ISAHP 2005, Honolulu, Hawaii, July 8-10, 2003

SUPPLIER SELECTION AND PLANNING MODEL USING AHP

Heung Suk Hwang [1]

1: Department of Business Administration, Kainan University, Taiwan
No. 1 Kainan Rd., Lu-jhu, Taoyuan, Taiwan 338,
e-mail : hshwang@mail.knu.edu.tw

Chun-Ling Chuang [2]
2: Department of Information Management, Kainan University, Taiwan
No. 1 Kainan Rd., Lu-jhu, Taoyuan, Taiwan 338,
e-mail : clchuang@mail.knu.edu.tw

Meng-Jong [3]
3: Department of Information Management, Kainan University, Taiwan
No. 1 Kainan Rd., Lu-jhu, Taoyuan, Taiwan 338,
e-mail : mjkuan@mail.knu.edu.tw

Keywords: Supplier selection, AHP, MCDM, Fuzzy set ranking

Summary: *Supplier selection is a multi-criteria decision making problem which includes evaluation factors. In order to select the best suppliers it is crucial to considering the both qualitative and quantitative factors simultaneously. In the supplier selection process, manager also has to consider multi- criteria factors related. Thus the integration of all the multi-criteria analysis and those analysis results by multi-analysis teams has an important meaning in supply chain design. In this paper we suggest a supplier selection analysis problem considering both by AHP method and integration method of analysis results. The proposed first analysis model using AHP which is a three-step decision analysis model which converts the qualitative factors of suppliers transferred into the quantitative measure reliability. Then, the integration model integrates the results of multi-analysis and selects the best supplier. We develop a computer program for both the AHP model and for integration model.*

1. Introduction

The purpose of this study is to develop a supplier's performance evaluation model for a third party logistics (TPL) in supply chain management (SCM). Recently, with the increasing trends of the study in the third party logistics system (TPL) that some of production of supply chain works are outsource to the other companies, the supplier performance evaluation model for TPL becomes one of the important research areas. The supplier performance analysis problem is one of the multi-criteria decision making (MCDM) problem considering a lot of factors in a hierarchical structure of decision analysis system. Thus in this study we used a MCDM method for supplier selection problem.

Recently, the outsourcing problem in supply center and its practices have evolved significantly in the last 20 years for the purchasing managers. These researches have shown that suppliers are becoming increasingly critical for the competitive success cost reduction. This research is concerned with supplier selection problem under the condition of high service level for customers, total logistics cost saving, and supply efficiency increasing. The major researches on suppliers selection problem are as follows: Boer (2001) reviewed the methods of supplier selection problems, Ghodsypour and O'Brien (1998) used an integrated analytic hierarchy process to overcome the multi-criteria decision problem, Dulmin and Mininno (2003) used multi-criteria decision analysis method in supplier selection problem, and Wang and

1. Corresponding Author

Huang (2004) used a product-driven method for supply chain selection using integrated multi-criteria decision making methodology. A great deal of studies have examined evaluation problems for the suppliers selection, but the results of these studies do not provide a basis upon which to construct comprehensive evaluation criteria in terms of suppliers performance evaluation or to identify relative weights of these criteria. We propose a method to select supplier for the third party logistics (TPL) using multi-attribute decision analysis method. First, we use the solution methodology of analytic hierarchy process (AHP) to select the supplier with lots of factors, second, we apply the fuzzy set ranking methodologies to integrate the special decision problems, and then we develop computer programs and demonstrate a methodology for the supplier evaluation based decision support system using this computer programs. These programs can transform several individual multi-criteria rank-ordered lists of decision alternatives into one aggregated and prioritized rank-ordered list. We apply this model in supplier evaluation problem of third party logistics and compared with the results with that of other methods and show the sample outputs.

2. Conventional Suppliers Performance Evaluation and Third Party Logistics

Third party logistics is originated by the council of logistics management (CLM) of United State. For the purpose of the improvement of customer service, the logistics cost saving, and logistics management improvement, a part of supply chain works is transferred to outsourcing. Recently, there are many researches on the supplier selection problems using AHP, and mathematical programming methods.

This kind of third party logistics has several advantages and disadvantages instead of working by their own companies or sub-companies. We can summarize as following;

Advantages:

- Economical advantages by outsourcing to a specialized company,
- The risk can be reduced.

Disadvantages:

- Uncertainty of services,
- The beliefs will be worse by the customers,
- Internal company information security problem,
- Labor problem by reducing the workers for outsourcing part of work,
- Difficulties of fast reply to customer claims,
- Difficulties of knowledge accumulation for outsourcing area.

