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Supplier Selection Based on Multi-criteria for Multi-product: A Case Study

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ABSTRACT

Now-a-days, owing to the development of information technology and the removal of trade barriers, the supplier selection issue is becoming increasingly popular. A sound supplier selection decision today can prevent a host of problem tomorrow. Supplier selection problems with numerous criteria are examples of the multi-criteria decision-making problems (MCDMs), which are highly challenging to solve. The purpose of this study is to select best suppliers using an MCDM technique considering few specific criteria. In this study, a Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method utilized to tackle a multi-supplier selection problem considering multi-criteria for multi-product. The different criteria considered to select the suppliers are cost, products quality, innovation and development capability, delay in delivery, delivery capability and flexibility, and lead time of the suppliers. The applicability of proposed method is validated by a case study on a transformer company named Energypac Engineering Ltd., Dhaka, Bangladesh. The findings obtained from the implementation show the applicability and efficiency of the proposed approach. The current study is a cutting-edge investigation that makes use of the TOPSIS method to resolve the supplier selection issue. This research not only clearly advances methodological selection of the best suppliers, but it can also be used by businesses as a decision-making tool and a management guide.

Keywords: Supplier Selection, Multi-criteria Decision-making, Multi-product, TOPSIS, Transformer Company.

1. Introduction

The concept of "Supply Chain Management" (SCM) has attracted a lot of attention in academia and business since the 1990s, along with the backdrop of economic globalization, advancements in information technology, and personalization of client needs. A successful SCM depends in large part on the evaluation of the suppliers. As a result, choosing the best suppliers and evaluating them has become a key decision for manufacturing business activities [1].

Supplier selection is a key component of SCM. Choosing the right supplier can make or break a business. A poor supplier can hurt the client relations, lower the quality of the goods and services, disrupt business operations, and raise costs all while lowering sales revenues and margins. This is crucial since modern supply chains must adhere to tight standards, making it challenging for managers to select the best evaluation for potential suppliers. This will guarantee effective production and the establishment of final prices that will be competitive on the market. The correct suppliers can satisfy needs and requirements that are established in the supply subsystem and include quality, price, quantity, delivery dates, flexibility, reliability, and other deadlines [2, 3, 4]. The main objective is to look for suppliers who can meet these specifications or criteria. It is vital to regularly gather and process data about suppliers to get the aforementioned, and to build and maintain relationships with them. Thus, the research question is how can we select multiple suppliers for multi-product that will meet multi-criteria of the customer? The present study will answer the abovementioned question.

Examination of the supplier selection problem has great practical significance in addition to being of great theoretical worth. Recently, the study of supplier selection has gained significant importance and caught the interest of many scholars. The supplier selection dilemma with numerous criteria is a multi-criteria decision-making problem (MCDM), which is a highly difficult decision-making procedure [5]. As a result, several methodologies and procedures have been suggested and used in the evaluation and choice of the best suppliers. There are several MCDM methods available such as the analytical hierarchal process (AHP) [6, 7], the analytical network process (ANP) [8], VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [8], TOPSIS [9], and fuzzy decision-making [10]. While other methods take a long time to develop and are rather sophisticated, TOPSIS is a simple and quick to apply method that simultaneously measures the positive and negative optimum solution. The TOPSIS method is therefore successfully applied in a variety of decision-making contexts.

The TOPSIS, sometimes referred to as the approximative ideal solution, is a useful information evaluation method that was first introduced by Hwang and Yoon [11]. In order to satisfy the nearest distance from PIS and the farthest distance from NIS, it finds the optimal solution based on their relative closeness to the positive ideal solution (PIS) and the negative ideal solution (NIS). This motivates this study to choose the

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ideal supplier from the available options using the TOPSIS as an MCDM technique to select multiple suppliers for multi-product.

The objective of selecting proper suppliers is to maximize quality, delivery capability and flexibility, innovation and to minimize cost, delay time, lead time. Selecting suppliers who can satisfy all standards is challenging. As a result, the issue must be reduced to a single objective decision-making issue by TOPSIS. We have reduced a multi-objective combination optimization issue to a single problem using TOPSIS. Then, this study selects the best suppliers with the maximum objective value. A case study on a transformer company called Energypac Engineering Ltd., Dhaka, Bangladesh, validates the applicability of the proposed method.

The rest of the paper is organized as follows. Section 2 presents a literature review related to the supplier selection problem and solution methods. Section 3 describes the methodology. Section 4 presents the computational results and discussion. Finally, section 5 presents the conclusion with the limitations of this study and future research directions.

