Jurnal Teknologi Industri Pertanian 33 (3): 216-227, Desember 2023
DOI: https://doi.org/10.24961/j.tek.ind.pert.2023.33.3.216
ISSN: 0216-3160 EISSN: 2252-3901
Terakreditasi Peringkat 2
SK Dirjen Pendidikan Tinggi, Riset, dan Teknologi No. 158/E/KPT/2021
Tersedia online http://journal.ipb.ac.id/index.php/jurnaltin

INTEGRATION OF SCOR AND FUZZY AHP FOR LOCATION SELECTION OF EDIBLE WHITE COPRA AGRO-INDUSTRY

INTEGRASI SCOR DAN FUZZY AHP UNTUK PEMILIHAN LOKASI AGROINDUSTRI KOPRA PUTIH KONSUMSI

Siti Wardah[1)]*, Marimin[2)], Wiwik Sudarwati[3)], Umi Marfuah[3)]

[1)]Department of Industrial Engineering, Universitas Islam Indragiri, Tembilahan, Indonesia, 29212
Jl. Propinsi Nomor 1, Tembilahan Hulu, Indragiri Hilir, Riau
Email: siti_wardah@unisi.ac.id
[2)]Department of Agro-Industrial Engineering, IPB University, West Java, Indonesia, 16680
[3)]Department of Industrial Engineering, Universitas Muhammadiyah Jakarta, Jakarta, Indonesia

Makalah: Diterima 24 Juli 2023; Diperbaiki 25 Agustus 2023; Disetujui 10 September 2023

ABSTRAK

Pemilihan lokasi agroindustri sangat penting dalam pendirian, pertumbuhan, dan relokasi sistem agroindustri untuk segala bentuk pengembangan produk. Salah satu produk kelapa yang permintaan ekspornya tinggi adalah kopra putih yang dapat dimakan. Pengembangan produk ini berpotensi untuk dilakukan di Kabupaten Indragiri Hilir Provinsi Riau Indonesia karena pengembangan agroindustrinya masih kurang sehingga produksi kelapa masih surplus dan harga rendah. Penelitian ini bertujuan untuk memilih lokasi terbaik untuk pengembangan agroindustri kopra putih konsumsi berdasarkan beberapa kriteria. Hasil penelitian menunjukkan bahwa penelitian ini berhasil mengembangkan integrasi baru SCOR dengan Fuzzy AHP berdasarkan pendekatan multikriteria. Pada level satu dan level dua masing-masing memiliki bobot yang sama untuk setiap atribut dan metrik, sedangkan pada level ketiga yang memiliki bobot paling tinggi adalah adaptibilitas peningkatan pengiriman, biaya pengadaan, jumlah hari persediaan bahan baku kelapa, dan jumlah hari penyediaan kopra putih konsumsi. Selanjutnya, level empat yang memiliki bobot tertinggi adalah kualitas kelapa sesuai pesanan, ketersediaan sarana transportasi, dan persentase pesanan yang diterima dengan isi yang benar. Urutan prioritas lokasi dari bobot tertinggi hingga terendah adalah Tembilahan Hulu (0,194), Tempuling (0,152), Batang Tuaka (0,160), Kempas (0,118), Kuala Indragiri (0,100), Tembilahan (0,100), Teluk Belengkong (0,087), Pelangiran (0,080) dan Enok (0,072). Penelitian ini diharapkan dapat meningkatkan pengembangan agroindustri kopra putih konsumsi di wilayah tersebut.

Kata kunci: integrasi, skor, Fuzzy AHP, multi-kriteria, kopra putih konsumsi

ABSTRACT

The selection of agro-industry location is essential in establishing, growing, and relocating agro-industrial systems for all forms of product development. In this regard, white copra has displayed a great economic potential due to export demand. To response this challenge, Indragiri Hilir Regency in Riau Province might become the most promising area since the location is lack of agroindustrial activity. Such condition leads to a excessive supply of coconut, which is in turn, causing the low price. This work aimed determine the best location for developing agroindustry for edible white copra based on multiple criteria. According to the findings, this research successfully created a new integration SCOR with Fuzzy AHP based on a multiple-criteria approach. At the first and second level, each option has equal rate of importance for each attribute and metric, while at the third level, corresponding to the highest importance, is the adaptability for increased shipping, procurement cost, days for coconut inventory, days for edible white copra stock. The fourth level, also corresponding to the highest importance, includes standard conformity, transportation facility, and the percentage of orders with the correct content. Based on the analysis, the locations showing the highest to the lowest importance were Tembilahan Hulu (0.194), Tempuling (0.152), Batang Tuaka (0.160), Kempas (0.118), Kuala Indragiri (0.100), Tembilahan (0.100), Teluk Belengkong (0.087), Pelangiran (0.080), and Enok (0.072). This research is expected to increase the development of edible white copra agroindustry in the Regency of Indragiri Hilir.

Keywords: integration, SCOR, FUZZY AHP, multicriteria, edible white copra

INTRODUCTION

The selection of agro-industry locations is critical in starting or expanding, and changing the location of agro-industrial systems for all types of product development. One of the goals for selecting agro-industrial locations is to find the location that best fits the desired conditions as determined by several selection criteria (Rikalovic *et al.,* 2014). It is essential to determine the most proper location conforming to the criteria (Nyimbili and Erden, 2020). Multi-criteria decisions on determination of

**Corresponding Author*

the best location is necessary because optimal location would result in a desirable performance when the agro-industry is operating needs to involve several decision factors, which are frequently in conflict with the other counterpart, and the process involves several possible criteria, each of which has benefits and drawbacks (Afolayan *et al.*, 2020; Nyimbili and Erden, 2020; Otay and Jaller, 2020; Genger *et al.*, 2021; Mohd Rosdi *et al.*, 2021; Li *et al.*, 2022). Industrial location decisions typically involve weighing several factors in light of many conflicting objectives. In this case, this work sets the criteria for site selection decisions to ensure that the agro-industry established in that location can be sustainable. Several studies on location selection for both the manufacturing industry, service industry and agro-industry have been carried out, including determining the industrial waste landfill (Hanine *et al.*, 2017), coconut sugar (Wardah *et al.*, 2022), Hospitals (Eldemir and Onden 2016), selection of fire stations (Nyimbili and Erden, 2020), industries (Mytilinou, 2017; Ozdemir and Sahin, 2018; Aly, 2020), cement plant (Mirhadi Fard *et al.*, 2016), solar power plant (Kabir and Sumi, 2014; Al Garni and Awasthi, 2017; Otay and Jaller, 2020; Genger *et al.*, 2021), sanitary landfill site selection (Sk 2020; Ilbahar *et al.*, 2021), methods for choosing a municipal landfill (Ali and Ahmad, 2020), utility tunnels (Genger *et al.*, 2021), construction (Yeoh, 2017), offices (Arar *et al.*, 2019), and distributors (Karaşan, 2019). Some of these studies have not reported the location selection of edible white copra agro-industry.

