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# An ERP model for supplier selection in electronics industry

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ABSTRACT

Asus Tech. is the largest motherboard manufacturer in Taiwan. Hundreds of suppliers cooperate with the company in business. So that supplier selection is the most important function of a purchasing department in the enterprise. An enterprise resource planning (ERP) system in the process of supplier selection may result in the great savings in both costs and man hours. In the concept of push and pull, an ERP system acts as an efficient tool in the resource integration and profit creation for a company. Through ERP, a decision manager can clearly realize the strength and weakness of the purchasing operation. To establish a real-time purchasing environment, a methodology of analytic network process (ANP), technique for order preference by similarity to ideal solution (TOPSIS) and linear programming (LP) are effectively applied in the supplier selection process. ANP and TOPSIS are used to calculate the weight and give suppliers a ranking; LP effectively allocates order quantity to each vendor. As to the result, four PC board suppliers are given orders for 1200, 727, 1000 and 73 pieces.



## 1. Introduction

ERP is an information system to plan and integrate all of an enterprise's subsystems including finance, purchase, production, human resources and sales. The primary function of ERP is to integrate the interdepartmental operation procedures and management information systems (Yang, Wu, & Tsai, 2007). ERP effectively reduces supply chain cost, shortens production time, improves products' quality, provides better service to the customer, and balances the forecasted supply and demand. Fig. 1 is an ERP integration system which includes the main divisions of the enterprise that need to link and integrate. Effectively implementing an ERP system from buyer to supplier may reduce significant cost and substantial amounts of time (Tarantilis, Kiranoudis, & Theodorakopoulos, 2008).

Supplier selection and order allocation are the most significant issues in the purchasing division of enterprises, and these two issues can be effectively integrated into an ERP system to optimize the purchase environment. Selecting the right suppliers not only brings substantial benefits for companies but also increases customer satisfaction. Chen, Lin, and Huang (2006) concluded that the supplier selection problem is a group-decision problem made under numerous criteria, as well as uncertain and imprecise data. Manufacturers must cooperate or have interactions with suppliers to maximize productivity and minimize the total cost (Chou & Chang, 2008). In the past, price was the key reason to choose a supplier because cost reduction is the main consideration for a decision maker. Thus, in the traditional scenario, a vendor provided the lowest price without more concern for other prerequisites, in order to earn more orders from customers. However, in today's competitive global business environment, if an enterprise strives to maintain its competitiveness, its decision maker needs to simultaneously consider suppliers' price, quality, service, etc. Hence, supplier selection is a multiple criteria decision-making (MCDM) problem that requires consideration of both tangible and intangible factors.

Ghodsypour and O'Brien (1998) provided a model combining analytic hierarchy process (AHP) and linear programming to take into account tangible as well as intangible criteria for vendor selection, and to effectively solve order allocation problems among suppliers. This study combines two kinds of MCDM methods, ANP and TOPSIS and a multi-objective programming method. ANP is used to compute the weight of criteria and sub-criteria. After determining each criteria by ANP, TOPSIS is performed to calculate the final score of each alternative, giving each alternative a ranking. At the final step, bundled with the constraints of quality, capacity, delivery, etc., LP is used to compute the optimal order quantity of each supplier after assessing the weight of each alternative. The procedure of supplier selection can be shown in Fig. 2.

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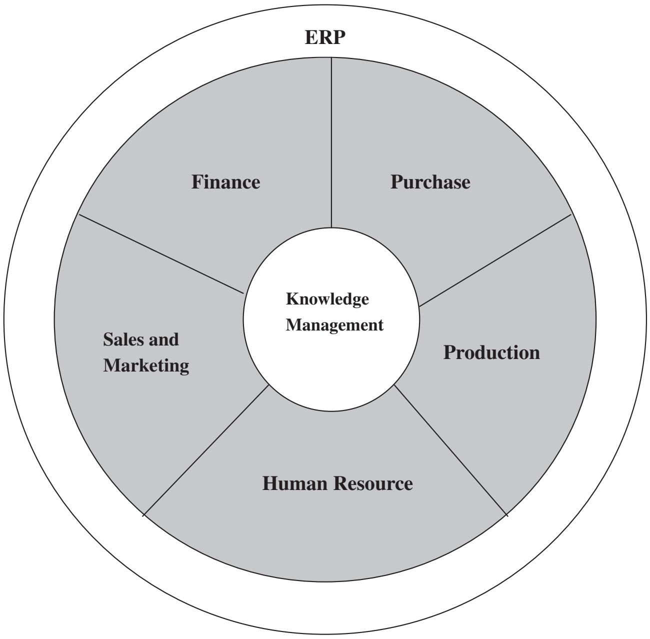


