Ranking Supplier by using Sustainable Supplier Evaluation Criteria (SSEC) and Multi Criteria Decision Making (MCDM) Method using AHP and ANP Process

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Abstract: *Most organizations prefer to outsource the activities which are not cost-efficient. With regard to the huge amount of expenditure in this area, proper selection of the desirable suppliers becomes significant. Previous studies indicated that the criteria of supplier selection might not be always independent, and this fact implies the existence of interdependencies among them that may affect the supplier selection. This study presents and compares two multi- attribute decision making (MADM) techniques to deal with the supplier selection problem with and without interdependency. An Analytic Hierarchy Process (AHP), and its extension, Analytic Network Process (ANP) are applied to find the final priorities of the suppliers respectively for the cases of independency and interdependency in an automotive manufacturing company. The two techniques lead to different rankings for the potential suppliers. The whole process is illustrated in a case study.*

Keywords: Supplier Selection, Interdependencies, Decision Makers, Analytic Hierarchy Process, Analytic Network Process.

I. INTRODUCTION

Several criteria have been identified for supplier selection, such as the net price, quality, delivery, capacity and communication systems, historical supplier performance and so forth (Bello, 2003 [4]). Multi-criteria decision-making (MCDM) techniques are typically utilized to rank potential suppliers of an outsourced part. These criteria play a key role in measuring performance of the suppliers and subsequently specifying the optimal ordering quantities to the favorable ones. Presented by some of the researchers (Ghodsypour and O'Brien, 1998 [10]; Wang et al., 2004 [25]; Hua et al. 2007 [12]) Analytic Hierarchy Process (AHP) is one of the most common techniques to be used in supplier selection. AHP makes trade-offs between quantitative and qualitative criteria in pair-wise comparison matrices, generated by decision makers, and rates the potential suppliers (Wang et al., 2004 [25]). Although the efficiency of AHP is undeniable, there is a significant drawback for it. This method is not capable of taking the possible interrelations among the criteria into account. This is discussed in the following sections. One of the main objectives of analysis is to understand and also to draw insights for the information collected. Therefore data analysis is the process to make collected data more understandable and summarizing the bulk information collected in the study. The type of results is expected for a study determines which analysis has to be conducted .In this paper we used Analytic Hierarchy Process- AHP and Analytic Network Process –ANP to analyze the data.

II. ANALYTIC HIERARCHY PROCESS (AHP)

Saaty (1980) [16] based the idea of AHP on pairwise comparisons between each two attributes which can be tangible or intangible. In this regard he proposed a 1-9 scale to compare the importance of those attributes with respect to a property they have in common. The smaller element is considered to be the unit and the decision maker estimates how many times more important, preferable, or generally "dominant "is one over another. The AHP has found widespread application in decision making problems, involving multiple criterion systems of many levels. The strongest features of the AHP are its ability to generate numerical priorities from the subjective knowledge expressed in the estimates of paired comparison matrices. By means of that, it makes some kind of trade-off between tangible and intangible factors to find the best alternatives (Liu and Hai, 2005 [14]). In order to achieve the overall ranking of the alternatives, the weights for major criteria should be attained through pairwise comparisons. The following steps show how AHP proceeds to obtain a final priority vector for alternatives:

Step 1 : Pairwise comparison between criteria;

Step 2 : Raising the attained matrix to an arbitrarily large power;

Step 3 : Normalizing row sums of raised matrix

Step 4 : Rating the alternatives in terms of the criteria;

Step 5 : Synthesizing the vectors from the last two steps to get the final priority vectors for the alternatives.

