Multiple Criteria Decision Making for Suppliers Evaluation: Using Analytic Network Process and VIKOR Approach

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Abstract: *The model for evaluation of suppliers has a very important influence on enterprise operations and promotion of competitiveness. The purpose of this paper is to establish a model for evaluation of suppliers for practice, thereby promoting the competitiveness of enterprises, and to apply academic patterns to practical problem solving. This paper established framework and criteria of evaluation by literature review and interviews. And then we find the weight for every dimension and criterion by analytic network process (ANP) and use VIKOR to rank. The application takes a supplier, which offers Surface Mount Technology (SMT) in TFT-LCD, as the research object.*

Keywords: *Analytic network process (ANP), TFT-LCD, Surface mount technology (SMT), VIKOR.*

1. INTRODUCTION

The increasingly fierce competition of the international market makes enterprises rethink and adjust procurement strategies in order to enhance competitiveness and expand market share. Krause think enterprises and suppliers have broken away from hostile relationship, not only to focus on price competition, but to see each other as a common partner to reduce costs; and, apart from the cost, quality and service is also quite important to performance measurement. However, the quality and services of products don't only depend on the manufacturer, but also will be affected by upstream suppliers; in order to ensure the quality of products and services, when manufacturers find the suppliers' performance is not good, they may change the suppliers. But for suppliers that they want to have long term cooperation with, they will help them to solve problems or develop their capability. A lot of evidence shows that enterprises improve their performance through "Supplier development program, SDP," so as to maintain its competitive advantage.

In modern enterprises, every function is very important, with procurement one of the main function in the business activity, especially procurement spending, which accounts for about 60% of the total manufacturing costs. And the choice of supplier is an important part of procurement. Therefore, if there are no suitable suppliers that can provide low cost and high quality material, enterprises must be unable to produce products or services of high quality and low cost.

There are many factors to consider in supplier selection, plus the current environment becomes complex and changeable and there are interactions between each factor. Therefore, this issue can't be weighed with a single criterion view; it is one of the multiple criteria decision making issues. This issue has been widely discussed by Dicskon in 1996. However, the supply chain today has two main characteristics. The first is that its life cycle is becoming shorter. Because there is an urgent need of new competitive products, it is impossible for manufacturers to predict customers' needs. The second is the large numbers of uncertainties in the quantity and quality of products provided by suppliers.

There are many methods for supplier selection. Jiang and Han introduced supplier selection methods into three categories: the first is to use the qualitative analysis method; the second is quantitative method; the third is a combination of qualitative and quantitative analysis evaluation. Weber classified supplier selection methods into three types: linear weighing model, quantity planning model and statistics/probability method respectively.

This study takes a supplier which offers Surface Mount Technology (SMT) in TFT-LCD as the research object, establish the network framework by means of literature review and expert interview, and then decide the relative proportion of every criterion by analytic network process (ANP) and use VIKOR to rank. The study will also be let companies attach importance to supplier selection, so as to increase the competitiveness of companies, and develop new business opportunities.

2. LITERATURE REVIEW

In today's competitive environment, the most important choice that enterprises are making is the selection of the right supplier. Therefore, the supplier can be considered as the best intangible resources of the enterprise. In the supply chain environment, the buyer and supplier shall establish a mutually beneficial relationship, in order to get the best interests for both sides, but the buyer still needs to pay attention to cooperation supplier's qualities. The buyer should first decide supplier selection criteria and then decide the weight of each selection criterion. According to the different importance of each criterion, he buyer gives different priority to different selection criterion and regards this as the basis for selection of suppliers. Therefore, some quantitative and qualitative factors need to be considered. Large amount of literature has mentioned that the main factors of supplier selection are quality, cost, delivery performance, elastic coordination, and customer service.

Ellram suggested that there were five steps to develop supplier relationships, which are respectively: building strategic requirements, defining the potential suppliers, filtering and selection, building and evaluating relationships. Most of the supplier evaluation models start with these five steps, but few researches pointed out how to evaluate relationships. Therefore, this research helps suppliers improve based on evaluation of supplier selection strategy, on the premise of continued cooperation. In supplier evaluation mode, the commonly used methods are the assessment project comparison method, cost comparison method, mixed integer programming, multi-objective programming, analysis of hierarchy process, principal component analysis, Monte Carlo simulation, data envelopment method, etc., each of which has its own advantages and disadvantages.

