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# Long-term supplier selection problem: A case study

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**Abstract**

The problem to select a supplier has taken the best supplier according to all combinations of sorting criteria. With regard to the supplier selection problem, the priority ranking of the criteria taken into consideration to solve this problem has a direct impact on the determination of the "optimum" supplier. This paper provides a case study made for the supplier selection problem involving all possible rankings in cable transfer pulleys used in rolling products by a company X which is active in a steel cable industry in Kayseri, Turkey. NG's model is used in the solution stage in the application. In this research, a new type of supplier selection problem called long-term supplier selection problem with a case study is proposed. Finally, solution of long-term supplier selection problem by a new approach is presented. According to the values obtained by scoring, it has been determined that a long-term agreement can be concluded with the supplier no. 4 (S4) and a long or medium-term agreement can be made with supplier no. 2 (S2). S1, S3 and S5 are determined as the suppliers with the worst performances. As a result, it has been shown to the company that working with S1, S3 and S5 suppliers will not generate any benefits.

Keywords: supply chain management; supplier development; multi-criteria supplier selection; long-term supplier selection problem; case study;

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## 1. Introduction

Competition-based advantages, which are associated with the supply chain management philosophy, can be realized with the help of long-term cooperation through service providers and suppliers. Ng (2008) stated that the success of supply chain management mostly depends on the selection of correct suppliers. Today trying to find the supplier which offers the lowest price is not "effective sourcing". In today's working conditions, it is necessary to take into consideration multiple criteria in the selection of suppliers in the supply chain management. Ho, Dey & Bhattacharya (2015) reported that a long-term supplier selection is different from conventional supplier selection. The number of criteria to consider the supplier selection by a company can vary, depending on the characteristics of the company. In addition, as each study which contributed to the literature has unique criteria, there is an abundance of criteria which are taken into consideration in the supplier selection problem by Ho, Xu & Dey (2010); by Weber, Current & Benton (1991); by Degrave, Labro & Roodhooft (2000); by De Boer, Labro & Morlacchi (2001); by Senyigit (2012); by Senyigit & Soylemez (2012); by Chai, Liu & Ngai (2013); by Senyigit (2013).

Some models from literature are mentioned in Section 2. In Section 3, we provide some explanations about the conceptual model that we have developed in order to utilize this model. In Section 4, we have used a mathematical model which took into consideration the priority sorting in terms of performing the selection of possible suppliers. This model was proposed in the literature by Ng. The data from a factory in Kayseri, Turkey was chosen for the case study and interpretation of the model. The company does not want to report its original name for strategic reasons, thus we did not use company's original name. The case study and its results will be explained in Section 5. In the final section information is given about the conclusion and further studies.

## 2. Literature review

Nine of the 78 studies conducted about supplier selection between 2000 and 2009 employed mathematical modeling types (linear programming, integer-linear programming, integer non-linear programming, purpose programming, multi-purpose programming etc.) (Ho et al. 2010). In the literature there are also some studies conducted with AHP, ANP and PROMETHEE, which are multi-criteria decision-making methods related to the supplier selection problem (Ghodsypour and O'Brien 2001; Ekici, 2013). The reason not to use multiple criteria decision-making criteria is that these methods do not guarantee the optimum solution.

Mathematical models, on the other hand, always guarantee the optimum result. A system with multiple-suppliers, multiple-products and multiple-period order sizes was examined by Basnet and Leung. In this study, the order size in the supplier selection problem was examined, and a complex integer-based mathematical model was constructed for this problem (Basnet and Leung 2005). Ng (2008) presented a weighted linear programming model for the problem to select a supplier. Che and Wang (2008) employed the linear programming model for problem to select a supplier with high quality, minimum cost and an appropriate time. Scott et al. (2013) employed an integrated quality function dispersion and analytical hierarchy process (KFY-AHP) in order to evaluate the potential which provides in renewable bioenergy industry in United Kingdom. This method depends on the critics on responses given to queries about shareholder necessities and evaluation, suitability for the determined criteria and the independent aspects of the participants. The study reveals conclusions obtained about the subject. Ho et al. (2011) employed an integrated quality function dispersion and analytical hierarchy process method.

