Application of TOPSIS Method to Green Supplier Selection for a Thai OTOP Producer

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Abstract

In recent years, the level of consciousness and awareness of environmental problems is increasingly concerned by society, businesses and governments globally. In order to decrease hazardous environment effects, a number of organizations have been forced to improve and diminish the harmful impact of business activities in terms of production, consumption and purchasing behavior which may affect the environment. Despite environmental concern, several consumers are also willing to pay more for environmental benefits. Supplier selection is one of the most crucial parts in the decision-making process by which the companies classify, assess and select the suppliers of their required raw materials. The appropriate supplier selection will lead to environmental performance which affect the quality of final product. Thus, this paper presents an approach for evaluating and ranking suppliers with respect to traditional and environmental criteria. Such problem is regarded as multi-criteria decision making (MCMD) in nature that both qualitative and quantitative criteria have to be considered. In this study, TOPSIS method was applied to rank the green suppliers. An illustrate example in herbal cosmetics and personal care products from a Thai OTOP producer, is conducted to demonstrate how to select the most suitable supplier. A set of criteria were identified from literature review and then confirmed by the case company. The decision was made on the basis of observation of three suppliers with ten criteria. The proposed model helps the case company in finding the suitable supplier according to the operating conditions and market performance of those potential suppliers. The findings of this study could contribute a noteworthy tool to help a small enterprise in the supplier evaluation more precisely and reduce the subjective bias to some extent.

Keywords: green supplier selection, multi criteria decision making (MCMD), technique for order of preference by similarity to ideal solution (TOPSIS), Thai OTOP producer
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1. Introduction

In recent years, the world has suffered from environmental destruction, resource depletion, pollution problems and global warming everywhere. The sources of pollution vary from small unit of natural sources to large volume of emission from industrial activities [1, 2].

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These issues have forced manufacturing companies to protect the environment by improving their environmental performance [3]. The growing awareness and consciousness of environmental pressures has led to the emergence of sustainable development, minimizing negative impact on nature, ecology and society. In order to decrease hazardous environmental effects, it is necessary to shift from traditional practices to a more sustainable practice across sectors. As a consequence of this effort, companies today have begun to incorporate green practices in their business activities [4] with all members in the supply chain to make their products universally accepted. It is quite clear that nowadays those companies have also realized the value arising from sustainable actions from markets such as cost reduction due to a consequence of waste reduction [5], as well as competitive advantage over competitors and so forth.

Supplier selection is one of the most crucial parts in the decision-making process by which the companies classify, assess and select the suppliers of their required raw materials. The appearances of those raw materials will be the dominant factor in forming final products' features [6] which is a significant role in meeting greater customers' satisfaction, stakeholders and government [6]. Appropriate supplier selection affects the total supply chain performance and the quality of the final product [7]. As such, it is almost impossible to magnificently produce high quality products without satisfactory supplier selection, especially in today's competitive marketplace. Nevertheless, this task is very complex due to the variety of factors that must be considered during the selection process. Moreover, those factors may vary from time to time and industry to industry.

Supplier selection is a part of any business; however, selecting suitable suppliers are complicated tasks by the fact that several steps and various criteria are involved in decision making process [7]. Such criteria are both quantitative (e.g. cost) and qualitative (e.g. delivery) aspects. This kind of problem is considered as a multi-criteria decision making (MCMD) problem in nature [8]. The increasing complexity of economic and social systems also results in an increase in the complexity of the related decision problems. In relation to the literature, a number of evaluation models for supplier selection were examined and investigated. Traditional model is usually considered economy aspects as a single objective [9]. Some example models are linear programming method and total cost ownership with main emphasis on minimizing costs of production. Recently, several supplier selection problems are addressed in the literature as multiple criteria decision-making (MCMD) problems [10]. These approaches enable the simultaneous assessment of numerous measurable and non-measurable strategic and operational factors, and also allow relevant decision-makers (DMs) in the decision-making process. Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Decision-making Trail and Evaluation Laboratory (DEMATEL), VIKOR, TOPSIS, PROMOTHEE are some of examples of these approaches which have been applied in supplier selection [11].

