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Analytic Network Process (ANP): An Approach for Supplier Selection in an Automobile Organization

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ABSTRACT

For any organization, the most important decision is purchasing goods and services selection is one of the most critical activities of purchase management in supply chain. Significant suppliers play an important role in the competitive market. Better suppliers perform the better organization. The supplier selection of a leading automobile organization is analyzed in this study. Analytic Network Process (ANP) is employed for the supplier selection. Authors make step wise pros and cons and list shortcuts under the guidance of an expert from the organization. Each supplier is evaluated and weights/rank of each supplier is determined. Highest rank supplier is shortlisted among the selectors.

Key words: Determinant, dimension, supplier evaluation, ratings, interdependency

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INTRODUCTION

From the past two decades with emerging competition and trends in market, more and more impression is on governing the supply chain. Supply Chain Management (SCM) is the formation of conceptual and technical methods. For customer satisfaction, each and every party directly or indirectly is practicing in forming the supply chain. This supply contains the mixture of buyers, transporters, retailers and customers too. The provision of services at low cost and at regular intervals of time is the key to success. Give and take is the essential link for an organization in growing the supply chain. Supplier quality directly affects the organization performance at cheaper rate with proportionate quantity in limited time. One of the most necessary functions to reduce material cost is the supplier selection [1]. The fail in the supplier selection is caused by distortion in the entire financial part of supply chain [2]. Selecting a desired supplier among available suppliers is a critical matter for the top authorities. Large scale industries with increasing production of raw materials and components equalize 70% product cost. In these circumstances, the purchasing department can play a major role in the reduction of cost and one of the most vital functions of purchasing management [3]. So, using an appropriate method for this purpose is the serious matter and supplier selection has been becoming a Multiple Criteria Decision Making (MCDM) problem [4]. In the supply chain, the coordination between a manufacturer and suppliers is a typical and vital link in the channel of distribution. Being the manageable and established supplier in the supply chain, this relationship will accomplish a lasting effect on the ability of the entire supply chain [5].

The organization of the paper is as follows: the first part gives the introduction and literature survey on supplier selection criteria and related methods are discussed. Later the theory of ANP and step by step procedure for ANP implementation is discussed. Finally the results and conclusions are explained.

A supply chain which provides the required quantity of the end product at right place and at right time is considered to be a capable and successful supply chain [6]. The one of the basic strategies for enhancing the quality of output of any organization is the selection of appropriate suppliers and company's reputation is also influenced with this strategy [7]. These days, supply chain management tries to achieve the long term participation with more trustworthy suppliers [8]. Therefore, choosing required suppliers is a difficult task as compared to just looking at the list of suppliers' suggested prices and selection of suppliers depends upon many factors which are qualitative and quantitative[9]. There are various supplier selection techniques available in the literature Supplier selection

techniques are the different ways for conducting the selection process. There has been the development of various famous selection methods over the years which are differentiated by many scholars [10] such as: Analytic Hierarchy Process (AHP), Analytical Network Process (ANP), Artificial Neural Networks (ANN), Case-Based Reasoning (CBR), Data Envelopment Analysis (DEA), Genetic Algorithm (GA), Fuzzy Set Theory, Mathematical Programming (MP) etc.

Jiann et al [11] suggested a unified MCDM approach for solving trader selection problem. Authors made use of triangular perplexed number to express the subjective preference of evaluators as related to the observed criteria. Banar et al [12] used ANP, one of the MCDM tools to opt one o the four selective landfill sites for the city of Eskisehir, Turkey. Cevriye et al [13] used Analytical Network Process (ANP) for choosing suppliers in an electronic industry. Supplier's selection is the first move of the activities in the product realization process which has been starting from the purchasing of basic crude material till the end of delivering the products, is evaluated as an important factor for the companies which are having the desire to be acknowledged in today's competitive condition. Hsu Shih et al [14] used an extension of TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), a multi attribute decision making (MADM) technique, to a group decision environment. TOPSIS is a constructive approach for ranking and selection of a number of externally determined choices through distant measures. Filip et al [15] proposed an activity based costing approach for supplier selection and evaluation.

