# Implementing Shannon Entropy, SWOT and Mathematical Programming for Supplier Selection and Order Allocation

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***Abstract*— Supplier selection is a multiple criteria decision making (MCDM) problem which is affected by several conflicting factors. In the business market of flaming competition in recent years, more attention has been paid to this problem. In this paper, a two-phased model is proposed for supplier selection and order allocation. At first, suppliers are evaluated according to both qualitative and quantitative criteria resulting from SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. SWOT is a useful technique in strategic management and is utilized to determine criteria and to deal with suppliers' situation in competitive market. Defining the criteria, Shannon entropy is then used to calculate weight of criteria. Then the results are used as an input for integer linear programming (ILP) to allocate order to suppliers. To our knowledge, none of the researchers have integrated Shannon Entropy and SWOT to supplier selection problem. This helps managers to understand the position of suppliers in a competitive environment with a glance at SWOT matrix.**

***Keywords*—** *Supplier selection, Order allocation, SWOT Analysis, Shannon Entropy.*

## 1. Introduction

Increasing globalization, diversity of the product range and increasing customer awareness are making the market(s) highly competitive. Increasing competition has been forcing the manufacturing organization to respond to dynamic demands of the customers (Vanteddu et al., 2010; Zhang and Zhang, 2010). Supplier selection is one of the most critical issues in supply chain management that is important in constructing relationship with partners. The research on the subject of methods that are used in supplier selection problem is abundant. First publications can be traced back to the 1960s. A detailed overview of other supplier selection methods till 2009 can be found in Weber et al., (1991), De Boer et al., (2001) and Ho *et al.* (2010). To date, many researches have been made to deal with this problem. Wang et al. (2009) utilized a hierarchical TOPSIS for supplier selection. They used a numerical example to show effectiveness of their model. Önut *et al.* (2009) applied MCDM techniques to determine long term relationship with suppliers. ANP is used to determine weights of criteria and TOPSIS is used to rank alternatives. Fuzzy logic is also incorporated to deal with vagueness and uncertainty of human. Chen et al. (2010) utilized SWOT to identify enterprise market strategy. Then, potential suppliers were screened through data envelopment analysis (DEA). Consequently, TOPSIS method was adapted to rank suppliers. Zeydan *et al.* (2011) proposed a two stage method for supplier selection considering qualitative and quantitative variables. In the first stage MCDM techniques were used and in the second stage, DEA is performed to rank suppliers. Amin *et al.* (2011) integrated fuzzy logic with SWOT analysis in the context of supplier selection problem. In their article, weights of internal and external factors were calculated by using linguistic variables. Then, the output of SWOT analysis was applied as an input in the fuzzy linear programming (LP) model. Chunjie *et al.* (2012) adopted DEA/AHP model to rank the optional vendors based on the main factors of procurement and then, determined the optimal supplier.

In this paper, a two phase method is applied to select supplier. First SWOT analysis is used to determine criteria. Then, Shannon entropy is used to determine weight of criteria and finally, order allocation is conducted with the aid of the integer linear programming method. The paper is organized as follows. Section 2 describes SWOT. Shannon entropy is represented in section 3. A numerical example is conducted in section 4 to show the usefulness and effectiveness of the proposed model. The paper concludes in section 5.

## 2. SWOT Analysis

SWOT analysis is an important support tool for decision-making, and is commonly used as a means to systematically analyse an organization's internal and external environments (Yuksel and Dagdeviren, 2007). SWOT maximizes strengths and opportunities, and minimizes threats and weaknesses. Chang and Huang (2006) also suggested the quantified SWOT analytical method which was adapted to the concept of Multiple-Attribute Decision Making. They used AHP and a multi-layer scheme to simplify complicated problems. They performed SWOT analysis on several enterprises concurrently. Yuksel and Dagdeviren (2007) proposed analytical network process (ANP) in a SWOT analysis. However, the problems of pairwise comparisons are remained.

## 3. Shannon Entropy

The concept of Shannon's entropy (Shannon, 1948) has a dominant role in information theory. This concept has been developed to different scientific fields, such as physics, social sciences, and so on. We use this formula to obtain the degree of importance of alternatives in the following four steps (M. Soleimani-damaneh, 2011):

**Step 1: Normalization:**

$$P_{ij} = I_{ij} \Big/ \sum_{i=1}^{m} I_{ij} \quad i = 1,2,\ldots,m \; ; \quad j = 1,2,\ldots,n \quad (1)$$

Where $C_1, C_2, \ldots, C_m$ are the criteria and $A_1, A_2, \ldots, A_n$ are alternatives and $a_{ij}$ is the assigned rate for criteria *i* and alternatives *j*.

**Step 2: Compute entropy $e_j$:**

$$e_j = -e_0 \sum_{i=1}^{m} P_{ij} \ln P_{ij} \quad j = 1,2,\ldots,n \quad (2)$$

Where $e_0$ is the entropy constant and is considered equal to:

$$e_0 = (\ln m)^{-1} \quad (3)$$

**Step 3: Set** $d_j = 1 - e_j$ as the degree of diversification for $j = 1,2,\ldots,n$ .

**Step 4: Set**

$$W_j = d_j \Big/ \sum_{j=1}^{n} d_j \quad j = 1,2,\ldots,n \quad (4)$$

As the degree of importance of alternative $A_j$ .