**Fig. 1.** Main divisions improvement through ERP system.

### 1.1. Push and pull

Adopting an ERP system in a purchasing department has two incentives, push and pull. In today's fast-paced, quickly changing environment, enterprises confront more pressure and more challenges from internal forces within the company, as well as from factors external to the company. Hence, enterprises expect to phase in an efficient tool, ERP, to optimize the company operation. The substantial benefits of phasing in ERP are integration, flexibility and real-time responses. The two incentives of push and pull are the main reasons that enterprises adopt an ERP system to

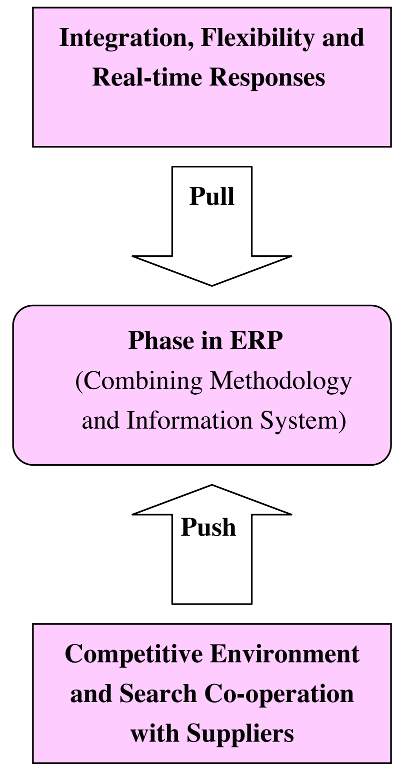


**Fig. 3.** Push and pull concept in an ERP system.

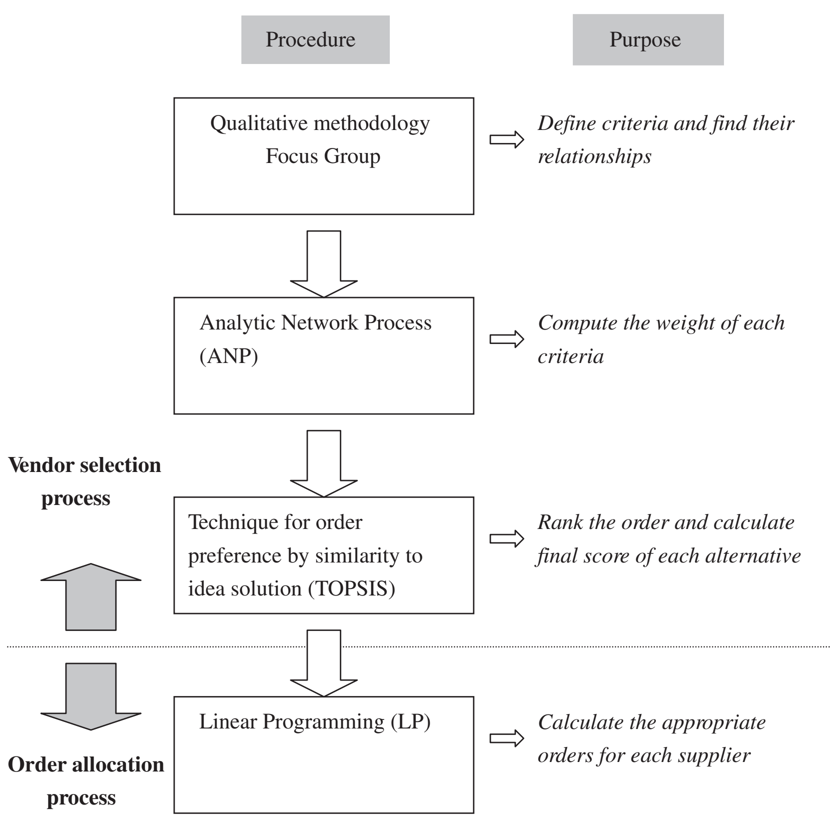


**Fig. 2.** Procedure of supplier selection system.

improve purchase flow. Push and pull concept applying in ERP can be shown in Fig. 3.

## 2. Methodology

To apply the ERP system for the motherboard manufacturer and its four suppliers, in this section, three methods are combined into the ERP system for solving the problem of supplier selection and order allocation. ANP is the extension of AHP and is more suitable for dealing with dependence and feedback. Combining two MCDM methods (ANP and TOPSIS) helps to determine the final score of each supplier. The final score of each supplier is the coefficient of objective function of linear programming. The optimal order quantity can be obtained by maximizing the total purchasing value (TVP) of the objective function.

### *2.1. ANP method*

ANP is an extension of the AHP method. Satty (1990) established an AHP model which contains both tangible and intangible factors and in which each factor is independent. AHP helps decision makers to decompose a complex problem from the top overall goal, breaking it down into concrete criteria and sub-criteria that assist managers in making a decision clearly. A growing number of studies have applied the AHP method for management performance (Wu, Lin, & Peng, 2009). Chang, Wu, and Lin (2007) evaluated digital video recorder systems by using the AHP method. Researchers (Bhutta & Huq, 2002; Liu & Hai, 