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Supply chain management for a purchasing model: A case study in an electronics firm

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Abstract

Nowadays, enterprises emphasize quick and accurate responses. Vendor selection and order allocation are the two most important functions in the purchasing management of supply chain management (SCM). This article outlines two efficient ways implemented in SCM. The methodology of Analytic Hierarchy Process (AHP) helps decision managers choose the most appropriate supplier in the shortest time, and linear programming (LP) assists a purchasing member to order adequate quantities from each selected suppliers, greatly reducing costs. In most companies, a purchasing department acts as an important and quick link between the internal and external affairs of the firm. In addition to a quick response, cost reduction is the most important goal in the purchasing department of SCM. By combining two methods, AHP and LP, an enterprise not only chooses the "best suppliers", but also greatly reduces costs.

Keywords: *SCM; AHP, linear programming; supplier selection; order allocation*

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1. Introduction

Supply chain management (SCM) is often defined as optimization of the network of the company. SCM comprises a number of relative departments such as procurement, manufacturing, warehousing and transportation activities. SCM is generally considered as an effective method for helping a company reduce costs, increase competitiveness and improve operation flow. To increase quick responses to end order users, all supply chain networks should be designed as integrated systems. Suppler selection and evaluation have an important role in the supply chain process and are crucial to the success of a manufacturing firm (Deagraeve *et al.*, 2000). To carry out the just in time system (JIT) and total quality management (TQM) in the company, cooperation between buyer and supplier includes specified work-flow, and sharing information through electronic data interchange (EDI) (Spekman *et al.*, 1998). Automated supplier selection and order allocation not only save costs but also make the SCM system more flexible. Selecting the right suppliers and quota allocations significantly reduces purchasing costs, improves competitiveness, and enhances end user satisfaction (Kumar, 2004). A buyer usually makes a decision about "which supplier is the best choice," while confronting several equivalent suppliers. Supplier selection and evaluation needs to consider both tangible and intangible factors, such as price, quality, service, delivery,…etc. so that selecting the right suppliers is a multiple-criteria decision-making (MCDM) problem. Basically, there are two kinds of supplier selection problems:

(1) Single sourcing: One supplier can satisfy all of the buyer's needs. Supplier selection when there is no constraint. One supplier can fulfill the buyer's requirements for quality, demand, service,…etc.
(2) Multiple sourcing: Supplier selection when there are some limitations. No one supplier can satisfy the buyer's total requirements, and the buyer needs to purchase some parts from another supplier to compensate for the shortage of capacity or the inferior quality of the previous supplier. In other words, the buyer wants to split order quantities among suppliers because of various reasons including price, quality, capacity,…etc.

In literature reviewing, there have been some methods proposed for single and multiple sourcing problems (Ghodsypour, 1998). The supplier selection issue was treated as an optimization problem which requires the formulation of an objective function (Wang *et al*., 2004). A supply chain is the context in which goods, services and information flow from the earliest supplier to the end user. (Tuncdan, *et al*., 2007) In this research, a supply chain network for mother-board firm is provided in Figure 1. When receiving sales orders from a customer, a series department needs to work together to fulfill order requests in the shortest possible time. In this situation, buyers need to select suppliers and purchase a certain quantity of a component to satisfy the manufacturing department for motherboard production.

In the SCM concept, a buyer needs to fulfill all materials supply and preparation for the manufacturing department. To avoid production line interruptions, the purchasing department needs to supply sufficient materials. When materials can not be provided in a timely manner, causing production line interruptions, there may be two kinds of loss. One is the loss of production as the production line sits idle, and the other is the delay in shipping products to customers, which might cause customer dissatisfaction, increasing the risk of customers transferring their orders to other companies. In the traditional purchasing approach, the buyer gets internal orders from the production department and begins to source