2. Literature Review

The issue of supplier selection has become a burning topic in recent years, with a lot of research done on it. This section reviews literature based on the supplier selection related problems and solutions.

There exists extensive volume of work to select suppliers considering different factors and methods. Dickson [12] is a pioneering researcher in the field of supplier selection. Based on questionnaires returned by 170 buying managers of businesses in the United States and Canada, Dickson [12] came up with 23 criteria. A survey of each criterion's importance was also conducted empirically. Then, to provide a comprehensive overview of the criteria and procedures utilized in supplier selection within the industrial sector, Weber et al. [13] analyzed 74 pertinent publications that were published between 1966 and 1990. Many American businesses across a wide range of industries were investigated by Simpson et al. [14], who also highlighted the important standards used to evaluate suppliers. Since most businesses continue to use informal, subjective methods for supplier selection, the results showed that over half of the respondents had no formal system in place for evaluating supplier’s performance. Wetzstein et al. [15] reviewed 221 supplier selection publications that were published between 1990 and 2015.

Table 1 shows a summary of recent studies on supplier selection problem in different application areas with their solution methods. Past studies show that, to identify the best suppliers among the options, a variety of MCDM strategies have been utilized in various sectors [6-9, 14-24]. For instance, AHP [5-6], Fuzzy [10], weighted aggregated sum product assessment (WASPAS) [17] have been used by the researchers to select the suppliers. Hosseini and Khaled [6] made decisions for the resilient supplier selection using AHP in a plastic pipe manufacturing company which produces water and sewage plastic pipes in USA. Besides, Abdel-Basset et al. [7] a quality function deployment (QFD) based AHP to select suppliers for a pharmaceutical manufacturing company. However, AHP cannot guarantee that the decisions it makes are always correct because of its subjective character [20].

Table 1 Literature on supplier selection problems.

Authors	Application area	Solution techniques
Hosseini and Khaled [6]	Resilient supplier selection in a plastic pipe manufacturing company which produces water and sewage plastic pipes in USA	AHP
Abdel-Basset et al. [7]	Supplier selection for a pharmaceutical manufacturing company	AHP-QFD
Abdel-Basset et al. [8]	Supplier selection for an importing corporation	ANP and VIKOR
Sukmawati et al. [9]	Green supplier selection for manufacturing industries	AHP and TOPSIS
Akhtar and Ahmad [10]	Sustainable vendor selection in petroleum refining sector	Fuzzy
Stević et al. [16]	Supplier selection in a lime manufacture company	SAW
Stojić et al. [17]	Supplier selection in a PVC carpentry products manufacturing company	WASPAS
Tanti et al. [18]	Health equipment supplier	TOPSIS
Sembiring et al. [19]	Supplier selection in a rubber industry	ANP and TOPSIS
Lei et al. [20]	Green supplier selection with probabilistic linguistic information	TOPSIS
Alone et al. [21]	Brick material supplier selection in a construction industry	TOPSIS
Sarıçam and Yilmaz [22]	Supplier selection in apparel retail industry	TOPSIS

Abdel-Basset et al. [8] used ANP and VIKOR to select suppliers for an importing corporation. Besides, Stević et al. [16] used a simple additive weighting

(SAW) method for supplier selection in a lime manufacture company. Stojić et al. [17] used WASPAS method to select suppliers in a manufacturing company. However, WASPAS does not consider all performance values; it only considers the minimum (for non-benefit qualities) and maximum (for advantageous attributes) values [23]. Fuzzy approach was utilized by Akhtar and Ahmad [10] for sustainable vendor selection in a petroleum refining sector. However, Fuzzy Analysis is difficult because its outputs can be interpreted in a variety of ways [24]. Moreover, fuzzy rules and membership functions take a long time to design [24]. On the other hand, TOPSIS is a rapid and easy to use method that simultaneously measures optimum solutions that are both positive and negative [18-22]. The TOPSIS is thus successfully applied in a variety of decision-making contexts [18-22, 24]. It is a popular ranking and/or selection method among the MCDM techniques. For instance, TOPSIS has been used to select suppliers for health equipment [18], rubber industry [19], and sustainable consideration [20]. Besides, Alone et al. [21] used TOPSIS for brick material supplier selection in a construction industry. Furthermore, TOPSIS is used Supplier selection in apparel retail industry [22]. The TOPSIS is straightforward to comprehend as it chooses the candidate with an overall performance that is farthest from the peer group's worst values and closest to each criterion's top performers. The closeness coefficient to the ideal solutions, which can be calculated at the end of the procedure for each alternative, is then utilized as a composite index to compare and rank alternatives. Therefore, this study aims to apply TOPSIS method in solving the multi-criteria-based supplier selection problems for a transformer company.