Many particular approaches are used supplier selection. It has been seen that lone approaches are slightly more popular than mixed approaches [3]. Integrated approach is extensively used for assigning weights to the criteria and for ranking the suppliers. Hence in consideration of this, it is suggested to apply ANP for selection of supplier in an automotive manufacturing industry. The Analytic Network Process (ANP) is used to rank the suppliers. Its benefits over the other techniques is that, it permits one to include all the factors and principles, real or unreal, which can put influence on the decision making process. It considers interdependencies among the criteria and strict hierarchy need not be followed.

ANALYTIC NETWORK PROCESS (ANP)

The Analytic Network Process (ANP) developed by Thomas Saaty [16], in his work on multi criteria decision making. It is an addition of his Analytic Hierarchy Process (AHP) for decision making which involves breaking down a problem into its decision elements, arranging them in a hierarchical structure, making judgments on the relative importance of pairs of elements and synthesizing the results. ANP is combination of two parts:

- Network of criteria and sub criteria that control the interactions.
- The network of influences of elements and clusters.

Relationship among the levels is not represented by hierarchies in AHP. This shortcoming is removed in ANP feedback approach. For example, in AHP, importance of criteria determines the importance of alternatives but does not represent importance of alternatives which may have impact on importance of criteria. Therefore linear structure of top to bottom is not applicable for a complex system. The advantage of ANP is the capability of solving the problems in which alternatives and criteria have such interactions that cannot be shown in a hierarchy. When the decision-maker decides to model a problem as a network, it is not necessary to specify levels [17]. A network contains clusters (components, nodes or criteria) and elements (sub criteria) in these clusters [18]. The difference between a hierarchy and a network is shown in Fig. 1 [19]. The node elements may bring influence for some or all the elements of any other node. Relationships in a network are symbolized by arcs, and the directions of arcs signify dependence. Interdependency between two nodes, termed outer dependence, is represented by a two-way arrow, and inner dependencies among elements in a node are symbolized by a looped arc.

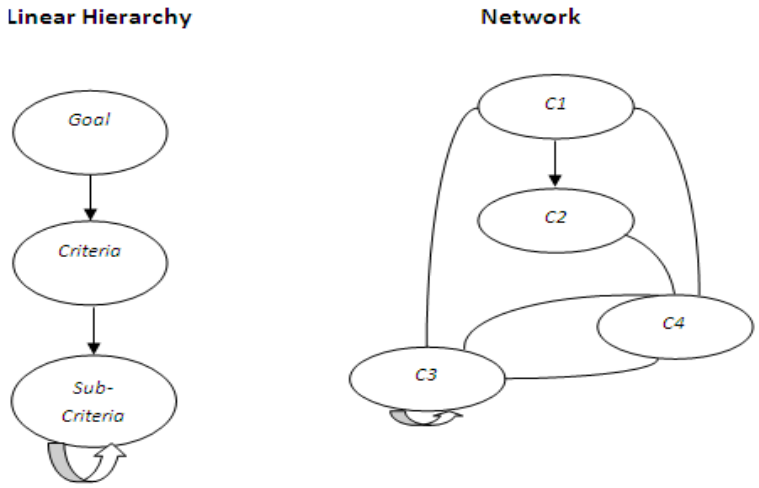

Fig.1 Structural Difference between a Hierarchy and a Network

ANP APPROACH FOR SUPPLIER SELECTION

The research has been executed in an automobile industry. Supplier selection is done for automobile industry manufacturing two types of products on two manufacturing plants. All the components/raw materials are classified using ABC Classification as per practice of industry. The utilization rates of the components/raw materials have been taken from the Bill of Material (BOM) for both the products. 74 suppliers have been approved which satisfies the company norms of quality standards and other technical requirements.

Keeping in view the volume and similarity of work, ANP approach in this research has been applied on a model section consisting of three suppliers. The same methodology can be extended to rest of suppliers for their selection. Selection of a supplier by ANP approach requires a systematic methodology. The various steps involved are illustrated below:

Step- 1 Model Development and Problem Formulation

Based on the literature review many parameters criteria have been identified for selecting a capable supplier. Dickson [20] first proposed the benchmark/foundation for supplier evaluation and selection, who established 23 different criteria, including quality, on-time delivery, price, performance history, warranty policy, technical capability and financial stability, and so on. Weber et al [21] surveyed the frequency of Dickson's 23 criteria and found that price, delivery, quality, and productive capability were mostly applied to measure suppliers' performance. The Quality is regarded the most decisive criterion for supplier selection.