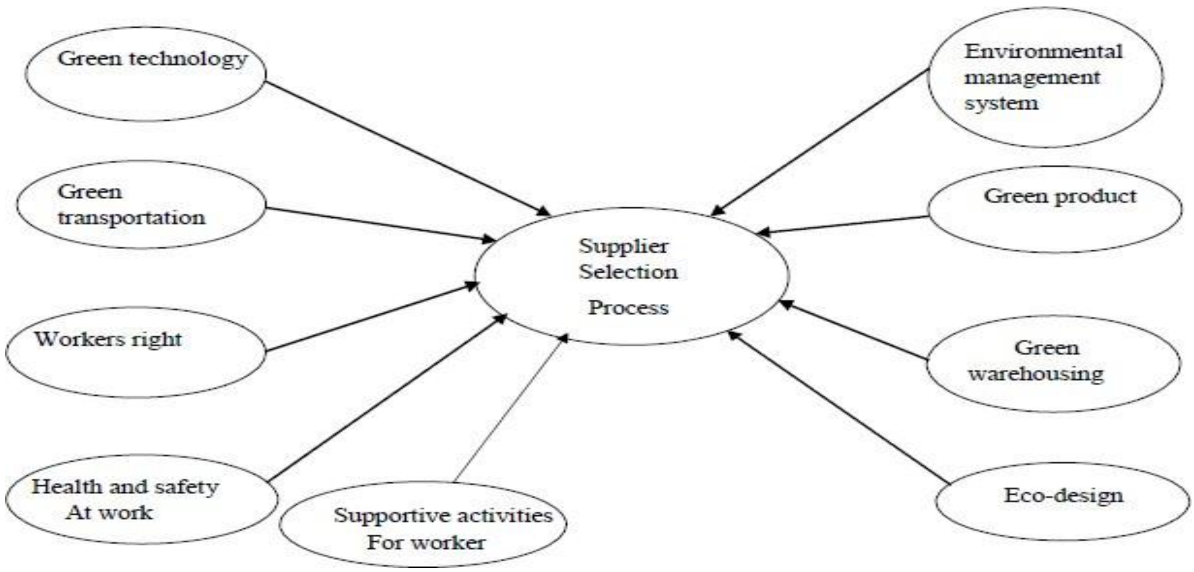


Fig. I: Criteria for Supplier Selection Process

Scale	Numerical Rating	Reciprocal
Extremely Preferred	9	1/9
Very Strong to Extremely	8	1/8
Very Strongly Preferred	7	1/7
Strongly to Very Strongly	6	1/6
Strongly Preferred	5	1/5
Moderately to Strongly	4	¼
Moderately Preferred	3	1/3
Equality to Moderately	2	½
Equally Preferred	1	1

Table I. Numerical Ratings and Its Reciprocals

	R (1)	R (2)	R (3)	1 2 3 4 5 6 7 8 9	Average
Green technology	9	8	9		8.66
Green transportation	8	8	9		8.33
Workers right	9	9	8		8.66
Health and safety At work	9	9	8		8.66
Supportive activities for women	8	9	8		8.33
Environmental management system	7	8	7		7.33
Green product	6	5	6		5.66
Green warehousing	7	6	7		6.66
Eco-design	8	9	9		8.66