Edible white copra has become an important commodity because it can be consumed, which is more valuable and superior to other types of copra. Coconut products with a high demand for exports are copra, with a percentage of 25.47% with a volume of 39,165,161 kg and an export value of 43,145,911 dollars. The highest exports of white copra are to India and Bangladesh. The raw material for white copra is a hybrid coconut. One of the world's top producers of coconuts is Indonesia (Kumar and Kunhamu, 2022). The area of coconut plantation in Indonesia reaches 3,323,232 hectares, with a production of 2,886,338 metric tons (Plantations, 2023). The largest coconut-producing district in Indonesia is Indragiri Hilir Regency, Riau Province. However, its agro-industrial development still needs to grow because it has a surplus of 6,588,667,000 kg/year of fresh coconut. The surplus refers to the quantity of coconut remained after used in industrial needs and consumption. Hence, the area is very potential for developing an edible white copra agro-industry. The location selection for agro-industrial development needs a suitable method to produce the correct location. Previous research has conducted site selection using various methods, including environmental quality index (Gaska *et al.*, 2021), preference selection index (Attri and Grover, 2015), picture fuzzy modelling (Zhang, 2018), GIS-AHP (Wardah *et al.*, 2022), OLAP/GIS-Fuzzy AHP-TOPSIS (Hanine *et al.*, 2017), fuzzy linear programming. However, many parameter uncertainties remain (Ilbahar *et al.*, 2021). Abdullah *et al*., 2023 and Arar, Karaoğlan, *et al*., 2019 selected locations with fuzzy AHP, which still needs to identify beyond economic, social and safety aspects (Abdullah *et al.*, 2023), while the use of fuzzy AHP and VIKOR (Arar *et al.*, 2019) needs to expand criteria and alternatives.

The MCDM technique also requires criteria that consider ambiguous, inconsistent, and inaccurate manufacturing-based data (Kamranzad and Hadadpour, 2020; Rezaeisabzevar, 2020; Mishra *et al.* 2023); the ANP and TOPSIS methods were applied with other MCDM techniques in solving site selection problems (Nong, 2022). Besides, the TOPSIS fuzzy method has difficulty in determining various decision criteria, and the interdependence between criteria and subcriteria is not considered (Memari *et al.*, 2019; Arunyanart *et al.*, 2021). Finally, the AHP-PROMETHEE method requires model testing (Abdel-Basset *et al.*, 2021). This research is a research development of previous works (Ilbahar *et al.*, 2021), (Abdullah *et al.*, 2023), (Arar *et al.*, 2019), (Memari *et al.*, 2019; Arunyanart *et al.*, 2021).

The development is a parameter or criteria and a subcriteria in selecting a location. Good supply chain performance must drive the selection of sustainable agro-industry locations (Qorri *et al.*, 2018). Farmers are at the beginning of the supply chain, and customers are at the end. The supply chain operations reference (SCOR) approach is the strategy for this improvement *(Ntabe et al.*, 2015*; APICS* 2017*; Dissanayake et al*., 2018; van Engelenhoven *et al.*, 2022) with the addition of environmental criteria because the SCOR approach have not covered environmental criteria. With the addition of these parameters, the location for the development of edible white copra agro-industry can be sustainable. A fuzzy method is necessary because of the uncertainty of the expert's subjective opinions (Mishra *et al.*, 2023). Researchers can suppress the ambiguity in human judgment and provide more reliable results using fuzzy theory rather than a Boolean theory (Rezaeisabzevar, 2020). The fuzzy analytic hierarchy process method (Fuzzy AHP) is a possible fuzzy approach. The fuzzy AHP method is a multicriteria decision-making method used to determine complex site selection because evaluating criteria is flexible and can be integrated with other methods or approaches (Ahmed and Kilic, 2019; Mohd Rosdi *et al.*, 2021). It has proven to be an innovative site selection method (Abdullah *et al.*, 2023). The integration of SCOR with Fuzzy AHP is state of the art because literature reviews and field observations show that the SCOR and Fuzzy AHP methods are widely used for performance measurement

(Akkawuttiwanich and Yenradee, 2018; Dissanayake and Cross, 2018; Qorri *et al.*, 2018; Ayyildiz and Taskin Gumus, 2021).

Based on aforementioned details, the primary objective of this research is to develop a new integration method by combining the SCOR approach and the Fuzzy AHP method for location selection for the development of edible white copra agro-industry in Indragiri Hilir Regency, Riau Province, Indonesia.

RESEACRH AND METHOD

Research Framework

This research aimed to select the location of the edible white copra agro-industry. The steps and methods used are determining criteria with SCOR, level hierarchy, Fuzzy AHP, and calculating normalized weights. The method used is a new approach to integrate SCOR with Fuzzy AHP with several criteria as presented in Figure 1.

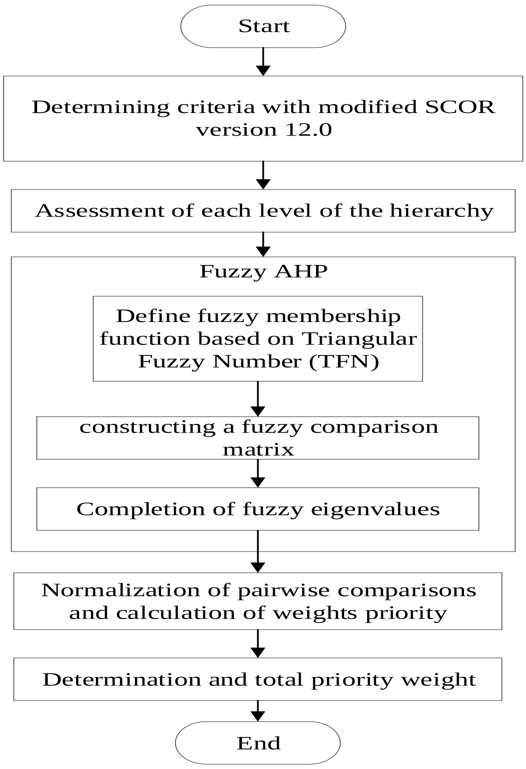

Figure 1. Research Framework

Data Collection

This study collected qualitative and quantitative data from primary and secondary sources. Respondents were academics, business practitioners, and regional experts in The Indragiri Hilir District. Table 1 summarises the data, types, sources, methods of collection, and analysis.

