Sustainable Supplier Selection in a Hospital Using the Fuzzy TOPSIS method: a Case Study

Sengpheng To and Duangpun Kritchanchai
Mahidol University, Department of Industrial Engineering, Faculty of Engineering,
25/25 Phutthamonthon 4 Road, Salaya, Nakhon Pathom, 73170, Thailand
sengpheng.sp@gmail.com, duangpun.skr@mahidol.ac.th

Abstract

The sustainability of the supply chain has emerged as a major concern that is getting a lot of attention nowadays. and supplier selection can be optimizing the overall value of the supply chain in maintaining the company's profitability and sustainability. In the healthcare section, greater attention to maximizing revenue and less attention is paid to sustainability in the organization. Furthermore, the effect of the important weight of sub-criteria on the Fuzzy TOPSIS approach was not attempted in the field of choosing a hospital supplier. To address this problem, this research conducts a new Fuzzy TOPSIS approach to examine the considerable influence of sub-criteria for sustainable hospital supplier problems, which sub-criteria and criteria for sustainability in this hospital environment are employed by the argument of decision-makers. Based on a comprehensive literature study and the perspectives of decision-makers; there are twenty-four sub-criteria and ten of their criteria confirmed the validity of evaluating the three hospital supplies. In addition, a sensitivity analysis was conducted to assess the proposed framework by implying a change in the different criteria and decision-makers. As the results show that suppler one is the best sustainable supplier in most scenarios. Alternatively, if the hospital supplier selection process is considered only economic criteria, aiming to maximize revenue, this issue suggested supplier two is the best performance ranking. This research suggested frameworks can help hospital managers make decisions on potential suppliers within the sustainability dimensions of their supply chain operations and practices.

Keywords
Sustainability, Supply Chain, Hospital Supplier, Fuzzy TOPSIS

1. Introduction

Supply chain sustainability refer to the strategic and methodical management of an enterprise's internal operations and the enterprise's supply chain in order to increase long-term benefits (Mentzer et al. 2001). The sustainability performance of a company should not focus solely on increasing shareholder profits, the company should pay attention to the object of everyone or stakeholders (Tseng et al. 2020). Furthermore, the company is expected to meet full sustainability while taking into account the triple bottom line (TBL) of these criteria altogether, such as economic, social, and environmental dimensions (Sivarajah et al. 2020). Moreover, sustainability in the supply chain has become one of the most popular problems among researchers over the last 20 years and a major issue that is getting a lot of attention nowadays. There are so many strategies to maintain the company's sustainability and profitability including product development, supplier selection, sustainable manufacturing, sustainable transportation, etc. (Li et al. 2019). However, the best decision is supplier selection for enhancing the supply chain's overall value (Zhou & Xu 2018) and critical strategic decisions to maintain the company's profitability and long-term existence (Shaw et al. 2012).

Recently, sustainable supplier selection has shown an increased interest in solving various industries, although this range of studies implemented in the healthcare sector has limitations. To determine which method to employ, one must match up the specifics of the current situation with the features of the method (Ertuğrul and Karakaşoğlu 2008). For a situation of supplier selection, the method that needs to employ should consider the five factors including sufficient to support the group decision-maker, adaptation to modifications in criteria and alternatives, performs quickly interact with decision-maker in data collection, the complexity of computation, and decision-making capture uncertainty (Lima Junior et al. 2014). Multi-criteria decision-making (MCDM) are an effective technique for dealing with contradictory tangible and intangible criteria for deciding on the right supplier for selecting suppliers (Kirytopoulos et al. 2008; Shahin et al. 2017). Among MCDM methods, the Fuzzy TOPSIS method followed five factors that were proposed above. Moreover, the effect of the influent sub-criteria on the Fuzzy TOPSIS technique for hospital supplier selection was not investigated. Hence, a new Fuzzy TOPSIS technique is developed in this study to

consider the sub-criteria's influence on selection of sustainable suppliers in Cambodia hospital. This research is increasing of contribution to the healthcare industry area in providing a suggestion for sustainable supplier selection.

1.1 Objectives

This study intended to choose the sub-criteria and criteria of three dimensions (economic, social, and environmental dimensions) for supplier selection to choose concerning this hospital. This research also aims to develop the Fuzzy TOPSIS model framework for choosing the most sustainable hospital supplier. The proposed model's output will assist decision-makers in benchmarking potential suppliers and finding the finest sustainable supplier in this hospital.

2. Literature Review

The function of supplier selection in the supply chain is critical to maintain the company's profitability and long-term operation (Shaw et al. 2012). Moreover, choosing potential suppliers or product distributors cautiously be able to boost the supply chain's overall value. Two issues are very important in the terms of sustainable supplier selection. Firstly, the performance evaluation criterion and sub-criteria, and the second is the method that should be used to find the best supplier.