Table II. The Saaty Rating Scale

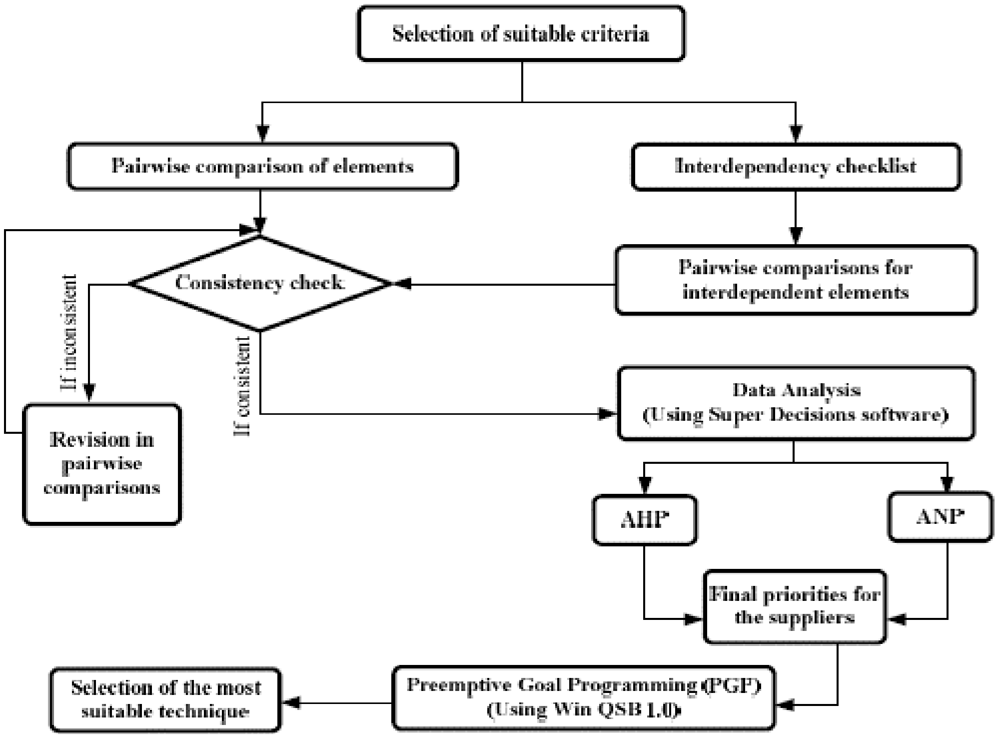
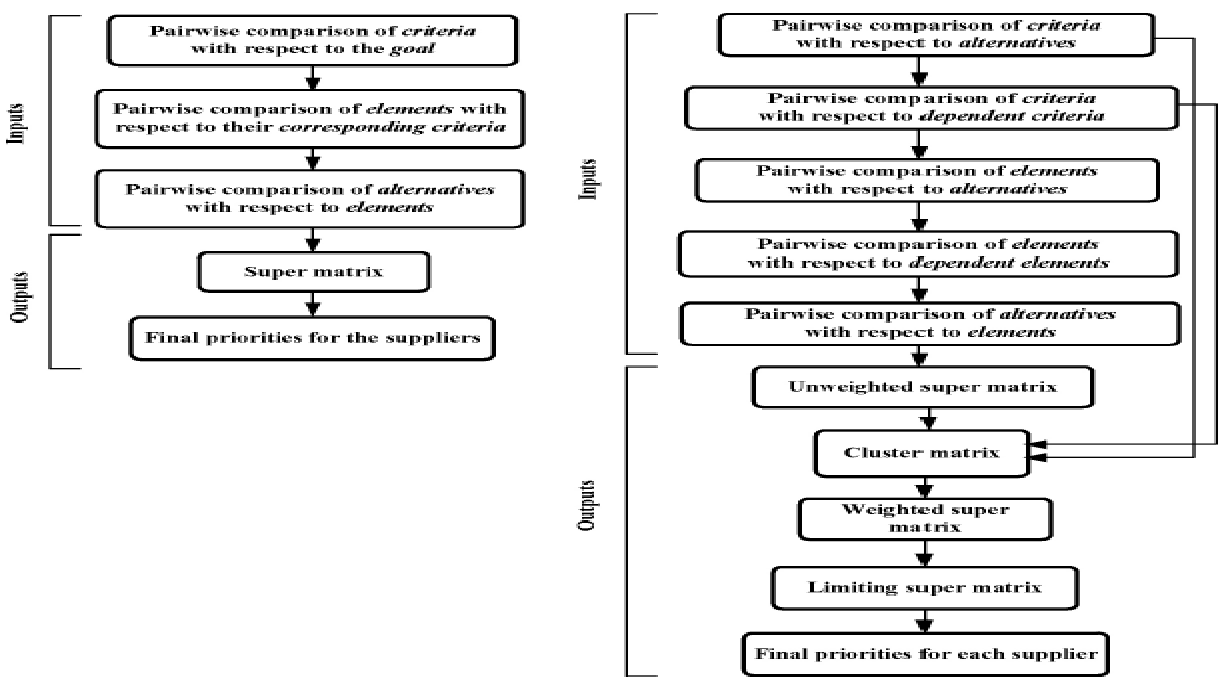


Fig.2: Elements Corresponding To Six Major Criteria



a) b)

Fig .II (a) Inputs And Outputs Required To Form The AHP Model (Left side) and

II (b) Inputs And Outputs Required To Form The ANP Model (right side)

In order to present a more comprehensive framework for the supplier selection process, the sub-criteria (elements) of the major criteria were identified from the relevant literature to form another level. Above shown figure outlines the most commonly used elements corresponding to each of the six major criteria. Thus for making determination of suitable supplier category we have obtained the input data values of each priorities from the Literature titled as "Ranking supplier by using sustainable supplier evaluation criteria (SSEC) and multi criteria decision making (MCDM) method by Tallat Mehmood Farnaz . The input datas obtained is tabulated in the following table.