2005; Saen, 2007) applied the AHP approach to determine suppliers' priority. Actually, some managerial problems cannot apply AHP to solve these types of problems because of influences among criteria. Hence, Saaty (1999) specified that the ANP approach is suitable for dealing with problems of criteria dependence and is much more matched with a practical situation. The structural differences between AHP and ANP are shown in Fig. 4.

By combining the most recent five years' supplier selection criteria and Focus Group methodology, the hierarchical structural was established in Fig. 5. The main criteria of supplier selection in Asus Tech. are price, quality, service, delivery and trust.

### *2.2. TOPSIS method*

The TOPSIS method is an approach for solving multi-criteria problems (Wang & Chang, 2007; Yurdakul & IC, 2005). TOPSIS was first proposed by Hwang and Yoon (1981) and is a widely accepted MCDM technique because of its logic and its programmable computation procedure (Onut, Kara, & Isik, 2008). Chang, Horng, and Lin (2009) improved supply chain management systems for decision makers by applying the TOPSIS. Lin and Tsai (2009) applied the TOPSIS approach to select an ideal city for medical service. Some Scholars proposed a preferable strategic alliance model by applying the TOPSIS approach (Wu, Lin, & Lin, 2009). The method assumes that each attribute has a monotonically increasing or decreasing utility. This makes it easy to define and locate the ideal solution and the negative ideal solution. The concept of TOPSIS is that an alternative which is closest to the ideal solution and farthest from the negative ideal solution in a multi-dimensional computing space is the optimal choice (Deng, Robert, & Yeh, 2000). Therefore, the preference order of alternatives is yielded through comparing Euclidean distances. Supposed there are three alternatives $A_1$, $A_2$, and $A_3$for a single choice. The distance between the alternative and the ideal solution needs to be compared. If the result is $A_2 < A_1 < A_3$, $A_2$ is closest to the ideal solution and $A_2$ is the optimal solution; $A_3$ is the worst choice. Fig. 6 is the explanation for the logic concept of the TOPSIS.

