EVALUATING AND SELECTING SUSTAINABLE SUPPLIERS BASED ON FUZZY-VIKOR METHOD: CASE STUDY FOR SOCAL CO., LTD

ỨNG DỤNG PHƯƠNG PHÁP FUZZY-VIKOR TRONG ĐÁNH GIÁ VÀ LỰA CHỌN NHÀ CUNG ỨNG BỀN VỮNG: TRƯỜNG HỢP CỦA CÔNG TY SOCAL VIỆT NAM

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ABSTRACT

This study aims to provide a solution to evaluate and select a sustainable supplier based on the Fuzzy - VIKOR method in an automobile company in Vietnam. By using an integrated Fuzzy - VIKOR method, we find that the "Quality of product", "Price of product", and "Environmental Management System" are the top three criteria in the criteria for evaluating sustainable suppliers that are prioritized by the members of the expert's opinions. This study contributes to limited current research on supplier evaluation and selection in Vietnam. Besides that, the proposed integrated approach gives more insight to decision-makers in the company.

Keywords: Fuzzy-Vikor method; sustainable suppliers; multi-criteria-decision-making; sustainable supply chain management..

TÓM TẮT

Nghiên cứu được thực hiện nhằm đưa ra giải pháp hỗ trợ quá trình đánh giá và ra quyết định lựa chọn nhà cung ứng bền vững dựa trên phương pháp Fuzzy-VIKOR, trường hợp của một doanh nghiệp Ô tô tại Việt Nam. Kết quả nghiên cứu cho thấy, ba tiêu chí quan trọng và cần được ưu tiên nhất khi doanh nghiệp đánh giá tính bền vững của nhà cung ứng là "Chất lượng sản phẩm", "Giá sản phẩm", và "Hệ thống quản lý môi trường". Nghiên cứu giúp làm giàu nền tảng học thuật, vốn còn hạn chế, liên quan đến đánh giá và lựa chọn nhà cung ứng tại Việt Nam. Bên cạnh đó, kết quả ứng dụng phương pháp Fuzzy-VIKOR mở ra thêm nhiều góc nhìn cho các nhà quản trị của doanh nghiệp.

Từ khóa: Fuzzy-Vikor method; sustainable suppliers; multi-criteria-decision-making; sustainable supply chain management.

1. Introduction

Over the last two decades, more systematic approaches to supplier selection have received special attention from researchers. These supplier selection strategies have been highlighted as critical for reducing risk in the automotive industry (Carvalho et al., 2016). When selecting suppliers, purchasing individuals/groups always evaluate based on multi-criteria approaches (Holt et al., 1994). According to Azadi et al. (2014), finding the right supplier for the organization to form deep relationships is a strategic issue. Supplier evaluation and selection (SES) is a crucial factors for managing, and developing an efficient and effective supply chain. The problem of choosing sustainable suppliers became more serious as there are complex relationships between the criteria (Deng et al., 2014). In order to better meet the sustainability goals of the supply chain, this study suggests a practical method for evaluating and selecting sustainable suppliers.

Among common Multi-Criteria Decision Making (MCDM) approaches, the Fuzzy set

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theory (FST) proposes a precise mathematical approach to modeling ambiguous preferences, such as in the decision of setting the weight of performance scores on criteria (Azadi et al., 2014). In addition, to enhance the quality of tools, FST can be used in combination with other techniques. According to Wang et al., (2019), Fuzzy multi-criteria techniques are classified into 4 types: (1) Methods for multi-attribute utility; (2) Methods for ranking and scaling; (3) Compromising procedures, such as the technique for order preference by similarity to ideal situation (TOPSIS) and the Vlse Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR); (4) Other techniques: SMART.

There are also a number of other studies that have used the TOPSIS model to support managers in making decisions related to many different areas such as: Using Fuzzy-TOPSIS to evaluate suppliers (Tran et al., 2019); Assessing the potential of Japan's FDI attraction location in Quang Ninh (Pham Hong Bien, 2022); Using the Fuzzy-AHP-TOPSIS model integration in evaluating and selecting logistics service providers (Nguyen et al., 2023). Thus, it shows that research on the application of FUZZY-VIKOR in selecting warehouse locations in Vietnam is still limited.