Selection of suppliers is confronted by various criteria, as well as alternatives for the final outcome. As such, applying the right supplier selection criteria play a critical role in helping companies reach an effective result. Conventionally, price, quality and delivery are the dominant factors when considering any suppliers [12, 13]. Over the last two decades, the sustainable supplier selection has gained attention from industry practices [14, 15] by taking into account the supplier's environmental responsibility due to the competitive market and global warming concerns. Selecting green supplier is the key process of finding a sustainable partnership that will be able to provide customers with lower prices, higher quality, on-time delivery, flexibility, as well as consideration on minimizing the environmental effects [16].

The green supplier selection problem and suitable criteria selection are very important for operations and can directly affect the success of businesses [17]. On basis of the literature

analysis, there are various publications concerning supplier selection and evaluation. However, Akman and Piskin [3] claimed that most studies employed in this area are relatively limited attention on large companies such as petrochemical [18], textile industries [19] and so forth. Nielsen *et al.* [17] argued that finding specific green supplier selection criteria in specific products or different industries are important areas for investigation. Hence, in this paper multi-criteria decision making (MCMD) is employed to implement and analyze for selecting the most efficient supplier among a set of alternatives in green suppliers using a case study of One Tumbon One Product (OTOP) in Thailand. This paper investigates on the application of the proposed model that is a major contributor for a community enterprise to effectively select the best possible sustainable supplier in the global warming and the competitive environment.

2. Materials and Methods

2.1 TOPSIS method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was first introduced by Yoon [20] and further extended by Hwang and Yoon [21]. It is one of the multi-criteria decision making methods which attempts to rank different alternatives through numerical evaluations by the decision maker's performance with respect to certain criteria. The method tries to indicate the best alternative that simultaneously has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The positive ideal solution is a solution that attempts to maximize the profit criteria and minimize the cost criteria, while the negative ideal solution is just opposed to previous one. An alternative with the maximum similarity to the ideal solution will then be selected [22].

This method is relatively simple to understand. Furthermore, it does not have strict assumptions compared to the other MCDM models such as AHP and ANP [23]. One of the benefits of TOPSIS over AHP and ANP is that the method avoids pair-wise comparison process or a consistency check. Moreover, it is simple and quick to apply and a measurable assessment accounts for both the ideal and non-ideal choices at the same time [24]. TOPSIS has been successfully applied to a wide range of application areas and industrial fields, including supply chain management and logistics, engineering and manufacturing systems, and business and marketing management [25]. Accordingly, in this paper TOPSIS method is employed to evaluate suppliers of a community enterprise based on their performance towards criteria. The steps of TOPSIS can be summarized as follows:

Step 1: Construct normalized decision matrix $R= (r_{ij})_{m*n}$.
This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Vector normalization is the most frequently used methods for calculating the normalized value [26]. The procedure depends on the type of attribute.

For benefit attribute,

$$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{m} x_{ij}^2} \quad (1)$$

For cost attribute,

$$r_{ij} = 1 - (x_{ij} / \sqrt{\sum_{i=1}^{m} x_{ij}^2}) \quad (2)$$

where i = 1, … , m; j = 1, … , n , m is the number of attribute value in each criterion, n is the number of criteria and x_{ij} is original score of decision matrix, respectively.

Step 2: Construct the weighted normalized decision matrix.
Here w_j represents a weight of each criterion for j = 1,…,n. Given $w_j \in [0,1]$ with $w_1+w_2+\ldots+w_n = 1$. Then multiply each column of the normalized decision matrix by its associated weight to get v_{ij}. The weighted normalized decision matrix is written as equation (3):

$$v_{ij} = w_j r_{ij} \quad (3)$$

These weights can be directly determined by the decision maker or using other methods such as ROC and AHP.

Step 3: Determine the positive ideal A* (PIS) and negative ideal solutions A' (NIS).

$$A^* = \{ v_1^*, \ldots, v_n^* \} = \{ (\max_i (v_{ij}), j \in J) (\min_i (v_{ij}), j \in J') \} \; i = 1, \ldots, m \quad (4)$$

$$A' = \{ v_1', \ldots, v_n' \} = \{ (\min_i (v_{ij}), j \in J) (\max_i (v_{ij}), j \in J') \} \; i = 1, \ldots, m \quad (5)$$

where J is associated with “the more, the better” or “benefit” criteria and J' is associated with “the less, the better” or “cost” criteria.