PAIR WISE COMPARISON	MS TOOS	PART SAZAN	AZIN TANEH	ROBAT MACHINE	AID CO PRESS	MAJIN SANAT	SHAMIM PAJOUESH	NTH ROOT PRIORITY WEIGHT	EIGEN VECTOR (Λ)
MS TOOS	1	1/3	4	4	5	1/2	1/4	1.282	0.188
PART SAZAN	3	1	3	6	6	3	1/2	3.083	0.428
AZIN TANEH	3	1/3	1	8	7	2	1/5	2.062	0.298
ROBAT MACHINE	¼	1/5	1/6	1	4	1	1/6	0.6	0.069
AIDCO PRESS	1/5	1/4	1/7	1/4	2	1/6	4	0.278	0.054
MAJIN SANAT	1	1	1	3	1	3	1/2	0.346	0.246
SHAMIM PAJOUESH	2	2	2	1/4	4	4	3	0.244	0.268
	10.56	5.14	11.62	22.66	29	13.75	14.25	7.895	1.551

Table III. : Comparison Matrix for Environmental Management System

λ1 = First element value of N^th vector / total of N^th vector values , so then λ1 = 5.266,

similarly λ2 = 5.49, λ3 = 5.784, λ4 = 5.771, λ5 = 5.261, λ6= 5.892, λ7= 5.986

λ max = 5.986

CI = 5.986 – 7 / 7-1 = 0.169.

The comparison matrix for environmental management system is tabulated and by hence we can able to determine the eigen Values (λ) for individual suppliers. There are several methods for calculating eigen vector. Multiplying together the entries in each row of the matrix and then taking the n ^th root of that product gives a very good approximation to the correct answer.

The n^th roots are summed and that sum is used to normalize the eigenvector elements. In the matrix above the first row 1.282 and that is divided by the total value of n^th matrix to give the first element in the eigen vector.

Note: Same as the determination of eigen vectors of environmental management system, similarly the eigen values of all other Priorities is determined and it is tabulated in the following table.

Suppliers	**Environ mental manage ment system**	**Green product**	**Green wareh ousing**	**Eco design**	**Green technolo gy**	**Green transpo rtation**	**Workers right**	**Health and safety**	**Support activities**
Ms toos	0.188	0.221	0.210	0.240	0.100	0.115	0.141	0.134	0.178
Part sazan	0.428	0.538	0.578	0.478	0.337	0.358	0.389	0.278	0.428

Azin taneh	0.298	0.178	0.278	0.780	0.063	0.055	0.333	0.502	0.288
Robat machine	0.069	0.049	0.490	0.390	0.174	0.198	0.092	0.056	0.069
Aid copress	0.054	0.034	0.054	0.154	0.325	0.271	0.043	0.027	0.034
Majin sanat	0.246	0.166	0.186	0.156	1.000	1.000	1.000	1.000	0.256
Shamim pajouhes h	0.268	0.580	0.480	0.450	1.0245	0.589	0.025	0.980	0.258

Table IV: Determination of Suitable Supplier Category

By making comparison tabulations for all priority based suppliers, the overall matrix suggested that supplier B is better than others in terms of all aspects whereas supplier C is better in collaboration. Multiply Option performance matrix (OPM) by the relative value vector (RVV) to obtain the vector for selecting the supplier.

For supplier A

$(0.188\times0.58) + (0.428 \times 0.90) + (0.298 \times 1.12) + (0.069 \times 1.24) + (0.054\times 1.32) +(0.246 \times 1.41)+(0.268 \times 1.45) = 1.7203$

Here the priority values of all seven suppliers have been obtained by making comparative matrix of all suppliers.