Because of these disadvantages, it is very important to evaluate the supplier selection problems considering the most of important factors of supplier evaluation indicators.

The objectives of the outsourcing policy in TPL is concerned with customers to service with a customer centric new logistics service level with a good supplier selection, thus it has been an important evaluation in logistics decision area. The conventional approach of supplier selection process is given by Figure 1.

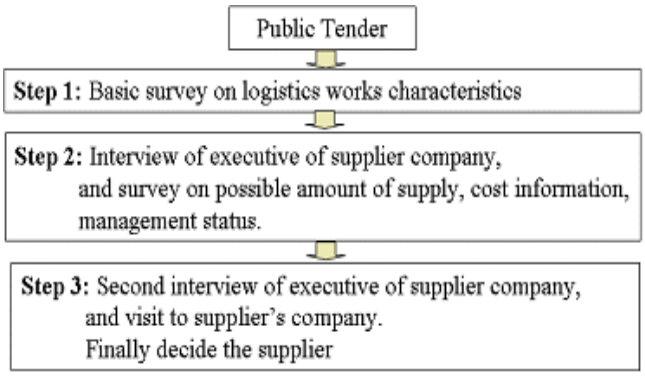

Figure 1. Conventional process of supplier selection

This supplier selection problem has to be evaluated considering all the related supplier performance indicators and evaluated by a hierarchical decision structure, but the conventional process for supplier

selection didn't considered these major analysis factors. There are many difficulties in analyzing to select suppliers such as:

- The increasing of factors to be considered,
- Difficulties for holding in common the SCM information between related industries,
- Difficulties of evaluation for the supplier's performance,
- Strategic priority of objects and weighted values.

In this study, we propose a systematic approach and evaluation method using AHP and fuzzy-AHP methods to consider the hierarchical decision structure considering all the related factors and we develop computer softwares for the proposed method. Figure 2 shows the schematic diagram of proposed model.

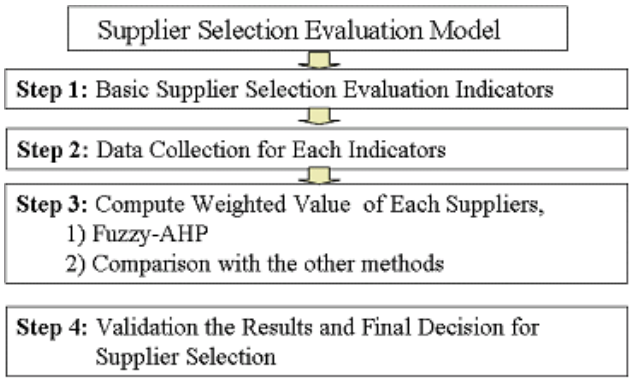

Figure 2. Supplier selection model

3. A Decision Analysis Model for Supplier Selection

3.1 Fuzzy-AHP Method

The theory of fuzzy sets has extended traditional mathematical decision theories so that they can cope well with any vagueness problems which cannot adequately be treated by probability distributions. The impacts and the relationships among the characteristics in any decision problems can sometimes be described only by vague verbal descriptions. The concepts and rules of fuzzy decision making provide us with the necessary tools for structuring a decision from a kind of information. The model used in this study had a limited capability in studying the fuzzy set priority that could be obtained from the summed frequency matrix of Shannon (1986) method. The fuzzy priority is computed and compared with the rank order of Shannon method. The fundamental concept of fuzzy set priority relation R was derived from the result obtained by Shannon method.

From the Shannon's summed frequency matrix for complementary cells, A_{ij} and A_{ji}, an additional fuzzy set matrix was made by considering $A_{ij} = 1 - A_{ji}$ for all cells. The fuzzy matrix complement cell values sum to 1 and fuzzy set difference matrix is defined as follows:

$$R - R^T = \text{U(A,B)-U(B, A), if U(A, B)>U(B, A),}$$
$$= 0 \quad \text{otherwise}$$

where, for U(A, B) quantifies, A is preferable to B.

To obtain fuzzy preferences, the following five steps were considered:

Step 1 : Find the summed frequency matrix (using Shannon method)

Step 2 : Find the fuzzy set matrix R which is the summed frequency matrix divided by the total number of evaluators

Step 3 : Find the difference matrix

$$R - R^T = \text{U(A, B)-U(B, A), if U(A, B) > U(B, A),}$$
$$= 0 \quad \text{otherwise}$$

where, for U(A,B) quantifies, A is preferable to B.