2.1 Factors affecting Sustainable Supplier Selection

Because of the high level of confidentiality associated with this hospital, one of the primary issues is the exchange of information across supply chain tiers in one of the key concerns. Before addressing some of the sub-criteria and main criteria that contribute to hospital's supplier selection process, the selection of the criterion and sub-criteria was based on a prior literature evaluation conducted for the study of sustainable supplier selection. By evaluating journal articles that covered the selection of sustainable suppliers within the health sector. As a result of the scarcity of studies examining sustainable supplier selection in the healthcare industry, articles examining sustainable and green supplier selection in other industries were also considered for inclusion in this research. During the scanning of these sub-criteria and criteria, duplicates were removed. Forty-one sub-criteria and associated ten criteria representing three dimensions were chosen (economic, social, and environmental) as indicated in Table 1,2, and 3.

Table 1. List of economic factors relevant to sustainable supplier selection

Criteria	Sub-criteria	Relevant literature
Quality	Capability of quality management Capability of handling abnormal quality Rejection rate of the product Packing quality	Ebrahim Qazvini et al. (2021); Forghani et al. (2018); Lee et al. (2009)
Cost/price	Product price Transportation cost Ordering cost Quantity discount rate	Akcan and Güldeş (2019); Forghani et al. (2018); Janatyan et al. (2019); Mehralian et al. (2012); Memari et al. (2019); Venkatesh et al. (2015)
Service	After sales service/warranty Case of communication Flexibility	Ebrahim Qazvini et al. (2021); Forghani et al. (2018); Janatyan et al. (2019); Mehralian et al. (2012); Ortiz-Barrios et al. (2021)
Delivery	Delivery Quantity shortage Lead time to order Capacity On time delivery Geographical location	Ebrahim Qazvini et al. (2021); Forghani et al. (2018); Memari et al. (2019); Stević et al. (2020); Venkatesh et al. (2015)
Financial status	Past Finance performance Payment deadline Income and earning	Ortiz-Barrios et al. (2021); Venkatesh et al. (2015)

Table 2. List of environmental factors relevant to sustainable supplier selection

Criteria	Sub-criteria	Relevant literature
Environmental management system	Environmental management certification Green policy Green image Eco-labeling Regulatory compliance and continuous monitoring	Chiou et al. (2008); Forghani et al. (2018); Lee et al. (2009); Memari et al. (2019); Ortiz-Barrios et al. (2021)
Environmental competencies	Green R&D Green production technologies Green packing Reverse logistics Green design and recycling Waste management	Chiou et al. (2008); Ebrahim Qazvini et al. (2021); Forghani et al. (2018); Hoseini et al. (2020); Mehralian et al. (2012); Ortiz-Barrios et al. (2021); Song et al. (2017); Stević et al. (2020); Yu et al. (2019)

Table 3. List of social factors relevant to sustainable supplier selection

Criteria	Sub-criteria	Relevant literature
Social responsibility	Information disclosure Community development Respect to policy	Hoseini et al. (2020); Janatyan et al. (2019); Memari et al. (2019); Ortiz-Barrios et al. (2021); Song et al. (2017); Stević et al. 2020; Yu et al. (2019)
Safety and health	Health and safety incidents Certificate (OHSAS 18001) Health and safety practices	Forghani et al. (2018); Memari et al. (2019); Ortiz-Barrios et al. (2021)
Employment practices and working conditions	Disciplinary and security practices Employee contracts Job opportunities Child and forced labor Employee right and welfare	Hoseini et al. (2020); Memari et al. (2019); Song et al. (2017); Stević et al. (2020); Yu et al. (2019)

2.2 Methods to apply for sustainable supplier selection

Different industries perhaps have a distinct methodology for ranking suppliers based on different preferences. To address the best method for this content, previous study aid to choose the appreciated method. As indicated in our literature review, there have been a variety of supplier selection methods used in the healthcare industry. The most utilized methods for addressing the supplier selection challenge in healthcare are as follows: ANP, AHP, Fuzzy AHP TOPSIS, Fuzzy TOPSIS, as well as AHP-ANN combination detailed in Table 4. To determine which method to employ, one must analyze the compatibility between the circumstances at hand and method's qualities (Ertuğrul et al. 2008). For the situation of supplier selection, the method needs to employ that should consider the five factors including sufficient to support the group decision-maker, adaptation to modifications in alternatives and criteria, decision-making quickness, decision-making capture uncertainty, and complexity of computation (Junior et al. 2014). Among the modeling approaches, the Fuzzy TOPSIS method followed five factors, mentioned previously. The Fuzzy TOPSIS supports group decision making, be able to deal with adequacy to changes of criteria or alternatives, performs quickly interact with decision-maker in data collection, and deals with uncertainty and subjectivity in supplier selection issues (Junior et al. 2014). For the last factor, the computational complexity, the calculations of Fuzzy TOPSIS were done using Microsoft Excel or by hand, it is also a simple method for the computation process and