A team is formed of experts from all functional areas within the organization such as sales, marketing, manufacturing, finance, logistics and expertise in supply chain management for identification of decision making criteria. After brain storming five decision criteria for supplier selection has been identified. These are cost, quality, performance history, long term relationship and on time delivery. Out of these three criteria namely cost, quality and long term relationship has been used in this research.

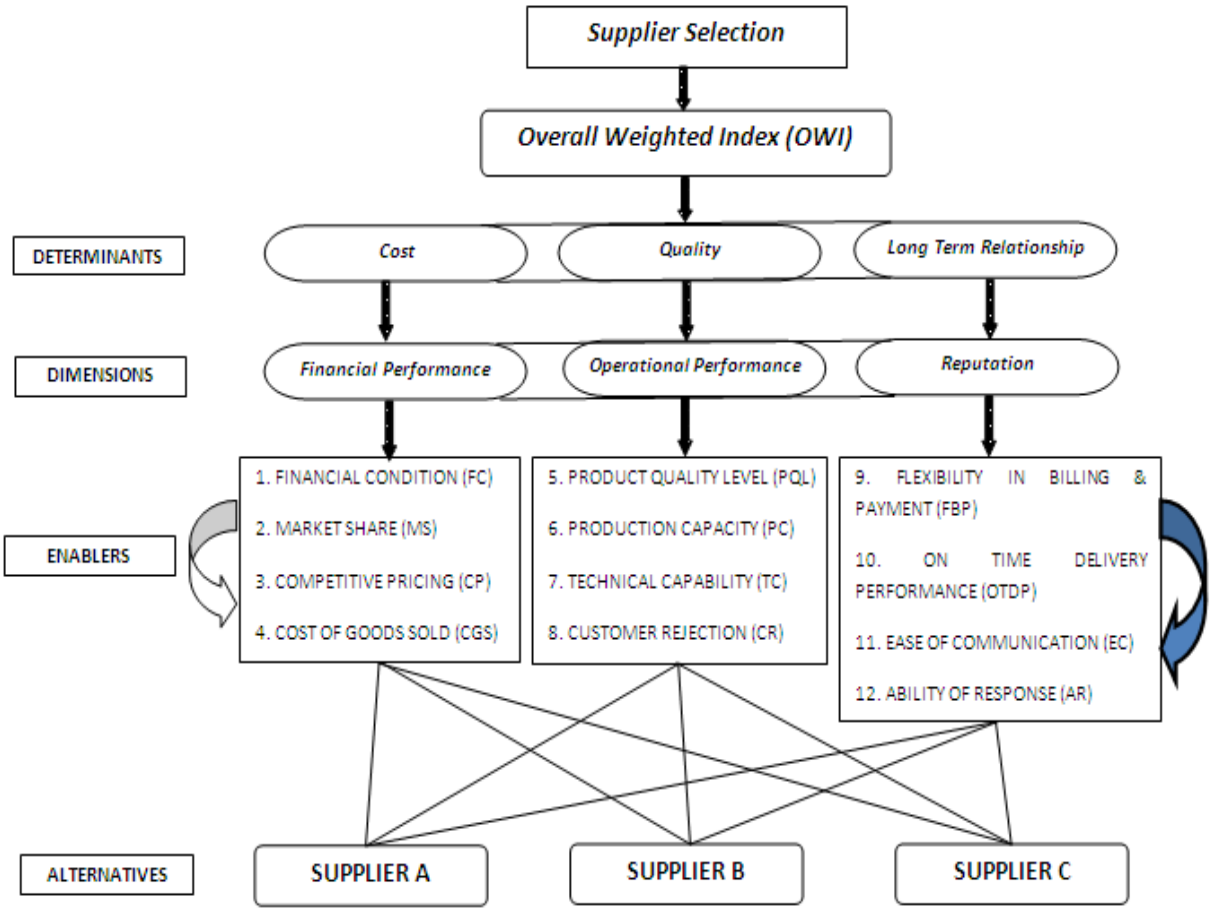

Fig. 2 ANP Model for Supplier Selection

ANP model has been developed based on the criteria identified. The criteria have been classified into various levels for instance determinants, dimensions, and enablers. Generally the higher level criteria or the determinant play a serious role in strategic decision making thus the criteria of Cost, Quality and Long Term Relationship (LTR) of a supplier are grouped in highest level. In the middle-level criteria are named as dimensions, these are Financial

Performance (FP), Operational Performance (OP) and Reputation (REP). The third level criteria in the ANP model are termed as enablers. The enablers support the dimensional criteria as well as other enablers. Hence interdependencies exist among enablers as shown in the figure 1. The various supplier choices are placed at the bottom for the required decision making. Figure 2 graphically depicts the ANP model.

