Supplier Selection Problem based on Integration of MCDM Methods

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ABSTRACT
Selecting the most appropriate supplier is considered to be the main primary concern in supply chain because the producers spend most of their time on supplying the raw materials and component parts. Moreover a lion’s share of cost is allocated to buying goods and services. The aim of this study is applying an integrated method for supplier selection. In this paper, the weights of each criterion are calculated using Shannon’s Entropy method. After that, VIKOR is utilized to rank the alternatives. Then we select the best supplier based on these results. The outcome of this research is ranking and selecting supplier with the help of Shannon and VIKOR techniques. At the end a numerical example is presented to demonstrate the application of proposed method in selecting the suppliers.

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1. Introduction

Nowadays the products and services are so sophisticated that it rarely occurs that an organization or a corporate can solely offer a service or product without cooperating with others. So many organizations are often involved in producing goods or offering services: raw material suppliers, spare part producer and at last organizations which transfer the finished goods to the customers through distribution channels. A system of organizations, people, technology, activities, information and resources that cooperate to produce and supply goods are called as supply chain. Therefore supply chain refers to flow of materials and information, storage of raw material, work-in-process inventory, and finished goods from point of origin to point of consumption [1]. A supply chain management involves processes which directly or indirectly play a role in creating or responding to the demands of customers. Not only Supply chain includes suppliers and producers but also it consists of distribution channels, warehouse, retailers and even customers. In other words supply chain is a set of activities which is to produce and transfer the products and services to the final customer [2]. Therefore supply chain management involves all management activities that can help to satisfy the customer needs along with minimizing the costs of the organizations involved in producing and delivering the goods and services to the customers [3]. Copczak refers to supply chain as group of institutions consisting of suppliers, logistic service providers, producers, distributors and sellers that are connected through flow of information, materials and products [4]. Because the price and quality of the products are directly related to the price and quality of purchased raw material, supplier evaluation and selection is very crucial in manufacturing companies’ success [5]. Furthermore Ellarm indicated in his study (1994) that purchase plays an important role in organization's strategic success by selecting the appropriate supplier and supporting the long-term strategic goals [6]. It can be concluded that implementing an efficient purchase strategy can lead to saving on costs of manufacturing companies and service-provider organizations and selecting appropriate supplier can considerably affect the costs and it contributes to improve the competitive advantage of the companies. On the other hand selecting the inappropriate supplier can lead to many financial and operational problems [7]. The more companies are dependent on suppliers, the more serious is the outcome of a decision related directly or indirectly to supplier selection. The companies are consistently cooperating with suppliers to remain in competition stage and suppliers' performance influences product quality improvement, the decrease in product development time and delay time [8]. The process of supplier selection requires systematic and efficient methods that help the buyer to make best decision [9]. Considering the fact that supplier selection is a multi-criteria problem, it's recommended to apply multiple criteria for measuring the optimum solution and also multiple-criteria decision-making model. These decision-making models are categorized in two...
groups: multiple objective decision-making models (MODM) and multiple attribute decision-making models (MCDM). While multiple objective models are used to design, multiple attribute models are used to select the best alternative. Since this paper intends to evaluate, select and rank the suppliers, multiple attribute decision-making models (MADM) are applied. In MADM problem, particularly in MCDM, we need to have the relative importance of the criteria. This relative importance shows the importance of each criterion in respect to other criteria for decision-making. There are two different methods to obtain these weights: 1) subjective method, 2) objective method; subjective techniques are criticized for their nature and due to their dependence on personal judgment are prone to mental error. One of the most applicable techniques to obtain the relative importance is entropy. In traditional models all criteria values were known while in real world this cannot be true. Due to uncertainty in data, most of decision-makers are faced with imprecise data [10]. Hence the purpose of this paper is to first obtain the weights of interval, qualitative or ordinal criteria in selecting suppliers by interval Shannon entropy and then select the best supplier or suppliers by interval VIKOR method. First paper on supplier selection was written by Dikson in 1966. Dikson introduced 23 criteria in supplier selection. This greatly influenced the researchers in this area [11]. Linear weighting is one of the most common methods for ranking and selecting the different suppliers regarding their performance criteria. This method was introduced in 1968 by Robinson and Wind [12]. Anthony and Buffa formulated the supplier selection problem by linear programming method to minimize the overall costs of purchase and warehouse [13]. Timmerman introduced a comprehensive weighting method to rank the suppliers [14]. Gregory (1986) applied a matrix method to rank suppliers based on scoring and weighting to factors [15]. Weber and et al (1991) reviewed the literature of supplier selection and its methods [16]. Weber and et al categorized quantitative approaches on supplier selection into 3 groups: 1) linear weighing models (Analytic Hierarchy Process (AHP), Interpretive Structural modeling (ISM), and etc.). 2) Mathematical programming models (Goal programming (GP), Multi-objective programming, mixed integer programming, zero-one integer programming, mixed integer nonlinear programming, Data envelopment analysis (DEA), and etc.). 3) Statistical probabilistic approaches [16]. Min (1994) utilized quantitative and qualitative criteria to select effective and efficient international supplier [17]. Ghodsypour and O’Brien introduced a model consisting of AHP and linear programming for supplier selection [18]. Liu (2000) applied DEA method based on multiple objectives to evaluate and rank the suppliers. The model introduced by him was intended to evaluate the suppliers for selecting the best one [19]. Chen (2001) presented a fuzzy MCDM model to study the supplier selection [20]. Baker and Talluri (2202) designed a new multi-step mathematical programming model for supplier selection [21]. Bayraktar and Cebi (2003) presented an integrated model based on four major criteria such as logistic, technology, business and relationships [22]. This paper is organized as follows. Section 3 presents the methodology. The application of the proposed method is addressed in Section 3. Finally, conclusions are provided in Section 4.