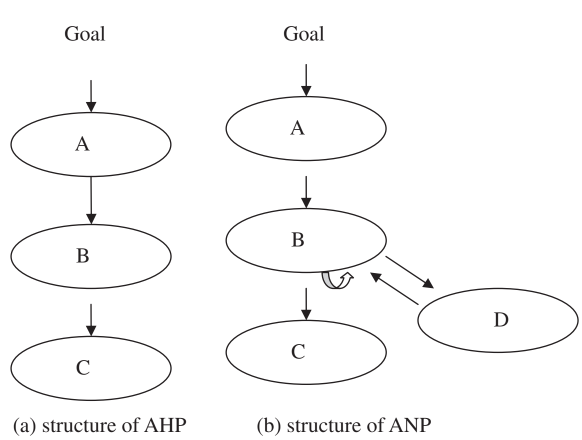


**Fig. 4.** Structure differences between AHP and ANP. Source: Saaty (1999).

Step 1: Build a decision matrix ($D$) with values of criteria

$$D = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} X_{11} & X_{12} & \cdots & \cdots & X_{1j} & X_{1n} \\ X_{21} & X_{22} & \cdots & \cdots & X_{2j} & X_{2n} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ X_{i1} & X_{i2} & \vdots & \vdots & X_{ij} & X_{in} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & \cdots & \cdots & X_{mj} & X_{mn} \end{bmatrix}.$$

Step 2: Normalize the decision matrix ($D$) through the following equation

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}}, \quad j = 1, \dots, n; \; i = 1, \dots, m.$$

Step 3: Establish the weighted normalized decision matrix ($V$)

$$V = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_j r_{ij} & \cdots & w_n r_{1n} \\ \vdots & \vdots & & \vdots & & \vdots \\ w_1 r_{i1} & w_2 r_{i2} & \cdots & w_j r_{ij} & \cdots & w_n r_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_j rmj & \cdots & w_n r_{mn} \end{bmatrix}.$$

Step 4: Determine the ideal solution and negative ideal solution through the following equation

$$A^* = \{(\max V_{ij} | j \in J), (\min V_{ij} | j \in J'), i = 1, 2, \dots, m\} = \{V_1^*, V_2^*, \dots, V_j^*, \dots, V_n^*\}.$$

$$A^- = \{(\min V_{ij} | j \in J), (\max V_{ij} | j \in J'), i = 1, 2, \dots, m\} = \{V_1^-, V_2^-, \dots, V_j^-, \dots, V_n^-\}.$$

Step 5: Compute the distance between ideal solution and negative ideal solution for each alternative

$$S_i^* = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^*)^2}, \quad i = 1, 2, \dots, m,$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2}, \quad i = 1, 2, \dots, m.$$

Step 6: Calculate the relative closeness to the ideal solution of each alternative

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \quad i = 1, 2, \dots, m.$$

Step 7: Rank the order of alternatives.

