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A MODIFIED AHP ALGORITHM FOR NETWORK SELECTION

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ABSTRACT

This paper addresses the concept of ranking networks to the multiple criteria of customers to find the best and alternative networks. The use of modified AHP algorithm has been shown to provide better network ranking for reasonable customer objectives than the traditional AHP method. Both the traditional method and the proposed method produced results subjective to the customer requirements. However, the proposed method is more intuitive to the customers through direct capture of their exact requirements rather than an interpretation of their requirements through pair-wise comparison alone. Also, the proposed method is less time-consuming and results are of higher quality.

Keywords: AHP, Manufacturer networks, Multiple Criteria Decision Making.

1 INTRODUCTION

The manufacturing network should provide alternatives to the current network when it is being affected by unforeseen problems which stem from today's uncertain and turbulent markets and some environmental factors (Christopher et al. 2004). However, in the midst of the problems that a manufacturing network may face, the customer requirements must still be met as far as possible. Therefore, the ranking of alternative networks by the analysis of the multiple criteria request by customers should be provided. This method is referred to as Analytical hierarchy process (AHP) (Saaty 1990).

There are several methods to solve ranking problems. The weighted sum model (WSM) method is probably the most commonly used approach (Fishburn 1967). However, the model does not perform well on multi-dimensional problems. The weighted product model (WPM) method can be applied in ranking of networks but the result of AHP would be more credible. Since there is no dependency between the decision criteria and the alternatives, analytical network process (ANP) method is not necessary for the scope of the project (Saaty et al. 2006). The AHP method appears to be the best method for the scope presented. The method has been applied in several areas of manufacturing and has been shown to yield better results for the selection of machine centres based on individual usage performance of the components of the machine rather than other decision making methods (Ic et al. 2012). The AHP method has also been found in hybrid methods for the selection of best suppliers in small scale manufacturing organizations (Singh Verma and Pateriya 2013). Fuzzy Analytical Hierarchy Process has been used to determine the most important supply chain risks and the corresponding risk management strategies for an iron and steel manufacturer (Sofyalıoğlu and Kartal 2012). Another application example of the method is the strategic planning in manufacturing firms by evaluating the importance of the SWOT factors affecting the firms and the marketplace (Görener et al. 2012).

AHP method relies on a well-defined mathematical structure of consistent matrices and their associated eigenvector to generate weights for every criterion of decision (Forman 2001). There are some limitations when using the AHP approach. Firstly, when the number of matrices become large, the consistency will become very poor (Saaty 1977). To reduce the biases caused by subjective judgment, modified Fuzzy AHP with kernel density estimation was proposed (Li et al. 2012). Secondly, the completion of n(n-1)/2 comparison, where n is the number of tasks, can become an onerous task if n become larger (Harker 1987). However, for the purpose of the paper, one well-defined matrix was used.

In this paper, a modified AHP algorithm which can be used in the networks ranking is presented. The comparison between traditional AHP method and modified AHP method is made. Finally, the benefit and limitation of modified AHP algorithms is mentioned.

2 METHODOLOGY

For the network ranking model to work, for each job of the manufacturing networks, the cost, lead time and quality performance must be available. The goals of the jobs are set as the variables namely maximum cost, maximum time, maximum quality, expectation cost, expectation time, expectation quality as well as a ranking scale. These information are used by the traditional and proposed AHP algorithms to calculate the rank of the networks. In section 2.1, the variables are described. Section 2.2 presents the AHP algorithm and section 2.3 describes the modified AHP algorithm.

2.1 Definition of input variables

When a set of jobs was issued, the simulation software allocated the jobs to the manufacturers on first come first served basis. This allowed the cost, lead time and quality of each job to be initially determined. At this point, the customer objectives for the job was inputted in terms of maximum cost, quality, lead time and expectation cost, quality and lead time. The maximum values were what the customer was ready to accept for that job. The expectation values were what was thought to the competitive values expected by the customer for that job. The customers would set these values based on their requirements. The criterion tolerance is defined as the difference between the maximum criterion value and the respective expectation value. The AHP scale denotes the maximum value a pair-wise comparison can received in the AHP matrix. The traditional scale is a one to nine scale. In later sections, the influence of AHP scale on the results is presented.