doesn't require specialized software and qualified personnel who are experts (Govindan et al. 2013). Moreover, most methods like to evaluate suppliers with economic criteria solely, economic along with risk criteria, and economic together with environmental as well as risk criteria. However, the effect of the important weight of criteria, as well as sub-criteria from three dimension (economic, social and environmental dimensions) on the Fuzzy TOPSIS method, was not attempted in the field of hospital supplier selection as shown in Table 4. Consequently, a new Fuzzy TOPSIS method is developed in this research for sustainable supplier selection in the hospital. This research is increasing of contribution to the healthcare industry area in providing a suggestion for sustainable supplier selection.

Table 4. Methods apply to supplier selection in the healthcare industry

Researcher	Factor	Methodologies	Application Area/ Place of Application
Asamoah et al. (2012); Enyinda et al. (2010)	Criteria of economic, environmental, and risk factors	AHP	Evaluating pharmaceutical firm suppliers
Malik et al. (2016)	Criteria and sub-criteria of economic and environmental factors	AHP	Evaluating healthcare organization suppliers
Fashoto et al. (2016)	Criteria of economic and risk factors	AHP, AHP-ANN	Suppliers in the healthcare unit of the tertiary institution
Manivel and Ranganathan (2019)	Criteria of economic factor	Fuzzy AHP, Fuzzy TOPSIS	Hospital Pharmacy suppliers
Mehralian et al. (2012); Nag and Helal (2016); Sabbaghi (2020)	Criteria of economic, environmental, and risk factors	Fuzzy TOPSIS	Evaluating pharmaceutical company and pharmaceutical distributor suppliers
Ganguly et al. (2019); Tas (2009)	Criteria of economic criteria	Fuzzy AHP	Suppliers in pharmaceutical Organizations
Kirytopoulos et al. (2008)	Criteria of economic and risk factors	ANP	The pharmaceutical industry suppliers
Venkatesh et al. (2015)	Criteria with economic factor	TOPSIS	Suppliers in the Blood bags manufacturing Industry
Current study	Criteria and sub-criteria of economic, social, and environmental factors	Fuzzy TOPSIS	Evaluating medicine suppliers in hospital

2.3 Fuzzy TOPSIS method

In a real-life situation, the judgment must be made by taking uncertainty and vagueness into account. As a result, rather than assigning a single value to judgment, the decision-maker might use interval judgment and the linguistic word to evaluate the problem (Kannan et al. 2009; Yang and Hung 2007). Numerous academics have incorporated fuzzy set theory into TOPSIS, utilizing the linguistic word to deal with imprecise and ambiguity information (Kharat et al. 2019). This paper proposes the fuzzy technique for Order Performance by Similarity to Ideal Solution (TOPSIS) for selecting sustainable suppliers. The fuzzy TOPSIS technique is predicated on the idea that the chosen option should be as far away as possible from the Fuzzy Negative Ideal Solution (FNIS) and as close as possible to the Fuzzy Positive Ideal Solution (FPIS) (Sevkli et al. 2010). The Fuzzy TOPSIS technique used in the healthcare industry consists of the phase described for the evaluation purpose, as indicated below (Manivel and Ranganathan 2019; Nag and Helal 2016).

(1) Define criteria and potential alternatives.
(2) Assigning weights to each criterion and evaluating alternatives under criteria.
(3) Computing the scores of each alternative and ranking the alternatives.

3. Methods

The following case study, this study examines sustainable supplier selection in a hospital in Cambodia. This hospital is a significant milestone for medical care in Cambodia and the modern facility quickly established a reputation as a center of medical excellence, providing world-class healthcare services for Cambodian and international patients. In 2017, its standing was strengthened further when it became the first and only Joint Commission International (JCI) accredited hospital in Cambodia. This case hospital was selected with the object to rank three suppliers ($A_1, A_2, and\ A_3$) that are taken from suppliers of Ferrovit is top medicine in high usage. This research used a modified version Memari et al. (2019)'s Fuzzy TOPSIS method to calculate the ratings assigned to suppliers based on the sustainable factors. As indicated in Figure 1, the methodology framework utilized in this research to choose a sustainable supplier consists of many phases.

