p-ISSN: 1907-8056
e-ISSN: 2527-5410
AGROINTEK
Jurnal Teknologi Industri Pertanian
journal homepage: journal.trunojoyo.ac.id/agrointek

The selection of sago flour suppliers using multi criteria group decision making approach with different sets of criteria

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Article history
Received:
2 May 2025
Revised:
28 Nopember 2025
Accepted:
3 March 2026

Keyword
Decision making;
Sago;
Suppliers

ABSTRACT

Tiga Hati Mutiara, a producer of pearl sago, has only one supplier of raw material for sago flour for the production of sago pearls. Based on data from the Indonesian Ministry of Agriculture, there are 13 sago-producing provinces. These 13 sago-producing provinces can become alternative sago suppliers for Tiga Hati Mutiara. The purpose of this research is to find the best supplier of sago flour for Tiga Hati Mutiara, in accordance with its needs and goals. To address the problem under concern, this research uses the MCGDM approach with a different set of criteria. This method requires expert data, such as decision makers, supplier alternatives, and supplier criteria. The study found that supplier alternative 2, namely Terong Mas, was chosen as the main supplier of sago flour out of six supplier alternatives and fifteen sub-criteria used. This research is expected to be a suggestion for improvement in supplier selection decision-making for the company, as well as material for further research literacy.

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DOI 10.21107/agrointek.v20i2.29902

INTRODUCTION

Suppliers in the production chain have an important role (Tirkolaee et al. 2021) and are considered the most common source of external risk found in companies (Hosseini and Khaled 2019). In the agribusiness sector, suppliers are one source of risk from the supply side (Imbiri et al. 2021). Supplier selection has the potential to impact the company's performance significantly (Masudin and Ayni 2018, Hosseini et al. 2019). It is a strategic matter that has an impact on a company's competitive advantage (Rezaei et al. 2016); and directly affects a company's cash flow and profitability (Banaeian et al. 2018). Supplier performance plays an important role in terms of quality, shipping, cost, and service for achieving supply chain goals (Nulsyah et al. 2022). For world-class companies, the quality of their products and services is directly related to the quality of their suppliers and the products and services they provide (Sitio 2017).

The availability of raw materials affects the smoothness of production (Lapko et al. 2016). This, for example, was conveyed by (Salima and Johansson 2016) regarding the manufacturing of wood products; (Chen et al. 2017) regarding the addition of wood chips to the carbon-containing raw material mixture and its positive effect on the performance of the silicon furnace; and (Lakio et al. 2017) related to the impact of the properties of particulate raw materials on the quality attributes of pharmaceutical products in tablet form.

Thus, selecting the right raw material supplier is important, as explained by, for example, (Frej et al. 2017, Haekal and Setio 2017, Puška and Stojanović 2022). If the raw material supplier is a competent supplier, the company will be greatly helped in running its business. On the other hand, if the supplier is less competent or consistent in its role as a raw material provider, the company will not be able to run its business optimally.

Sago has a substitutive capacity in the food industry (Hayati et al. 2014) as an alternative food (Yusuf et al. 2019), including as a substitute for rice (see, for example, (Dewayani et al. 2022, Rahayu et al. 2023)), and therefore, sago has the potential to be developed into various processed materials with high economic value (Hasbi and Sari 2020). Sago companies must be able to provide raw material needs quickly so that the production process is not hampered, and therefore, communication between the company and suppliers must run well, so that the fulfillment of needs for the production process runs smoothly (Herlon et al. 2022).

Tiga Hati Mutiara Company, located in Kwarasan, Grogol, Sukoharjo, Central Java, Indonesia, is a producer of sago pearls, which are food ingredients made from sago flour. So far, Tiga Hati Mutiara has received supplies of sago flour raw materials for the production of sago pearls from suppliers located in Lampung, Indonesia. According to the company management, the selection of this supplier was based on the better quality of sago flour when compared to sago flour from areas located on Java Island.