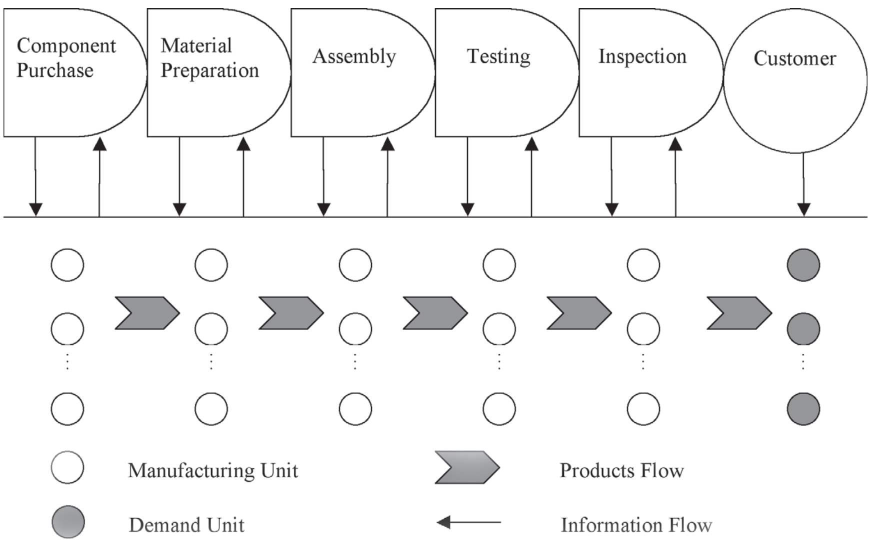

Figure 1

Motherboard supply chain distribution network

the component. The sourcing process includes searching for the appropriate supplier that has the best price and concurrently considering factors of quality, delivery and service. To avoid lots of routine operations of sourcing suppliers, a conceptual architecture of an automated purchasing system is shown in Figure 2. The model combines two methodologies, Analytic Hierarchy Process (AHP) and Linear Programming (LP). Through the calculation of AHP, the priority of suppliers can be realized, and a purchasing manager can easily understand "which supplier is the best." After calculating the priority and weight of each supplier, the most appropriate order quantity can be obtained by Linear Programming. The application software for AHP and LP are Expert Choice and LINDO. By combining two kinds of software and information systems, a purchasing system with automation can be effectively implemented in enterprises.

The relation between customer and supplier can be divided into four segments. They are supplier-dominated, strategically cooperative, absolutely independent, and customer-dominated. Figure 3 presents the four kinds of customer-supplier relationships in the motherboard industry.

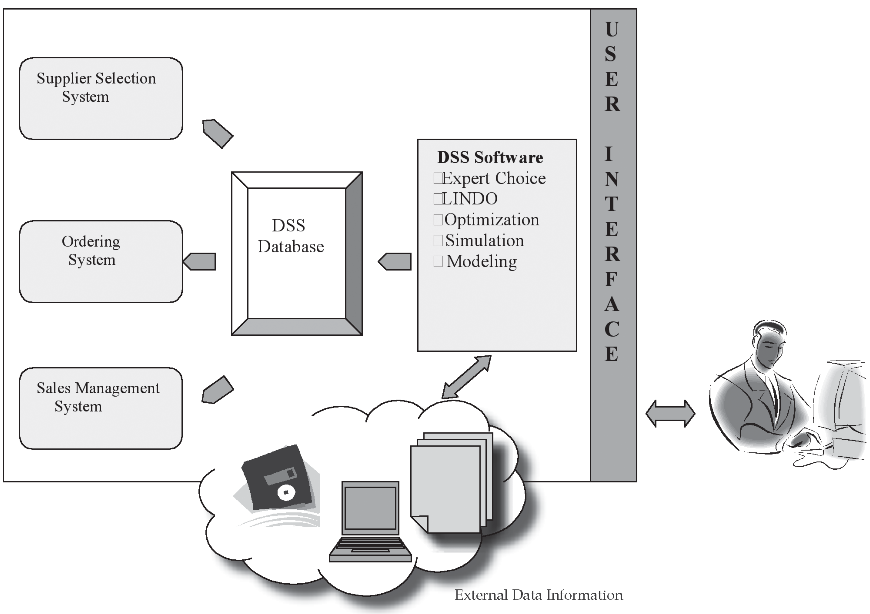

Figure 2

Conceptual architecture of automated purchasing system

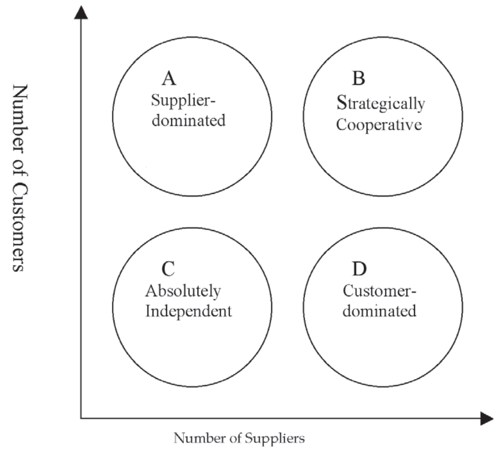

Figure 3

Relationships between supplier and customer (Sha and Che, 2005)