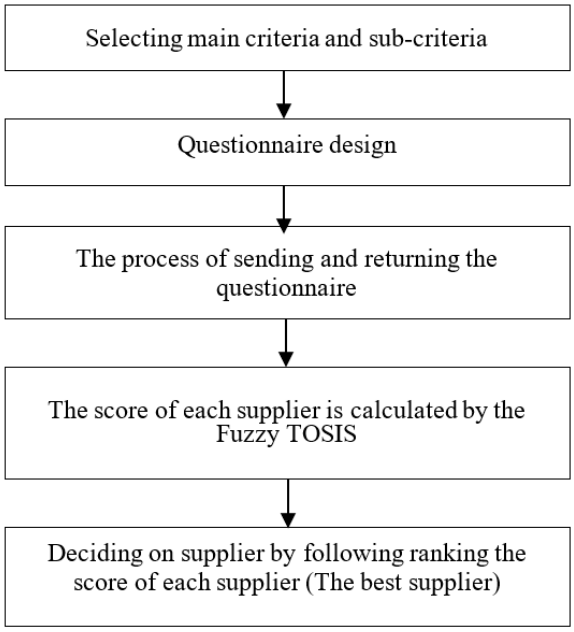

Figure 1. The phases of the research methodology

This research will do the decision making on the priority of weight in each criterion, sub-criteria, and supplier selection in the hospital by asking the expert's questionnaire design and judge the weight of criteria. The proposed study procedures have five phases are to describe in the following:

Step 1: The sub-criteria and criteria for this study were derived from the review of relevant literature in section 2.1 and the discussion of decision-makers who work in this hospital. They consider the appropriate sub-criteria and criteria for supplier selection in the context of the hospital. Only the ten criteria and twenty-four sub-criteria have been selected for further study as shown in Figure 2 below.

Step 2: The questionnaire design was divided into two parts including main criteria/sub-criteria as well as a supplier questionnaire part. According to Tables 5 and 6, the questionnaire will be created to be the kind of Linguistic variable.

Step 3: After that, the questionnaire will be sent to the experts by email. The experts will complete the questionnaire by ticking the boxes and returning it via email.

Step 4: Using the Fuzzy TOPSIS approach to generate the score of each supplier, this research will order the scores of suppliers from highest to lowest value.

Step 5: The decision-making tool (Fuzzy TOPSIS) will identify the best hospital supplier based on the raking of scores.

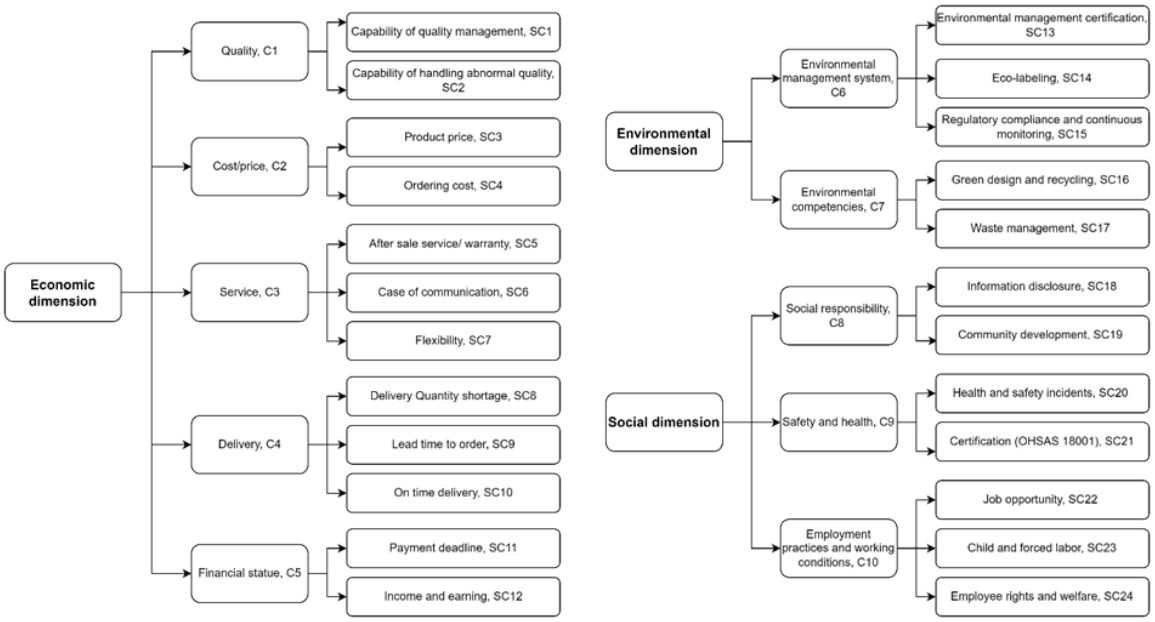

Figure 2. The proposed sub-criteria and criteria for selecting sustainable suppliers