Therefore, this paper aims to apply the Fuzzy - VIKOR method in evaluating and selecting sustainable suppliers at a distribution company in Vietnam. In fact, we first use the Fuzzy set theories to evaluate suppliers based on aspects of sustainability, then apply the VIKOR method to rank and choose the best supplier at Socal Vietnam company. The results show that Quality, Price, and Environmental Management systems are the top three criteria for evaluating sustainable suppliers that are prioritized by the members of the review team. This suggests to suppliers who want to

become the official supplier for Socal Vietnam company with information on assessment standards, so they can focus on orienting and developing core competencies to achieve the best assessment results. This study contributes to a limited amount of existing research into supplier assessment and selection in Vietnam. Besides that, the proposed integrated approach gives more insight to decision-makers in the company.

2. Sustainable supplier selection

2.1. Supplier Sustainable Evaluation and Selection

The dependence on purchased raw materials and outsourced production of enterprises is increasing, leading to the selection of suitable supplier based on sustainable criteria (Liaqait et al., 2021). The role and impact of these suppliers on sustainability, organization and supply chain requires strongly and rigorous evaluation and selection of supplier. Strategic sourcing is built based on the supplier selection process, which also forms the basis of supply advantage. Carvalho et al. (2016) indicate that reducing the risk of purchasing, maximizing the overall value of the buyer and building a close and lasting relationship between the buyer and the supplier are the main objectives of the supplier selection process.

With the emergence of Sustainable Supply Chain Management (SSCM), the selection process can be carried out with expanded criteria based on three aspects of sustainability. According to Amindoust et al. (2012), supplier selection plays a crucial role in the development of sustainable supply chain partnerships, on the other hand, creates complexity in the multi-supplier evaluation process. They also proposed a framework for supplier evaluation and selection based on three key aspects of sustainability. The result indicates that besides the utility of the

framework, the acceptance of the management board is also crucial. Recently, more and more studies are being done on choosing sustainable suppliers since the topic has recently attracted interest from academics and experimentation (Wang et al., 2019).

2.2. Criteria for sustainable supplier selection

Supplier audits are classified into two types, process-based and performance-based. The former is performed by evaluating websites and supplier certificates, resulting the performance of their actual production and service processes. It is based on the real performance of the supplier, in relation to several criteria such as cost and delivery reliability (Amindoust et al., 2012). The performance assessment is more commonly used than process-based assessment due to the availability of objective data and ease of measurement (Monczka et al., 2009).

The number of criteria for selecting supplier selection will vary depending on the quantity, qualitative attributes, and quantitative factors. Dickson (1966) was one of the first researcher to propose 23 various criteria for choosing on supplier selection, including Price, Quality, Capacity, Distribution, and Performance. From the seven-C model that includes capacity, capacity, commitment, control, cash, cost, and consistency), he updated with three new C's culture, cleanliness and communication and changed the name to the 10C model.

Recently, Luthra et al (2017) provide a summarizes 19 studies about evaluating and selecting suppliers based on sustainability attribute criteria within three mains dimensions including Economic (ECO), Environment (ENV), and Social (SOC). Accordingly, The most frequently used criteria in 15 out of 19 studies were "Product prices", "product quality" or "Delivery and servicing". Followed by "Environmental

management system" (11), "Flexibility" (10), "Technological and financial capacity" (10), Green design and purchasing (10). The criteria with the least frequency of use are "R&D and green improvement" (2), "Profit per product" (3), "Green management" (3), "Transportation cost" (3).

2.3. Methodology

2.3.1. Data collection

Firstly, a set of evaluation criteria is required for supplier evaluation. Information about the evaluation criteria was collected through a semi-structured interview with the Manager of the Sourcing Department of Socal Vietnam. They have been asked to evaluate the sustainability criteria they apply in their purchasing process, as well as other supply risks. After that, they were given a list of sustainability criteria compiled from the document (Table 1) and might adjust their opinions based on this list, which provides a foundation for managers' opinions.

Secondly, a group of three members of the Sourcing department conduct supplier evaluation based on the official set of criteria. They should be ensured to have a basic understanding of the supplier base to evaluate and select suppliers. Each member assesses the importance of the criteria and assesses the alternatives on the basis of linguistic variables.