## 4. Numerical example

In this paper, Shannon entropy, as one of the most powerful MCDM tools, is used to deal with the supplier selection problem. In this section, we describe our proposed model simultaneously with numerical example.

### 4.1 Supplier evaluation

***Step 1:*** First, list of potential suppliers are determined. Then using SWOT analysis, criteria are categorized into internal and external. We consider a hypothetical case and define three internal criteria and four external criteria with six alternative suppliers. Internal criteria are price (C1), delivery (C2) and quality (C3) and external criteria are geographical location (C4), financial stability (C5), position in industry (C6) and management (C7).

***Step 2:*** Then decision-makers use following scale to determine importance weight of criteria and to rate alternative suppliers. Table 1 shows the rating scale for the proposed method and Table 2 shows the decision matrix.

**Table 1.** The grading scale

| Grading | Status |
|---|---|
| 7 | Definitely satisfactory |
| 6 | Almost satisfactory |
| 5 | Satisfactory |
| 4 | Average |
| 3 | Unsatisfactory |
| 2 | Almost unsatisfactory |
| 1 | Definitely unsatisfactory |

***Step 3:*** After constructing decision matrix, Shannon entropy is then applied to determine the degree of importance of alternative suppliers. Table 3 shows the results.

**Table 2.** Ratings of six candidates by decision-makers under various criteria

| | | A1 | A2 | A3 | A4 | A5 | A6 |
|---|---|---|---|---|---|---|---|
| Internal | C1 | 4 | 3 | 7 | 3 | 2 | 6 |
| | C2 | 5 | 3 | 1 | 7 | 2 | 1 |
| | C3 | 3 | 4 | 3 | 3 | 3 | 2 |
| External | C4 | 3 | 3 | 5 | 6 | 1 | 3 |
| | C5 | 7 | 1 | 3 | 3 | 7 | 4 |
| | C6 | 3 | 6 | 2 | 3 | 2 | 4 |
| | C7 | 1 | 4 | 4 | 3 | 2 | 1 |

***Step 4:*** In this step, benchmark values are determined for the internal and external factors. Benchmarking value is defined as the average of total weighted values. The coordinated value is computed by subtracting benchmarking values from total weighted score for each alternative. The supplier possesses strengths and opportunities when the coordinated value is larger than the benchmarking value. On the other hand, the supplier is comparatively weak and faces threats when the coordinated value is smaller than the benchmarking value. Table 4 shows the internal and external coordinated values.

**Table 3.** degree of importance of internal and external criteria

| | A1 | A2 | A3 | A4 | A5 | A6 |
|---|---|---|---|---|---|---|
| degree of importance of internal criteria importance | 0.3087 | 0.1077 | 0.3734 | 0.0142 | 0.0678 | 0.1281 |
| degree of importance of external criteria importance | 0.0426 | 0.1759 | 0.2520 | 0.0126 | 0.2085 | 0.3083 |

**Table 4.** coordinated values under the SWOT analysis

| | A1 | A2 | A3 | A4 | A5 | A6 | Benchmarking value |
|---|---|---|---|---|---|---|---|
| Internal coordinated value (x-axis) | 0.1420 | -0.0589 | 0.2067 | -0.1524 | -0.0988 | -0.0385 | 0.1666 |
| external coordinated value (y-axis) | -0.1240 | 0.0092 | 0.0853 | -0.1540 | 0.0418 | 0.1416 | 0.1666 |

Comparative analysis now can be conducted based on SWOT matrix. It is obvious that the position in the quarter of strengths and opportunities is the most suitable position in this figure. Fig. 1 can help DMs to evaluate suppliers very quickly.

***Step 5:*** In this step, integer linear programming is applied to determine the quantity of order for each supplier. This model is based on internal and external criteria and their relative importance weight.

Decision variables:

$X_i$ the amount of order allocated to supplier *i* (*i* = *1*, *2*,…, *m*).

Parameters:

$\alpha_{int}$ weight of internal criteria

$\alpha_{ext}$ weight of external criteria

$I_i$ internal total weighted value for supplier *i* from SWOT analysis

$E_i$ external total weighted value for supplier *i* from SWOT analysis

$v_i$ capacity of supplier *i*

$D_{max}$ maximum demand

$D_{min}$ maximum demand

$g$ unit volume of part

$h$ total capacity of warehouse

Mathematical Model:

$$Max \sum_{i=1}^{n}\sum_{j=1}^{m}(\alpha_{int}I_i + \alpha_{ext}E_i)X_i \qquad (5)$$

$$s.t. \quad D_{min} \le \sum_{j=1}^{m} X_i \le D_{max} \quad \forall i \qquad (6)$$

$$X_i \le v_i \quad \forall i,j \qquad (7)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} gX_i \le h \qquad (8)$$

$$X_{ij} \ge 0, integer \quad i = 1,2,\dots,n, \; j = 1,2,\dots,m$$

(5) is the objective function of the model. It refers to the value of cooperation between supplier and customer. Eqs. (6-9) describe the list of constraints introduced into the model,
(6) determines the maximum demand for parts,
(7) describes the maximum capacity of ith supplier,
(8) describes the inventory capacity limitation according to the capacity of a warehouse,
(9) ensure that decision variable is positive and integer.