3. Methodology

In the supplier selection problem, a few suppliers are available in the market to supply different products. Selection of the suppliers depends on different criteria. The decision maker or manager evaluates each supplier using different supplier selection methods (e.g., TOPSIS) based on multiple criteria to find the best suppliers. An overview of the supplier selection method is illustrated in Fig. 1.

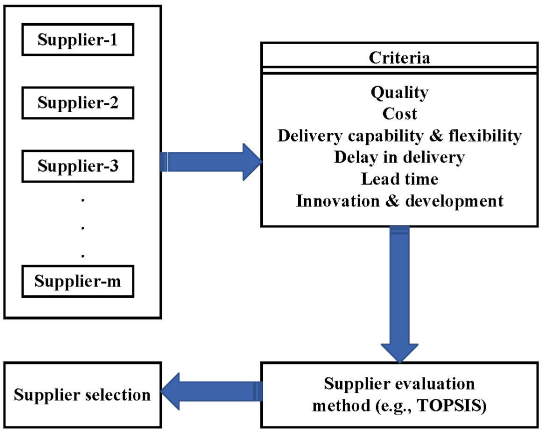

Fig. 1 Supplier selection method.

Based on the literature and experience of the supply chain manager of the company, six different criteria are considered to select the suppliers for different products such as quality, delivery capability and flexibility, innovation, cost, delay time, lead time. Each criterion is divided into different sub-criteria. Fig. 2 presents the main criteria and their sub-criteria to select the suppliers for the transformer company. The objective of selecting proper suppliers is to maximize quality, delivery capability and flexibility, innovation and to minimize cost, delay time, lead time.

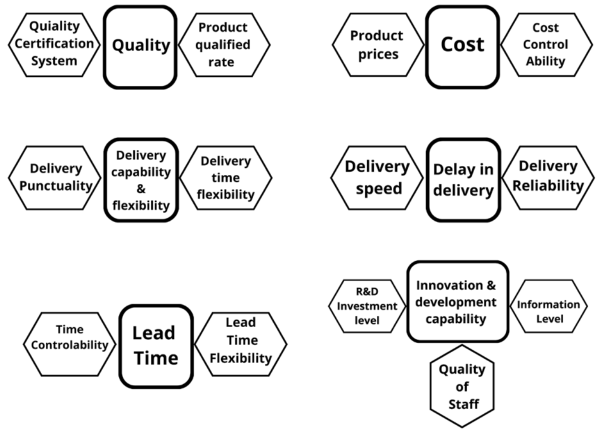

Fig. 2 Main criteria and their sub-criteria.

The supplier selection problem is undoubtedly a combinatorial explosion problem. Selecting suppliers who can satisfy all standards is challenging. As a result, the issue must be reduced to a single, objective decision-making issue. When performing a multi-objective decision analysis, TOPSIS is a particularly efficient method that transforms a multi-objective combination optimization issue to a single-objective problem.

To avoid an unreasonably large number of pair-wise comparisons, the TOPSIS uses the ranking technique because of its concept's case of use. In TOPSIS method, first, with the assistance of experts, we attempt to identify variables and useful criteria for supplier selection are applied. Their revaluation is extracted, after which a list of suitable providers is found, and the decision-making team approves the criteria. We assigned weight to the decision criteria after they were approved. The decision-making panel then approves the computed weight of the criteria. The TOPSIS Method is then used to determine ranks. There are basically six steps of the TOPSIS method that are described in Fig 3 to select the best suppliers.

The TOPSIS method starts with generating a decision matrix for ranking that consists of m suppliers and n alternatives. This decision matrix is also known as *evaluation matrix*. Then, the decision matrix is normalized. After the, a weighted normalized matrix is calculated using the weight of each criterion. Note that, each criterion has a weight based on industry standard or expert's knowledge. Next, the positive and negative ideal solutions are determined. After that, for each alternative supplier, we determine the positive and negative separation measures from the positive and negative ideal solutions, respectively. Finally, the relative closeness to the ideal solution is determined for each alternative supplier. The value of the relative closeness coefficient lies between 0 and 1. The alternative that has the highest closeness coefficient value is the best supplier among the alternatives.