A review for a long-term (strategic) problem to select a supplier is proposed by Ho et al. (2015). Ji, Ma & Li (2015) proposed an evolutionary game model for the cooperation of suppliers and manufacturers. Environmental performance of service supply chains with multiple criteria decision making approaches is evaluated by Chithambaranathan,Subramanian, Gunasekaran & Palaniappan

(2015). A bayesian framework and Monte Carlo Markov chain simulation are used by Sarkis and Dhavale (2015) to sort and select suppliers. Evaluation criteria for benchmarking the potential suppliers in United Kingdom based carpet manufacturing company is taken into account by Dey, Bhattacharya & Ho (2015). Chai and Ngai (2015) developed a soft decision model for long-term supplier selection. Scott, Ho, Dey & Talluri (2015) proposed a decision support system to selecting appropriate suppliers.

## 3. Problem statements

This research focuses on multi-criteria supplier selection considering all combinations of sorting criteria with a new approach. In the application, a linear model developed by Ng (2008) in multi-criteria supplier selection model was used. In this model, the combination of the criteria which will be used for the evaluation is generated according to the possible priority sorting that will be decided by the company. The objective and constraint functions belonging to the model and the definitions of the notations are given in nomenclature.

### Nomenclature

| | |
|---|---|
| I | Suppliers |
| J | Criteria |
| $X_{ij}$ | j.criteria value of the supplier i |
| $W_{ij}$ | j.criteria weight of weight of the supplier i |
| $Y_{ij}$ | Transformed value of criteria I of supplier j |
| $G_i$ | Goodness score of supplier i |

$$Max\ S_i = \sum_{j=1}^{J} W_{ij} * Y_{ij} \tag{1}$$

s.t.

$$w_{ij} - w_{i(j+1)} \geq 0 \qquad j = 1, 2, \ldots, (J-1) \tag{2}$$

$$\sum_{j=1}^{J} \mathrm{w}_{ij} = 1 \tag{3}$$

$$w_{ij} \geq 0 \qquad j = 1, 2, , \ldots, 5 \tag{4}$$

$$\mathrm{Y}_{ij} = \frac{\left(\mathrm{X}_{ij} - \mathrm{Min}_{i=1,2,\ldots,\{\mathrm{X}_{ij}\}}\right)}{(\max_{i=1,2,..,I\{\mathrm{X}_{ij}\}} - \min_{i=1,2,..,I\{\mathrm{X}_{ij}}\}} \tag{5}$$

Equation 1 is used to calculate the weighted sum of transformed measures for suppliers. Equation 2 is a constraint equation which connotes that the weight values of suppliers be calculated according to the determined criteria combination objectives. Equation 3 is a constraint expressing that the sum of weights should be 1, whereas equation 4 is a constraint that prevents the weight values from being negative. Thus, when the maximization problem is solved and the appropriate $G_i$ value becomes the maximal score, the supplier with this value will turn out to be the suitable supplier for sourcing. Equation 5 shows the normalization function of supplier evaluation scores. The most important reason to apply this equation is that the score unit of each criterion is different from one another. While the unit of quality criterion is percentage, that of the distance criterion is km. For example, while the score scale for such criterion as quality is between 0 and 100 percent, there is no such interval for the distance criterion. Due to such reasons, normalization is made; so that these compiled score values can be organized in a certain interval (0-1 interval for the model). The equation used for normalization is an equation 5 commonly used linear transformation equation.

## 4. The case study

The case study was made, so that a company which is active in Kayseri, Turkey can determine the suitable suppliers for sourcing the pulleys that it uses in rolling its products. It works with five different suppliers in order to procure this product. The picture of this procured product is given in figure 1.

**Figure 1. Picture of the pulley.**

As a result of the interviews conducted with the company, it was determined that four different criteria are taken into consideration on supplier selection. These can be explained as follows:

- Quality (Q): this is an output showing what percentage of the goods is delivered intact.
- Price (P): shows the money paid for one unit of raw material to the supplier (TLs)
- Delivery (DE): percentage of the timely delivered goods.
- Distance (DI): the distance of the supplier to the company. Its unit is km.

After the criteria are determined, data for these criteria which was gathered by this company are given in table 1. In table 1, the price and distance criteria for normalization of the obtained data are classified as cost criteria and quality and delivery criteria are classified as benefit criteria. The basic reason of this classification is that while benefit criteria are being maximized, cost criteria are being minimized. For this reason it is not normalized similarly and the reverse of the criteria belonging to "cost" option are taken. Once the basic evaluation criteria are determined, the combinations belonging to these criteria are begun to be arranged. All 24 different combinations for 4 different criteria (4! =24) were constructed. These combinations are show in table 2.

The data obtained under the light of these explanations which are normalized according to the equation-5 defined in the mathematical model is given in table 3. When this last step is realized, the preparation stage is finalized and modeling and solution stage begins.