Because in the process of evaluation, different criteria should be considered at the same time, criteria will be changed to be quite complex, which may include quantitative and qualitative factors, and may be conflicting with each other. While a strategic evaluation method must also consider multiple criteria. Dickson has investigated industrial purchasing managers, and identified 23 supplier selection factors. He points out that the most important factors are quality and delivery time. And Stevenson also simplified supplier evaluation indexes to the eight items, respectively: production time and delivery, quality and quality assurance, elasticity, place, price, product and service changes, reputation and financial stability as well as the others. Choi and Hartley put forward 26 evaluation factors for the selection of suppliers of the automobile industry. Simpson et al. randomly selected 110 purchasers from top 150 companies of Fortune and 2001 members from American Association of Supplier Management, to sort out 19 important factors. With the above literature, this study will use the five indexes which include price (cost), delivery, quality, service and technical ability, and the three indicators mentioned in the reference (including the production, the whole organization and operating conditions of the supplier, and information connection and exchange capacity), altogether eight criteria, as the basis for development of supplier selection model.

3. RESEARCH METHOD

3.1. Analytic Network Process

ANP was proposed by Saaty in 1975, which was extended from analytical hierarchy process. Because of in many practical problems, internal elements of the criteria of various levels are interdependent. Low-level elements also control high-level elements, namely there is a feedback relationship between them. The structure of the system is similar to a network structure, and the generation of ANP is for resolving this kind of network system structure. The system can be divided into two parts: the first part is the Control Hierarchy, including the network among Goal, Criteria and Subcriteria, which affects the internal relationship of the system; the second part is the Network hierarchy, which refers to the interacting network of Element and Clusters.

ANP network can show a correlation among criteria as well as calculate the relative weight (characteristic vector) of each criterion to form a Super matrix. Finally, through operation of the Super matrix and after comprehensive evaluation, the priority weight of the interdependence between evaluation criteria and the scheme can be obtained. And the greater the priority weight is, the higher priority it will be adopted. So you can choose the most appropriate scheme. Among relevant literature which adopted ANP, Saaty & Takizawa proposed to solve the network structure of ANP with matrix application, which is similar to ANP, but mainly considers the interdependent relationship between criteria and the relationship between criteria and selection schemes. Meade & Sarkis proposed to use

ANP method for decision analysis to evaluate schemes and help the organization become more agile, which helps improve specific goals of enterprise application. Lee & Kim applied ANP method, and Zero-One Goal-Programming (ZOGP) mode to information system scheme selection. They have reflected the dependency between evaluation criteria and feasible scheme. Jharkharia & Shankar used ANP to evaluate and select the scheme of logistics service providers. They pointed out that ANP let decision makers have a better understanding of the complex relationship among evaluation criteria in decision making, and also improve the reliability of decision-making in the process of decision evaluation. According to the above research literature, ANP is mainly applied to selection of a variety of feasible schemes, such as resource allocation and sorting in order to improve the reliability of decision-making in the evaluation process. Therefore this study, through ANP, defines relative weights of the evaluation criteria of suppliers which offer production schemes of Surface Mount Technology (SMT) in TFT-LCD.

3.2. VIKOR Method

VIKOR, introduced by Opricovic and Tzeng, is one of the best compromise solution methods in multi-criteria decision making. Its basic idea is to define Positive ideal solution and Negative-ideal solution. The Positive-ideal solution refers to best alternative in the evaluation criteria; while the Negative-ideal solution refers to worst alternative in the evaluation criteria. Compare the degree of closeness between the evaluation value of each alternative and the ideal solution, and on the basis of the total distance of each solution, to put the priority of each solution in order.

In calculating the closeness between each solution and the ideal solution, the scores of each evaluation criteria must be added up. The adding up method evolves from Lp-metric of the compromise programming method; its main characteristic lies in providing the maximum "Group benefit" and minimizing "individual regret of objection", so the compromise solution can be accepted by policy makers.