Step 4 : Determine the portion of each project that is not dominated as follows :

$$A_{ColA}^{ND} = 1 - \max\left(X_{1.ColA}, X_{2.ColA}, \ldots, X_{n.ColA} \right)$$

Step 5: The priority of the fuzzy set is then the rank order of XND values with a decreasing order. An example is shown as follows:

$$R = \begin{bmatrix} 0.0 & 0.8 & 0.6 & 0.6 \\ 0.2 & 0.0 & 0.0 & 0.4 \\ 0.4 & 0.1 & 0.0 & 0.4 \\ 0.4 & 0.6 & 0.6 & 0.0 \end{bmatrix} \qquad R^T = \begin{bmatrix} 0.0 & 0.2 & 0.4 & 0.4 \\ 0.8 & 0.0 & 0.1 & 0.6 \\ 0.6 & 0.0 & 0.0 & 0.6 \\ 0.6 & 0.4 & 0.4 & 0.0 \end{bmatrix}$$

$$R - R^T = \begin{bmatrix} 0.0 & 0.6 & 0.2 & 0.2 \\ 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.1 & 0.0 & 0.0 \\ 0.0 & 0.2 & 0.2 & 0.0 \end{bmatrix}$$

X_A^{ND} = 1 - Max(0.0) = 1 - 0.0 = 1.0, X_B^{ND} = 1 - Max(1.0) = 1 – 0.6 = 0.4

X_C^{ND} = 1 - Max(0.2) = 1 - 0.2 = 0.8, X_D^{ND} = 1 - Max(0.2) = 1 - 0.2 = 0.8

Thus, the fuzzy set priority score is given by 1.0 > 0.8 > 0.8 > 0.4 and the alternative priority is given by A > C > D > B.

3.2 Evaluation for Supplier Selection (Example)

Step 1: Basic Supplier Selection Indicators and AHP Structure
To construct the hierarchy structure of AHP decision process, we use the integrated decision analysis model (Hwang, 2004) which can drive out the indicators by web-based brainstorming. For example the results of brainstorming ranking of the 3 major indicators and 11 most important sub-indicators are shown in Table 1. Four supplier candidates are considered in this example.

Table 1. Supplier Selection Indicators

Major indicators	Sub-indicators
1. Serviceability	Meet the lead time
	Inventor rotation rate
	Lead time
	Customer satisfaction
	Market share
2.Supply capability	Production flexibility
	Multi-item production capability
	New item development/production capability
3. Quality	Quality assurance
	Return penalty
	After service level

These indicators can be transferred to AHP structure as Figure 3 and 4 which show the sample output of alternative generated by brainstorming process and construct the decision structure of the example of supplier selection problem by the integrated decision analysis model (Hwang, 2004).