On the other hand, sago flour producers are not only found in Lampung. Based on data from the Indonesian Ministry of Agriculture (Setyowati 2020), there are 13 provinces producing sago, namely Papua, West Papua, North Maluku, South Sulawesi, North Sulawesi, Central Sulawesi, South Kalimantan, West Kalimantan, Riau, Riau Islands, West Sumatra, Bangka Belitung, and Aceh. Considering the importance of raw material suppliers for a company, as explained previously, the existence of various sago flour producers can be an alternative choice of supplier for Tiga Hati Mutiara in determining the best supplier according to production needs and company goals.

This article discusses the selection of sago flour suppliers at the Tiga Hati Mutiara company. Supplier selection is often a multiple criteria group decision-making (MCGDM). The characteristics of the MCGDM method problem are the existence of more than one alternative, attributes whose sizes cannot be compared, and a team of experts in the field numbering more than one (Herman 2019). The involvement of various individuals makes it possible for consensus not to be achieved, which is one of the stages in group decision making (GDM) (see, for example, Gou et al. 2021b regarding the process of generating consensus in GDM). One form of failure to achieve consensus is the emergence of different sets of selection criteria (see, for instance, Fan et al. 2018). This article accommodates decision-making situations with multiple criteria, involving multiple individuals, as well as with different sets of criteria.

To the best of the authors' knowledge, research on the selection of sago flour suppliers using the MCGDM approach and accommodating different sets of criteria has never been conducted. On a broader scale, research on MCGDM has been

going on for a long time and has been widely conducted, including (Djunaidi et al. 2018, Setiawan et al. 2018, Fauzi and Setiawan 2021, Setiawan and Murti 2022). In addition, the selection of suppliers in the agricultural-based food sector using MCGDM and research on MCGDM with differences in assessment by decision makers have also been widely conducted. The following paragraphs present several examples of research on supplier selection in the agricultural-based food sector using MCGDM, as well as research on MCGDM with differences in assessment by decision makers.

(Puška and Stojanović 2022) conducted a study on environmentally friendly supplier selection using several fuzzy MCGDM approaches – fuzzy SWARA for criteria weighting and fuzzy MABAC, fuzzy MARCOS, and fuzzy CRADIS for alternative ranking – using Biljana Brko, an agri-food company, as a case study. They used cost/price, quality, innovation, partnership relations, organization and management, environmental management systems, recycling, pollution control, environmentally friendly products, and environmental competence as criteria; three experts as parties involved in the assessment; and four suppliers as choices. The study concluded that environmental management systems and partnership relations were the criteria with the highest weight, while environmental competence was the criterion with the lowest weight. The application of various fuzzy MCGDM methods in the study also found that the 2nd supplier was the best choice.

The use of the analytic hierarchy process (AHP) – one of the MCGDM methods – to select mineral fertilizer suppliers in an agricultural company was carried out by (Nedeljković and Krstić 2018). Using product quality, price, delivery time, payment terms, and supplier reliability as criteria, company management and acquisition reference managers as parties involved in the assessment, and by determining four suppliers as alternatives, the study found the first supplier as the best supplier alternative.

(Zhou and Chen 2020) developed a series of MCGDM processes by integrating AHP, VIKOR, and median ranking method (MRM) to select environmentally friendly suppliers in a fuzzy Pythagorean scenario. The method was further applied to the selection of raw oil suppliers for an edible oil manufacturer in China.

Fan et al. (2018) proposed a method to solve MCGDM problems with a special problem where several experts from different organizations or departments take part in the decision-making process, and each expert pays more attention to the criteria related to his/her own task. As a result, the set of criteria considered by experts is different, and the criteria scores are also presented in different formats.

Research on efforts to gain consensus in GDM was conducted by (Gou et al. 2021b). In this case, the researchers used the double hierarchy linguistic preference relation (proposed by (Gou et al. 2021a)) with self-confidence degrees (see (Liu et al. 2017)).

In this study, several problem formulations will be presented, namely how to determine the best sago flour supplier for the company, what the criteria are for sago flour suppliers that suit the company's needs, and which suppliers are the best choices for the company. The purpose of this study is to help companies determine the best supplier based on selection criteria to meet the company's needs and objectives, to know the criteria for selecting suppliers according to the company's needs and objectives, and to know alternative suppliers in the selection process. It is also hoped that this research can provide suggestions for improvements in supplier selection decisions for companies and serve as material for further research literature.