Key components such as the CPU and chipset are dominated by supplier INTEL, and motherboard manufacturers must purchase these components from this designated supplier. A key component supplier usually has two specific traits: strong research and development capabilities, and a large market share. In the motherboard industry, a new specification for the CPU is created and subsequently many series components and peripheral parts are generated. Mechanical parts such as a case, a heat-sink, a fan with a frame, and a power supply belong to cooperative suppliers. A manufacturer needs to cooperate with a supplier for designing component sizes and testing their functions. In this study, we focused on a mechanical component, a heat-sink, which is important for distributing the heat inside a desktop PC or a notebook computer. A motherboard manufacturer's R&D member needs to cooperate with a supplier's R&D member to specify a heat sink's size and test its functioning. If the function of heat spreading can not reach a certain level, this kind of heat-sink would not be produced. Absolutely independent suppliers are usually vendors who produce electronic parts like DRAM/DDR, a LAN (local area network) chip, a wireless LAN chip, capacitors, and resistors. The component that is most dominated by a customer is a PC board. A PC manufacturer must release all layouts to a supplier when producing PC boards. A supplier has no capability to produce PC boards without a customer's information.

2. Methodology

De Boer *et al*. (2001) performed an extensive review of decision methods, listed in the literature. Thereafter, Talluri and Narasimhan (2003) and Kumar (2004) proposed a stream of conceptual studies regarding supplier selection solutions. Figure 4 summarizes some well-known methods presented by the above scholars. In the recent research, more and more scholars applied combined model to find the optimal solution. Lin and

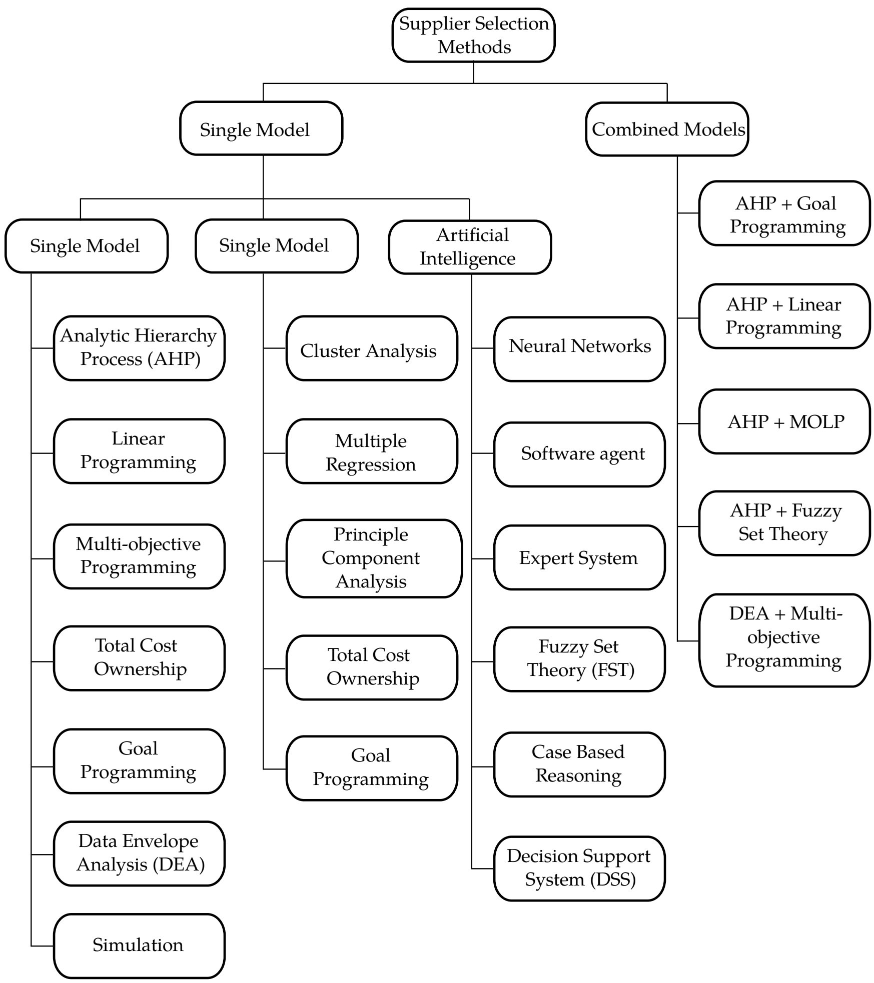

Figure 4

Several analytical methods for suppler selection

Chen (2008) used AHP and Grey Relational Analysis (GRA) to rank the alternatives. Lin and Tsai (2008) used Analytic Network Process (ANP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to find the optimal location.