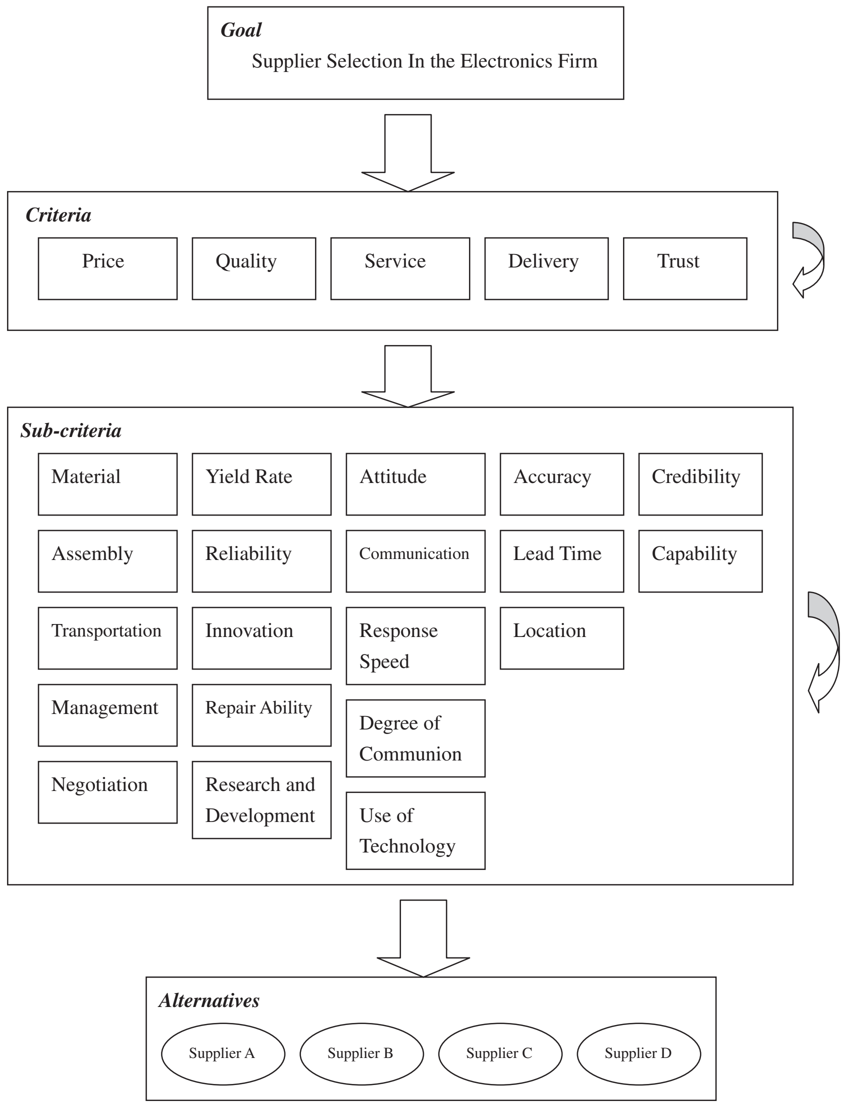


**Fig. 5.** Supplier selection criteria in the electronics firm.

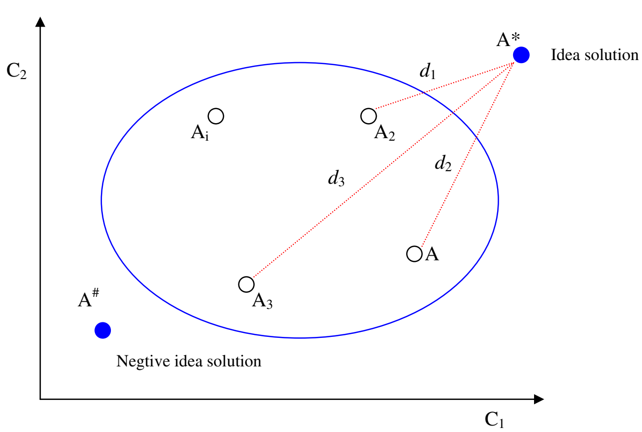


**Fig. 6.** The logic concept of the TOPSIS.

*2.3. Linear programming method*

Ghodsypour and O'Brien (1998) applied the AHP and LP approaches to propose a supplier selection model. Further, Ghodsypour and O'Brien (2001) surveyed several methods such as linear programming, non-linear programming, mixed-integer programming, goal programming and multi-objective programming in the supplier selection process. Gao and Tang (2003) developed a multi-objective linear programming model in the purchasing division of a large-scale steel plant. Xia and Wu (2007) established a multi-objective, mixed-integer programming model for multiple sourcing when ordering large quantities with a discount. Based on previous scholars' research, in our manuscript, we propose an integration model combining the approaches of ANP, TOPSIS and LP. LP model configuration can be written as follows:

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

$$\text{Subject to}: \sum_{i=1}^{n} X_i = Q \quad (\text{Demand Constraint}),$$

$$\sum_{i=1}^{n} X_i d_i \leqslant BQ \quad (\text{Quality Constraint}),$$

$$\sum_{i=1}^{n} X_i p_i \leqslant UQ \quad (\text{Delivery Constraint}),$$

$$\sum_{i=1}^{n} X_i a_i \leqslant UA \quad (\text{Budget Constraint}),$$

$$X_i \leqslant C_i \quad (\text{Capacity Constraint}),$$

$$X_i \geqslant 0, \quad i = 1, 2, \ldots, n,$$

where $S_i$ is the final ratings of $i$th supplier based on the weight in the TOPSIS method; $X_i$ is the order quantity for $i$th supplier; $C_i$ is the capacity of $i$th supplier; $Q$ is the demand from buyer; $d_i$ is the defect rate of $i$th supplier; $p_i$ is the delayed rate of $i$th supplier; $a_i$ is the unit price of $i$th supplier; $A$ is the Buyer's maximum acceptable unit price for an order quantity and $B$ is the buyer's maximum acceptable defect rate; $U$ is the Buyer's maximum acceptable delivery delayed rate.

## 3. Numerical example

The ERP model for purchase integrates three kinds of methodology which are ANP, TOPSIS and LP. The purchase model is applied in a large-scale high-tech firm, Asus Tech., in Taiwan; the firm is dedicated to motherboard production and has already become the largest motherboard supplier worldwide. To assemble a motherboard, hundreds of parts need to be sourced and purchased. The example used in the research is a PC board which is the main component of a motherboard. The PC board example is shown in Fig. 7. When receiving motherboards sales orders from customers, thousands of PC boards need to be purchased from suppliers. At this time the proposed ERP model is applied. The PC board supplier selection and order allocation are determined through the information system. The ANP and TOPSIS decide the optimal suppliers to quote orders, and the optimum order quantity is determined by LP. By using the ERP model, not only can companies save human operation cost, but they can also save a substantial amount of time in placing orders and making negotiations. Moreover, the model shortens the component shipping time and implements the Just In Time (JIT) theory. Fig. 8 is a "success" indication determined by three key elements.

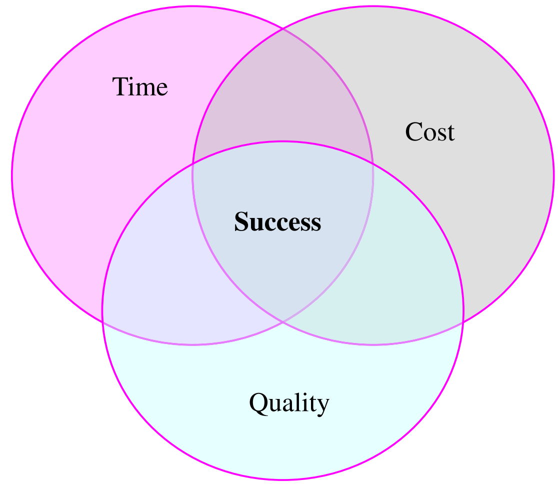


**Fig. 8.** Three key elements for an ERP model.

**Table 1**
Suppliers' information.

| Supplier | Info | | | |
|---|---|---|---|---|
| | Quality defect rate | Delivery delayed rate | Capacity | Unit price |
| Supplier 1 | 0.02 | 0.05 | 1200 | 500 |
| Supplier 2 | 0.03 | 0.08 | 850 | 600 |
| Supplier 3 | 0.02 | 0.03 | 1000 | 550 |
| Supplier 4 | 0.015 | 0.025 | 500 | 630 |

## 4. Results

After calculation of ANP and TOPSIS for four suppliers, the weights for the suppliers are 0.26, 0.32, 0.25 and 0.18, respectively. Then, the optimal order quantity of the four suppliers can be obtained through the LP operation.