Step -2 Pair wise Comparison of Determinants

A pair wise comparison is made between the determinants for obtaining the relative weights in step 2. The e–vector is calculated after obtaining the relative weights in between the determinants. For this, a question should be asked to make a decision. The question is like "what is the relative impact on selection of supplier, when cost is compared to quality?" The answer on a scale of 1 – 9 (Refer Saaty Scale in Table 1) in was 2 and this is placed as a second entry of cost row. Similarly, for the remaining, the comparisons are made and the weighted priority (e–vector) is calculated as shown in Table 2. These e–vectors would be used for calculation of overall weighted index of alternatives.

Table -1 Saaty Scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favour one over another
5	Strong Importance	Experience and judgment strongly favour one over another
7	Very strong Importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute Importance	The evidence favoring one activity over another is of the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above
Reciprocal of above non-zero numbers	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then activity j has the reciprocal value when compared with i	

Table -2 Pair wise Comparison Matrix for Relative Importance of Determinants

	Cost	Quality	Long Term Relationship	e-Vector
Cost	1	2	3	0.5389
Quality	0.5000	1	2	0.2973
Long Term Relationship	0.3333	0.5000	1	0.1638
	1.8333	3.5000	6	1

Table -3 Pair wise Comparison Matrix for relative importance of Dimensions on Determinant Cost

	FP	OP	REP	e-Vector
FP	1	5	4	0.6214
OP	0.2000	1	6	0.2819
REP	0.2500	0.1667	1	0.0967
Total	1.4500	6.1667	11	1

Table -4 Pair wise Comparison Matrix for attribute enablers under determinant Cost and the dimension Financial Performance (FP)

	FC	MS	CP	CGS	e-Vector
FC	1	4	4	0.3333	0.3274
MS	0.2500	1	0.5000	0.3333	0.0939
CP	0.2500	2	1	0.5000	0.1549
CGS	3	3	2	1	0.4238
TOTAL	4.5000	10	7.5000	2.1666	1

Step -3 Pair wise comparison of Dimensions

In this step, a pair wise comparison matrix is prepared for determining the relative importance of each of these dimensions in the implementation of the supplier model clusters on the determinant. One such matrix for the determinant Cost is shown in Table 3. There will be two more matrices, one for each of the determinants Quality and Long Term Relationship.

Step -4 Pair wise comparison of Enablers

The pair wise comparison of enabler can be carried out at various levels with respect to the upper level dimension and determinants. One such pair wise comparison matrix for Financial Performance (FP) dimension under Cost determinant is shown in Table 4. The number of such pair wise comparison matrices depends on the number of determinants and the dimensions in the ANP model. In this model, 9 such pair – wise comparison matrices are formed.

Step -5 Pairwise Comparison of Matrices for Interdependencies

Pairwise comparison matrices for interdependencies may be prepared for each enabler with reference to the determinant and dimension. One such comparison under determinant Cost is illustrated in Table 5. For each determinant, there will be 12 such matrices at this level of relationship. The e – vectors from these matrices are used in the formation of super matrices. As there are three determinants, 36 such matrices will be formed. The e – vectors from matrix in Table 5 have been used in making of super matrix in Table 6.

Step -6 Supermatrix Formation and Analysis

The super matrix is a partitioned matrix where each sub–matrix is composed of a set of relationships between and within the levels as represented by the decision maker's model. The present model represents three super matrices for each of the three determinants of Cost, Quality and Long Term Relationship, which need to be evaluated. One such super matrix shown in Table 6, presents the results of the relative importance measures for each of the enablers for the determinant Cost. The values of the elements of the super matrix have been imported from the pair–wise comparison matrices of interdependencies. The super matrix is made to converge to obtain a long–term stable set of weights in next stage. For convergence to occur, super matrix needs to be 'column stochastic', i.e. the sum total of each of the columns of the super matrix needs to be one. In this example, convergence is reached at $M^{54.}$ The converged super matrix is shown in table 7.