Model Development

Determining Criteria with Modified SCOR Version 12.0

This work designed a hierarchical location selection metric for edible white copra agro-industry with mapping performance metrics that modifies the model in SCOR version 12.0. Metric mapping was based on a situational analysis along the edible white copra supply chain network.

Assessment of Each Level of The Hierarchy

The preparation of the metric weighting questionnaire directly complied with the hierarchical structure. Assessment of each hierarchical level employed experts who completely understand the location of research and the development of edible white copra agro-industry.

Fuzzy AHP

The steps for measuring priority weights are as follows:

1. Establish a fuzzy membership function based on a Triangular Fuzzy Number (TFN)
2. Constructing a fuzzy comparison matrix

   The matrix of fuzzy ratings $\tilde{A}$ ($\tilde{a}_{ij}$) uses pairwise comparisons of fuzzy numbers as in equation 1.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \cdots & \cdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} \quad \text{........ (1)}$$

   with $\tilde{a}_{ij}$ a = 1, if i = j, and $\tilde{a}_{ij}$ a = $\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ or $\tilde{1} - 1, \tilde{3} - 1, \tilde{5} - 1, \tilde{7} - 1, \tilde{9} - 1$ if $i \neq j$ 3.
3. A fuzzy eigenvalue solution

   Solving the fuzzy eigenvalues is using equation 2.

$$\tilde{A}\tilde{x} = \tilde{\lambda}\tilde{x} \quad \text{…………….. (2)}$$

Table 1. Data, types, sources, collection procedures, and analysis.

No	Data	Type	Origin	Data retrieval	Analysis
1	Location of the location selection area	Secondary Primary	Reports and journals Experts	 Field survey and Interviews	Analysis
2	Hierarchical design of location selection matrix	Secondary Primary	Reports and journals Experts	 Interviews and Questionnaires	Modified SCOR version 12.0 analysis
3	Assessment of each level of the hierarchy	Primary	Experts	Interviews and Questionnaires	
4	Priority weight measurement	Primary	Experts	Interviews and Questionnaires	Fuzzy AHP

$\tilde{A}$ is (n x n), Fuzzy numbers including in a fuzzy matrix $\tilde{a}_{ij}$ $\tilde{x}$ is (n x 1), Fuzzy numbers contain a fuzzy vector $\tilde{x}_i$. Then, depending on the cut value, the upper and lower bounds of the fuzzy number are calculated using the equation below:

$$\tilde{1}_a = [1, 3-2\alpha] \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$\tilde{3}_\alpha = [1 + 2\alpha, 5-2\alpha] ; \sim 3_\alpha^{-1} = \left[\frac{1}{5-2\alpha}, \frac{1}{1+2\alpha}\right] \quad (4)$$

$$\tilde{5}_\alpha = [3 + 2\alpha, 7-2\alpha] ; \sim 5_\alpha^{-1} = \left[\frac{1}{7-2\alpha}, \frac{1}{3+2\alpha}\right] \quad (5)$$

$$\tilde{7}_\alpha = [5 + 2\alpha, 9-2\alpha] ; \sim 7_\alpha^{-1} = \left[\frac{1}{9-2\alpha}, \frac{1}{5+2\alpha}\right] \quad (6)$$

$$\tilde{9}_\alpha = [7 + 2\alpha, 11-2\alpha] ; \sim 9_\alpha^{-1} = \left[\frac{1}{11-2\alpha}, \frac{1}{7+2\alpha}\right] .. \quad (7)$$

The degree to which decision-makers or experts trust their judgment is known as the α-cut. According to the optimism index, the assessment matrix A's level of satisfaction is estimated. Combining linear convex functions, as shown in equation 8, creates the optimism index.

$$\widetilde{\alpha_{ij}^{\alpha}} = \omega\, \widetilde{\alpha_{iju}^{\alpha}} + (1-\omega)\, \widetilde{\alpha_{ijl}^{\alpha}} \; ; \forall\, \omega \in [0,1] \quad \ldots\ldots\ldots \quad (8)$$

Equation 9 simplifies the calculation of priority weights.

$$\mathbf{x_i} = \frac{\sum_{i=1}^{n}\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)}{n} \quad \ldots\ldots\ldots\ldots\ldots. \quad (9)$$

The calculation of the eigen vectors involved the calculation of priority weights and normalisation of pairwise comparisons. The outcomes regulate each matrix's Consistency Ratio (CR) and the hierarchy's total calculation. CR for the research, which is ≤ 0.1. According to Saaty (Saaty, 2008), random consistency index (RI) value about matrix size

Decision and the sum of the priority weights

The following equation, 10, determines the priority weights for each choice.

$$k = \sum_{i=1}^{t} x(attribute\ weights\ x\ assessment_{ij}) \ldots.\ 10)$$

for i = 1,2, ... t; with = x; attribute t; total number of attributes j; alternative

RESULTS AND DISCUSSION

Location of The Site Selection Area

The raw material for edible white copra is hybrid coconut. Hybrid coconut is obtained from the largest coconut-producing district in Indonesia, Indragiri Hilir Regency, Riau Province, with an area of 303,556 hectares and a total production of 263,732 tons. According to data from the Directorate General of Plantations, hybrid coconut production in each sub-district, is shown Table 2 (BPS-Statistics of Indragiri Hilir Regency, 2023). Table 2 states the potential locations for the availability of raw materials based on area and amount of production. The total potential for hybrid coconut raw materials in Indragiri Hilir Regency is 35,398 Ha, with a total production of 50,156 tons. Table 1 shows that the sub-districts that meet the planned capacity of 300 tons with an area of over 214 hectares are the sub-districts of Enok, Kuala Indragiri, Tembilahan, Tembilahan Hulu, Tempuling, Kempas, Batang Tuaka, Pelangiran and Teluk Blengkong. Pulau Burung and Tanah Merah sub-districts were not included in the selection alternatives even though they met the required capacity. These locations already had industries that used coconut as raw material. In addition, the Keritang sub-district still needs to fulfil the hybrid coconut production capacity based on field studies.