VIKOR calculation steps are as follows:

Step 1: find out positive-ideal solution and negative-ideal solution

$$F_i^* = [\langle \max_j F_{ij} \mid i \in I_1 \rangle, \langle \max_j F_{ij} \mid i \in I_2 \rangle] \quad \forall i \tag{1}$$

$$F_i^- = [\langle \min_j F_{ij} \mid i \in I_1 \rangle, \langle \min_j F_{ij} \mid i \in I_2 \rangle] \quad \forall i \tag{2}$$

In the above formulas, j refers to each alternative, and i refers to each evaluation criterion; F_{ij} refers to the performance evaluation value of the evaluation criterion of alternative i, which is obtained through questionnaire; I_1 refers to the collection of benefit evaluation criteria, and I_w is the collection of cost evaluation criteria; F_i^* is the positive ideal solution; F_i^- is the negative ideal solution.

Step 2: calculate S_j and R_j

$$S_j = \sum_{i=1}^{n} w_i (F_i^* - F_{ij}) / (F_i^* - F_i^-) \quad \forall j \tag{3}$$

$$R_j = \max_i [w_i (F_i^* - F_{ij}) / (F_i^* - F_i^-)] \quad \forall j \tag{4}$$

In formulas (3) and (4), w_i is the relative weight of each evaluation criteria, which is also the relative weight of each criterion calculated by applying ANP in this study.

Step 3: calculate Q_j

$$Q_j = v(S_j - S^*)/(S^- - S^*) + (1 - v)(R_j - R^*)/(R^- - R^*) \quad \forall j \tag{5}$$

In formula (5), v refers to the decision making mechanism coefficient. When v is bigger than .5, it means that decision making is based on most resolution; when v approximate to .5, it means decision will be made according to how much it is agreed; when v is less than .5, it means decisions will be

made according to how much it is declined. In VIKOR, v is set to .5, to maximize "Group benefit" and minimize "individual regret". In the above equation:

$$S^* = \underset{j}{Min} S_j \text{ (the group majority rule)} \qquad S^- = \underset{j}{Max} S_j$$

$$R^* = \underset{j}{Min} R_j \qquad R^- = \underset{j}{Max} R_j \text{ (the minimum individual regret)}$$

Q_j reflect the benefit rate of solution j.

Step 4: put the solutions in order according to the relationship among Q_j, S_j and R_j

To rank according to each solution and Q_j. The smaller the value of Q_j, the better.

4. RESEARCH RESULT

4.1. Introduction to the Case Company

T Technology is a global leading provider of Surface Mount Technology (SMT) in TFT-LCD, whose business includes procurement and management of raw materials and accessories, engineering design process, SMT assembly process, quality assurance, logistics management and after-sales service. Employed by domestic famous companies, a number of professional managers together build a professional management team, which maintains its leading position in the industry.

With the growth of production bases, the products are also increasingly diversified, from PC motherboard of its early time to mobile phone, and even LCD display. With electronic science and technology changing with each passing day, our services tend to be diversified, always acting as an important driving force of globalization.

4.2. Establish the Model for Suppliers Evaluation

No more than 3 levels of headings should be used. Other headings must be in 11pt font except Level-1 Heading. Every word in a heading must be capitalized except for short minor words. With the above literature, this study will use the five indexes which include price (cost), delivery, quality, service and technical ability, and the three indicators mentioned in the reference, which respectively are the production, the whole organization and operating conditions of the supplier, and information connection and exchange capacity, as the initial framework. Through interviewing experts and their revising suggestions, the eight dimensions and thirty-nine criteria are modified into five dimensions and 18 criteria. Experts' profiles are shown in table 1; The estimation mode after modifying is shown in Table 2. Next, discuss with the experts again about the relationship among dimensions, criteria and the network relationships among dimensions and criteria, the diagram of which is shown in Figure 1.