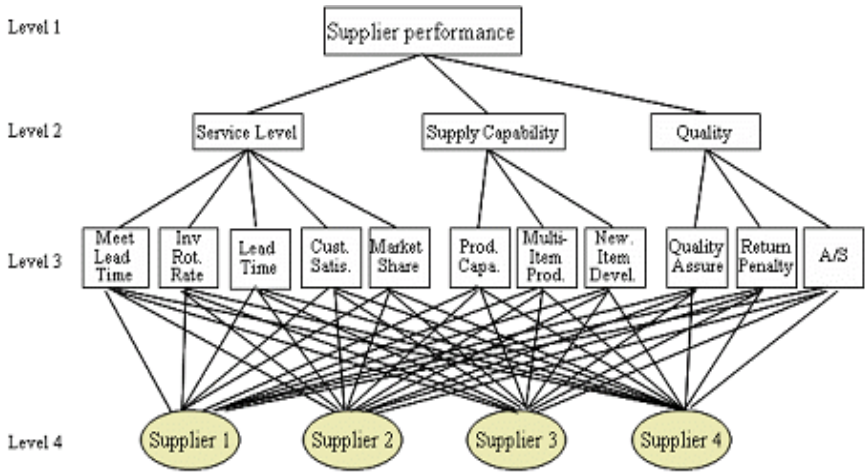

Figure 3. AHP structure of example problem

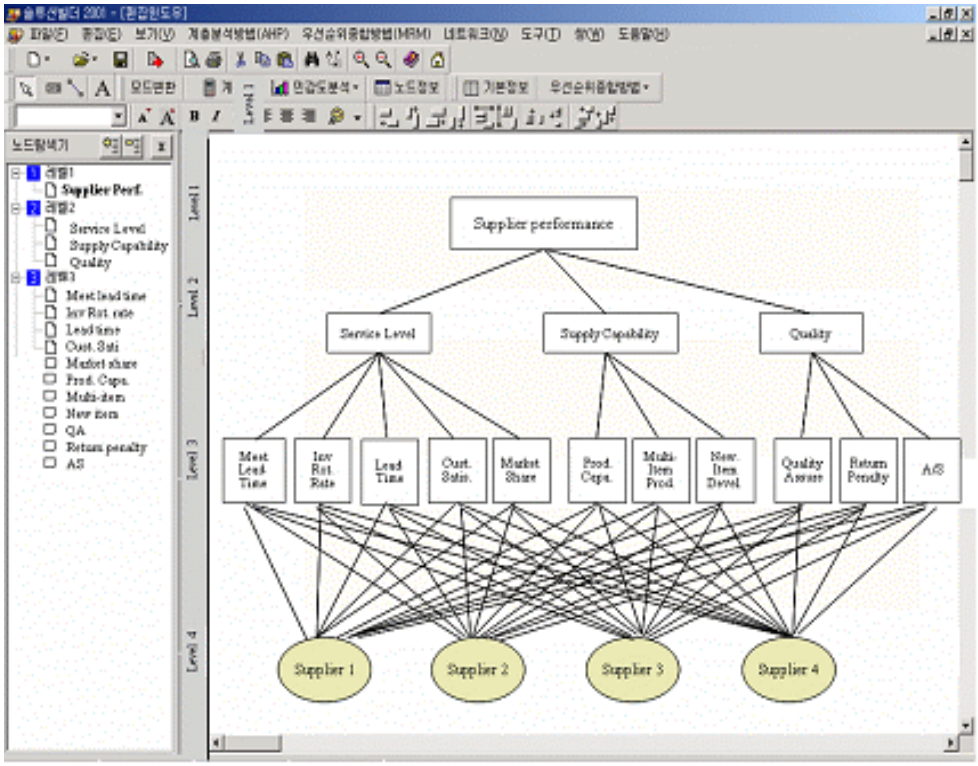

Figure 4. AHP structure of example problem by web-program

Step 2: Data collection by basic evaluation indicators

First we collect the detail data related with supplier selection problem, and then we used these data in evaluating the selection of supplier performance. Following data are collected for the sample problem.

Table 2. Suppliers data for evaluation indicators

Indicator	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Meet the lead time	91%	80%	85%	90%
Inventory rotation rate	15 times	12 times	16 times	13 times
Lead time	15 days	17 days	16 days	143 days
Customer satisfaction	42	48	52	55
Market share	12%	18%	19%	15%
Production flexibility	20 days	27 days	16 days	18 days
Multi-item Prod. Capa.	2 ea	4 ea	3 ea	1 ea
New item dev./ prod.	1 ea	2 ea	1 ea	1 ea
Quality assurance	ISO9001	ISO9001	ISO9001	none
Return penalty	12%	3%	1%	4%
A/S	3 days	6 days	2 days	5 days

Step 3: Compute the weighted values of each suppliers using fuzzy-AHP
Using fuzzy-AHP method, we find the weighted value of each evaluation factors as in Table 3. Table 4 shows the weighted values of each evaluation indicators by four supplier candidates. In Table 4 we can see that supplier candidate #1 (Supplier 1) is the best candidate. For the detail out sourcing policy it has to be more analyzed to maximize the weighted values of suppliers selection factors and lower cost of logistics operations. For the comparison purpose, we summarized the sample results of this problem both by AHP and fuzzy AHP as Table 5. To validate the final results of supplier selection problem, we have to collect real data more and analyze the supplier selection problems with various areas of industries and compared with several methods. This work will be done in further study.