Table 2. Indragiri Hilir regency estate crop planted area by subdistrict and type of crops, 2022 (BPS-Statistics of Indragiri Hilir Regency 2023)

No	Subdistrict	Planted Area (Hectar)
1	Keritang	356
2	Kemuning	1
3	Reteh	129
4	Sungai Batang	23
5	Enok	249
6	Tanah Merah	777
7	Kuala Indragiri	995
8	Concong	0
9	Tembilahan	322
10	Tembilahan Hulu	928
11	Tempuling	2,940
12	Kempas	3,246
13	Batang Tuaka	455
14	Gaung Anak Serka	7
15	Gaung	0
16	Mandah	230
17	Kateman	0
18	Pelangiran	6,090
19	Teluk Belengkong	7,975
20	Pulau Burung	10,472

Determining Criteria With Modified SCOR Version 12.0

Designing metrics for selecting edible white copra agro-industry locations for Levels 2, 3, 4 and alternative agro-industry locations is done by mapping the metrics contained in the SCOR model version 12.0 and validated by experts. The series of explanations is built on the hierarchy, as seen in Figure 2. The performance metrics successfully defined are perfect order fulfilment, order fulfilment cycle time, supply chain improvement adaptability, total supply chain management costs, and cash-to-cash cycle time. Use perfect order fulfilment to assess the delivery performance of raw material orders.

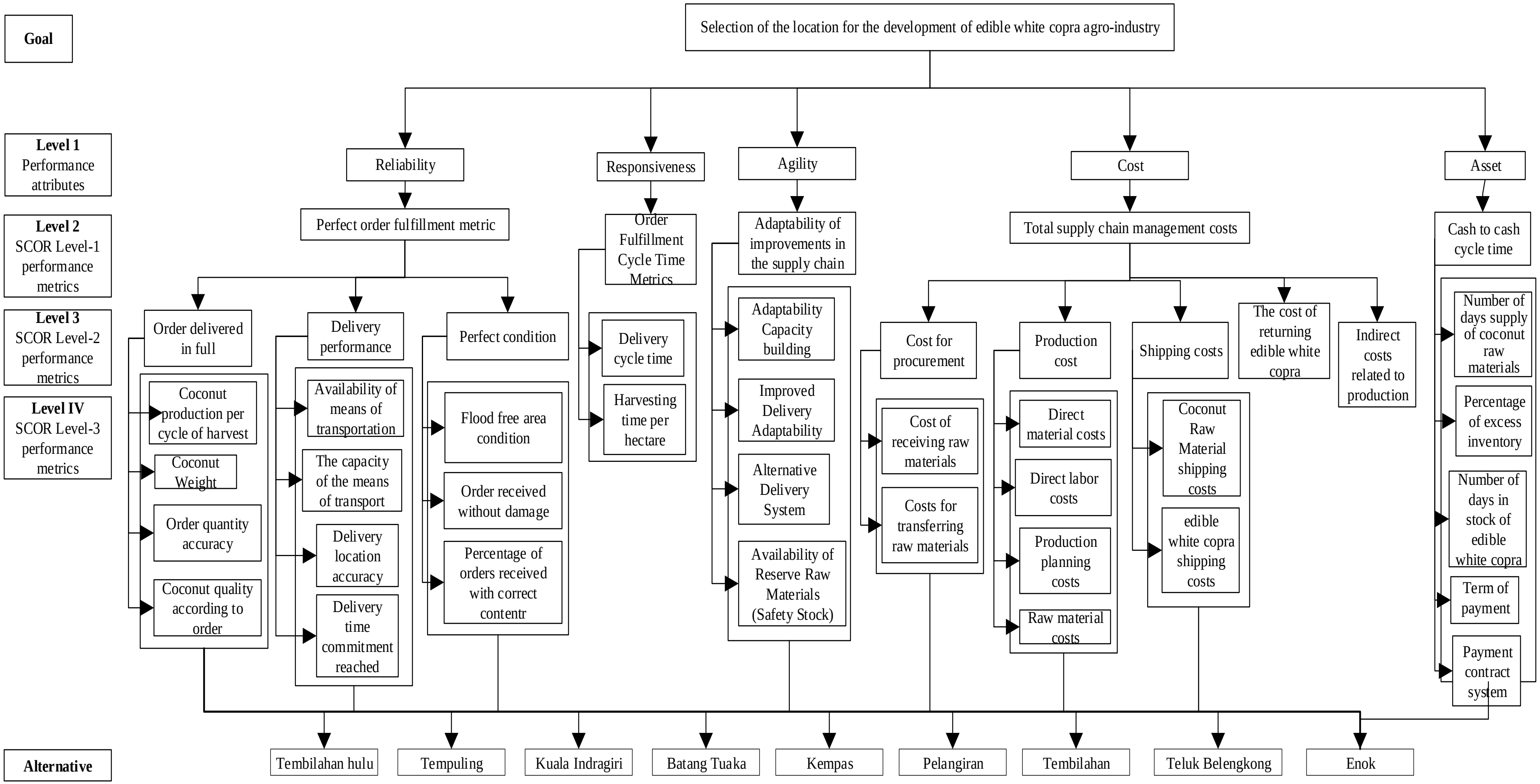

Figure 2. Hierarchical design of location selection matrix

Assessment of delivery performance is to prevent damage to the delivery of raw material orders. The series of explanations is built on the hierarchy, as seen in Figure 2. Reduce, Reuse, Recycles, Refill, Replace, Repair, Replant (7R), which stands for the right product, the right amount, the right circumstances, the right place, the right time, the right customer, and the correct cost, is how Association for Supply Chain Management (APICS) makes this crucial assessment. This 7R precision can result in perfect condition performance achieved. The raw material for edible white copra is a hybrid type of coconut. The raw material for white copra coconuts is not always given hybrid coconuts from farmers because farmers sometimes, in order to meet the target order for raw materials, mix it with small-sized inner coconuts. If raw materials mix, the resulting product differs from what consumers want.

Establishing perfect order fulfilment metrics to assess location selection is essential because unsuitable raw materials will disrupt the supply chain (Schrijvers *et al.*, 2020). The ordering cycle time is essential in assessing the location of the edible copra agro-industry because this metric shows the readiness of the agro-industry to respond to consumer demand by paying attention to the length of the harvesting process per hectare and the delivery time because coconut has a coconut harvesting cycle time of around one to two months and has a time of about one to two weeks for harvesting per hectare by farmers. This assessment becomes very important when the consumers served are on a vertical line and can never predict when to place an order – an assesment for adaptability due to adaptability in the event of a sudden increase in product demand. The assessment starts with the adaptability of increased delivery, alternative delivery systems and the availability of reserve raw materials.

