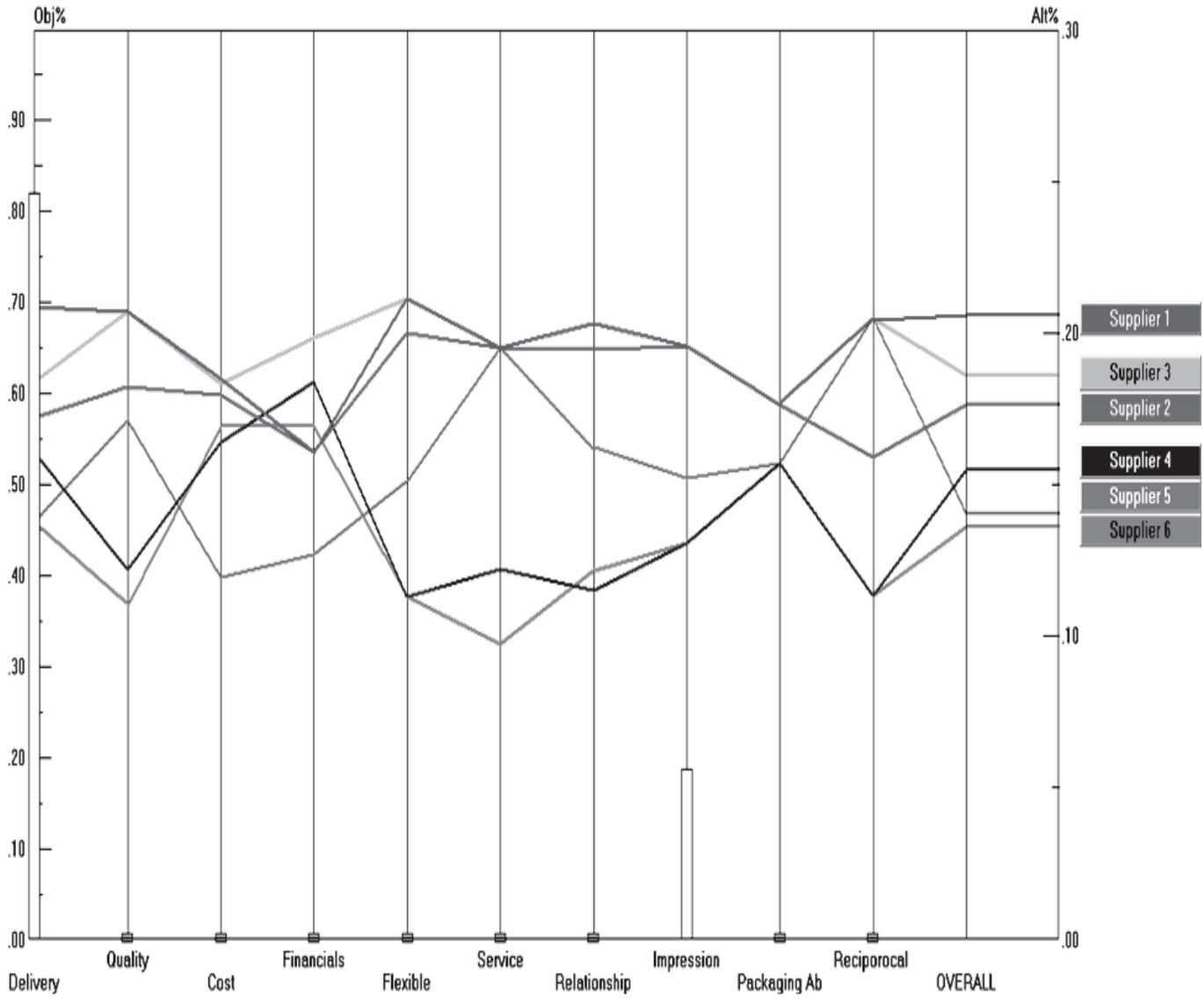


Fig 3 Sensitivity Curve for supplier rating

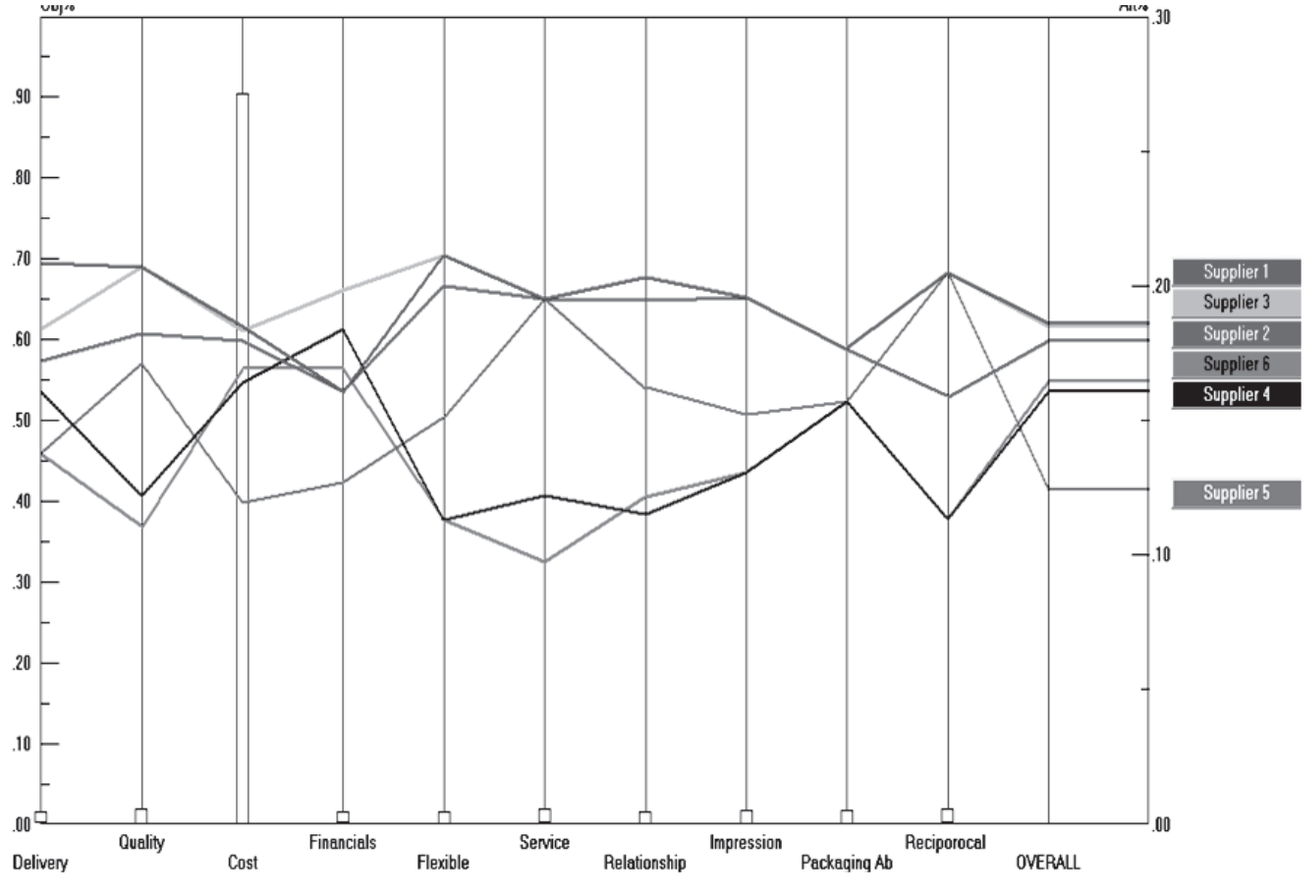