**Table 1. Supplier Selection Criteria of the Company and Data Belonging to the Criteria.**

| Suppliers | Q (%) | P (TL) | DE (%) | DI (Km) |
|---|---|---|---|---|
| S1 | 94 | 210 | 60 | 3.5 |
| S2 | 100 | 230 | 80 | 679 |
| S3 | 99 | 220 | 40 | 619 |
| S4 | 95 | 190 | 100 | 3 |
| S5 | 90 | 179 | 60 | 1186 |

**Table 2. Combinations Belonging to Selection Criteria.**

| No | Combinations | | | | No | Combinations | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Q | P | DE | DI | 13 | DE | Q | DI | P |
| 2 | Q | P | DI | DE | 14 | DE | Q | P | DI |
| 3 | Q | DE | P | DI | 15 | DE | P | Q | DI |
| 4 | Q | DE | DI | P | 16 | DE | P | DI | Q |
| 5 | Q | DI | P | DE | 17 | DE | DI | P | Q |
| 6 | Q | DI | DE | P | 18 | DE | DI | Q | P |
| 7 | P | Q | DE | DI | 19 | DI | Q | P | DE |
| 8 | P | Q | DI | DE | 20 | DI | Q | DE | P |
| 9 | P | DE | Q | DI | 21 | DI | P | Q | DE |
| 10 | P | DE | DI | Q | 22 | DI | P | DE | Q |
| 11 | P | DI | Q | DE | 23 | DI | DE | P | Q |
| 12 | P | DI | DE | Q | 24 | DI | DE | Q | P |

**Table 3. Normalized Data.**

| Suppliers | Q | P | DE | DI |
|---|---|---|---|---|
| S1 | 0.400 | 0.330 | 0.330 | 0.860 |
| S2 | 1.000 | 0.000 | 0.670 | 0.002 |
| S3 | 0.900 | 0.160 | 0.000 | 0.002 |
| S4 | 0.500 | 0.740 | 1.000 | 1.000 |
| S5 | 0.000 | 1.000 | 0.330 | 0.000 |

## 5. Modeling and solution

We modeled as follows the supplier selection problem by using the proposed mathematical model Ng (2008). Supplier score for each supplier can be calculated as follows:

$$Max\ G_i = w_{i1}Q + w_{i2}P + w_{i3}DE + w_{i4}DI$$

St.

$$w_{i1} - w_{i2} \geq 0$$

$$w_{i2} - w_{i3} \geq 0$$

$$w_{i3} - w_{i4} \geq 0$$

$$w_{i1} + w_{i2} + w_{i3} + w_{i4} = 1$$

$$w_{ij} \geq 0$$

This mathematical model is solved 120 (24x5) times for each supplier according to the combinations given in table 2. Table 4 shows the all values obtained as a result of the solution of the model. For example, first row of table-4 is calculated by solving mathematical model for each supplier. S1 has 0.48 goodness score while S2 has 1 goodness score. For this row, according to the sorting of the criteria S2 is the best supplier.

When we want to provide a general interpretation taking into consideration the average values given in table 4, it is observed that S4 supplier has to be the primary supplier in procuring the product "pulley" with the highest score (0.92). In addition, when we examine each combination according to especially the top factor of significance degrees, it can be seen that some suppliers having score (1) can be evaluated under the significant category.

If the company is to make an evaluation in terms of long-term management and planning, if it works primarily with S4 and secondarily S2 for product procurement, the highest quality, best price, timely delivery and short distance strategies which were expressed as "purpose" for the selection criteria will be realized.

## 6. Modeling and solution

As long as the companies continue to exist, they have to work with suppliers; hence, it can be claimed that determining the supplier for procurement of the needed raw materials is a long-term decision. However, priorities of the company, its expectations from suppliers and needs can change in time.

Taking into consideration these changes, making long-term supplier selection will secure considerable advantage to the companies against their competitors. In this research, a supplier selection problem and model have been presented which taking into consideration the priorities of the company and changes. This problem was applied to an X company which is active in Kayseri, Turkey. An attempt was made to solve this problem with quality, price, delivery and distance criteria based on the mathematical model which was introduced to the literature by Ng (2008). In this analysis, 24 different combinations for 4 different criteria were calculated in order to determine changing situations.

According to the values obtained with scoring, it was determined that a long-term agreement can be concluded with S4 and a long or medium-term agreement can be made with S2. S1, S5 and S3 are determined as the suppliers having the worst performance. It was shown to the company that working with S1, S5 and S3 suppliers will not generate any benefits.