Table1. *Profile of experts*

	Position	Education
1	Purchasing supervisor for 15 years	College degree
2	Purchasing supervisor for 13 years	College degree
3	General manager for 6 years	Master
4	Vice general manager of a science and technology factory for 5 years	Master
5	General manager of a science and technology factory for 5 years	College degree

Table2. *Dimensions and criteria of ANP Model*

Dimensions	Price (cost)	Delivery	Quality	Service
Criteria	Payment mode	Lead time	Reliability of product	Response capability
	Quantity discount	Deliver on time	Consistency of specifications	Communication ability
	Cost of product	Distribution capabilities	Sales return ratio	After service

4.3. The Relative Weights of Evaluation Criteria

This study integration five experts' ANP questionnaires were input into the Super Decisions software. After calculating the ANP limit matrix of the five experts with Super Decisions software, the weights

of different evaluation criteria as a whole can be obtained. Because five experts were invited to be interviewed in this study, after collecting each expert's interviewing questionnaire, the questionnaire data are integrated, and then the average was calculated, after which the final overall weight value of dimensions and criteria can be got, as is shown in Table 3.
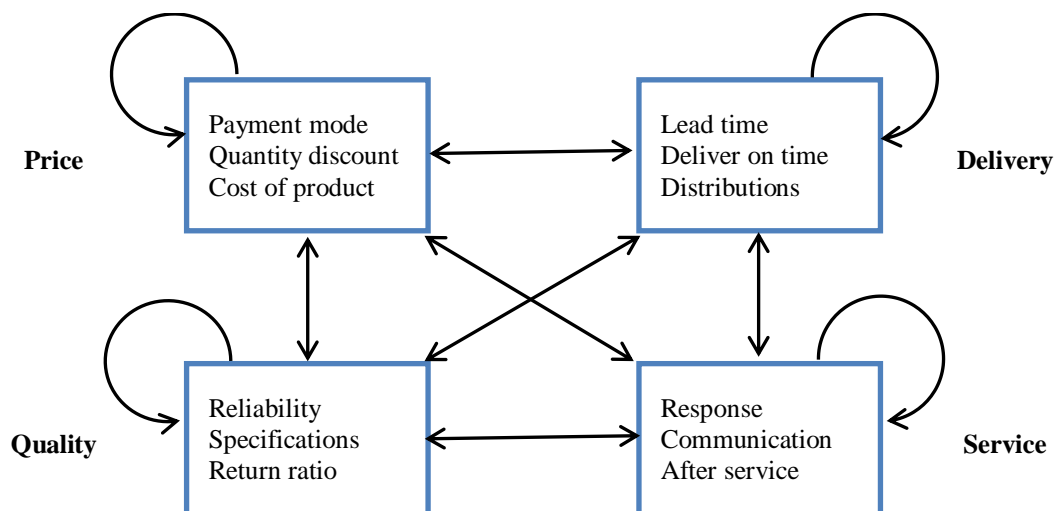

Fig1. *The Network Structure of supplier selection*

Dimensions are ranked in accordance with their weight, with quality (.6667) ranking the first, followed by service (.1989), delivery (.0699) and price (.0644). Criteria are ranked according to their weight, the top three being specification consistency (.2480), product reliability(.2291), and return ratio (.1897), and the final three quantity discounts (.0194), communication ability(.0083), and mode of payment (.0081).

Table3. *The average weighting and ranking of evaluation criteria*

Dimensions / Criteria		Average	Rank
Dimensions	Price(cost)	.0645	4
	Delivery	.1989	2
	Quality	.6667	1
	Service	.0699	3
Criteria	Payment mode	.0081	12
	Quantity discount	.0194	10
	Cost of product	.0370	6
	Lead time	.0776	5
	Deliver on time	.0916	4
	Distribution capabilities	.0297	9
	Reliability of product	.2291	2
	Consistency of specifications	.2480	1
	Sales return ratio	.1897	3
	Response capability	.0324	7
	Communication ability	.0083	11
	After service	.0298	8

4.4. Ranking by VIKOR

In this stage, the relative weight of each criterion is produced by ANP, and the ranking of suppliers of T technology is conducted by using VIKOR which is characterized by having compromise solutions. Because VIKOR mainly deals with conflicts among the evaluation criteria and produce the best compromise solution, each supplier's performance value and the Gap between the positive ideal solution and negative ideal solution can be obtained. In this study, the value of v is set to be .5. Through normalized calculation, with the weight produced by using ANP, and by finding the positive ideal solution or negative ideal solution and the calculation of distance and the comprehensive index, the supplier A is .983, B is 1 and C is zero respectively. Three suppliers are evaluated, with C being the most suitable suppliers, and supplier B ranking the last.