This assessment becomes even more meaningful when it can continuously serve foreign consumer requests. The metrics for total supply chain management costs are procurement, production costs, shipping costs, returning edible white copra, and direct costs related to production. The SCOR model hypothesises an overlap between indicators for the cost of goods sold and supply chain management in performance appraisal analysis. Cost measures for Efficiency in cost allocation are a top priority for supply chain management since they will affect the cost of production and the price of the items sold. When determining the value of this product in the supply chain network, the cost of manufacturing and the commodities sold will take into account the cost of production that benefits all supply chain network participants. Due to the need for the edible copra agro-industry to be able to produce goods in response to erratic free-market customer demand, the number of days of supply is a crucial measure in evaluating the location selection process. Therefore, the agro-industry needs an economical supply of edible white copra to overcome this. In addition, it is necessary to prepare a payment contract system based on the availability of capital.

Fuzzy AHP

Setting The Fuzzy Membership Function Based on the TFN

TFN is used in fuzzy AHP to indicate the weight of a nine-point rating scale to reflect the hierarchy of significance. Figure 3 illustrates the membership function of TFN, a distinct number type defined by three real numbers (ℓ, m, and u). The parameters ℓ and u limit the possible evaluation fields, and m gives the maximum degree of membership function. The geometric mean method is used in this study and considers a triangular fuzzy membership function to reduce the weight of the fuzzy criteria. Figure 3 shows how TFN generates a triangular fuzzy comparison matrix to convey expert judgement. TFN show which item in each pair in a hierarchy gives more weight than the other. The completion of each undetermined number is present as having a certain level of importance in Table 3

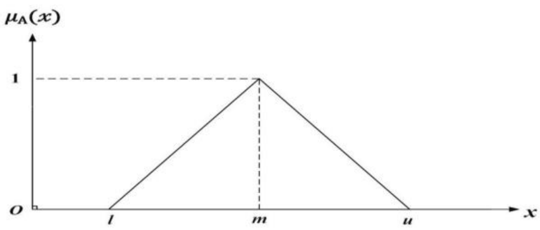

Figure 3. TFN, A = (l, m, u)

Table 3. Fuzzy number, definition and membership function

Importance Level	Fuzzy Numbers	Definition	Function of membership
1	$\tilde{1}$	Both equally important	(1,1,3)
3	$\tilde{3}$	A little more important	(2,3,4)
5	$\tilde{5}$	Obviously more important	(4,5,6)
7	$\tilde{7}$	Very clearly more important	(6,7,8)
9	$\tilde{9}$	Absolutely more important	(8,9,10)

Constructing A Matrix of Fuzzy Comparison

This stage begins with transforming an ordinary matrix into a TFN matrix form. This transformation was performed by inserting the guidelines from Table 2 into Equation 1. After the TFN matrices develop for all pairwise comparison matrices, the pairwise comparisons responded to by the three experts as primary data to be processed. Thus, a response is obtained from the geometric mean (xg), which combines expert opinions according to the root of the number of respondents (n) and multiplication (π) of expert judgment (Xi) so that equation 12. As mentioned, four sets of matrices will develop from the geometric mean of expert responses with the dimensions of each matrix—fuzzy pairwise comparisons using Equation 1.

Solution For Fuzzy Eigenvalues

Once the TFN matrices have formed for all pairwise comparison matrices, it is crucial to find the fuzzy eigenvalues. To start, depending on the fuzzy comparison matrix, equations 3 to 7 were applied to find the upper and lower bounds of the fuzzy numbers based on the -cut. At the time of the evaluation, the average confidence level was 0.5. Equation 8 converts the value of the -cut fuzzy comparison matrix into a crisp value with an optimism index of ω= 0.5, indicating that the provided judgment is neither excessively optimistic nor underly pessimistic.

Decision and The Total Sum of Priority Weights

Normalising the value of xi to represent the level of importance of these components will obtain the weight value of each level to the total weight. They assess the relative significance of each level using ratio CR and offer substitutes. According to the calculations, CR is less than 0.1. Because dependability, responsiveness, agility, cost, and asset management efficiency (assets) are equally crucial for choosing edible white copra agro-industry locations, Table 4 and Table 5 shows that all level 1 and level 2 performance criteria traits have the same weight.

Predictability focuses on process results, and reliability emphasises the need for timely delivery, correct quantity, and high quality. The supply chain's responsiveness refers to how quickly it delivers goods to clients. Agility, which includes adaptability and the overall value of risk, is the capacity to respond to external pressures and market changes to establish or preserve a competitive advantage. The cost of managing supply chain activities comprises labour, material, management, and transportation, with the cost of goods sold as a standard indicator. Asset management methods in the supply chain, such as inventory reduction and insourcing, as opposed to outsourcing with metrics, such as day-to-day inventory supply and capacity utilisation, are examples of asset management strategies.

Table 4. Weight Level 1 Attribute Performance Criteria

Hierarchical Metrics	Weight
Reliability	0.200
Responsiveness	0.200
Agility	0.200
Cost	0.200
Asset	0.200

Table 5. Weights at level 2 of the performance metric

Hierarchical Metrics	Weight
Perfect order fulfilment metric	0.200
Order Fulfillment Cycle Time Metrics	0.200
Adaptability of improvements in the supply chain	0.200
Total supply chain management costs	0.200
Cash to cash cycle time	0.200

The metric weights at the third level are presented in Table 6. The Table indicates that the metrics of flawless order fulfilment and order fulfilment cycle time have the same weight because all subcriteria are equally important. Contrarily, the weights of flexibility, the overall cost of supply chain management, and cash-to-cash cycle time are different in supply chain optimisation. The adaptability of Improvement in Delivery has the highest to lowest weighting order. Therefore, supply chain improvement adaptability is not equally weighted. Improvement of delivery adaptability has the highest weight because reliability is needed in shipping according to consumer desires (Junior and Carpinetti, 2020).

Furthermore, Table 6 also presents the normalised weight values for the total cost of supply chain management. Among the sub-levels, costs for procurement rank top priority over shipping and production costs because they are one of the most dominant determinants in determining profits as a product producer (Sana, 2022). Finally, Table 6 presents level 3 that the cash-to-cash cycle time with the highest weight is the number of days of raw material supply and the number of days of edible white copra stock because edible white copra stock requires a drying process from day to day (Sagayaraj *et al.*, 2021). In addition, the raw material for edible copra is in the form of coconut, which is easily damaged (susceptible to decay); availability depends on harvest, growth and season, final shape and size variations, and voluminous (Wardah *et al.*, 2020)

Table 7 presents the weights at each level 4. At each level with the highest weight is the quality of coconut according to the order with a weight of 0.568, the percentage of orders received with the correct content with a weight of 0.624, Costs for transferring raw materials 0.739, and raw material costs 0.499, Availability of transportation facilities with a weight of 0.526.