2.1. *AHP*

The AHP is a theory of measurement for dealing with tangible and intangible criteria, and it has been applied to numerous areas such as decision theory and conflict resolution (Vargas, 1990). The AHP helps the analyst to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. The AHP not only helps the analyst to arrive at the best decision, but also provides the analyst with a clear rationale for the choice made (Chin, 1999). The operating process of the AHP can be summarized as follows (Saaty, 1990):

Step 1: Establish a decision hierarchy by breaking down the problem into a hierarchy of decision elements.

For constructing the relationship among supplier selection criteria in the motherboard supply chain, a qualitative method, Focus Group is used. In this step, the overall hierarchy, number of levels, and decision elements need to be considered and established. A hierarchy structure has several traits as follows:

(a) The highest level stands for the goal, and in our research, the goal is "supplier selection in an electronics firm."
(b) Elements (Factors) which are of the same importance need to be placed in the same level.
(c) Factors of each level should not exceed seven elements in the case of the influence of consistency. If one level has more than seven factors, it should be decomposed to another level.
(d) Factors of each level should be independent.
(e) Elements of the lowest level are alternatives.

Step 2: Collect input by a pair-wise comparison of decision elements. The pair-wise comparison $n \times n$ is expressed as:

$$A = [a_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{1n} & \ldots & 1 \end{bmatrix} \end{array}, \quad (1)$$

If A is a consistency matrix, relations between weights W_i and judgements a_{ij} are given by $W_i/W_j = a_{ij}$ (for $i,j = 1,2,\ldots,n$) and matrix A can be written as:

$$A = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \ldots & w_n/w_n \end{bmatrix} \end{array}, \tag{2}$$

Step 3: Calculate the eigenvalue and eigenvector

To express the relative degree of importance between decision elements, the eigenvector is solved by the eigenvalue method. The largest eigenvalue $\lambda_{\max}$ can be written as:

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} W_j / W_i.$$

If A is a consistency matrix, the eigenvector can be calculated through the following formula:

$$(A - \lambda_{\max} I)X = 0.$$

Step 4: Determine whether the input data satisfies a "Consistency Test".

Saaty utilized two index consistency index (*CI*) and consistency ratio (*CR*) to verify the consistency of the comparison matrix. The accepted upper limit value for *CR* is 0.1. If the consistent test is not eligible ($CR > 0.1$), go back to Step 2 and redo the pair-wise comparisons. CI and CR are defined as follows:

$$CI = (\lambda_{\max} - n)/(n-1), \tag{5}$$

$$CR = CI/RI, \tag{6}$$

where *RI* denotes the average *CI* over numerous random entries of same order reciprocal matrices.

Step 5: Calculate the relative weights of the decision elements, and then compute the entire hierarchical weight.

Step 6: Obtain scores and ranks for the decision alternatives.

After element weights and entire hierarchical weights are calculated, a decision maker is able to make appropriate choice.

2.2. *The hierarchical structure for supplier selection*

There are several methods used to build the AHP hierarchical structure. Lin and Juan (2008) used the modified Delphi approach to build the selection model. In our research, we reviewed the latest five years' literature on selecting criteria to establish the initial hierarchical structure. Nine dimensions and thirty criteria were obtained. In order to match the real case situation of the selection criteria of Taiwanese electronics firms, the qualitative methodology, Focus Group, was used, and five professional buyers and three purchasing managers were group team members. Through Focus Group, we found that an important factor "*trust*" was a key element while making decisions for supplier selection. Monica (2008) indicates that trust is the key element in the process of customer referral management. Five dimensions and twenty criteria were obtained by Focus Group, as shown in Figure 5.