Table 3. Results of integrated priority

Evaluation factors		Weighted value	
1. Serviceability, 0.48	Meet the lead time	0.190	0.091
	Inventory rotation rate	0.315	0.151
	Lead time	0.120	0.058
	Customer satisfaction	0.301	0.145
	Market share	0.074	0.035
2.Supply capability, 0.25	Production flexibility	0.160	0.040
	Multi-item Prod. Capa.	0.499	0.125
	New item dev./ prod.	0.341	0.085
3. Quality, 0.27	Quality assurance	0.591	0.160
	Return penalty	0.211	0.057
	A/S	0.198	0.053

Table 4. The weighted value for each suppliers candidates for sub-factors

Indicator	Weighted value	Supplier 1	Supplier 2	Supplier 3	Supplier 4
P_1: Meet the lead time	0.091	0.26, 0.024	0.23, 0.021	0.25, 0.023	0.26, 0.024
P_2: Inventory rotation rate	0.151	0.36, 0.054	0.21, 0.031	0.29, 0.044	0.14, 0.021
P_3: Lead time	0.058	0.58, 0.034	0.09, 0.005	0.08, 0.005	0.25, 0.015
P_4: Customer satisfaction	0.145	0.32, 0.046	0.25, 0.036	0.27, 0.039	0.18, 0.026
P_5: Market share	0.035	0.19, 0.007	0.28, 0.010	0.30, 0.011	0.23, 0.008
P_6: Production flexibility	0.040	0.25, 0.010	0.33, 0.013	0.20, 0.009	0.22, 0.009
P_7:Multi-item Prod. Capa.	0.125	0.20, 0.050	0.40, 0.05	0.30, 0.038	0.10, 0.013
P_8: New item dev./ prod.	0.085	0.20, 0.017	0.40, 0.034	0.20, 0.017	0.20, 0.017
P_9: Quality assurance	0.160	0.48, 0.077	0.11, 0.018	0.30, 0.048	0.11, 0.018
P_{10}: Return penalty	0.057	0.60, 0.034	0.15, 0.009	0.05, 0.003	0.20, 0.011
P_{11}: A/S	0.053	0.19, 0.018	0.38, 0.020	0.12, 0.006	0.31, 0.017
Total	1.000	0.368	0.180	0.243	0.179

Table 5. Results of Sample problem by both AHP and fuzzy set ranking method

Evaluation method	Priority of Suppliers and Weighted Values of factors	Selected Supplier
1. Fuzzy Set Ranking Method	S_1 (0.368), S_3 (0.243), S_2 (0.180), S_4 (0.179) P_9 (0.160), P_2 (0.151), P_4 (0.145), P_7 (0.125), P_1 (0.091), P_8 (0.085), P_3 (0.058), P_{10} (0.057), P_{11} (0.053), P_6 (0.040), P_5 (0.035),	S_1: Supplier #1
2. AHP Method	S_3 (0.342), S_1 (0.330), S_2 (0.180), S_4 (0.148) P_2 (0.170), P_9 (0.141), P_1 (0.140), P_5 (0.125), P_4 (0.101), P_3 (0.090), P_{10} (0.062), P_8 (0.060), P_9 (0.041), P_7 (0.040), P_5 (0.030),	S_3: Supplier #3

For this example, we used two evaluation methods, fuzzy set ranking and AHP method for the comparison purpose. We compared the results of both AHP and fuzzy set ranking method. These both methods are theoretically similar except the fuzzy relation functions. We developed the computer programs and applied it in the given example problem. Table 5 summarizes these results for the comparative purpose. By the results of fuzzy set ranking method, the reasonable supplier is known to be supplier 1, while by the result of AHP we can decide the supplier 3to be the best one.

Some of the other methods and more example problems can be considered to validate this problem. However, the AHP method gives a multi-criteria decision making structure considering all the related factors in a hierarchical decision structure.

4. Conclusion Remarks

In this paper, we proposed supplier selection methods using a multi-criteria decision making methods which include multipurpose and hierarchical analysis and also its programs. We used AHP and fuzzy-AHP method for purpose of multi-attribute characteristics of supplier selection problems. In the third party logistics system, some of works are done by outsourcing , thus the supplier selection problem is one of the most important works which can save logistics cost. In this study, we used a three-step approach based on web-based decision model for multi-structured decision support systems (Hwang, 2004, 2002) in the view of multi-attribute evaluation. These steps are: 1) brainstorming to define the alternatives and performance evaluation factors, 2) individual evaluation the alternatives using fuzzy-AHP, heuristic and fuzzy set reasoning methods, and 3) integration the individual evaluations using majority rule method.

For the computational purpose, we developed a GUI-type computer program for supplier selection model. We applied this method in a supplier selection problem in Taoyuan area of Taiwan for a third party logistics considering the 11 evaluation factors and 4 supplier candidates. By the sample results of both AHP and fuzzy set reasoning method, it is known that the proposed model is a good method for the performance evaluation of multi-attribute and multiple goals. For the academic users, we would provide this software and user manual. For the problems of data collecting and its analysis in hierarchical decision structures, the DHP (Delphic Hierarchy Process) method can be used in future study.