2. Research Methodology

In this paper, the weights of each criterion are calculated using Shannon’s Entropy. After that, VIKOR is utilized to rank the alternatives. Finally, we rank the suppliers based on these results.

2.1. Shannon’s Entropy

In most of MCDM problems (particularly in MADM) it is required to have the relative importance of the criteria. This relative importance shows the importance of each criterion in respect to other criteria for decision-making. There are two different methods to obtain these weights: 1) subjective method, 2) objective method; one of the most applicable methods to obtain the relative importance is entropy. Entropy is a crucial concept in social science and information theory. This method is based on the diversification of the values. The more diverse are the values of a criterion, the more important is that criterion. Whether the criterion is positive or negative has no impact on obtaining the weight. The decision-making matrix contains information that is used by entropy as a criterion to evaluate it. Assume the decision-making matrix demonstrated below:

Table 1: Structure of the alternative performance matrix

<table>
<thead>
<tr>
<th>A_i</th>
<th>C_1</th>
<th>...</th>
<th>C_j</th>
<th>...</th>
<th>C_n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f_{11}</td>
<td>...</td>
<td>f_{ij}</td>
<td>...</td>
<td>f_{1n}</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>A_i</td>
<td>f_{11}</td>
<td>...</td>
<td>f_{ij}</td>
<td>...</td>
<td>f_{in}</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>A_m</td>
<td>f_{m1}</td>
<td>...</td>
<td>f_{mj}</td>
<td>...</td>
<td>f_{mn}</td>
</tr>
<tr>
<td>W_i</td>
<td>W_{i1}</td>
<td>W_{ij}</td>
<td>W_{in}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where A_1, A_2, ..., A_m are possible alternatives among which the decision-maker must choose. C_1, C_2, ..., C_n are criteria with which alternative performance is measured. f_{ij} is the rating of alternative A_i with respect to criterion C_j. W_i are the weights of criteria,
expressing their relative importance. To obtain the criteria weights follow the steps given below:

1) Compute the normalized values \( P_{ij} \) by relations illustrated below:

\[
P_{ij} = \frac{f_{ij}}{\sum_{j=1}^{n} f_{ij}}, \quad \forall j.
\]  

(1)

2) Compute entropy values \( E_j \) applying following relations:

\[
E_j = -k \sum_{i=1}^{m} [P_{ij} \ln P_{ij}], \quad \forall j.
\]  

(2)

Where \( k \) is entropy constant and is equal to \((\ln m)^{-1}\)

3) Define \( d_j \) as degree of diversification through:

\[
d_j = 1 - E_j, \quad \forall j.
\]  

(3)

4) Determine the normalized weights \( w_j \) as followed below:

\[
w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \quad \forall j.
\]  

(4)

5) Obtain the balanced weights \( w'_j \) by adding subjective weights \( \lambda_j \) to the previous-step-computed values through:

\[
w'_j = \frac{\lambda_j w_j}{\sum_{j=1}^{n} \lambda_j w_j}, \quad \forall j.
\]  

(5)

\( \lambda_j \) indicates subjective weight. It is applied when the decision-maker determines certain subjective weights for some particular attributes. If there is no subjective weight the fifth stage will be canceled. Therefore, the entropy is an objective method to obtain the weight. However subjective weights can be added at the final stage [23, 24, 25 and 26].