There is also limitation in selecting suppliers. Management decides to choose the maximum of three suppliers. Data of Table 5 are used as inputs for mathematical modeling as follows:

**Table 5.** Input data for the mathematical model

| | $\alpha_{int,i}$ | $\alpha_{ext,i}$ | $D_{i\,min}$ | $D_{i\,max}$ | $g_i$ | $h$ |
|---|---|---|---|---|---|---|
| $P$ | $^3/_7$ | $^4/_7$ | 120 | 140 | 0.3 | 40 |

$$Max \;\; ^3/_7 \times [0.3087\,X_1 + 0.1077\,X_2 + 0.3734\,X_3 + 0.0142\,X_4 + 0.0678\,X_5 + 0.1281\,X_6]$$
$$+ \;\; ^4/_7 \times [0.0426\,X_1 + 0.1759\,X_2 +$$
$$s.t. \quad 120 \le X_1 + X_2 + X_3 + X_4 + X_5 + X_6 \le 140$$
$$X_1 \le 40Y_1, \quad X_2 \le 50Y_2, \quad X_3 \le 40Y_3, \quad X_4 \le 45Y_4, \quad X_5 \le 40Y_5, \quad X_6 \le 50Y_6$$
$$Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + Y_6 \le 3$$
$$0.3 \times [(X]_1 + X_2 + X_3 + X_4 + X_5 + X_6) \le 40$$
$$X_i \ge 0, int \;\; Y_i \; binary \qquad i = 1, \ldots, 6$$

This ILP optimization problem with maximization objective is solved by LINGO. Output of this model is the allocated order for each supplier. Results of the proposed model are illustrated in table 6. The objective function is calculated as 30.021.

**Table 6.** Results of linear programming model

| Allocated order | Supplier 1 | Supplier 2 | Supplier 3 | Supplier 4 | Supplier 5 | Supplier 6 |
|---|---|---|---|---|---|---|
| | 0 | 43 | 50 | 0 | 0 | 40 |

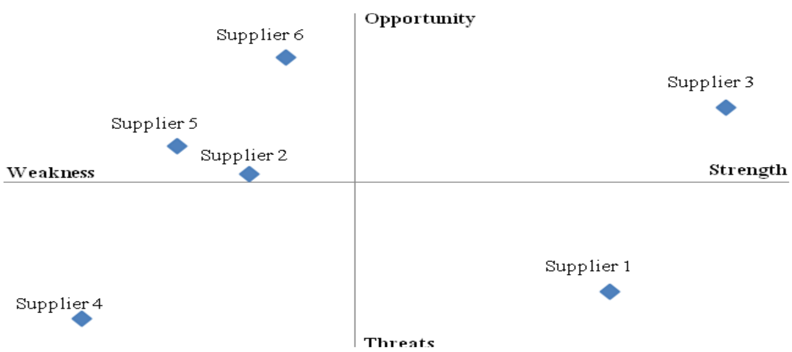


**Figure 1.** Comparative analysis based on SWOT matrix.

## 5. Discussion

If a decision maker or a manager want to decide about suppliers, according to figure 1, it's obvious that supplier 3 is the most suitable supplier. Supplier 1 in comparison with suppliers 2, 5 and 6 has the same status. The only difference is that when managers are emphasizing on internal factors, supplier 1 is better than suppliers 2, 5 and 6 and when managers are emphasizing on external factors, suppliers 2, 5 and 6 are better than supplier

To determine the best mix of orders to allocate to suppliers, linear programming was used. The constraints and management policy was also considered in the proposed model. Capacity constraints such as the capacity of warehouses and suppliers are also considered in the proposed model. As a result, it can be seen that orders are allocated to suppliers 2, 3 and 6.

## 6. Conclusion

In this paper we considered a hypothetical case as a numerical example. It's important in supply chain management to construct reliable and collaborative relationship with partners. To perform SWOT analysis, a matrix was defined to identify the position of suppliers. Considering strengths, weaknesses, opportunities and threats, four regions were made. Certainly, suppliers that are in opportunities-strengths region are the best and those are in the threats-weaknesses region are the worst.

The main characteristics and innovations of the proposed model can be listed as below:

- Proposing a model which simultaneously accomplish; supplier selection and order allocation,
- Determining criteria from strategic point of view,
- Taking into account the internal and external factors,
- Applying fuzzy logic to deal with uncertainty of human mind,
- Considering policies of the company (e.g. warehouse capacity).

Further research may seek to incorporate a method to consider more constraints in proposed linear programming. Other MCDM techniques such as ANP or AHP seem to be useful to calculate the rank of suppliers.

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