Step 4: Calculate the separation measures for each alternative from A* and A'.
The separation measured from the ideal alternative is calculated using the m-dimensional Euclidean distance. The distance of each alternative from A* and A' is calculated using the following formulas:

$$S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{1/2} \qquad i = 1, \ldots, m \quad (6)$$

$$S_i' = [\Sigma (v_j' - v_{ij})^2]^{1/2} \qquad i = 1, \ldots, m \quad (7)$$

Step 5: Calculate the relative closeness to the ideal solution C_i^*.

$$C_i^* = S_i' / (S_i^* + S_i') \qquad 0 < C_i^* < 1 \quad (8)$$

Step 6: Rank the preference order.
Rank the preference order and select the alternative with maximum C_i^* which is closest to 1 or rank alternatives according to C_i^* in descending order. The larger value of C_i^* indicates the better performance of the alternatives [25, 26].

2.2 Supplier criteria

Aforementioned studies reveal varieties of factors involving in supplier selection decisions factors. The pioneer work was done by Dickson [27] who conducted a survey with 273 US companies to identify the important factors for vendor selection. The study identified 23 criteria and revealed that product quality, on-time delivery and performance history of supplier and

warranties were the most significant factors for supplier selection. This study was re-examined by Weber *et al.* [13] via reviewing all seminal articles between 1996-1990. The results of their study illustrated that 23 criteria still remained but the ranking of those criteria had been changed.

In the last two decades, supplier selection based on environmental/green consideration has been attracted the attention of numerous researchers. For instance, Govindan *et al*. [23] studied 33 previous papers from 1996 to 2011 on green supplier selection. Later, Nielsen *et al.* [17] reviewed international journal articles from the appearance to 2013. Both studies revealed the growth of green criteria taking into consideration in supplier selection process. Some environmental aspects are green image, environmental management system, pollution control and so on.

In this study, green supplier selection criteria are summarized into ten criteria from reviewing twenty publish articles between 2010-2019 [3-4, 18, 23, 28-41]. These criteria can be grouped into two categories, i.e. economy and environmental aspects which are displayed in Table 1.

2.3 The empirical case of a Thai OTOP producer

An empirical case study of XYZ for a Thai OTOP producer, located in Samutprakarn province, is selected to illustrate the applicability of the proposed methodology. XYZ, a micro enterprise, produces herbal cosmetics and personal care products such as body cream, facial cream, hand cream, cleansing lotion, bath foam, shampoo, toothpaste and liquid soap. Products are sold to local markets though online and offline marketplace, as well as selling directly to other consumers through regional exhibitions and fairs organized by the government.

Due to the rising awareness in health and environment, it is a must for producers to provide trustfulness with high quality standard natural products to their consumers. Therefore, it is necessary that herbal in process and product from upstream to downstream has to be reassured. Selecting the right suppliers in relation to such production is very crucial. Such raw materials of XYZ are aloe, butterfly pea, purple rice, lemon-grass, peppermint oil and lime. Most local suppliers are found in the Eastern and Central parts of Thailand. Management team is responsible to plan when to produce each product as well as helping each other to find raw materials and select appropriate suppliers. Lately, XYZ considers 3 main suppliers (S_1, S_2,S_3) and also aims to develop supplier selection intensively with respect to environmentally friendly targets and natural based ingredients products.

However, at present there is no any tool to help the case company to select the proper suppliers as yet. Accordingly, development of the right supplier evaluation criteria and model is essential for this case enterprise. It will not only enable the producer to promptly deliver the quality goods, reduce its operating costs but will also take environmental issues into the consideration at the same time. The application of the proposed algorithm is divided into 5 steps i.e. 1) determination and evaluation criteria, 2) assigning weights criteria, 3) determining qualified suppliers, 4) evaluation of alternatives by implementing TOPSIS method and 5) obtaining the final rank.