2.2 AHP Algorithm

The AHP algorithm involves constructing a matrix expressing the relative values of a set of attributes. The judgments are assigned a number on a scale. Table 1 shows the conventional scale.

Table 1: Scale of Relative Importance (Saaty 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement strongly favour one over the other.
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	when compromise is needed

Considering a set of n objects to be compared C = $\{C_1, C_2 \cdots C_n\}$ and the relative importance weight of C_i to C_j is denoted by a_{ij} to form a square matrix A for a job where $a_{ij} = \frac{1}{a_{ji}}. a_{ij}$. Therefore, a_{ij} is either a number in Table 1 or its reciprocal number.

The weights are consistent if they are transitive, that is $a_{ik} = a_{ij}a_{jk}$ where i, j and k = 0, 1, 2 … n and k is the index of unique pair of objects. Then the eigenvector ω and the eigenvalue λ is calculated for which $A\omega = \lambda\omega$. This is called the eigenvector analysis. If matrix A is a consistent matrix, $\lambda = n$. The probability of getting a consistent matrix based on human judgment is low and therefore, the ω vector satisfies the following equation instead: $A\omega = \lambda_{max}\omega$ and $\lambda_{max} \geq n$.

A Consistency Index is calculated and needs to be evaluated against judgments made completely at random. The Consistency Index is given by $(\lambda_{max} - n)/(n-1)$. Then a true consistency ratio is calculated by dividing the consistency index for the set of judgments by the index corresponding to the random matrix. The consistency index is accepted when consistency ratio is smaller than 0.1.

The final weight of each network is the sum of the vector of a network in every criteria times the vector of that criteria.

$$\text{Final weight} = \sum_{n,c} [w_n] * [w_c] \tag{1}$$

The traditional AHP algorithm is appropriate for analysing a small number of objects however when the number of comparison increases, the error by human judgment and therefore the decrease in matrix consistency become significant. The next section addresses the issue with a proposed modifications to the AHP algorithm.

2.3 Modified AHP Algorithms

The number of manufacturing networks can become a large number and the pair-wise comparison of objects based on human judgment can become unreliable. A large number of comparison will increase the consistency ratio above 0.1 which means that the resultant weights cannot be used. Therefore a different method is proposed. The criteria of cost, time and quality are all quantifiable. Traditional AHP method acquire the pair-wise comparison values for the criteria by human judgment. In the modified AHP method, the formula below would be used.

$$p_k = \frac{P_k}{t_1}$$ where P_k is the cost of network k (2)

$$r_{k,j} = \frac{p_j}{p_k}$$ where $r_{k,j}$ is pair-wise number in reciprocal matrix (3)

$$t_1 = p_{max} - p_{exp}$$ where t_1 is price tolerance, p_{max} and p_{exp} is max and expectation price (4)

$$t_2 = l_{max} - l_{exp}$$ where t_2 is time tolerance , l_{max} and l_{exp} is max and expectation time (5)

$$m_{0,1} = \frac{p_{max} t_2}{l_{max} t_1}$$ where $m_{0,1}$ is the relation between price and lead time (6)

Similar equations can be used for the criteria of time and quality. The reciprocal matrix will remain consistency in the whole procedure as it is not subject to the bias of human judgment.

The modified AHP algorithm is performed in five steps using an in-house simulation software:

1. Create manufacturing scenario with jobs and manufacturers

2. Generate the cost, time and quality offered by each manufacturing network for every job on a first come first served basis
3. Remove the networks that offer values larger than the maximum lead time, cost and quality
4. Utilize the AHP algorithms to calculate the weight of every remnant network
5. Rank the networks by total weighted score

3 RESULTS AND DISCUSSION

The results obtained in this study can be divided into two sections. The first section shows how the proposed modified AHP algorithm performs when the scale is 0...9, 0…1000 and when the scale uses discrete and continuous numbers. Also presented is the change of the weight of the criteria when the maximum and expectation values are changed.

3.1 Relationship between weight and customer objectives

The parameters used to define the customer objectives for a job is as follows: (i) maximum price = 24000, (ii) maximum time = 6, (iii) maximum quality = 16, (v) expectation time = 5, (vi) expectation quality = 12. Table 2 shows the possible manufacturing networks for the job.