Table 6. Weights at level 3 of the performance metric

Level 3: Perfect order fulfilment metric	**Weight**
Order delivered in full	0.333
Delivery performance	0.333
Perfect condition	0.333
Level 3: Order Fulfillment Cycle Time Metrics	
Delivery cycle time	0.500
Harvesting time per hectare	0.500
Level 3 Adaptability of improvements in the supply chain	
Adaptability Capacity building	0.303
Improved Delivery Adaptability	0.436
Alternative Delivery System	0.155
Availability of Reserve Raw Materials (Safety Stock)	0.106
Level-3: Total supply chain management costs	
Cost for procurement	0.384
Production cost	0.180
Shipping costs	0.256
The cost of returning edible white copra	0.091
Indirect costs related to production	0.091
Level-3: Cash to cash cycle time	
Days' supply of raw coconut materials	0.315
Percentage of excess inventory	0.183
Number of days in stock of edible white copra	0.315
Term of payment	0.094
Payment contract system	0.094

Table 7. Weights at Level 4 Performance metrics

Level 4: Orders metrics delivered in full	**Weight**
Coconut production per cycle of harvest	0.175
Coconut Weight	0.081
Order quantity accuracy	0.175
Coconut quality according to order	0.568
Level 4: Delivery performance metrics	
Availability of means of transportation	0.526
The capacity of the means of transport	0.276
Delivery location accuracy	0.130
Delivery time commitment reached	0.068
Level 4: Perfect state metric	
Flood-free area condition	0.110
Order received without damage	0.266
Percentage of orders received with the correct content	0.624
Level 4: Cost Metrics for Procurement	
Cost of receiving raw materials	0.261
Costs for transferring raw materials	0.739
Level 4: Cost of production metrics	
Direct material costs	0.286
Direct labour costs	0.135
Production planning costs	0.080
Raw material costs	0.499
Level 4: Shipping cost metrics	
Coconut Raw Material shipping costs	0.500
Edible white copra shipping costs	0.500

The quality of raw materials holds the highest weight because the availability of high quality coconut for edible copra is critical. The toxic sulfur is often used, and this is prohibited due to its harmful health effects such as respiratory and skin problems (Lakshmanan *et al.* 2020; Ng *et al.* 2021; Sagayaraj *et al.* 2021). No defect in coconut is also important. It takes several days to transport the coconut harvested to agro-industrial locations, usually using water transportation. The percentage of orders received with the correct content has the highest weight because, as previously explained, coconut raw materials from plantation locations to agro-industry take time to cause shrinkage. The availability of transportation facilities has the highest weight compared to the capacity of transportation facilities, the accuracy of delivery locations, and delivery time commitments achieved. In addition, the availability of transportation facilities to transport raw materials to edible copra agro-industry locations and products produced to consumers in export destination countries, so this criterion is more critical than followed by the other criteria. Raw material costs are affected by transportation costs, raw material quality, and raw material transportation costs which significantly affect profits (Kaur *et al.*, 2018).

The first order of priority for developing edible copra agro-industry is based on Table 8 Tembilahan Hulu because it has the highest weight. The highest weight is the order delivered in full, including coconut weight, coconut quality according to order, production costs including raw material costs, direct labour costs, direct material costs, costs for procurement including costs for transferring products and product receiving costs, increased adaptability in the chain supply including capacity building, order fulfilment cycle time including length of harvesting process per hectare, cost of returning edible white copra, indirect costs related to production, the number of days of raw coconut inventory, the percentage of excess inventory, the days' supply of edible white copra, the payment term, and the payment contract system.

MANAGERIAL IMPLICATIONS

The edible white copra agro-industry location was determined by using a new approach of SCOR and fuzzy AHP, which was based on a multi-criteria approach. The results of this study resolves the critical site selection challenges for the growth of the edible white copra agro-industry. The problems include the problem of excessive supply of coconut in Indragiri Hilir Regency, Riau Province, Indonesia and the opportunity for the high demand for exports, which provides significant input for the Indragiri Hilir Regency government to act decisively to develop an edible white copra agro-industry.

Table 8. Weights at the level of alternative locations for edible white copra agro-industry

Performance Metrics	Weight	Priority Order
Tembilahan hulu	0.187	1
Batang Tuaka	0.153	2
Tempuling	0.145	3
Kempas	0.111	4
Kuala Indragiri	0.093	5
Tembilahan	0.093	6
Teluk Belengkong	0.080	7
Pelangiran	0.073	8
Enok	0.065	9

The creation of edible white copra has a remarkable economic impact that enables it to overcome significant issues like an excess of coconut raw materials with a low price impact while ensuring market stability. The final objective is to enhance farmers' welfare. Due to the complicated multi-criteria, location selection for the edible white copra agro-industry is challenging. As a result, a new integration of SCOR and Fuzzy AHP is created in a transparent and systematic hierarchical structure, producing a focused and recognisable output. Agro-industry can apply this approach to identify potential locations for developing edible white copra agro-industry to enhance its agro-industrial development. In addition, selecting the location for the edible white copra agro-industry can provide input for the government, especially Indragiri Hilir Regency, the largest coconut-producing district in Indonesia, regarding industrial areas based on coconut products.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The results showed that this present study successfully developed a new approach by integrating SCOR and Fuzzy AHP, in selecting edible white copra agro-industry location. The locus of the research was Indragiri Hilir Regency, Riau Province, Indonesia, and critical subcriteria and criteria for each area were obtained based on each level's SCOR performance attributes and metrics. At level one and level two, each has the same weight for each attribute and metric, while at the third level, which has the highest weight, is adaptability of increased shipping, costs for procurement, number of days of coconut raw material inventory, and days for supply of edible white copra. Furthermore, level fourth which has the highest weight, is the quality of the coconut according to the order, the availability of transportation facilities, and the percentage of orders received with the correct content. Finally, in the priority order, the potential areas for the development of edible white copra agro-industry are Tembilahan Hulu and continued in the following order are Batang Tuaka, Tempuling, Kempas, Kuala Indragiri, Tembilahan, Teluk Belengkong, Pelangiran and Enok.

Recommendations

In the future, this research needs to integrate spatial methods, thus it can be seen visually on the map of the location area based on the priority order of the location of the edible white copra agro-industry development.

ACKNOWLEDGEMENT

Volunteers assisted the research project implementation on data collection in the coconut field in Indragiri Hilir Regency, Riau Province, Indonesia, and the Bekawan Agro Mandiri MSME engaged in the coconut product business.