Similarly,

For supplier B = 1.8963, For supplier C = 1.5896,For supplier D =1.6325, For supplier E = 1.2569 For supplier F = 1.2278,

For supplier G = 1.5621

DEFINITION OF CONSISTENCY RATIO VALUES

$\lambda1=[(1)] = 0.0089$

Similarly, $\lambda2 = 0.0080$, $\lambda3 = 0.0081$, $\lambda4 = 0.0092$, $\lambda5 = 0.0095$, $\lambda6= 0.0089$, $\lambda7=0.0081$, $\lambda8=0.0082$,$\lambda9=0.00809$

Maximum eigen value (λmax) = $\lambda1+\lambda2+\lambda3+\lambda4+\lambda5+\lambda6+\lambda7+\lambda8+\lambda9 = 0.0092 /9 = 0.0010229$

Therefore Consistency Index (C.I.) =0.001022-9/9-1 =1.12487

Therefore Consistency Ratio (C.R.) = CI /RI = 1.12487/ 1.45= 0.7757724

Saaty argues that a CR >0.1indicates that the judgments are at the limit of consistency though CR's > 0.1 (but not too much more) have to be accepted sometimes. In this instance, we are on safe ground. A CR as high as, say, 0.9 would mean that the pair wise judgments are just about random and are completely untrustworthy.

Note: Hence hereby we have determine the individual eigen values from comparison tabulation of each priorities and then the Eigen maximum (λmax) values are obtained . Then the λmax values are substituted in Consistency Index (C.I.) to find Out the Consistency Ratio (C.R.) to provide the ranking preferences of the suppliers.

Sr. No.	Supplier (A,B,C,D,E,F,G)	Priorities	Rank (Preferences)
1	1.7203	G Tech	II
2	1.8963	GT	I
3	1.5896	WR	IV
4	1.6325	HSR	III
5	1.2569	SAW	VI
6	1.2278	EMS	VII
7	1.5621	GP	V

Table V : Ranking Preferences Of Suppliers

III. ANALYTIC NETWORK PROCESS –ANP

Developed by Thomas L. Saaty in 1996, Analytic Network Process (ANP) is a method pertaining to the American School of Multiple Criteria Decision Making (MCDM). Considered a generalization of the Analytic Hierarchy Process (AHP), the ANP, uses a grid (instead of hierarchy) without the necessity to specify levels, besides allowing relations of dependence between its clusters and elements (nodes) (SAATY, 2005).

Priorties (aspects)	0.064	0.1625	0.1345	0.0815	0.0355	0.0666	0.0179	0.0083	0.1996	0.2288	
Supplier	**GTech**	**MS**	**GT**	**WR**	**HSR**	**SAW**	**EMS**	**GP**	**ED**	**GW**	**Totals**
Ms toos	1.0000	1.0000	1.0000	0.1429	0.3952	0.3952	1.0000	1.0000	0.3952	1.0000	0.7477
Part sazan	1.0000	0.3952	1.0000	0.1429	0.3952	0.3952	0.3952	1.0000	0.3952	0.3952	0.5002
Azintaneh	0.1428	0.0937	1.0000	1.0000	1.0000	1.0000	0.0937	0.1429	1.0000	0.3952	0.6354
Robat Machine	1.0000	0.0937	1.0000	1.0000	1.0000	1.0000	0.3952	0.1429	0.0937	0.3952	0.5155
AID co press	1.0000	0.3952	1.0000	0.1429	0.0937	0.0937	0.3952	1.0000	0.3952	0.3952	0.4694
Majin sanat	0.1428	0.0937	0.1428	0.1429	0.3952	0.3952	0.0937	0.1429	1.0000	0.0937	0.3196
Shamim pajouhesh	1.0000	0.0937	1.0000	1.0000	1.0000	1.0000	0.3952	1.0000	0.0937	1.0000	0.6610

Table.VI: Suppliers And Numerical Equivalence Of The Ratings According To The Elements

And hence again we have obtained the input data values of each priorities from the Literature titled as "Ranking supplier by using sustainable supplier evaluation criteria (SSEC) and multi criteria decision making (MCDM) method by Tallat Mehmood Farnaz . The input datas obtained is tabulated in the above table.