Table 5. Linguistic variables for sub-criteria and criteria importance weight

Linguistic variables	Triangular fuzzy number
Not at all important (NI)	(0.0, 0.0, 0.25)
Low important (LI)	(0.0, 0.25, 0.50)
Neutral (N)	(0.25, 0.50, 0.75)
Important (I)	(0.50, 0.75, 1.0)
Very important (VI)	(0.75, 1.0, 1.0)

Table 6. Linguistic variables for rating alternative

Linguistic variables	Triangular fuzzy number
Very low (VL)	(0.0, 0.0, 2.5)
Low (L)	(0.0, 2.5, 5.0)
Medium (M)	(2.5, 5.0, 7.5)
High (H)	(5.0, 7.5, 10.0)
Very High (VH)	(7.5, 10.0, 10.0)

4. Data Collection

This research used a questionnaire survey to collect primary data for analysis throughout this phase, and the questionnaire was delivered by responsible decision-makers in this hospital. A questionnaire is sent to each decision-maker by email for processing sustainable supplier selection. The questionnaire design is made to conduct a survey to assess the relative relevance of sub-criteria and criteria, as well as to evaluate suppliers. In the first section, decision-makers analyze selected criteria and sub-criteria; and at that time, respondents from decision-makers employ Linguistic variables, as mentioned in Table 5. The final section, in which suppliers are rated according to every one of the criteria via a Linguistic variable, is shown in Table 6. Participants in this questionnaire design included two from purchasing department and a member of the inventory department with more than five years of hospital experience. In addition, we reassured the responders that the data gathered would only be utilized for research purposes, and had adequate experience, and understanding of the problem under consideration.

5. Fuzzy TOPSIS method to Prioritize Suppliers

The fuzzy TOPSIS method of Memari et al. (2019) was used to calculate the ratings assigned to suppliers based on the sustainable factors. After collecting data from questionnaires, there are so many steps of analyzing data are totally used the Fuzzy TOPSIS tool to evaluate data collection, which is discussed below.

5.1 Assigning Weights to Criteria and Sub-criteria and Rating Suppliers under Criteria:

A questionnaire is sent to decision-makers for processing sustainable supplier selection. In answering the questionnaire survey, respondents of decision-makers were firstly asked for their opinion to rate the relative relevance of each of the selected sub-criteria and criteria and secondly, to assess the level of performance of suppliers considered within the study in terms of each criterion. In order to emphasize the significance of sub-criteria and criteria, in addition to using language variables for evaluating the performance of alternatives, the triangular fuzzy numbers were employed to translate linguistic variables into triangle fuzzy numbers that were proposed by Junior et al. (2014); Nag and Helal (2016) in Table 5 and 6.

5.2 Aggregate Weight of Sub-criteria and Criteria:

The aggregate weight (ACS_k) of kth DMs of i criteria and their related j sub-criteria can be determined using Equation (1) (Zimmermann 1987). Suppose $\tilde{A}_k = (l_{ik},\ m_{ik},\ u_{ik})$ is a triangular fuzzy number that represents the weight of the criteria i decided by DM k, and $\tilde{B}_k = (l_{jk},\ m_{jk},\ u_{jk})$ is a triangular fuzzy number that also indicates the weight assigned of sub-criteria j of criteria i by kth DM as well.

$$ACS_k = (\alpha, \beta, \gamma) \qquad (1)$$

where $\alpha = \min(l_{ik},\ l_{jk})\ and\ \beta = \sqrt[k]{\prod_{k=1}^{n} m_{ik} \cdot m_{jk}}\ and\ \gamma = \max(u_{ik},\ u_{jk})$.

5.3 Aggregate the DMs' opinions

In this phase, the combining the DM weights for the various criteria and sub-criteria employing the same procedures as described in Step 5.2 that have been calculated.

5.4 Create the Aggregated Fuzzy decision matrix of Supplier

Assume that $\tilde{a}_{ij}$ assign the rate of alternative A_i $(i = 1, \dots, n)$ relation to the aggregated weights of DMs' sub-criteria and criteria or the aggregated weights of DMs' criteria (determined in Step 5.3), The following equation (2), $\widetilde{M}$ is an aggregated fuzzy decision matrix that could be created.

$$\begin{array}{cccccccc}
 & \boldsymbol{C_1} & \boldsymbol{C_2} & \boldsymbol{C_3} & \cdots & \cdots & \boldsymbol{C_m} & \\
\boldsymbol{A_1} & \tilde{a}_{11} & \tilde{a}_{12} & \tilde{a}_{13} & \cdots & \cdots & \tilde{a}_{1\mathrm{m}} & \\
\boldsymbol{A_2} & \vdots & \vdots & \vdots & \cdots & \cdots & \vdots & \\
\vdots & \vdots & \vdots & \vdots & \cdots & \cdots & \vdots & \\
\boldsymbol{A_n} & \tilde{a}_{\mathrm{n}1} & \tilde{a}_{\mathrm{n}2} & \tilde{a}_{\mathrm{n}3} & \cdots & \cdots & \tilde{a}_{\mathrm{n}m} & (2)
\end{array}$$