Table 2: Possible networks for a job

Networks	Price (£)	Quality (dppm)	Lead Time (h)
1	7879	13	4.92
2	23352	10	
3	41717	13	
4	35803	8	
5	8762	15	
6	49513	8	
7	13224	10	
8	34099	11	
9	20584	10	
10	42134	13	

When the expectation price was set to 10600 and when a discrete scale was used, the network ranking yielded completely different rank than when the AHP algorithm used the continuous scale. The network rank result provided by discrete one was {7, 9, 2, 1, 5} comparing with the result {1, 7, 5, 9, 2} created by the continuous scale. The continuous scale created a smoother profile and relative to the objectives of the customer, a much better ranking of manufacturing networks was generated. When using a discrete scale of 9 or 1000, the turbulence was generated because of the error of utilizing integer to replace decimals. However, the modified AHP algorithms can naturally generate a perfect curve when a continuous scale is used. Furthermore, the AHP with discrete scale cannot detect slight differences in the network offerings. Although network 1 had better cost, quality than network 5, the discrete type could not identify that network 1 was better. On the contrary, the modified AHP algorithm which is more sensitive can discern which network is better even when the difference is inconspicuous. Figure 1 shows the change in the importance of the price when the expectation price changes.

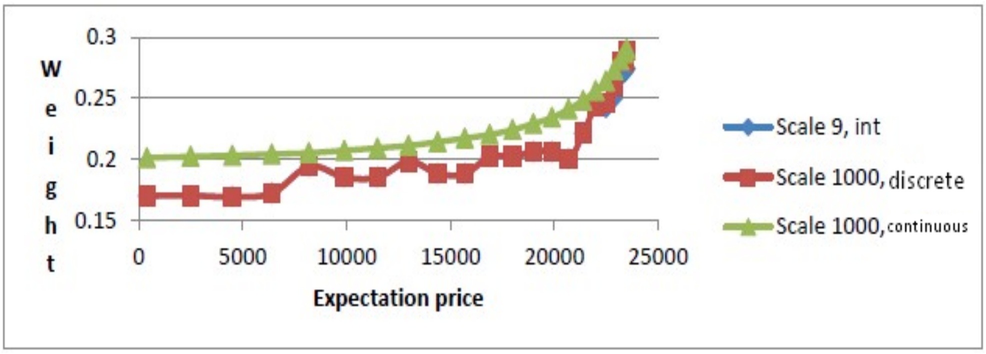

Figure 1: Comparison of price weights based on different scales

Next, a sensitivity analysis was carried out to show how the criteria weights changed when the objectives of the customer changed. Given that the difference between the expectation price and the maximum acceptable price for the job is high, the weight on the price is low as the algorithm assumes that the customer is willing to accept a good range of prices. This is defined in this paper as the criterion tolerance. As the expectation price approaches the maximum acceptable price, the price criteria increases in importance and consequently the associated weight increases. It is important to notice how the weights of the lead time and quality changes accordingly because the weights must sum up to 1. Figure 2 shows the profile of the weights of every criterion when expectation price is changed.

Figure 2: Criterion weight based on different expectation prices

Given that the maximum acceptable price for a job is changed and the expectation price is fixed at 12, 000, the price tolerance decreases as maximum price decreases. Therefore, the algorithm assigns a higher weight for price and consequently lower weights for lead time and quality. Small criterion tolerance indicates the customers are much more concerned in that criterion. Figure 3 shows the criteria weights when maximum price is changed.