Table -5 Pairwise Comparison Matrix for Attribute Enablers under Determinant Cost and Dimension Financial Performance (FP)

FC	MS	CP	CGS	e-Vector
MS	1	0.3333	4	0.2842
CP	3	1	5	0.6194
CGS	0.2500	0.2000	1	0.0964
Total	4.2500	1.5333	10	1

Table -6 Super Matrix for Cost before Convergence

COST	FC	MS	CP	CGS	PQL	PC	TC	CR	FBP	OTDP	EC	AR
FC	0	.3896	.1018	.3333	0	0	0	0	0	0	0	0
MS	.2842	0	.5321	.3127	0	0	0	0	0	0	0	0
CP	.6194	.3104	0	.3540	0	0	0	0	0	0	0	0
CGS	.0964	.3000	.3661	0	0	0	0	0	0	0	0	0
PQL	0	0	0	0	0	.1199	.0952	.1561	0	0	0	0
PC	0	0	0	0	.1279	0	.6505	.6196	0	0	0	0
TC	0	0	0	0	.3601	.2721	0	.2243	0	0	0	0
CR	0	0	0	0	.5120	.6080	.2543	0	0	0	0	0
FBP	0	0	0	0	0	0	0	0	0	.0952	.1180	.1279
OTDP	0	0	0	0	0	0	0	0	.3016	0	.2431	.5603
EC	0	0	0	0	0	0	0	0	.1587	.2543	0	.3118
AR	0	0	0	0	0	0	0	0	.5397	.6505	.6389	0

Table -7 Super Matrix for Cost after Convergence

LTR	FC	MS	CP	CGS	PQL	PC	TC	CR	FBP	OTDP	EC	AR
FC	.2063	.2063	.2063	.2063	0	0	0	0	0	0	0	0
MS	.2345	.2345	.2345	.2345	0	0	0	0	0	0	0	0
CP	.3001	.3001	.3001	.3001	0	0	0	0	0	0	0	0
CGS	.2319	.2319	.2319	.2319	0	0	0	0	0	0	0	0
PQL	0	0	0	0	.1131	.1131	.1131	.1131	0	0	0	0
PC	0	0	0	0	.3102	.3102	.3102	.3102	0	0	0	0
TC	0	0	0	0	.2121	.2121	.2121	.2121	0	0	0	0
CR	0	0	0	0	.3218	.3218	.3218	.3218	0	0	0	0
FBP	0	0	0	0	0	0	0	0	.1011	.1011	.1011	.1011
OTDP	0	0	0	0	0	0	0	0	.3133	.3133	.3133	.3133
EC	0	0	0	0	0	0	0	0	.1878	.1878	.1878	.1878
AR	0	0	0	0	0	0	0	0	.3890	.3890	.3890	.3890

Step -7 Evaluations of Alternatives

The final set of pair–wise comparisons is made for the relative impact of each of the alternatives Supplier A, Supplier B and Supplier C on the enablers in influencing the determinants. The number of such pair–wise comparison matrices is dependent on the number of enablers that are included in each of the determinants. In our present case, there are 12 enablers for each of the determinants, which lead to 36 such pair–wise matrices. One such pair–wise comparison matrix is shown in table 5.20, where the impacts of three alternatives are evaluated on the enabler Financial Condition (FC) in influencing the determinant Cost. The e–vectors from this matrix are used in columns 6–8 of compatibility desirability indices matrix in Table 9.

Step -8 Selection of the potential Supplier

The selection of the potential supplier depends on the values of various desirability indices. These desirability indices indicate the relative importance of the alternatives in supporting a determinant. In the present case, for each determinant, there are three desirability indices, one each for the three suppliers A, B, and C. The desirability index, *Dia*, for the alternative i and the determinant a is defined as

$$D_{ia} \equiv \sum_{i=1}^{j} \sum_{k=1}^{Kja} P_{ja} A^{D}_{kja} A^{I}_{kja} S_{ikja}$$

Where P_{ja} is the relative importance of dimension *j* on the determinant of a,

A^{D}_{kja} is the relative importance of an enabler *k* of dimension j in the determinant of (D) relationships between component levels,

A^{I}_{kja} is the stabilized importance weight of the enabler *k* in the dimension *j* and determinant a cluster for interdependency (I) relationships. These values are taken from the converged supermatrix.