5.5 Normalize the Aggregated Fuzzy decision matrix of the Alternatives

Using the linear scale transformation, the aggregated fuzzy decision matrix is normalized in Step 5.4. The normalization procedure is given by Equation (3), (4), and (5).

$$\tilde{R} = [\tilde{b}_{ij}]_{m\times n} \quad (3)$$

$$\tilde{b}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right), u_j^+ = Max_i = \{u_{ij}\}\ (benefit\ criteria) \quad (4)$$

$$\tilde{b}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right), l_j^- = Min_i = \{l_{ij}\}\ \text{(cost criteria)} \quad (5)$$

5.6 Calculate the Weighted Normalized fuzzy decision matrix

The product of the normalized aggregate fuzzy decision matrix, $\tilde{R}$ and the weights of aggregated criterion and sub-criteria of DMs, $\widetilde{ACS}$, to obtain the weighted normalized decision matrix, $\tilde{P}$.

$$\tilde{P} = [\tilde{p}_{ij}]_{m\times n} \quad (6)$$

Where

$$\tilde{p}_{ij} = \widetilde{ACS} \times \tilde{R} \quad (7)$$

5.7 Determine the FPIS and FNIS

The fuzzy positive ideal solution ($FPIS, I^+$) and fuzzy negative ideal solution ($FNIS, I^-$) were computed by Equation (8) and (9).

$$I^+ = \{\tilde{\tau}_1^+, \tilde{\tau}_j^+, \dots \tilde{\tau}_m^+\} \quad (8)$$

$$I^- = \{\tilde{\tau}_1^-, \tilde{\tau}_j^-, \dots \tilde{\tau}_m^-\} \quad (9)$$

Where $\tilde{\tau}_j^+ = (1,1,1)\ and\ \tilde{\tau}_j^- = (0,0,0)$ were suggested by Chen (2000)

5.8 Calculate the Distances of each Alternative from the FPIS and FNIS

Assume that S_i^+ and S_i^- denote the distances of each alternative form $\tilde{\tau}_j^+$ and $\tilde{\tau}_j^-$, correspondingly. Equation (10) and (11) state:

$$S_i^+ = \sum_{j=1}^{n} d_v(\tilde{\tau}_{ij}, \tilde{\tau}_j^+) \quad (10)$$

$$S_i^- = \sum_{j=1}^{n} d_v(\tilde{\tau}_{ij}, \tilde{\tau}_j^-) \quad (11)$$

For triangular fuzzy numbers, $S(\tilde{x}, \tilde{z})$ is the distance between two fuzzy numbers that are expressed as in Equation (12).

$$S(\tilde{x}, \tilde{z}) = \sqrt{\frac{1}{3}[(l_x - l_z)^2 + (m_x - m_z)^2 + (u_x - u_z)^2]} \quad (12)$$

5.9 Determine the Closeness Coefficient of each Supplier

The formula for calculating the alternative's closeness coefficient, CC_i, is given in Equation (13).

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (13)$$

5.10 Rank the Supplier

In the end, this study ranks the alternatives from larger value to lower value of the closeness coefficient, CC_i. The supplier with the highest score here is considered the most sustainable supplier selection in terms of the given criteria.

6. Results and Discussion

6.1 Evaluating Selected Factors and Potential Suppliers

After criteria and sub-criteria were selected, the questionnaire design was sent with a request to assess the selected criteria/sub-criteria and rank suppliers based on their experience. To calculate significance of criteria/sub-criteria and ranking suppliers, linguistic terms in Table 5 and 6 were performed, respectively. Their evaluation matrices were developed in Table 7, 8, and 9. The questionnaire has been given to them, and the decision-makers' views based on

Table 7. The criteria importance weight

Criteria	DMs		
	DM1	DM2	DM3
C1	VI	VI	VI
C2	I	I	N
C3	VI	I	N
C4	I	VI	VI
C5	I	N	I
C6	N	I	I
C7	N	N	LI
C8	I	N	LI
C9	N	LI	N
C10	I	N	LI