In further studies, the multi-criteria long-term supplier selection problem can be applied to different sectors and different materials (raw materials). With the help of smart optimization methods, the best suppliers can be determined. New case studies can be examined when the relevant problem is applied. Our next study will examine the problem determination on optimum number of suppliers which have to be used in procurement of materials needed by the company in a multi-criteria long-term supplier selection.

**Table 4. Results**

| Ranking No | Ranking of criteria | S1 | S2 | S3 | S4 | S5 | Ranking of suppliers |
|---|---|---|---|---|---|---|---|
| 1 | Q P DE DI | 0.48 | **1.00** | 0,90 | 0,81 | 0,50 | S2-S3-S4-S5-S1 |
| 2 | Q P DI DE | 0.53 | **1.00** | 0.90 | 0.81 | 0.50 | S2-S3-S4-S1-S5 |
| 3 | Q DE P DI | 0.48 | **1.00** | 0.90 | 0.81 | 0.44 | S2-S3-S4-S1-S5 |
| 4 | Q DE DI P | 0.53 | **1.00** | 0.90 | 0.83 | 0.33 | S2-S1-S4-S1-S5 |
| 5 | Q DI P DE | 0.63 | **1.00** | 0.90 | 0.81 | 0.33 | S2-S3-S4-S1-S5 |
| 6 | Q DI DE P | 0.63 | **1.00** | 0.90 | 0.83 | 0.33 | S2-S3-S4-S1-S5 |
| 7 | P Q DE DI | 0.48 | 0.56 | 0.53 | 0.81 | **1.00** | S5-S4-S2-S3-S1 |
| 8 | P Q DI DE | 0.53 | 0.50 | 0.53 | 0.81 | **1.00** | S5-S4-S3-S1-S2/S5-S4-S1-S3-S2 |
| 9 | P DE Q DI | 0.48 | 0.56 | 0.35 | 0.87 | **1.00** | S5-S4-S2-S1-S3 |
| 10 | P DE DI Q | 0.51 | 0.42 | 0.27 | 0.91 | **1.00** | S5-S4-S1-S2-S3 |
| 11 | P DI Q DE | 0.60 | 0.42 | 0.35 | 0.87 | **1.00** | S5-S4-S1-S2-S3 |
| 12 | P DI DE Q | 0.60 | 0.42 | 0.27 | 0.91 | **1.00** | S5-S4-S1-S2-S3 |
| 13 | DE Q DI P | 0.53 | 0.84 | 0.45 | **1.00** | 0.33 | S4-S2-S1-S3-S5 |
| 14 | DE Q P DI | 0.48 | 0.84 | 0.45 | **1.00** | 0.44 | S4-S2-S1-S3-S5 |
| 15 | DE P Q DI | 0.48 | 0.67 | 0.35 | **1.00** | 0.67 | S4-S2-S5-S1-S3 |
| 16 | DE P DI Q | 0.51 | 0.67 | 0.27 | **1.00** | 0.50 | S4-S2-S1-S5-S3 |
| 17 | DE DI P Q | 0.60 | 0.67 | 0.27 | **1.00** | 0.44 | S4-S2-S3-S5-S1 |
| 18 | DE DI Q P | 0.60 | 0.67 | 0.30 | **1.00** | 0.33 | S4-S2-S1-S5-S3 |
| 19 | DI Q P DE | 0.86 | 0.50 | 0.45 | **1.00** | 0.34 | S4-S1-S2-S3-S5 |
| 20 | DI Q DE P | 0.86 | 0.56 | 0.45 | **1.00** | 0.33 | S4-S1-S2-S3-S5 |
| 21 | DI P Q DE | 0.86 | 0.42 | 0.35 | **1.00** | 0.50 | S4-S1-S5-S2-S3 |
| 22 | DI P DE Q | 0.27 | 0.42 | 0.27 | **1.00** | 0.50 | S4-S5-S2-S3-S1 |
| 23 | DI DE P Q | 0.86 | 0.42 | 0.27 | **1.00** | 0.44 | S4-S1-S5-S2-S3 |
| 24 | DI DE Q P | 0.86 | 0.56 | 0.30 | **1.00** | 0.33 | S4-S1-S2-S5-S3 |
| | Average: | 0.59 | 0.67 | 0.49 | **0.92** | 0.57 | S4-S2-S1-S5-S3 |

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