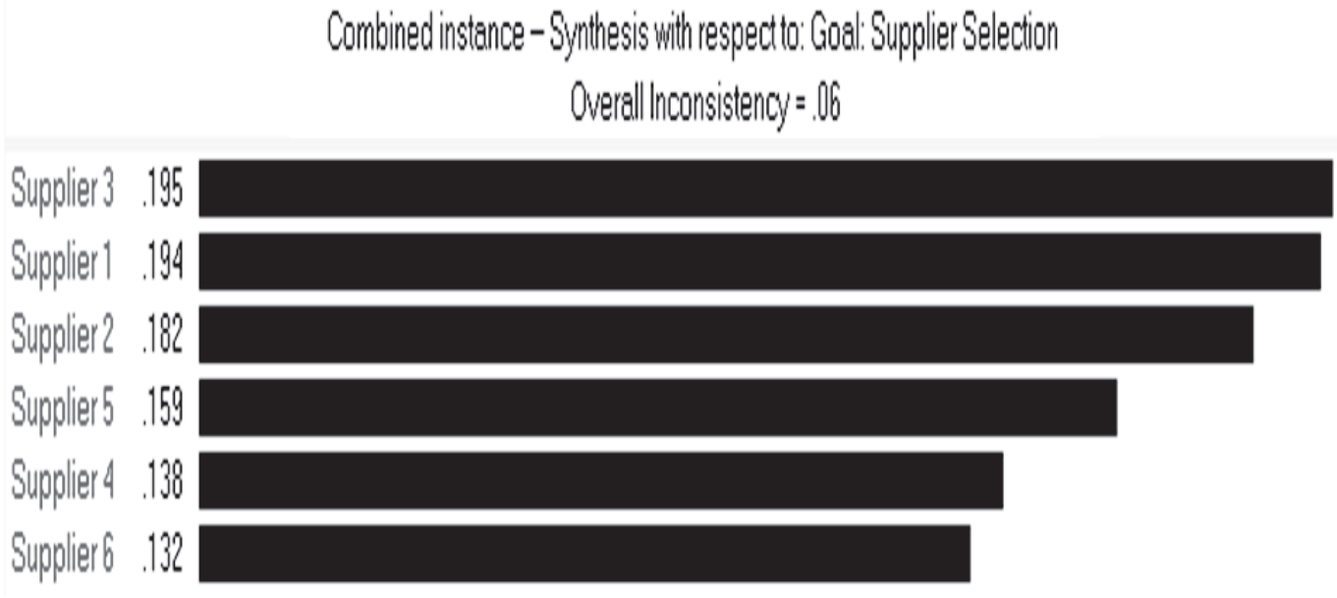


Fig 4 Priorities of criteria with respect to goal



Fiq 5 Sensitivity curve after further changing the criteria priorities