From the above results, supplier C is better than the other two. From this study, we know the reason is that in the selection of suppliers, companies of LCD industry first consider quality, and then delivery.

And this is just consistent with the results of the literature. Ranking with VIKOR, we not only can understand the relative position of each supplier and other competitors, but also can see the gap between the performance value of each supplier and the positive ideal solution. However, the suppliers shall also use their advantages as a market competitive strength, and continue to create their own characteristics, and then increase its market share. Relatively weaker projects also should be strengthened and follow up, to create a competitive advantage.

5. CONCLUSION

In such a competitive globalized world, enterprises can not only emphasize on product quality and price satisfaction, which were the only emphases of the past, but quality, price, service, delivery, technical capability and other new competitiveness. However, supplier selection by domestic enterprises is often affected by environmental factors or negotiation results. Also, in multiple criteria evaluation, it is often assumed that each criterion is independent of each other, but in reality, mutual dependency relationship among criteria is inevitable. Therefore, this paper adopts the method of ANP. In addition to reduce the complexity of decision making, it also can present a systematic way and effectively eliminate the subjective preferences of decision makers. Finally, with VIKOR and the weight value got by ANP, the gap of ranking and ideal value of the three LCD suppliers is reached.

In addition, from the results shown in Table 3, in supplier selection strategy evaluation, T technology gives first priority to "quality", with a high weight value of .6667. Because T technology belongs to the manufacturing industry, the first thing it gives weight to is the quality of the product provided by the supplier, which is generally one of the most important factors for manufacturing industry. In order to achieve high quality of the product, suppliers need to improve the product specifications, product reliability, product consistency returns ratio and so on. The required standards have been set by purchasing managers of T technology, who also conduct supplier evaluation and demand improvement.

The second dimension to consider is the delivery of goods, whose weight value is 0.198895, slightly lower than that of quality. It is because the ability of delivery represents the supplier's production process and process control and good production process and process control can effectively improve the accuracy of supplier delivery time. With a control of the delivery time, products can be delivered to the delivery place on time, upstream factory production lines can run smoothly, and there will be cases like lack of material or excessive material inventory.

In supplier selection strategy evaluation, the main criteria that enterprises attach importance to are specification consistency (weight value is .2480), product reliability (weight value is .2291) and the return ratio (weight value is .1897), which all belong to the quality dimension. This point shows that considered from the overall dimensions in the evaluation of strategies for enterprise supplier selection, their importance is higher than delivery. Even if narrowing the evaluation strategy down to criteria, the weight of specification consistency, product reliability and return rate are still higher than that of lead time and on-time delivery of the delivery dimension. So the three criteria should be listed as the first, second and third priority. In supplier management practices, enterprises still attach the most importance to the quality of products provided by the supplier. The overall product sales market is no longer as good as that of the past due to the recession and competition among the same industry at home and abroad, thus the performance of suppliers of adhesive technology (SMT) in TFT-LCD is also facing great challenges. Therefore, suppliers having stable quality must be selected and suppliers with poor quality should be suggested to be improved or eliminated, in order to achieve the business model of getting rid of the decayed and keeping the luxuriant, making enterprises pull through this difficulty.

The three criteria with the lowest priority weight are quantity discount (weight value is .0194), the ability to communicate (weight value is .0083), the mode of payment (weight value is .0081). They show that in the evaluation of enterprise supplier selection strategies, mode of payment is the least important among all the evaluation factors. The reason is that in evaluation of enterprise supplier selection strategies, mode of payment has little effect on the quality of the product and production costs, which is much lower than the effect of other factors, thus being the least important. The analysis of a single enterprise seems slightly insufficient for supplier selection, therefore it is suggested that further research consider the same industry for empirical analysis.

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