REFERENCES

Abdel-Basset M, Gamal A, Chakrabortty RK, Ryan M. 2021. A new hybrid multi-criteria decision-making approach for location selection of sustainable offshore wind energy stations: A case study. *Journal of Cleaner Production*.280:124462. doi:10.1016/j.jclepro.2020.124462.

Abdullah AG, Shafii MA, Pramuditya S, Setiadipura T, Anzhar K. 2023. Multi-criteria decision making for nuclear power plant selection using fuzzy AHP: Evidence from Indonesia. *Energy and AI*. 14 April:100263. doi:10.1016/j.egyai.2023.100263.

Afolayan AH, Ojokoh BA, and Adetunmbi AO. 2020. Performance analysis of fuzzy analytic hierarchy process multi-criteria decision support models for contractor selection. *Scientific African*.9:e00471. doi:10.1016/j.sciaf.2020.e00471.

Ahmed F, Kilic K. 2019. Fuzzy Analytic Hierarchy Process: A performance analysis of various algorithms. *Fuzzy Sets and Systems*. 362:110–128. doi:10.1016/j.fss.2018.08.009.

Akkawuttiwanich P, Yenradee P. 2018. Fuzzy QFD approach for managing SCOR performance indicators. *Computers and Industrial Engineering*. 122 May:189–201. doi:10.1016/j.cie.2018.05.044.

Ali SA and Ahmad A. 2020. Suitability analysis for municipal landfill site selection using fuzzy analytic hierarchy process and geospatial technique. *Environmental Earth Sciences*. 79(10). doi:10.1007/s12665-020-08970-z.

Aly MS. 2020. Towards using renewable energy on industrial location selection in Egypt. *Journal of Sustainability Science and Management*. 15(2):179–191. https://api.elsevier.com/content/abstract/scopus_id/85083919263.

APICS. 2017. Supply Chain Operations Reference Model SCOR -Intro to V12. *Supply Chain Operations Manag Version 120*.

Arar T, Karaoğlan S, and Dirik C. 2019. Office location selection by fuzzy AHP and VIKOR. *International Journal Information and Decision Sciences*. 11(1):36–54. doi:10.1504/IJIDS.2019.096630.

Arunyanart S, Sureeyatanapas P, Ponhan K, Sessomboon W, Niyamosoth T. 2021. International location selection for production fragmentation. *Expert Systems with Applications*. 171 December 2020:114564. doi:10.1016/j.eswa.2021.114564.

Attri R and Grover S. 2015. Application of preference selection index method for decision making over the design stage of production system life cycle. *Journal of King Saud University - Engineering Sciences*. 27(2):207–216. doi:10.1016/j.jksues.2013.06.003.

Ayyildiz E and Taskin Gumus A. 2021. Interval-valued Pythagorean fuzzy AHP method-based supply chain performance evaluation by a new extension of SCOR model: SCOR 4.0. *Complex and Intelligent Systems*. 7(1):559–576. doi:10.1007/s40747-020-00221-9.

BPS-Statistics of Indragiri Hilir Regency. 2023. *Indragiri Hilir Regency in Figures 2023*. Volume ke-13.

Dissanayake CK and Cross JA. 2018. Systematic mechanism for identifying the relative impact of supply chain performance areas on the overall supply chain performance using SCOR model and SEM. *International Journal of Production Economics*. doi:10.1016/j.ijpe.2018.04.027.

Eldemir F and Onden I. 2016. Geographical Information Systems and Multicriteria Decisions Integration Approach for Hospital Location Selection. *International Journal of Information Technology and Decision Making*.15(5):975–997. doi:10.1142/S0219622016500218.

van Engelenhoven T, Kassahun A, Tekinerdogan B. 2022. Systematic Analysis of the Supply Chain Operations Reference Model for Supporting Circular Economy. *Circular Economy and Sustainability*.(0123456789). doi:10.1007/s43615-022-00221-6.

Al Garni HZ and Awasthi A. 2017. Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia.

Applied Energy. 206 October 2017:1225–1240. doi:10.1016/j.apenergy.2017.10.024.

Gaska K, Generowicz A, Ocłoń P, Stelmach S. 2021. Location of the waste incineration plant with particular emphasis on the environmental criteria. *Journal of Cleaner Production*.303.doi:10.1016/j.jclepro.2021.126887.

Genger TK, Luo Y, and Hammad A. 2021. Multi-criteria spatial analysis for location selection of multi-purpose utility tunnels. *Tunnelling and Underground Space Technology*.115 June:104073.doi:10.1016/j.tust.2021.10407.

Hanine M, Boutkhoum O, Tikniouine A, Agouti T. 2017. An application of OLAP/GIS-Fuzzy AHP-TOPSIS methodology for decision making: Location selection for landfill of industrial wastes as a case study. *KSCE Journal of Civil Engineering*. 21(6):2074–2084. doi:10.1007/s12205-016-0114-4.

Ilbahar E, Kahraman C, and Cebi S. 2021. Location selection for waste-to-energy plants by using fuzzy linear programming. *Energy*. 234:121189. doi:10.1016/j.energy.2021.121189.

Kabir G and Sumi RS. 2014. Power substation location selection using fuzzy analytic hierarchy process and PROMETHEE: A case study from Bangladesh. *Energy*. 72:717–730. doi:10.1016/j.energy.2014.05.098.

Kamranzad B and Hadadpour S. 2020. A multi-criteria approach for selection of wave energy converter/location. *Energy*. 204:117924. doi:10.1016/j.energy.2020.117924.

Karaşan A. 2019. A novel intuitionistic fuzzy DEMATEL - ANP - TOPSIS integrated methodology for freight village location selection [Cited By (since 2019): 20]. *Journal of Intelligent and Fuzzy Systems* . 36(2):1335–1352. doi:10.3233/JIFS-17169.

Kaur H, Singh SP, Garza-reyes JA, Mishra N. 2018. Sustainable Stochastic Production and Procurement Problem for Resilient Supply Chain. *Computers & Industrial Engineering*.

Kumar BM and Kunhamu TK. 2022. Nature-based solutions in agriculture: A review of the coconut (Cocos nucifera L.)-based farming systems in Kerala, "the Land of Coconut Trees."*Nature-Based Solutions*. 2 February:100012.doi:10.1016/j.nbsj.2022.100012.

Lakshmanan MK, Chinnu T, and Arvamuthan G. 2020. Near-infrared reflectance spectroscopy based online moisture measurement in copra. *Journal of Food Process Engineering*. 43(3). doi:10.1111/jfpe.13383.