2.2. VIKOR

The VIKOR method, introduced by Opricovic in 1998, is an effective technique in multi-criteria decision-making (MCDM) which is originated from the compromise programming method in solving problems with conflicting criteria. This method focuses on evaluating, ranking and selecting from a set of alternatives in the presence of conflicting criteria. It is particularly used when the decision-maker is not capable of uttering his preferences at the beginning of designing a system. The decision-maker needs a solution which is closest to the ideal. Assume the same multi attribute decision-making matrix demonstrated above (Table 1). Development of the VIKOR method is started with the following form of \( L \)-metric:

\[
L_{pi} = \left\{ \sum_{j=1}^{n} (f_j^+ - f_{ij})/(f_j^+ - f_j^-) \right\}^{1/p}, \quad 1 \leq p \leq \infty, \quad i = 1, \ldots, m.
\]  

(6)

In the VIKOR method \( L_{S_i} \) (as \( S_i \)) and \( L_{R_i} \) (as \( R_i \)) are used to formulate ranking measure. The solution obtained by \( \min S_i \) is with a minimum individual regret of the a maximum group utility (“majority” rule), and the solution obtained by \( \min R_i \) is with a minimum individual regret of the (“opponent”).

(a) Determine the best \( f_j^+ \) and the worst \( f_j^- \) values of all criterion functions \( j = 1, 2, \ldots, n \). If the \( j \)th function represents a benefit then:

\[
f_j^+ = \max_{ij} f_{ij}, \quad f_j^- = \min_{ij} f_{ij}.
\]

(b) Compute the values \( S_i \) and \( R_i \; i = 1, 2, \ldots, m \), by following relations:

\[
S_i = \sum_{j=1}^{n} w_j (f_j^+ - f_{ij})/(f_j^+ - f_j^-).
\]  

(7)

\[
R_i = \max_{j} w_j (f_j^+ - f_{ij})/(f_j^+ - f_j^-).
\]  

(8)

(c) Compute the values \( Q_i \; i = 1, 2, \ldots, m \), by the relation given below:

\[
Q_i = V(S_{i} - S')/(S^- - S') + (1 - V)(R_{i} - R^+)/R^- - R^+.
\]  

(9)

where

\[
S = \min_i S_i \quad S^- = \max_i S_i \quad R^+ = \min_i R_i \quad R^- = \max_i R_i.
\]

\( V \) is introduced as weight of the strategy of “the majority of criteria” (or “the maximum group utility”), here assume that, \( v = 0.5 \). It can be interpreted that the less is the amount of \( V \), the more is accentuated the idea of the individuals and vice versa.

(d) Rank the alternatives, sorting by the values \( S \), \( R \) and \( Q \) in decreasing order. The results include three ranking lists.

(e) Propose as a compromise solution the alternative \( A' \), which is ranked the best by the measure \( Q \) (Minimum) if the following two conditions are satisfied:
C1. Acceptable advantage:

\[ Q(A'') - Q(A') \geq DQ \]  

where \( A'' \) is the alternative with second position in the ranking list by \( Q \); \( DQ = 1/(m-1) \); \( m \) is the number of alternatives.

C2. Acceptable stability in decision making:

Alternative \( A' \) must also be the best ranked by \( S \) or/and \( R \). This compromise solution is stable within a decision making process, which could be “voting by majority rule” (when \( v > 0.5 \) is needed), or “by consensus” \( v \approx 0.5 \), or “with veto” \( v < 0.5 \). Here, \( v \) is the weight of the decision making strategy “the majority of criteria” (or “the maximum group utility”).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives \( A' \) and \( A'' \) if only condition C2 is not satisfied, or
- Alternatives \( A', A'', \ldots, A^{(M)} \) if condition C1 is not satisfied; \( A^{(M)} \) is determined by the relation \( Q(A^{(M)}) \leq Q(A') \times DQ \) for maximum \( M \) (the positions of these alternatives are “in closeness”).