Table 8. The sub-criteria importance weight

Sub-criteria	DMs		
	DM1	DM2	DM3
SC1	VI	VI	VI
SC2	VI	I	I
SC3	VI	I	I
SC4	I	N	VI
SC5	I	N	LI
SC6	I	N	I
SC7	LI	N	N
SC8	I	I	I
SC9	I	I	VI
SC10	I	I	VI
SC11	LI	N	N
SC12	LI	NI	N
SC13	N	I	N
SC14	N	N	VI
SC15	N	N	LI
SC16	I	VI	LI
SC17	LI	LI	I
SC18	N	I	LI
SC19	LI	I	I
SC20	I	LI	LI
SC21	N	N	LI
SC22	I	LI	LI
SC23	N	LI	LI
SC24	LI	N	N

the sub-criteria and criteria were gathered. The responses of the hospital's three decision-makers responded that the collected data for this research. Then, each member of the decision-making group provides linguistic evaluations of the criteria and sub-criteria, respectively. As illustrated by Table 7 and Table 8, there are three decision-makers which their opinions have been obtained for significant sub-criteria and criteria in linguistic terms, Table 5 contains the linguistic words (NI, LI, N, I, and VI) was employed. On the other hand, the ratings given to three suppliers respecting to criteria provided by DMs using linguistic word (VL, L, M, H, and VH) are also displayed in Table 6. As the result, the quality assessment of each existing supplier based on the ten criteria was presented in Table 9 (see below).

Table 9. The ratings of the alternatives

Criteria	Supplier	DMs		
		DM1	DM2	DM3
C1	A1	H	VH	VH
	A2	H	H	H
	A3	VH	VH	VH
C2	A1	VH	VH	VH
	A2	VH	H	H
	A3	H	H	H
C3	A1	VH	VH	VH
	A2	H	H	H
	A3	M	M	M
C4	A1	H	H	VH
	A2	VH	H	VH
	A3	VH	H	VH
C5	A1	H	H	M
	A2	M	H	M
	A3	M	M	L
C6	A1	M	L	M
	A2	M	M	L
	A3	L	L	L
C7	A1	M	M	L
	A2	L	M	L
	A3	M	H	M
C8	A1	H	H	H
	A2	H	M	M
	A3	H	M	M
C9	A1	M	VH	M
	A2	L	H	L
	A3	L	H	H
C10	A1	H	H	H
	A2	M	H	H
	A3	M	M	M

6.2 Aggregate the Weights of Sub-criteria and Criteria of DMs

In this selection, the data obtained from the survey will be translated to triangular fuzzy numbers. Thus, a fuzzy decision matrix based on triangular fuzzy numbers has been given for sub-criteria and criterion. After the fuzzy decision matrix were determined, the next step is to aggregate the weights of the sub-criteria/criteria and the DMs' opinions and the outcome is displayed in Table 10.

Table 10. Aggregate the weights of sub-criteria and criteria of DMs

ACS	Aggregated
ACS1	(0.50, 0.96, 1.00)
ACS2	(0.25, 0.87, 1.00)
ACS3	(0.00, 0.54, 1.00
ACS4	(0.50, 0.88, 1.00)
ACS5	(0.00, 0.00, 1.00)
ACS6	(0.00, 0.67, 1.00)
ACS7	(0.00, 0.70, 1.00)
ACS8	(0.00, 0.57, 1.00)
ACS9	(0.00, 0.49, 1.00)
ACS10	(0.00, 0.52, 1.00)

6.3 Calculating the Score and Ranking the Suppliers

In this part, the Fuzzy TOPSIS was employed to calculate the score and select the three suppliers based on the sub-criteria and main criteria. To preserve the supplier's and hospital's confidentiality, the identities of the supplier have not been revealed. Fuzzy evaluation matrices for TFNs were created using the linguistic variables based on the expert group's analysis in this study. In this supplier selection problem, C2 is a cost criterion, while the remaining criteria are benefit criteria. Next, equation 10 and 11 were used to compute the distance from each alternative to S^+ and S^-. Finally, CC_i were calculated by using Equation 13. The outcomes of the fuzzy TOPSIS analyses the priority rankings for the three suppliers are listed in Table 11. According to the CC_i values, in descending order, the classification of alternatives was A1, A2, and A3. With a CC_i value of 0.488, the findings of the model suggest that A1 was the best option. So, supplier one is recommended as the best option at this hospital for supplier selection.

Table 11. The supplier's ordering ranking

Supplier	$\boldsymbol{CC_i}$	**Final Ranking**
A1	0.488	1
A2	0.487	2
A3	0.473	3

6.4 Sensitive analysis

A sensitivity analysis is carried out to establish the resilience of the proposed model. A sensitivity analysis was carried out on the ranking of suppliers to examine the effect of various conditions. According to nine separate criteria and DMs, the sensitivity of nine scenarios has been demonstrated in a report by Memari et al. (2019). First, scenario 1, 2, and 3 divide the criteria into three categories: economic criteria solely, environmental criteria only, and social factors only, accordingly. Second, in scenario 4,5, and 6, the list of criteria is permuted from three dimensions: economic with environmental criteria, economic with social criteria, and environmental with social criteria. Thirty, only DM1, DM2, and DM3 are used in scenario 7, 8, and 9, correspondingly. Table 12 summarizes the scenarios that were considered, along with the outcomes for each scenario.