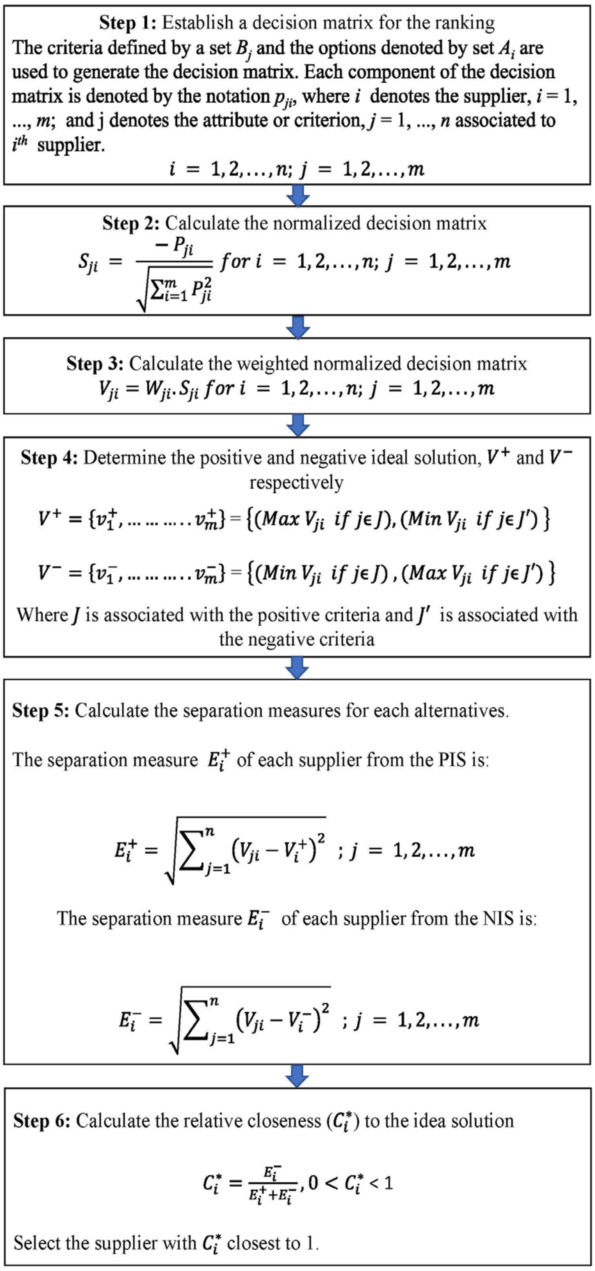

Fig. 3 Procedure of TOPSIS method.

4. Results and Discussion

4.1 Data

This study conducted a case study to select the suppliers for multiple products needed for transformer production. Industrial data were collected from EnergyPac Engineering Ltd. which is the leading transformer company in Bangladesh. Various products are needed to produce a transformer. Among these, eight different products are considered each with three different suppliers. A list of the various products needed for transformer production which is considered in this study is presented in Table 2.

Data related to each supplier's product quality, delivery capability and flexibility, innovation, cost, delay time, lead time are also collected from the EnergyPac Engineering Ltd. Although multi-criteria are considered for selecting suppliers, however the weight for each criterion is not same. The weight for each criterion is considered from the experts who works in the transformer company for more than eight years. Table 3 shows the opinion of the experts regarding the weights on different criteria to select the suppliers in a scale of 10.

Table 2 Types of products.

Product no.	Name of the products
Product-1	Electrical silicon steel sheet in coil
Product-2	Winding copper conductor wire
Product-3	Oil tap changer
Product-4	Transformer oil
Product-5	Insulation materials
Product-6	Programmable kilowatt meters
Product-7	Protection relay
Product-8	Low voltage breaker

Table 3 Weight for each criterion.

Criteria	Experts' opinion		
	E1	E2	E3
Quality	8	10	9
Delivery capability & flexibility	7	8	6
Innovation & development capability	4	7	7
Cost	2	4	6
Delay time	6	7	8
Lead time	3	4	5

4.1 Computational results

This section presents the computational results with discussion to select suppliers for multiple products needed for transformer production. This section first describes the TOPSIS calculations for selecting the bess supplier for the first product, Electrical silicon steel sheet in coil. Then, this section summarizes the results of the selected suppliers for all the products.

Table 4-8 presents the results of TOPSIS method step-by-step like the normalized decision matrix, weighted normalized decision matrix, negative and positive ideal solution, separation from positive and negative ideal solution, and closeness coefficient, respectively for selecting the best supplier for the electrical silicon steel sheet in coil, i.e., the product-1.

Table 4 Normalized decision matrix.

Criteria	Supplier		
	1	2	3
Quality	0.66	0.59	0.46
Delivery capability & flexibility	0.51	0.58	0.64
Innovation & development capability	0.69	0.55	0.48
Cost	0.60	0.58	0.55
Delay time	0.69	0.48	0.55
Lead time	0.24	0.56	0.80

Table 5 Weighted normalized matrix.