3. Linear programming model

The supplier selection problem consists of both qualitative and quantitative factors. Hence, Ghodsypour and O'Brien (1998) proposed a supplier selection model which is an integration of AHP and LP. In our research, the AHP factors for choosing suppliers were discussed in advance and it was found that "*trust*" criteria is emphasized by today's enterprises. Further, Ghodsypour and O'Brien (2001) examined a numerous techniques for supplier selection, including linear programming, non-linear programming, mixed-integer programming, goal programming and multi-objective programming. Gao and Tang (2003) developed a multi-objective linear programming model for purchasing raw material in a large steel plant and indicated that selecting suppliers and deciding order quantities are the key issues in the purchasing department. X_{ia} and *Wu* (2007) established a multi-objective, mixed-integer programming model for multiple sourcing and multiple products problems under price discounts when ordering large quantity.

In our manuscript, the proposed linear programming model is used to maximize the total purchasing value (TVP). The coefficients of an objective function are provided from AHP which calculates the weights of selected suppliers. When TVP value is maximized, optimal order quantities for each supplier are determined.

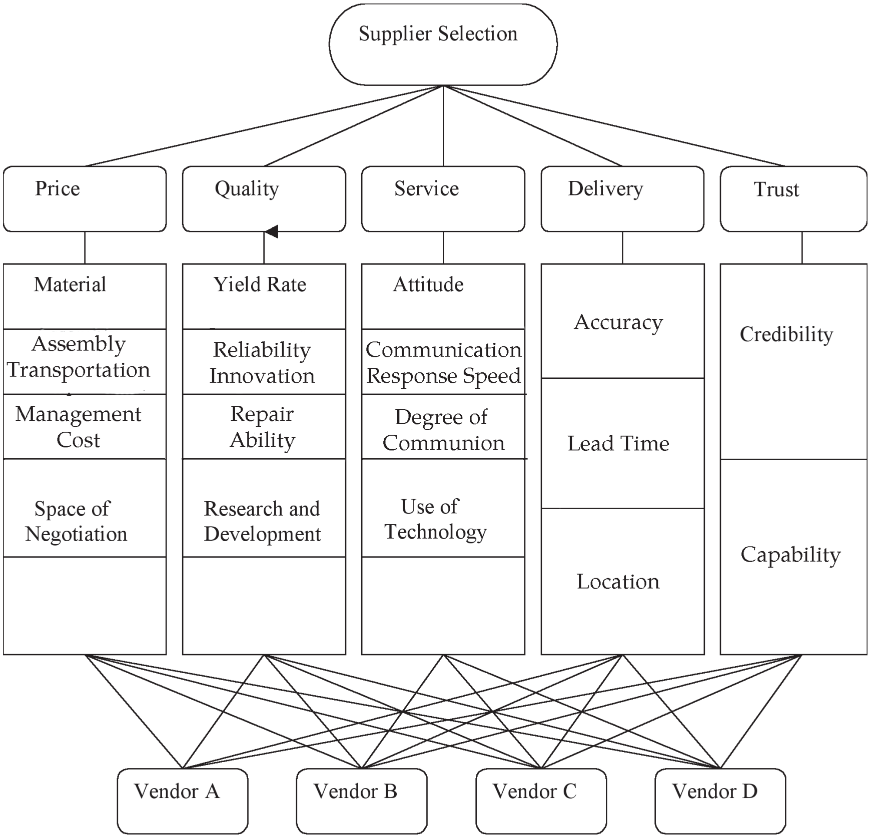

Figure 5

Supplier selection criteria for electronics firms in Taiwan

3.1. *Model configuration*

The objective function and constraints of this model can be written as:

$$\text{Max (TVP)} = \sum_{i=1}^{n} S_i X_i \tag{7}$$

$$\text{Subject to: } \sum_{i=1}^{n} X_i = Q \tag{8}$$

$$\sum_{i=1}^{n} X_i d_i \leq BQ \tag{9}$$

$$\sum_{i=1}^{n} X_i\, p_i \leq UQ \tag{10}$$

$$X_i \leq C_i \tag{11}$$

$$X_i \geq 0, \quad i = 1, 2, \ldots, n \tag{12}$$

where S_i = final ratings of i^{th} supplier;

X_i = order quantity for i^{th} supplier;

C_i = Capacity of i^{th} supplier;

Q = Demand from buyer;

d_i = Defect rate of i^{th} supplier;

P_i = Delayed rate of i^{th} supplier;

B = Buyer's maximum acceptable defect rate;

U = Buyer's maximum acceptable delivery delayed rate.