Table 12. Sensitivity analysis results for various scenarios

Scenarios	Decision criteria (Aggregated criteria and sub-criteria)	Decision makers	Suppliers ranking (respectively)
Current case	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM1, DM2, DM3	A1, A2, A3
Scenario 1	C1, C2, C3, C4, C5 (Economic criteria only)	DM1, DM2, DM3	A2, A1, A3
Scenario 2	C6, C7 (Environmental criteria only)	DM1, DM2, DM3	A1, A2, A3
Scenario 3	C8, C9, C10 (Social criteria only)	DM1, DM2, DM3	A1, A2, A3
Scenario 4	C1, C2, C3, C4, C5, C6, C7 (Economic with environmental criteria)	DM1, DM2, DM3	A2, A1, A3
Scenario 5	C1, C2, C3, C4, C5, C8, C9, C10 (Economic with social criteria)	DM1, DM2, DM3	A1, A2, A3
Scenario 6	C6, C7, C8, C9, C10 (Environmental with social criteria)	DM1, DM2, DM3	A1, A2, A3
Scenario 7	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM1	A1, A3, A2
Scenario 8	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM2	A2, A1, A3
Scenario 9	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10	DM3	A1, A3, A2

6.5 Discussion

According to the results, supplier 1 performs better in terms of sustainability in the majority of scenarios, according to DMs, and supplier 3 places third place and with a lower overall performance score. In the adopted scenario, the sequence of suppliers for the second and third providers is different. For instance, supplier 2 is usually the second place in the supplier ranking in almost all of the scenarios (except scenario 1, 4, 7, and 8). If procurement of supplier selection in the hospital is examined primarily economic criteria, with the purpose of overall profit maximization. With this suggestion scenario, supplier 2 is the best performance ranking. Anyway, the most profitable supplier regards the social attribute, this issue suggested suppler 1. The ordering of various suppliers' ranking may be dependent on the way of weighing criteria and rating the alternatives. In scenarios 7, 8, and 9, different DMs make decisions that affect the rating of the suppliers. As a consequence, supplier 1 and supplier 2 have swapped places with each other. The issue is very variable in rating suppliers with respect to Safety and health criteria, it might be hard to judge by DMs as such criteria do not have historical data on supplier's performance, and difficult measure intangible criteria of supplier performance.

7. Conclusion

In terms of sustainable supplier selection, two issues are very important. Firstly, the performance evaluation criterion and sub-criteria, and the second is the method that should be used to identify the finest supplier. According to the research literature and sustainability criteria were generated with the use of a survey questionnaire. A questionnaire was created to assess and suggest the suitable criteria and sub-criteria utilizing decision-makers from this hospital. Only ten criteria and twenty-four sub-criteria were selected for decision-making. So, ten criteria include Quality, Cost/price, Service, Delivery, Financial state, Environmental management system, Environmental competencies, Social responsibility, Safety and health, Employment practices, and their sub-criteria are considered to determine which of the three competing suppliers is the best depending on the preferences of the three concerned decision-makers. The proposed methodological framework aids hospital decision-makers in choosing the most sustainable supplier from among a variety of available suppliers regarding sustainable factors. During the first phase, identify possible suppliers, selection sub-criteria and criteria for choosing hospital suppliers in term of green and sustainable considerations. During the second phase, the sub-criteria and criteria for selecting the hospital supplier are established, after weighting the selected sub-criteria/main criteria and evaluating the suppliers using Linguistic variables by decision-makers. In the third phase, the Fuzzy TOPSIS methodology is used to rank and choose suppliers based on their sustainable capabilities in order to select the best potential supplier. According to the execution of the recommended methodological framework, supplier one was identified as the greatest and nicest of the three suppliers.

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Biography

Sengpheng To graduated from the Institute of Technology of Cambodia with a Bachelor's Degree in Mechanical and Industrial Engineering in 2019. He is currently a student of a Master's Degree in the Mahidol University in Thailand, Department of Industrial Engineering. His research interests are supply chain management, sustainable supply chain, healthcare supply chain, and inventory management.

Duangpun Kritchanchai obtained her Ph.D. in Operations Management from the University of Nottingham, UK. Her research interests are in supply chain management, information technology in logistics and supply chain, and healthcare supply chain. She is currently serving at Mahidol University, Thailand in the capacity of Associate Professor and Director in the Centre of Logistics Management, as well as holding the position of Coordinating Chair of Logistics Research Group, Thailand Research Fund.