The qualitative data gathered based on the official set of sustainability criteria will be quantified. Transformation scales are commonly used to convert language variables into fuzzy numbers. The process of interpreting visual evaluation by converting languages into fuzzy sets is described in the following section.

2.3.2. Methodology

According to Opricovic & Tzeng (2004), the VIKOR method is utilized to optimize the criteria of complex systems (Chu et al.,

2007). In this study, the integrated model of Interval type-2 fuzzy sets and VIKOR method is performed in six steps as presented in following steps:

Step 1: Form a group of decision-makers, defined a set of criteria and appropriate linguistic variables.

First, forming a group of decision-makers in which each member has a certain understanding of the supplier base for the objectives of supplier evaluation and selection. These team members may come from different departments within the organization, forming a cross-functional team. Then, from the criteria defined by the Supply Manager, each member is required to use the linguistic variables in Table 1 to rating and evaluate the importance of the criteria. There are seven language scales, ranging from "Very Low - VL" to "Very High - VH".

Table 1. *Set of criteria for sustainable supplier evaluation*

Code	Factors	Items	
CR1	Economic (ECO)	Quality of the Product	QP
CR2		Price of the Product	PP
CR3		Technology and financial capacity	TC
CR4		Production time	LR
CR5	Environment (ENV)	Environmental management system	EM
CR6		R&D and green development	GRD
CR7		Product Design	GDP
CR8		Environmental capacity	ENC
CR9	Social (SOC)	Rights of related parties	RS
CR10		Information Transparency	IS

Step 2: We provide the content of construct the fuzzy decision matrix and average fuzzy decision matrix. Fuzzy decision matrix $\widetilde{D}_k$ of the kth decision-maker, $1 \leq k \leq K$, m suppliers and n criteria

$$\widetilde{D}_k = (\tilde{x}_{ij}^k)_{m \times n} =$$

$$\begin{bmatrix} \tilde{x}_{11}^k & \tilde{x}_{12}^k & \cdots & \tilde{x}_{11}^k & \cdots & \tilde{x}_{1n}^k \\ \tilde{x}_{21}^k & \tilde{x}_{22}^k & \cdots & \tilde{x}_{2j}^k & \cdots & \tilde{x}_{21}^k \\ \vdots & \vdots & & \vdots & & \vdots \\ \tilde{x}_{i1}^k & \tilde{x}_{i2}^k & \cdots & \tilde{x}_{ij}^k & \cdots & \tilde{x}_{in}^k \\ \vdots & \vdots & \cdots & \vdots & & \vdots \\ \tilde{x}_{m1}^k & \tilde{x}_{m2}^k & \cdots & \tilde{x}_{mj}^k & \cdots & \tilde{x}_{mn}^k \end{bmatrix}$$

Where $\tilde{x}_{ij}^k$ is the fuzzy rating of ith regarding to f j^{th} criterion. In other words, it represents a positive trapezoidal set of the Interval Type-2 Fuzzy (IT2F) values of supplier A$_i$ of the kth decision-maker and takes the influence of criteria C$_j$ into account.

Step 3: Construct the Fuzzy Weighting Matrix and Average Fuzzy Weighting Matrix

Fuzzy Weighting Matrix $\widetilde{W}_k$

$$\widetilde{W}_k = (\widetilde{w}_j^k)_{1 \times n} = \begin{bmatrix} \widetilde{w}_1^k & \widetilde{w}_2^k & \cdots & \widetilde{w}_n^k \end{bmatrix}$$

Where $\widetilde{w}_j^k$ represents the positive trapezoidal set of IT2F values; Average Fuzzy Weighting Matrix $\overline{W}$

$$\overline{W} = (\overline{\tilde{w}}_j)_{1 \times n} \qquad (10)$$

Where $\overline{\tilde{w}}_{j1}$ represents positive trapezoidal set of IT2F values

$$\overline{\tilde{w}}_{j1} = \frac{\widetilde{w}_j^1 \oplus \widetilde{w}_j^2 \oplus \dots \oplus \widetilde{w}_j^k}{k}, 1 \leq j \leq n \quad (11)$$