Suppose the motherboard manufacturer needs to buy 3000 pieces of PC boards from vendors for production, and the maximum buyer acceptable unit price is NT600 dollars. Therefore, the buyer budget for PC boards is 3000 multiplied by 600, which means the budget is equal to NT1,800,000 dollars. For defective goods, 75 pieces is the upper limitation that the buyer can accept. As the goods that the supplier cannot deliver on time, 150 pieces are the buyer's maximum acceptable delayed quantity. Table 1 shows the detailed information for four PC board suppliers, including status of quality, delivery, capacity and unit price. Based on the suppliers' information, the formula can be written as follows:

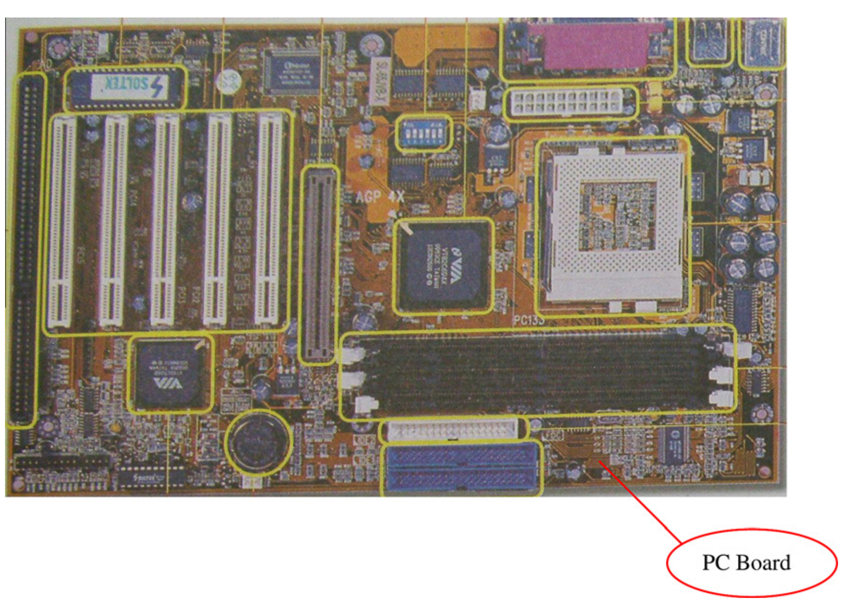


**Fig. 7.** The layout of a motherboard.

$$
\begin{aligned}
\text{Max} \quad & \text{TVP} = 0.26X_1 + 0.32X_2 + 0.25X_3 + 0.18X_4 \\
\text{Subject to}: & X_1 + X_2 + X_3 + X_4 = 3000, \\
& 500X_1 + 600X_2 + 550X_3 + 630X_4 \leqslant 1800000, \\
& 0.02X_1 + 0.03X_2 + 0.02X_3 + 0.015X_4 \leqslant 75, \\
& 0.05X_1 + 0.08X_2 + 0.03X_3 + 0.025X_4 \leqslant 150, \\
& X_1 \leqslant 1200, \\
& X_2 \leqslant 850, \\
& X_3 \leqslant 1000, \\
& X_4 \leqslant 500, \\
& X_i \geqslant 0, \quad i = 1, 2, 3, 4.
\end{aligned}
$$

This LP optimization problem could be solved by using the software LINDO. The optimal order quantities for each supplier are 1200, 727, 1000 and 73 pieces.

## 5. Conclusions

In the ERP environment, cost, time, and quality are three key elements for the success of enterprises. In push and pull concept, a competitive environment forces enterprises to adopt efficient ways, an ERP system, for integration, flexibility, and operation in real-time. Material cost, quality and time of delivery are controlled by buyers of a purchasing division. Cost savings for raw materials may lead higher earning per share (EPS); higher level quality of materials can increase customer satisfaction, causing them to become repeat customers; on-time delivery may reduce production loss and help customers receive their shipments on time.

In our manuscript, four PC board suppliers are given as alternatives. Through an ERP system, we found that supplier 1 obtains the most order quantity and supplier 4 obtains the least orders. From the cost point of view, placing more orders to supplier 1 may save more spending and placing orders to supplier 4 might lead to much higher costs. Due to capacity constraint, supplier 1 only can provide 1200 pieces though it has the lowest unit price, higher quality of material, etc. To save much more cost for the company, the motherboard manufacturer needs to cooperate with supplier 1 and must assist the vendor for enlarging its production capacity. This manufacturer-supplier cooperation concept may create the most value for both sides and proves that the ERP system certainly makes the enterprise competitive and unique.

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