References

Barbarosoglu, G. & Yazgas, T. (1997), Application of the analytic hierarchy process to the supplier selection problem, *Production and Inventory Management Journal*, Vol.38, No.1, pp.14-21.

Blin, J. M. (1974), Fuzzy Relations in Group Decision Theory, *International Journal of Cybernetics*, Vol.4, No.2, pp.17-22.

Boer, L., Labro, E. and Morlacchi P. (2001), A review of methods supporting supplier selection, *European Journal of Purchasing & Supply Management*, 7, pp. 75-89.

Cakravastia, A., Toha, I. S. and Nakamura, N. (2002), A two-stage model for the design of supply chain networks, *International Journal of Production Economics*, 80, pp. 231-248.

Ching-Hsue Cheng (1996), Evaluating Naval Tactical Missile Systems by Fuzzy AHP Based on the Grade Value of Membership Function, *European Journal of Operation Researc*h, Vol. 96, pp.343-350.

Dritina, R.E. (1994), The Outsourcing Decision, *Management Accounting*, March, pp 56-62.

Dulmin, R. and Mininno, V. (2003), Supplier selection using a multi-criteria decision aid method, *Journal of Purchasing & Supply Management*, 9, pp. 177-187.

Eilram, L. M. (1991), Supply Chain Management: The Industrial organization Perceptive, *International Journal of Physical Distribution & Logistics Management*, Vol.21, No 1, pp.13-22.

Fishburn, P. C.(1970), Utility Theory for Decision Making, New York, John Wiley and Sons, pp.227, .

Ghodsypour, S.H. and O'Brien, C. (1998), A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming, *International Journal of Production Economics*, 56-57, pp. 199-212.

Ghodsypour, S.H. and O'Brien, C. (2001), The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint, *International Journal of Production Economics*, 73, pp. 15-27.

Heung Suk Hwang (2002), "Web-based Decision Support System-Multi-attribute and Fuzzy Reasoning Approach", *Journal of Dongeui University*, Vol. 36, pp.377-388.

Heung Suk Hwang (2004), "Web-based Multi-Attribute Analysis Model for Engineering Project Evaluation", *International Journal of Computers & Industrial Engineering*, Vo. 46. 1, pp. 669-678,

Itina, R.E. (1994), The Outsourcing Decision, *Management Accounting*, pp.56-62.

Kamarani, A.K. (1995), *Planning, Design, and Analysis of Cellular Manufacturing Systems*, Elsevier.

Leung Y.T. and R. Sure,(1990), Performance Evaluation of Discrete Manufacturing Systems, *IEEE Control Systems Magazine*, Vol. 10, No.4, pp.77-86.

Leong, G.K. Snyder, D.L., & Ward, P.T. (1990). Research in the Process and Content of Manufacturing Strategy, *OMEGA International Journal of Management Science*, 18(2), 109-122.

Murphy C. K. (1995) Limits on the Analytic Hierarchy Process from Its Consistency Index, *European Journal of Operation Research*, 65, pp. 138-139.

Qinn, J.B., & MHilmer, F.G. (1994), Strategic Outsourcing, *Sloan Management Review*, Summer, 43-55.

Saaty, T.L. (1980), *Analytic Hierarchy Process*, McGraw-Hill.

Shannon, R.E, (1986), The Amalgamation of Group Opinions or Evaluations, *Journal of Industrial Engineering*, Vol. 19, No.6.

Saaty, T. L. (1981), *The Analytic Hierarchy Process*, McGraw-Hill, New York.

Talluri, S. and Baker, R. C. (2002), A multi-phase mathematical programming approach for effective supply chain design, *European Journal of Operation Research*, 141, pp. 544-558.

Talluri, S., Baker R.C. and Sarkis J. (1999), A framework for designing efficient value chain networks, *International Journal of Production Economics*, 62, pp. 133-144.

Thomas, D. and Griffin, P. M. (1996), Coordinated Supply Chain Management, *European Journal of Operation Research* 94, pp. 1-15.

Verma, R. and Pullman, M.E. (1998), An analysis of the supplier selection process, *International Journal of Management Science*, Vol. 26, No. 6, pp. pp. 739-750.

Zahedi, F.(1986), The analytic Hierarchy Process - A Survey of the Method and it's Applications, *Interfaces*, Vol. 16, No. 4, pp.96-104.