Criteria	Supplier		
	1	2	3
Quality	5.93	5.34	4.15
Delivery capability & flexibility	3.58	4.02	4.47
Innovation & development capability	4.11	3.29	2.88
Cost	2.41	2.31	2.20
Delay time	4.80	3.36	3.84
Lead time	0.95	2.23	3.18

Table 6 Positive (V^+) and negative (V^-) ideal solution.

Criteria	1	2	3	4	5	6
V^+	5.93	4.47	4.11	2.20	3.36	0.95
V^-	4.15	3.58	2.88	2.41	4.80	3.18

Table 7 Separation from positive ideal solution.

Criteria	Supplier		
	1	2	3
Quality	0.00	0.35	3.17
Delivery capability & flexibility	0.80	0.20	0.00
Innovation & development capability	0.00	0.68	1.52
Cost	0.05	0.01	0.00
Delay time	2.07	0.00	0.23
Lead time	0.00	1.62	4.96

Table 7 Separation from negative ideal solution.

Criteria	Supplier		
	1	2	3
Quality	3.17	1.41	0.00
Delivery capability & flexibility	0.00	0.20	0.80
Innovation & development capability	1.52	0.17	0.00
Cost	0.00	0.01	0.05
Delay time	0.00	2.07	0.92
Lead time	4.96	0.91	0.00

Table 8 Summary of negative and positive ideal solutions and closeness coefficient.

Measure	Supplier		
	1	2	3
$\mathbf{S_i^*}$	1.71	1.69	3.14
$\mathbf{S_i'}$	3.11	2.18	1.33
$\mathbf{C_i^*}$	**0.65**	0.56	0.30

The results show that, for product-1, the positive ideal solution for the suppliers are 1.71, 1.69 and 3.14 respectively. On the other hand, the values of the negative ideal solution for the suppliers are 3.11, 2.18 and 1.33, respectively. Thus, the closeness coefficient values for suppliers are 0.65, 0.56 and 0.30, respectively. A higher closeness coefficient value indicates better supplier. A supplier with the highest closeness coefficient value is the best supplier. Therefore, for product-1, electrical silicon steel sheet in coil, supplier-1 is the best supplier.

Similarly, using the TOPSIS method, suppliers are selected for the other products. Table 9 presents the results of the selected suppliers for the eight different products that are needed to produce transformer. It is seen that, for the products like electrical silicon steel sheet in coil, winding copper conductor wire, oil tap changer, transformer oil, Insulation materials, protection relay and low voltage breaker, the best suppliers are supplier-1, supplier-3, supplier-2, supplier-2, supplier-3, supplier-3, supplier-3, and supplier-3, respectively.

Table 8 Selected suppliers.

Product	Name of the products	Selected Supplier
Product-1	Electrical silicon steel sheet in coil	Supplier-1
Product-2	Winding copper conductor wire	Supplier-3
Product-3	Oil tap changer	Supplier-2
Product-4	Transformer oil	Supplier-2
Product-5	Insulation materials	Supplier-3
Product-6	Programmable kilowatt meters	Supplier-3
Product-7	Protection relay	Supplier-3
Product-8	Low voltage breaker	Supplier-3

5. Conclusion

This study provides an illustrative case study for multi-supplier selection of different products in a leading transformer company in Bangladesh using multi-criteria. Six different criteria are considered to select the suppliers for eight different products needed for transformer production. Among the criteria, quality, delivery capability and flexibility, innovation and development capability are maximization criteria; whereas cost, delay time, and lead time are minimization criteria. An MCDM technique named TOPSIS is utilized to select the best suppliers for purchasing the products. The benefit of TOPSIS is it transforms the multi-objective supplier selection problem to a single-objective problem. This method makes it evident that choosing a supplier for a certain sector entails several factors, all of which play a significant role. For industrial sectors, the TOPSIS method offers a practical method for choosing the best supplier. The suggested approach can be used as a system to assist practitioners in choosing suppliers in practical situations.

The traditional TOPSIS model has some limitations, such as correlations between criteria, uncertainty in obtaining the weights only by objective methods or subjective methods. In the future, a combination of the TOPSIS technique and Fuzzy can be used to solve these issues. Moreover, to validate the results of this study, a comparison other MCDM techniques like AHP [25] with the current method, TOPSIS, would be a fruitful future scope for this study. The current study has a great importance from both academic research and business perspectives as it helps the managers to select multi-suppliers considering multi-criteria.

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