Table 1. Summarization of common supplier selection criteria

Category	Criteria	Definition	References
Traditional aspects	(A) Cost	Cost of acquisitioning product including material, transportation, inventory, etc.	[18,28,29,30,31, 32,33,34, 35,36.37]
	(B) Delivery Reliability	Ability to fulfill shipping orders within the period of time promised	[18,29,33,34,35, 36, 37,38]
	(C) Quality	Meet the quality requirements	[18, 29,30,31, 32, 34,35,36,38,39,40]
	(D) Flexibility and responsiveness	Ability to tolerate the variability	[18,23,33,34]
	(E) Service capability	Ability to provide added service value	[18, 28, 29, 31,32, 33,35,36,37]
	(F) Strategic alliance	Willingness to share information, capability of building long term relationship	[33,36]
Environmental aspects	(G) Pollution control	The control of emissions and wastes into air, soil and water	[3,32,33,34,35,36,41]
	(H) Green competencies	The competencies of supplier in improving green production such as a use of environmentally friendly materials	[3, 32,33,34,35,36]
	(I) Environment Management System (EMS)	A set of systematic practices reducing environmental impacts	[3,4,18,23,31,32,34, 35,36]
	(J) Green image	Market share changes due to the adoption of environmentally friendly products or implementing green program	[3,18,32]

3. Results and Discussion

3.1 Determination and evaluation criteria

The first step is to determine criteria that will be used for the selection of alternatives or suppliers. An interview process is the important source to gain insight for the case practices. Regarding data collection of the case company through interviews and inquiries compared with those reported in the literature, the company owner was asked whether those attributes were appropriate for the company in the supplier selection. The case company has agreed with those 2 main categories with 10 criteria from the published literature, as mentioned in Table 1. However, some of those criteria are still at the beginning stage for implementation with suppliers.

3.2 Assigning weight criteria

First, five experts (three of them were management team of XYZ, one of them was a government officer who has responsibility to promote OTOP products in Thailand and the rest was a key customer of this company) were selected to involve in the process. They were asked to give their evaluation to those ten criteria according to their importance using score 1 to 10. One means that criteria were the least importance, whereas 10 means that criteria were the most importance. Then, Rank Order Centroid (ROC) technique [42] was employed to calculate weights of those criteria. ROC is simple, easy to follow and practical for determining criteria weight. According to Morais and de Almeida [43], it was found that ROC performed better than other approximate weights, i.e. Rank sum (RS), Rank reciprocal (RR) and Equal weight (EW) via testing with simulation study. Hence, it is widely applied in multi-criteria models in dealing with imprecise information [44].

Table 2 shows the results of important weights of the criteria provided by ROC and the ranking. It reveals that quality (C), cost/price (A) and pollution control (G) are the top three important criteria in the supplier selection process identified by ROC technique for this community enterprise.

Table 2. Weight and rank criteria

Criteria	Weight	Rank
(A) Cost/Price	0.192897	2
(B) Delivery reliability	0.109563	4
(C) Quality	0.292897	1
(D) Flexibility and responsiveness	0.033611	8
(E) Service capability	0.021111	9
(F) Strategic alliance	0.047897	7
(G) Pollution control	0.142897	3
(H) Green competencies	0.064563	6
(I) Environment management system (EMS)	0.010000	10
(J) Green image	0.084563	5

3.3 Determining qualified suppliers

The XYZ examined three main suppliers which were labeled as S_1, S_2 and S_3. The assessment was conducted in form of 1-10 scale (1-lowest performance,…, 10-highest performance according to ten criteria mentioned herein with the evaluation criteria being recorded as A, B, C,…J. Three key decision-makers from XYZ producer, i.e. the owner (DM_1), a financial manager (DM_2) and a purchasing manager (DM_3), were involved in the decision making process [45]. Practically, they are only three people in this community enterprise who take a responsibility for material management due to the small size of business. The results of the assessment of each supplier with respect to the ten criteria are displayed in Table 3.

Table 3. Input values of the TOPSIS analysis

Criteria	DM_1			DM_2			DM_3		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
A	8	7	6	10	9	8	9	9	8
B	9	9	7	9	8	7	8	8	7
C	8	9	6	8	10	5	9	10	8
D	7	7	8	8	8	7	7	7	7
E	8	9	8	7	8	10	7	7	9
F	9	8	6	9	9	7	7	9	5
G	8	7	7	9	8	8	10	7	7
H	9	8	7	9	9	7	8	8	6
I	6	6	6	7	7	6	8	8	7
J	8	8	7	7	7	7	7	7	6

3.4 Evaluation of alternatives by implementing TOPSIS method

The first step is to construct a normalized decision matrix using equations (1) and (2). After that a weighted normalized decision matrix is calculated using equation (3). The results are provided in Table 4.