METHODS

The methods used in this research are presented as part of two main stages of research, namely data collection and data processing. Further discussion of these stages will be presented as follows.

Data Collection

At this data collection stage, researchers looked for the data needed to identify the team of experts as decision makers, supplier criteria, and supplier alternatives. This data will later be processed to determine the best supplier alternatives for the company.

The preliminary phase of data collection in this study involved the identification of a team of experts to serve as decision makers. The expert identification process was guided by three principal criteria: (1) direct engagement in procurement-related tasks, (2) comprehensive knowledge of the material flow within the company, and (3) substantive experience

in evaluating supplier performance. Based on these criteria and the company's organizational structure—comprising office personnel (general support, secretarial, and cashier staff) and field personnel (production, raw material warehouse, and finished goods warehouse staff)—the individuals deemed most qualified to serve as experts were identified as follows:
E1 = general support staff, E2 = production staff, and E3 = raw material warehouse staff.

After determining the expert, the next step is to identify alternative suppliers. The identification of alternative suppliers was undertaken through a review of publicly available information on sago flour suppliers in Indonesia, in conjunction with interviews conducted with the selected team of experts. From the interview process, it was discovered that the supplier of Tiga Hati Mutiara, when the research was conducted, came from Lampung. Based on the results of the data collection conducted, it was decided that alternative suppliers of sago flour included in this study came from six places, namely A1 = SPM Company, A2 = Terong Mas Company, A3 = Agro Mas Company, A4 = Pringsewu Company, A5 = Wonogiri, Central Java, and A6 = Gunungkidul, Special Region of Yogyakarta. In this case, A1, A2, A3, and A4 are the suppliers that the company intends to come from Lampung. Meanwhile, A5 and A6 come from Java. These six alternatives have been chosen several times by companies as suppliers of sago flour in the past years.

The next stage of data collection is to determine supplier criteria based on the opinions of the expert team. Determination of these criteria is carried out through a process of interviews, discussions, and filling out questionnaires with the expert team as respondents. Initial findings revealed that Tiga Hati Mutiara relied on a single supplier of sago flour, with product quality serving as the only criterion in the supplier selection process. Later on, the criteria chosen by the expert team in selecting suppliers were eight criteria, namely price, quality, location, flexibility, delivery, response, warranty or service, and payment. The eight criteria are further broken down into fifteen sub-criteria, namely C1 = price suitability, C2 = white flour quality, C3 = dry flour quality, C4 = easy to process flour, C5 = easy to reach suppliers, C6 = able to respond to changes in demand, C7 = punctuality of delivery, C8 = accuracy of delivery quantity, C9 = security during delivery, C10 = neatness of packaging, C11 = responsiveness when responding to problems, C12 = responsiveness when there are sudden requests, C13 = provision of warranty, C14 = good communication, C15 = payment can be made in installments. Figure 1 presents the hierarchy of the criteria and sub-criteria in this study.

Data Processing

The collected data are then processed and used to find the best alternative supplier ranking for Tiga Hati Mutiara. The method used in processing this research data refers to the method used by (Fan et al. 2018) as described below.

First, construct a non-empty power set $\mathcal{P}(E)$ based on the set of experts E, and determine the set of sub-criteria $C(E`)$ regarding each $E`$ ($E` \in \mathcal{P}(E)$). Second, build an indicator matrix $T = [t_{kj}]q \times n$ and determine the indicator vector $t_j$ regarding criterion $C_j$. Third, build vector indicators $e(E`)$ according to the set $C(E`)$. Fourth, calculate the distance between $t_j$ and $e(E`)$ and then determine whether the criterion C_j belongs to the sub-criteria set $C(E`)$. Fifth, build a probability ranking matrix $r^{E`}$ regarding the set of sub-criteria $C(E`)$. Sixth, normalize the objective matrix. Seventh, determine the ranking value of alternative $A_i$ regarding the set $C(E`)$. Eighth, calculate the weight $w_{E`}$ of the sub-criteria set $C(E`)$. Ninth, construct the overall ranking probability matrix P. Tenth, build a linear assignment model based on the overall ranking probability matrix P. Eleventh, determine the final ranking results by completing the linear assignment model. Diagrammatically, these steps are presented in Figure 2.