Step 4: We provide the content of the construct weighted decision matrix ($\overline{D}_w$) as follows:

$$\overline{D}_w = (\tilde{f}_{ij})_{m \times n} =$$

$$\begin{bmatrix} \tilde{f}_{11} & \tilde{f}_{12} & \cdots & \tilde{f}_{1n} \\ \tilde{f}_{21} & \tilde{f}_{22} & \cdots & \tilde{f}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{f}_{m1} & \tilde{f}_{m2} & \cdots & \tilde{f}_{mn} \end{bmatrix} \qquad (12)$$

Where $\tilde{f}_{ij}$ represents positive trapezoidal set of IT2F values

$$\tilde{f}_{ij} = \bar{\tilde{x}}_{ij} \otimes \bar{\tilde{w}}_j, \ 1 \leq j \leq n \qquad (13)$$

Step 5: We provide the content of de-fuzzy weighted decision matrix into crisp value. Then, we compute the value of utility index S_i, regret R_i as described below

$$S_i = \sum_{j=1}^n w_{ij}(f_j^* - f_{ij})/(f_i^* - f_j^-)$$

$$R_i = \max w_{ij}(f_j^* - f_{ij})/(f_i^* - f_j^-)$$

$$S^* = \min(S_i), S^- = \max(S_i)$$

$$R^* = \min(R_i), R^- = \max(R_i)$$

Where v is the weight for the strategy of 'maximum group utility' and its parameter can take a value between 0 and 1.

Step 6: By sorting the values S, R, Q in descending order, the alternatives are ranked. Thus, the best solution shall be the one with the lowest index value Q.

3. Results

3.1. Applying Fuzzy approach in analyzing decision information

The linguistic variable evaluations obtained in Step 1 are converted into IT2F with upper and lower value. The results are presented in Table 2.

Table 2. *Average weight IT2F and Aggregated weight of 10 criteria*

Code	Average	Important
CR1	0.94	1
CR2	0.91	2
CR3	0.70	5
CR4	0.82	4
CR5	0.88	3
CR6	0.38	10
CR7	0.64	6
CR8	0.51	7
CR9	0.44	9
CR10	0.51	7

The result as shown in Table 3 indicates that four criteria off Economic aspect all have high positions in the correlation of the importance of ten criteria: Quality-1, Price-2, Production time-4, Technological and financial capacity-5; four environmental criteria have a ranking: Environmental management system-3, Green product design and purchasing-6, Environmental competence-7, R&D and green innovation-10; and two social criteria have a ranking: Training and development-9, Social competence-10.

The criterion "Quality" (0.94) is regarded as the most significant, followed by the criterion "Price" (0.91). This demonstrates that the decision-making team places a high value on the quality of materials in order to ensure the continuity of the production system. This finding is also consistent with previous research. According to various studies, managers believe that the most important criterion for selecting suppliers is quality (Lam et al., 2010). Furthermore, the criterion "Reasonable price" is prioritized second, which also supports the company's goal of reducing COGS.

Socal is an electrical components manufacturer in the distribution industry, operating under a highly competitive environment to keep cost down by 20% annual, which explains the emphasize of "quality" and "reasonable price". This is the reason why the whole company as well as its staff is forced to work hard to find new sources that can provide items at a lower price and/or negotiate with existing suppliers to cut down the purchase price compared to the previous year while consistently enhancing product quality. According to Khan et al. (2018), the buyers expect continuous improvement in supplier performance in relation to product quality and order fulfillment times. Suppliers who

are always improving their quality make the manufacturer more competitive in downstream markets (Wang et al., 2019). Furthermore, the criterion "Production time" (0.82) has the rating of Medium High (MH) - High (H) since it can impact on the order completion time for clients. The shorter the time from sending the order request to receiving the goods, the more timely it is to ensure the production system.

The crisp value of the supplier evaluation rating is calculated in the same way as aggregated fuzzy weights, as shown in Table 3 (from high to poor). Supplier SUP3 comes out on top with the highest score in all crisp values (0.74) and in seven criteria (CR1, CR2, CR3, CR5, CR7, CR9, CR10). Supplier SUP5 has the same rating and ranking with Supplier SUP1 in terms of C5 and C7. Supplier SUP1 has the highest rating on C4 (0.69) and Supplier SUP4 has the highest rating on C8 (0.42).