Li C, Zhang T, Wang X, Lian Z. 2022. Site Selection of Urban Parks Based on Fuzzy-Analytic Hierarchy Process (F-AHP): A Case Study of Nanjing, China. *International Journal of Environmental Research and Public Health*. 19(20). doi:10.3390/ijerph192013159.

Lima-Junior FR and Carpinetti LCR. 2020. An adaptive network-based fuzzy inference system to supply chain performance evaluation based on SCOR® metrics. *Computers and Industrial Engineering*. 139:106191. doi:10.1016/j.cie.2019.106191.

Memari A, Dargi A, Akbari Jokar MR, Ahmad R, Abdul Rahim AR. 2019. Sustainable supplier selection: A multi-criteria intuitionistic fuzzy TOPSIS method. *Journal of Manufacturing Systems*. 50 April 2018:9–24. doi:10.1016/j.jmsy.2018.11.002.

Mirhadi FM, Kibert CJ, and Chini AR. 2016. Decision-making for sustainable location of a cement plant in the state of Florida. *International Journal of Sustainable Engineering*.9(2):76–92. doi:10.1080/19397038.2015.1050971.

Mishra AR, Rani P, Saha A, Hezam IM, Cavallaro F, Chakrabortty RK. 2023. An extended DNMA-based multi-criteria decision-making method and its application in the assessment of sustainable location for a lithium-ion batteries' manufacturing plant. *Heliyon*. 9(3):e14244. doi:10.1016/j.heliyon.2023.e14244.

Mohd Rosdi MNH, and Wan Mahmood WH, Razik MA, Kamat SR. 2021. Fuzzy analytic hierarchical process implementation on enhancing manufacturing responsiveness. *Journal of King Saud University - Engineering Sciences*. xxxx. doi:10.1016/j.jksues.2021.10.006.

Mytilinou V. 2017. A multi-objective optimisation approach applied to offshore wind farm location selection [Cited By (since 2017): 12]. *Journal of Ocean Engineering and Marine Energy*. 3(3):265–284. doi:10.1007/s40722-017-0092-8.

Ng YJ, Tham PE, Khoo KS, Cheng CK, Chew KW, Show PL. 2021. A comprehensive review on the techniques for coconut oil extraction and its application. *Bioprocess and Biosystems Engineering*.44(9):1807–1818. doi:10.1007/s00449-021-02577-9.

Nong TNM. 2022. A hybrid model for distribution center location selection. *Asian Journal of Shipping and Logistics*. 38(1):40–49. doi:10.1016/j.ajsl.2021.10.003.

Ntabe EN, LeBel L, Munson AD, Santa-Eulalia LA. 2015. A systematic literature review of the supply chain operations reference (SCOR) model application with special attention to environmental issues. *International Journal of Production Economics*. 169:310–332.

doi:10.1016/j.ijpe.2015.08.008.

Nyimbili PH and Erden T. 2020. GIS-based fuzzy multi-criteria approach for optimal site selection of fire stations in Istanbul, Turkey. *Socio-Economic Planning Sciences* . 71 July 2019:100860.doi:10.1016/j.seps.2020.100860.

Otay I and Jaller M. 2020. *Multi-criteria and multi-expert wind power farm location selection using a pythagorean fuzzy analytic hierarchy process*. Volume ke-1029. Springer International Publishing.

Ozdemir S, Sahin G. 2018. Multi-criteria decision-making in the location selection for a solar PV power plant using AHP [Cited By (since 2018): 47]. *Journal of the International Measurement Confederation*. 129:218–226. doi:10.1016/j.measurement.2018.07.020.

Plantations DG of. 2023. Statistical Of National Leading Estate Crops Commodity 2021-2023.

Qorri A, Mujkić Z, Kraslawski A. 2018. A conceptual framework for measuring sustainability performance of supply chains. *Journal of Cleaner Production*. 189:570–584. doi:10.1016/j.jclepro.2018.04.073.

Rezaeisabzevar Y. 2020. Landfill site selection using multi criteria decision making: Influential factors for comparing locations [Cited By (since 2020): 12]. *Journal of Environmental Sciences (China)*. 93:170–184. doi:10.1016/j.jes.2020.02.030.

Rikalovic A, Cosic I, and Lazarevic D. 2014. GIS based multi-criteria analysis for industrial site selection. *Procedia Engineering*. 69:1054–1063. doi:10.1016/j.proeng.2014.03.090.

Saaty TL. 2008. Decision making with the analytic hierarchy process. *International Journal of Services Sciences* . 1(1).

Sagayaraj AS, Devi TK, and Umadevi S. 2021. Prediction of Sulfur Content in Copra Using Machine Learning Algorithm. *Applied Artificial Intelligence*. 35(15):2228–2245. doi:10.1080/08839514.2021.1997214.

Sana SS. 2022. A structural mathematical model on two echelon supply chain system. *Annals of Operations Research*. 315(2):1997–2025. doi:10.1007/s10479-020-03895-z.

Schrijvers D, Hool A, Blengini GA, Chen WQ, Dewulf J, Eggert R, van Ellen L, Gauss R, Goddin J, Habib K, *et al.* 2020. A review of methods and data to determine raw material criticality. *Resources, Conservation and Recycling*. 155 January:1–17. doi:10.1016/j.resconrec.2019.104617.

Sk MM. 2020. Optimal Sanitary Landfill Site Selection for Solid Waste Disposal in Durgapur City Using Geographic Information System and Multi-criteria Evaluation Technique [Cited By (since 2020): 2]. *Journal of Cartography and Geographic Information*. 70(4):163–180. doi:10.1007/s42489-020-00052-1.

Wardah S, Marimin, Yani M, Djatna T. 2020. Methods and Approaches of Decision Support System for Coconut Agroindustry Development and Down-streaming : A Systematic Literature Review and Future Agenda. *International Journal of Supply Chain Management*. 9 X:185–201.

Wardah S, Yani M, and Djatna T. 2022. Spatial-based multicriteria decision-making model for coconut sugar agro-industry location selection : A case Study at Indragiri Hilir District , Riau Province , Indonesia. Di dalam: *IOP Conference Series: Earth and Environmental Science*.

Yeoh JKW. 2017. Optimizing Crane Selection and Location for Multistage Construction Using a Four-Dimensional Set Cover Approach [Cited By (since 2017): 18]. *Journal of Construction Engineering and Management*. 143(8). doi:10.1061/(ASCE)CO.1943-7862.0001318.

Zhang X. 2018. Location selection of offshore wind power station by consensus decision framework using picture fuzzy modelling [Cited By (since 2018): 31]. *Journal of Cleaner Production*. 202:980–992. doi:10.1016/j.jclepro.2018.08.172