Table 4. Weighted normalized decision matrix

	S_1	S_2	S_3	A*	A'
A	0.0714	0.0804	0.0939	0.0714	0.0939
B	0.0683	0.0656	0.0551	0.0683	0.0551
C	0.1713	0.1987	0.1302	0.1987	0.1302
D	0.0194	0.0194	0.0194	0.0194	0.0194
E	0.0110	0.0120	0.0135	0.0135	0.0110
F	0.0297	0.0309	0.0214	0.0309	0.0214
G	0.0937	0.0763	0.0763	0.0937	0.0763
H	0.0407	0.0391	0.0313	0.0407	0.0313
I	0.0060	0.0060	0.0054	0.0060	0.0054
J	0.0503	0.05023	0.0457	0.0503	0.0457

3.5 Obtaining the final rank

After determining the weighted normalized decision matrix, the ideal and negative ideal solutions are computed using equations (4) and (5).Then the Euclidean separation distance between the positive ideal solution (A*) and the negative ideal solution (A') for each alternative are calculated using equations (6) and (7) in order to find the relative closeness to the ideal solution (C_i^*), which is shown in Table 5. Lastly, the closeness coefficient of each supplier is estimated, as presented in Table 6.

Table 5. Euclidean separation distance

	S_i^*			S_i'		
Supplier	S_1	S_2	S_3	S_1	S_2	S_3
Total	0.0276	0.0198	0.0767	0.0534	0.0719	0.0025

Table 6. Closeness coefficients and supplier ranking

Supplier	S_1	S_2	S_3
$\mathbf{C_i^*}$	0.6596	0.7837	0.0315
Ranking	2	1	3

4. Conclusions

Green supplier selection problem is still relatively new concept in Thailand, especially for SMEs and micro enterprises. However, in recent years a number of companies have started to realize the importance of sustainability due to an increasing awareness in environmental production and its long term effect on businesses' performance and marketing issue [8]. It is obvious that the choice of green suppliers relates to the long term development of any business. This research proposes the TOPSIS method for solving a real world OTOP producer in the selection of supplier with the incorporation of environmental requirements. TOPSIS is a good management tool for handling both qualitative and qualitative assessments of such problems. The foundation of TOPSIS is grounded on the logic of defining the positive ideal solution and the negative ideal solution points.

The decision making process involves multiple and conflicting criteria. Those criteria for green supplier selection of XYZ were firstly identified based on the published literature. With the validation of key experts in the case company, possible green supplier selection criteria were identified and ranked. According to Rank Order Centroid (ROC) technique, it reveals that quality (C), cost/price (A) and pollution control (G) are major influencing criteria for the XYZ to evaluate green suppliers. It could be concluded that 'S_2' is the best alternative supplier, followed by 'S_1' and 'S_3', respectively. The research demonstrates that this method can objectively evaluate criteria of listed green suppliers in the herbal cosmetics and personal care products producer, which is a small scale enterprise. The study indicates that TOPSIS can be used as a decision support model for making effective choice and could reduce subjective bias from decision makers in some extend [25].

Also, this study has shown some limitations that can provide opportunity for further study in this area. One of the limitations is that only a real case study is demonstrated, which limited to three suppliers. Moreover, these suppliers were determined by three related management team according to ten criteria. With the development of sustainability supply chain management, a social performance aspect could be incorporated in supplier selection for future studies [32]. Furthermore, another technique such as Structural Equation Modeling (SEM) could be employed to identify criteria and their sub-criteria from a group of community enterprises around the country. Analytical Hierarchy Process (AHP) could also be further employed to weight the importance of those factors in order to observe the changing of the results with respect to the changing of weights criteria. In addition, the proposed model of this study could be extended by taking fuzzy environments into consideration in order to deal with the imprecise judgments, and the ambiguity of human being's judgment [36]. Consequently, the efficiency of the evaluation could precisely be increased.

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