The best alternative, ranked by \( Q \), is the one with the minimum value of \( Q \). The main ranking result is the compromise ranking list of alternatives, and the compromise solution with the “advantage rate”. VIKOR is an effective tool in multi-criteria decision making, particularly in a situation where the decision maker is not able, or does not know to express his/her preference at the beginning of system design. The obtained compromise solution could be accepted by the decision makers because it provides a maximum “group utility” (represented by \( \min S \)) of the “majority”, and a minimum of the “individual regret” (represented by \( \min R \)) of the (“opponent”). The compromise solutions could be the basis for negotiations, involving the decision maker’s preference by criteria weights [27].

3. A Numerical Example

In this section, we presented a numerical example to demonstrate the application of proposed method. The alternative of this example including \( A_1, A_2, A_3, A_4, A_5 \), and \( A_6 \). In this paper criteria are taken from literature [28, 29, and 30]. These criteria include Capacity \( (C_1) \), Availability of Raw materials \( (C_2) \), Delivery \( (C_3) \), Quality \( (C_4) \) and Cost \( (C_5) \). In this paper, the weights of criteria are calculated using Shannon, and these calculated weight values are used as VIKOR inputs. Then, after VIKOR calculations, evaluation of the alternatives and selection of best Supplier is realized.

**Shannon Method:**

First of all we form the decision matrix, after that we compute \( h_i, d_i \), and \( w_i \) base on Shannon method that are shown in Table 2.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>( C_1 )</th>
<th>( C_2 )</th>
<th>( C_3 )</th>
<th>( C_4 )</th>
<th>( C_5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_i )</td>
<td>0.641</td>
<td>0.642</td>
<td>0.640</td>
<td>0.640</td>
<td>0.638</td>
</tr>
<tr>
<td>( D_j )</td>
<td>0.359</td>
<td>0.358</td>
<td>0.360</td>
<td>0.360</td>
<td>0.362</td>
</tr>
<tr>
<td>( w_l )</td>
<td>0.200</td>
<td>0.199</td>
<td>0.200</td>
<td>0.200</td>
<td>0.201</td>
</tr>
</tbody>
</table>

**VIKOR:**

The weights of criteria are calculated by Shannon up to now, and then these values can be used in VIKOR. According to VIKOR methodology, we obtained weighted normalized decision matrix. After that by following VIKOR procedure steps and calculations, the ranking of suppliers are gained. The results and final ranking are shown in Table 3.

<table>
<thead>
<tr>
<th>( i )</th>
<th>( E_i = \Sigma e_i )</th>
<th>( F_i = \max (e_i) )</th>
<th>( P_i )</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_1 )</td>
<td>0.786431</td>
<td>0.2</td>
<td>0.992333</td>
<td>6</td>
</tr>
<tr>
<td>( A_2 )</td>
<td>0.705023</td>
<td>0.2</td>
<td>0.890029</td>
<td>5</td>
</tr>
<tr>
<td>( A_3 )</td>
<td>0.583079</td>
<td>0.2</td>
<td>0.736781</td>
<td>4</td>
</tr>
<tr>
<td>( A_4 )</td>
<td>0.388564</td>
<td>0.135783</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>( A_5 )</td>
<td>0.551585</td>
<td>0.201</td>
<td>0.704869</td>
<td>3</td>
</tr>
<tr>
<td>( A_6 )</td>
<td>0.543376</td>
<td>0.184664</td>
<td>0.569305</td>
<td>2</td>
</tr>
</tbody>
</table>
According to Table 3, A_4 is the best Supplier among other Suppliers and other Suppliers ranked as follow: A_4 > A_6 > A_5 > A_1 > A_2.

5. Conclusions

Supplier selection is one of the most important decision making problems that identify Suppliers with the highest potential for meeting a firm’s needs consistently. The objective of Supplier selection is to identify Suppliers with the highest potential for meeting a company's needs consistently and at an acceptable cost. Selection is a broad comparison of Suppliers based on a common set of criteria and measures. However, the level of details used for examining potential Suppliers may vary depending on a company's needs. The overall goal of selection is to identify high potential Suppliers and their quota allocations. An effective and appropriate Supplier assessment method is therefore crucial to the competitiveness of companies. In this paper, Shanon and VIKOR are combined that VIKOR uses Shanon result weights as input. According to result, A_4 is the best Supplier among other Suppliers.

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