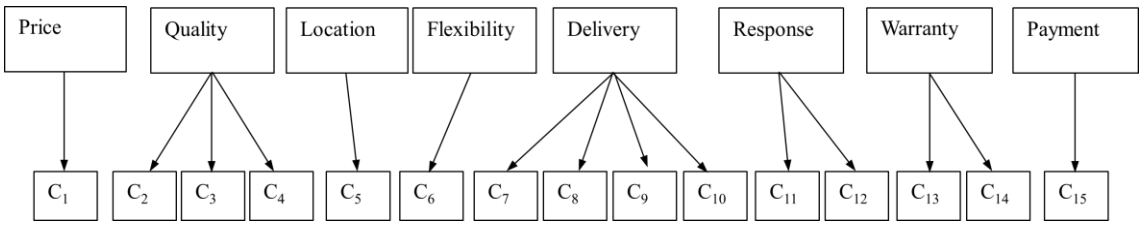


Figure 1 Hierarchy of criteria and sub-criteria (Source: Research data, 2022)

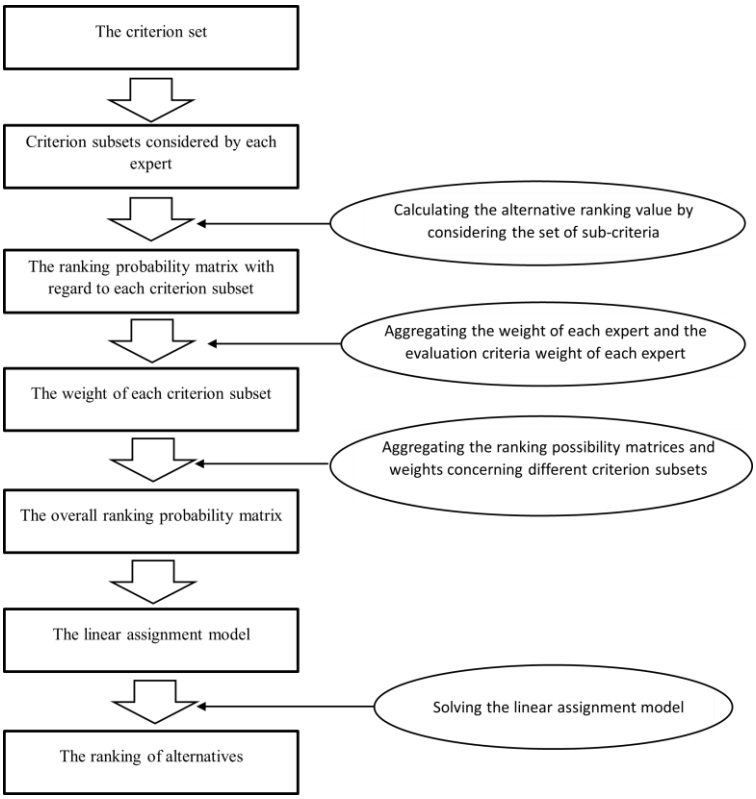


Figure 2 Research data processing steps (Source: (Fan et al. 2018))

Mathematical notation explanation

Some mathematical notations used in this research are described as follows.