S_{ikja} is the relative impact of alternative *i* on enabler *k* of dimension *j* for determinant a.

K_{ja} is the index set of enablers for dimension *j* of determinant *a*, and *J* is the index set for dimension *j*.

Table 9 shows the desirability indices calculated for the determinant Long Term Relationship (D_i LTR). It is based on using the relative weights obtained from the pairwise comparison of alternatives, dimensions and weights of enablers from the converged super matrix. These weights are used to calculate a score for the determinants of Overall weighted index (OWI) for each of the alternatives.

Step - 9 Calculation of Overall Weighted Index (OWI)

The overall weighted index (OWI) for an alternative i is the summation of the products of the desirability indices (Dia) and the relative importance weights of the determinants for the selection of the suppliers. The ANP model is capable of handling interdependencies and present decision model provides values in the form of weighted index for the three different suppliers in order to select the final supplier. The Overall Weighted Index (OWI) is the product of the desirability indices and the relative importance weights of the determinants for supplier selection. Table 10 indicates that for supplier selection of the mentioned component, the most significant supplier is Supplier A followed by supplier B and Supplier C. Similarly ANP approach has been used for supplier selection of other raw materials/components.

Table -8 Pair wise Comparison Matrix for the Relative Importance of Alternatives on Enablers for Cost/Financial Performance (FP)/Financial Condition (FC)

	Supplier A	Supplier B	Supplier C	e-Vector
Supplier A	1	4	3	0.5896
Supplier B	0.2500	1	4	0.2827
Supplier C	0.3333	.2500	1	0.1277
Total	1.5833	5.2500	8	1

Table -9 Compatibility Desirability Indices for Cost

Dimension	Enablers	Pja	A^{D}kja	A^{I}kja	S1	S2	S3	Supplier A	Supplier B	Supplier C
FP	FC	0.6214	0.3274	0.2063	0.5896	0.2827	0.1277	0.0247	0.0118	0.0054
	MS	0.6214	0.0939	0.2345	0.6079	0.2722	0.1199	0.0083	0.0037	0.0016
	CP	0.6214	0.1549	0.3001	0.6777	0.2418	0.1281	0.0195	0.0069	0.0036
	CGS	0.6214	0.4238	0.2319	0.6505	0.2543	0.0952	0.0397	0.0155	0.0058
OP	PQL	0.2819	0.0735	0.1131	0.6710	0.2438	0.0852	0.0016	0.0005	0.0002
	PC	0.2819	0.4890	0.3102	0.6194	0.2842	0.0964	0.0265	0.0122	0.0041
	TC	0.2819	0.3049	0.2121	0.5963	0.3191	0.0846	0.0108	0.0058	0.0015
	CR	0.2819	0.1326	0.3218	0.6389	0.2431	0.1180	0.0076	0.0029	0.0014
REP	FBP	0.0967	0.0816	0.1011	0.6505	0.2543	0.0952	0.0005	0.00006	0.00007
	OTDP	0.0967	0.2344	0.3133	0.6588	0.2246	0.1166	0.0046	0.0016	0.0008
	EC	0.0967	0.1744	0.1878	0.6853	0.2213	0.0934	0.0022	0.0006	0.0003
	AR	0.0967	0.5096	0.3890	0.6651	0.2311	0.1038	0.0127	0.0044	0.0019
Total								0.1587	0.0659	0.0267

Table -10 Overall Weighted Index (OWI) for various Suppliers

	Criteria			OWI
Alternatives	Cost	Quality	Long Term Relationship	
Weight	0.5389	0.2973	0.1638	
Supplier A	0.1587	0.1531	0.1591	.1571
Supplier B	0.0659	0.0768	0.0697	.0757
Supplier C	0.0267	0.0354	0.0326	.0302

CONCLUSION

It has been observed that Cost is the most important criteria in the selection of supplier for an automobile organization. This is followed by Quality and Long Term Relationship. In the selection of the supplier, automobile organization should take care of the Cost and should also increase the Quality. Long term relationship is less supported. Paper presented an ANP model for supplier selection of an automobile organization. It has become highly necessary for organizations to select the best supplier in the present scenario. Any wrong selection of supplier will affect the company's overall performance. As discussed in the literature review, comprehensive research is done in attempt to arrive at systematic framework for supplier evaluation and selection. This paper is an endeavor to utilize ANP for ranking the potential suppliers and making the final selection.

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