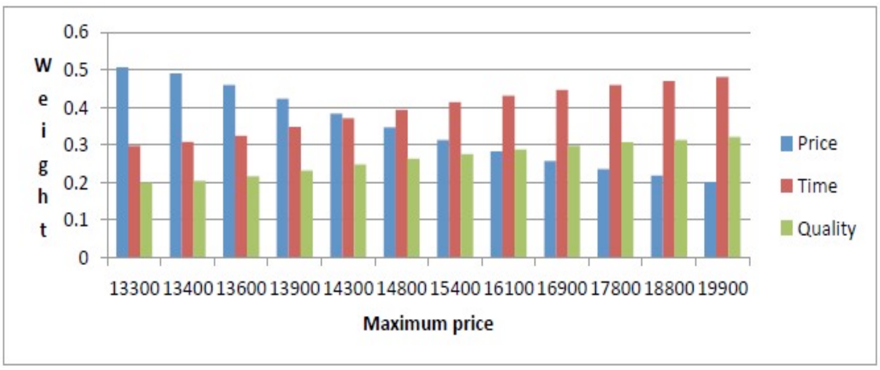

Figure 3: Criterion weight based on different maximum prices

3.2 Qualitative comparison between traditional AHP and modified AHP

There are several problems associated with using traditional AHP method in networks ranking. AHP scale from one to nine is evaluated by human nastic movement which may differ for different people. Nastic movement is the degree of response to stimulus, in this case the stimulus is the comparison of two criteria. Therefore, consistency ratio should be calculated to ensure reliability of the results. The traditional AHP method cannot avoid the error caused by the nastic movement when the number of objects increase. Modified AHP method guarantees the consistency by mathematical method and is more reasonable and tractable. Therefore, the consistency ratio need not be calculated because the formula, previously mentioned in section 2, guarantees the weights are consistency.

4 CONCLUSION

In this paper the modified AHP algorithm has been used to provide better network ranking. It has been demonstrated that the selection of networks based on multiple criteria using modified AHP has been successful. Once the number of network grows, the uses of modified AHP algorithm can prove to be an effective and reasonable method to rank manufacturing networks. This project demonstrated the benefits of using modified AHP in network ranking based on quantifiable criteria and made a comparison with traditional AHP. The results of this project improve traditional method in networks ranking.

REFERENCES

Christpher, M. and Peck, H. 2004. Building the Resilient Supply Chain. The International Journal of Logistics Management, 15(2) pp. 1 - 14.

Coyle, G. 2004. The Analytic Hierarchy Process (AHP) Introduction Practical Strategy. Open Access Material.

Fishburn, P.C. 1967. Additive Utilities with Incomplete Product Set: Application to Priorities and Assignments. Operation Research Society of America (ORSA). Baltimore, MD, U.S.A.

Forman, E.H. 2001. The Analytic Hierarchy Process - An Exposition. Operation Research, 49(4).

Görener, A., Toker, K., Uluçay, K. 2012. Application of Combined SWOT and AHP: A Case Study for a Manufacturing Firm. *Procedia - Social and Behavioral Sciences*, 58, 1525-1534

Harker, P.T. 1987. ALTERNATIVE Modes Of Questioning In The Analytic Hierarchy Process. Math Modeling, 9(3-5), pp. 353-360.

Ic, Y., Yurdakul, M., & Eraslan, E. 2012. Development of a component-based machining centre selection model using AHP. *International Journal Of Production Research*, *50*(22), 6489-6498.

Nan, L., Saadat, M., Jules, G. 2012. Supplier selection using modified Fuzzy AHP-based approach in manufacturing networks. Systems, Man, and Cybernetics (SMC), IEEE International Conference on, pp.1847-1852

Saaty, T. L., & Vargas, L. G. (Eds.). 2006. Decision making with the analytic network process: economic, political, social and technological applications with benefits, opportunities, costs and risks, 95. Springer Science+ Business Media

Saaty, T.L. 1977. A Scaling Method for Priorities in Hierarchical Structure. *Journal of Mathematical Psychology* 15, pp. 234-281.

Saaty, T.L. 1980. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York

Saaty, T.L. 1990. How to make a decision: the analytic hierarchy process. *European Journal of Operation Research* 48(1), pp. 9-26.

Singh Verma, D., Pateriya, A. 2013. Supplier Selection through Analytical Hierarchy Process: A Case Study In Small Scale Manufacturing Organization. *International Journal of Engineering Trends and Technology*, 4(5), 1428

Sofyalıoğlu, C., Kartal, B. 2012. The Selection of Global Supply Chain Risk Management Strategies by Using Fuzzy Analytical Hierarchy Process – A Case from Turkey, *Procedia - Social and Behavioral Sciences*, 58(12), 1448-1457