4. An example of application

This purchase model which combines AHP and LP is applied in a large-scale electronic firm in Taiwan. The company is a high-technology firm that manufactures motherboards for desktop PCs, notebook computers, and servers (industrial computers). There are 1200 employees in the company, and 530 of them are engineers. The electronics company is dedicated to the design, manufacture, purchase, and sale of its electronic products. The procurement department is responsible for material control, supplier selection, supplier performance evaluation, purchasing, and coordination with the production department. Supplier candidates need to be evaluated by criteria formed by the company, and purchase orders are given to approved suppliers after they pass the supplier evaluation. In this application, the component we selected to purchase is a high-tech product – a heat-sink. A heat-sink is located on the top of the CPU and the chipset of the motherboard, and its function is to lead heat distribution and lower the system's temperature. A heat-sink sample is shown in Figure 6, and the heat distribution direction of a heat-sink is shown in Figure 7, and thus, the system's temperature would be lower. The location of a heat-sink and the motherboard components of a desktop or notebook PC are shown in Figure 8.

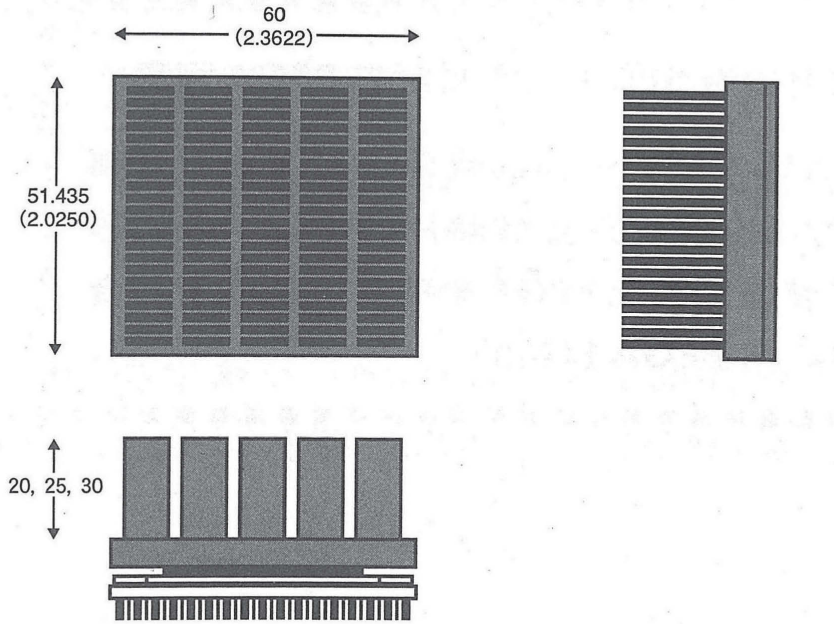

Figure 6

Heat-sink of the motherboard (3-dimensional diagrams)