Table 3. *Crisp value of weight and rating*

Code	Weighting value	Order
CR1	0.94	"SUP3>SUP1>SUP2>SUP5>SUP4"
CR2	0.91	"SUP3>SUP1=SUP5>SUP4>SUP2"
CR3	0.70	"SUP3>SUP5>SUP4>SUP1>SUP2"
CR4	0.82	"SUP1>SUP3>SUP4>SUP2=SUP5"
CR5	0.88	"SUP3=SUP5>SUP1>SUP2>SUP4"
CR6	0.38	"SUP5>SUP3>SUP2>SUP1>SUP4"
CR7	0.64	"SUP3=SUP5>SUP1>SUP2>SUP4"
CR8	0.51	"SUP4>SUP3=SUP5>SUP2>SUP1"
CR9	0.44	"SUP3>SUP4>SUP5>SUP1>SUP2"
CR10	0.51	"SUP3>SUP1=SUP5>SUP4>SUP2"

3.2. Applying VIKOR method in sustainable supplier selection

The most efficient sustainable supplier among alternatives is selected by using VIKOR analysis. The ideal and worst value of all alternatives are determined, as shown in Table 4. From Table 4, f* is expressed as the set of beneficial attributes, and f- is expressed as the set of negative attributes.

Table 4. *Ideal value (f*) and Worst value (f-)*

	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CR10
f*	0.72	0.60	0.63	0.67	0.53	0.32	0.55	0.40	0.35	0.39
f-	0.03	0.17	0.24	0.28	0.06	0.01	0.26	0.14	0.23	0.04

In order to make a optimization of the decision, the optimal compromise values can be set in descending order. The results are presented in Table 5. Based on the crisp value of Q_i, the descending order is SUP3-SUP1-SUP5-SUP2-SUP4. The most effective option is supplier 3 (SUP3).

Table 5. *S, R and Q value and supplier ranking order*

Value	Order
S	"SUP3>SUP5>SUP1>SUP2>SUP4"
R	"SUP3>SUP1>SUP5>SUP2>SUP4"
Q	"SUP3>SUP1>SUP5>SUP2>SUP4"

From Table 5, the combination of the values of S_3, R_3, Q_3 results in option SUP3 is met. Therefore, the alternative SUP3 has the advantage. At the same time, SUP3 always holds the highest rank in S rating and R rating, which ensure the stability of the compromise solution of decision making according to the consensus strategy.

4. Conclusions

In this study, we proposed an integrated approach to apply in the actual supplier evaluation and selection in Socal Vietnam company. It demonstrates that Sustainable Supplier Selection is crucial for every business involved in the distribution sector. Therefore, the evaluation to select the best

supplier has a significant impact on the existence and growth of firm. In addition, it must produce unbiased and accurate results. As a results, the production and supply of goods, moreover, the company's reputation in clients' mind will be guaranteed.

The study first systematizes the theoretical basis of Sustainable Supply Chain Management and criteria and models for selecting sustainable suppliers from previous published. Then a multi-criteria model based on the Fuzzy-VIKOR" method was constructed based on literature review and current assessment and subjective assessment of Sourcing Manager of Socal Vietnam. These various evaluations can be combined to determine the appropriate sustainable supplier by using the aggregated weights derived for each sustainable supplier selection criterion.

The results have provided valuable information to help group of decision-makers consider and choose suitable suppliers. Although the results of evaluation and ranking of suppliers are based on the integration of many criteria and the evaluation of many objects, based on the decision matrix and the standardized decision

matrix, it can be determined that Quality Quality, Price, and Environmental Management System are the three criteria considered by the staff to be the most important, having a great impact on the sustainable supplier selection at Socal Vietnam. Moreover, they serve to achieve the organization's supply and business goals.

This study demonstrates that the proposed fuzzy approach can effectively apply the criteria evaluation data provided by many decision makers in the context of ambiguous language. The reason is that it uses the range of values to capture the ambiguity in the process of assigning weighs to the criteria. Besides, decision-makers express their opinions in linguistic variables in supplier selection while taking the increasing environmental complexity and time pressure into account. Therefore, subjectivity and ambiguity are well applied in the proposed fuzzy model. The model also takes the decision maker's priorities into account. To sum up, the suggested Fuzzy-VIKOR method is a helpful multi-criteria decision-making technique for assessing and choosing sustainable suppliers in Sustainable Supply Chain Management.

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