Aspects		**Social aspects**			**Environmental aspects**			
Criteria		**G Tech**	**GT**	**WR**	**HSR**	**SAW**	**EMS**	**GP**
Priority matrix	FC	0.0648	0.0648	0.0648	0.0648	0.0648	0.0648	0.0648
	MS	0.1625	0.1625	0.1625	0.1625	0.1625	0.1625	0.1625
	TC	0.1345	0.1345	0.1345	0.1345	0.1345	0.1345	0.1345
Cluster priorities	ACT	0.0815	0.0815	0.0815	0.0815	0.0815	0.0815	0.0815
	EC	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355	0.0355
	WC	0.0666	0.0666	0.0666	0.0666	0.0666	0.0666	0.0666
Limiting priorities	D	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179
	F	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083
	P	0.1996	0.1996	0.1996	0.1996	0.1996	0.1996	0.1996
	Q	0.2288	0.2288	0.2288	0.2288	0.2288	0.2288	0.2288

Table VII: Limit Matrix

IV. DISCUSSION OF THE RESULTS

1. The elements presented the higher priorities in the social aspects, environmental aspects respectively. In *Cluster Capability* the highest priorities were given to the elements .

2. In the social aspects, the elements of higher weights. This comes from the judgements of the decisions that gave a higher importance . Both elements are very influent nowadays for much has been told about environment maintainability.

3. With relation to the social aspects, the elements of higher weights are Q and P which are relevant for the

suppliers' selection process. Therefore, each element obtained a priority that represents its importance in the selection of supplier for the company.

Aspects	Criteria	Social aspects	Environmental aspects
Priority matrix	G Tech	0.1791	0.0648
	GT	0.4492	0.1625
	WR	0.3717	0.1345
Cluster priorities	HSR	0.4439	0.0815
	SAW	0.1936	0.0355
	EMS	0.3626	0.0666
Limiting priorities	GP	0.0394	0.0179
	ED	0.0183	0.0083
	GW	0.4391	0.1996
	EA	0.5032	0.2288

Table. VIII : Normalized By Cluster Priorities And Limiting Priorities

The final ranking of the suppliers is presented in Figure. In this fictitious illustrative example, the supplier that presents a higher proportion of the ranking is the Supplier followed by suppliers 1, 7, 3, 4, 2, 5 , 6.

V. FINAL CONSIDERATIONS

- Currently, the globalization and the competitiveness has demanded that the supplies chain become more efficient. And the appropriate choice of the supply is relevant for a production of good quality and low cost. Inadequate selection of suppliers brings unsatisfaction to costumer and prejudice to company as well.
- Multiple Criteria Decision Making methods (MCDM), being among them the ANP, has been much appropriated for the SSP solution. ANP is characterized for including qualitative and quantitative criteria, structured in network, where the dependence relations among elements are allowed.
- The implementation of the Ratings model in the ANP consists in giving categories to the criteria in order to classify the alternatives, so as to select the best suppliers. With the advantages to allow the reduction of the number of judgements required to the decisor and allows the analysis of cases in which the alternatives are numerous.
- Besides making possible the insertion and retreat of alternatives during the decision process, without causing inversion of ranking. Such characteristics are advantageous as they allow the representation of a complex problem of supplier selection, making it more realistic.

VI. CONCLUSION

This research aims at solving the problem of supplier selection of Renault Group in Iran based on sustainability criteria through a questionnaire-based survey for determining the most suitable criteria and measuring their importance and applicability and applying AHP and ANP , as one of the most widely used decision making techniques, for ranking the suppliers and improving the lowest ranked supplier sustainability performance.

VII. FUTURE WORKS

There are several opportunities to extend this research in the future. The first objective of this research focused on sustainability criteria for evaluation of suppliers' performance. Adding the carbon management criteria and their corresponding sub-criteria 50 to this list could be worthy for the future work. Another room for future research that would be of interest is using fuzzy numbers for collecting data set. Sustainable supplier selection comprises ambiguity and fuzziness in a real life. Thus, fuzzy numbers are very useful to deal with imprecision and vagueness for data collection in a real life case study. Also, using other MCDEM methods as FPP and comparing their results with this study can be considered new idea for developing this study.

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