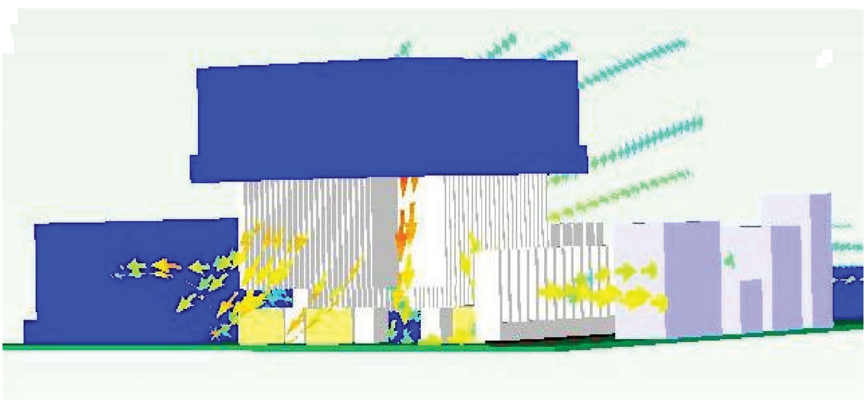

Figure 7

The function of the heat-sink

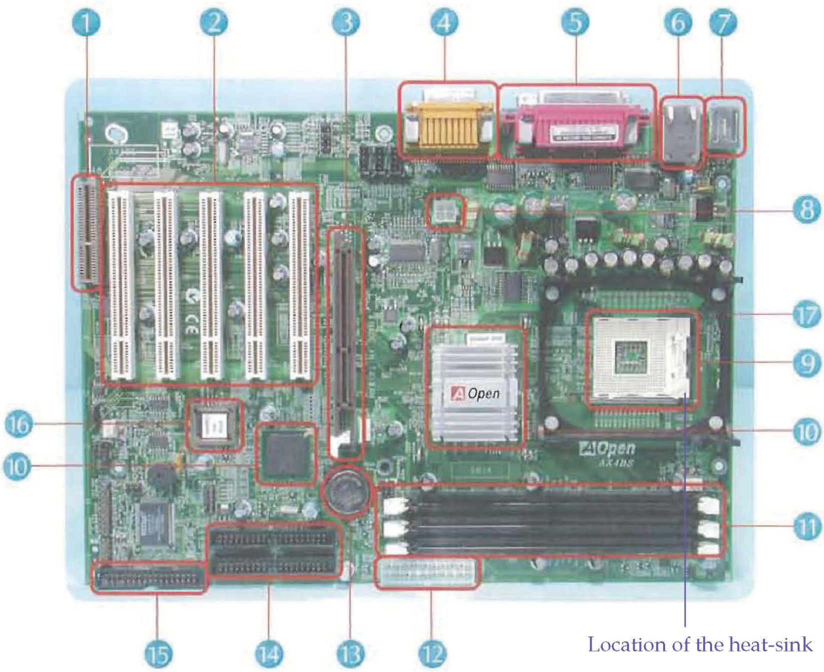

Figure 8
Motherboard components list

5. Results

By combining the weights of criteria, sub-criteria and suppliers' rating in the AHP calculation process, the final score of each supplier are 0.31, 0.32, 0.21 and 0.16 respectively.

After getting the weight for each supplier, the optimum order quantities can be found through the maximized TVP value. Suppose the motherboard manufacturer buyer wishes to buy 2000 pieces of heat-sink, and only 50 pieces can be defective goods. The buyer's maximum acceptable delivery delayed rate is 0.067. According to the specification of a 2000-piece order quantity to be placed to suppliers, the buyer's maximum acceptable delivery delayed quantity is 100 pieces. Based on the suppliers' information provided in Table 1, the formula can be written as follows.

$$\text{Max. TVP} = 0.31\,X_1 + 0.32\,X_2 + 0.21\,X_3 + 0.16\,X_4 \qquad (13)$$

$$\text{Subject to}: X_1 + X_2 + X_3 + X_4 = 2000 \qquad (14)$$

Table 1

Suppliers' information

	Quality defect rate	On time del.	Del. Delayed Rate	Capacity
Supplier 1	0.02	0.95	0.05	800
Supplier 2	0.03	0.92	0.08	900
Supplier 3	0.02	0.97	0.03	500
Supplier 4	0.015	0.0975	0.025	1000

$$0.02\,X_1 + 0.03\,X_2 + 0.02\,X_3 + 0.015\,X_4 \leq 50 \tag{15}$$

$$0.05\,X_1 + 0.08\,X_2 + 0.03\,X_3 + 0.025\,X_4 \leq 100 \tag{16}$$

$$X_1 \quad \leq 800 \tag{17}$$

$$X_2 \quad \leq 900 \tag{18}$$

$$X_3 \quad \leq 500 \tag{19}$$

$$X_4 \quad \leq 1000 \tag{20}$$

$$X_i \geq 0, i = 1, 2, 3, 4 \tag{21}$$

This LP problem can be solved by the software LINDO. The optimum order quantities are respectively: $X_1 = 800$, $X_2 = 500$, $X_3 = 500$ and $X_4 = 200$.

6. Conclusions

In this study, we can understand that a motherboard supply chain network is able to be automatically implemented by an information system which contains the methodology of AHP and LP. By identifying the relationship between a supplier and a customer, a purchasing decision is easily realized when considering "who dominates the purchasing behavior". In motherboard industry, CPU and chipsets are clearly defined as supplier dominated components, because a customer has no authority in processing vendor selection. Therefore, we can conclude that an automated purchasing system as proposed in this paper can be adapted to all components except the CPU and chipsets which are dominated by the supplier. By differentiating from the past research, we found that trust is an important intangible criteria for supplier selection in Taiwan's electronic firms. Cost is not the only reason that enterprises adopt suppliers.

The weights of intangible criteria such as trust and service have become more and more important in supplier selection.

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