1. A=$\{A_1, A_2, \ldots, A_m\}$: the set of m alternatives, where A_i denotes the ith alternative, $i = 1, 2, \cdots, m$.
2. E=$\{E_1, E_2, \ldots, E_q\}$: the set q experts, where E_k denotes kth expert, $k = 1, 2, \cdots, q$.
3. b=$\{b_1, b_2, \ldots, b_q\}$: the weight vector of experts, where b_k denotes weight or degree of importance of expert E_k, $k = 1, 2, \cdots, q$.
4. C=$\{C_1, C_2, \ldots, C_n\}$: the set of all criteria considered by the experts, where C_j denotes jth criterion, $j = 1, 2, \cdots, n$.
5. C^k: the set of criteria considered by the expert E_k, $k = 1, 2, \cdots, q$, $C^k \subset C$, $C^1 \cup C^2 \cup \ldots \cup C^q$=$C$. When $C^k = \varnothing$, it means that E_k does not pay attention to any criteria and E_k does not need to participate in the decision analysis as an expert. Thus, it is assumed that $C^k \neq \varnothing$ in this paper.
6. $w_k = (w_1^k, w_2^k, \cdots, w_n^k)$: the weight vector of the criteria provided by E_k, where w_j^k represents the weight or level of importance of the evaluation criteria C_j. If $C_j \notin C^k$, i.e. E_k does not consider criterion C_j, then $w_j^k = 0$; if $C_j \in C^k$, then $0 < w_j^k \leq 1$.
7. V=$[V_{ij}]_{m\times n}$: decision matrix, where V_{ij} represents the value of alternative A_i concerning criterion C_j, $i = 1, 2, \cdots, m$, $j = 1, 2, \cdots, n$.
8. $C(E`)$: the set of sub-criteria.

RESULTS AND DISCUSSION

This study discusses the selection of sago flour suppliers as raw materials for pearl sago produced by Tiga Hati Mutiara Company. Data collection was carried out in several ways, namely interviews, discussions, and filling out questionnaires.

Price as an important criterion in purchasing sago is in line with the research carried out by (Trisia et al. 2021). *Price* is also one of the criteria in the research conducted by (Rahmawati and Salimi 2022) regarding the supply chain of coffee in Indonesia; and in the research carried out by (Puška and Stojanović 2022, Puška et al. 2023) regarding the selection of environmentally friendly suppliers in the agribusiness sector. The selection of *quality* as one of the important criteria for selecting sago flour suppliers is in line with the findings of (Trisia et al. 2021) which stated that one of the main considerations for purchasing sago products is the quality of these products. In relation to the selection

of environmentally friendly suppliers, (Puška and Stojanović 2022) also found *quality* as one of the important criteria. (Tomasiello and Alijani 2021) stated that *price*, *quality*, and *level of service* are the most common criteria in selecting environmentally friendly suppliers. *Quality*, *price*, *delivery date* and, *payment terms* as supplier selection criteria in agricultural companies were proposed by (Nedeljković and Krstić 2018). (Ada 2022) includes *quality assurance*, *on-time delivery*, *distance*, *reactivity*, and *warranty* as some of the various sub-criteria in selecting environmentally friendly suppliers in the field of agri-food supply chain management. *Net price*, *responsiveness*, *delivery*, *flexibility*, *warranty and claim policy*, *customer service*, *geographic location*, *repair services*, *delivery speed*, and *delivery lead-time*, according to (Alshehri and Albukhari 2021) some of the criteria in selecting suppliers in the food and beverage industry in Saudi Arabia are: *Payment/payment can be made in installments* is the only criterion/sub-criterion that, to the best of the authors' knowledge, has not been found in previous research as a criterion/sub-criterion for supplier selection.

Table 1 provides the results of the assessment of alternative suppliers based on the selected sub-criteria.

The sub-criteria assessment is stated in a range of values 1-7 where 1 means the criteria are very inconsistent with expectations, 2 means the criteria are inconsistent with expectations, 3 means the criteria are less consistent with expectations, 4 means the criteria are neutral with expectations, 5 means the criteria are slightly consistent with expectations, 6 means the criteria are consistent with expectations, and 7 means the criteria are very consistent with expectations. Table 2 shows the weighting of the criteria from each expert. The weighting of the sub-criteria is determined such that the sum of the weights assigned by each expert equals 1. The weighting of each expert is based on the selected sub-criteria from each related expert.

The collected data were then processed using the method proposed by (Fan et al. 2018). These steps will be explained in detail in the following discussion.

First, E=$\{E_1, E_2, E_3\}$, so that a non-empty power set $P(E)$ is constructed, namely, $P(E)$ = $\{\{E_1\},\{E_2\},\{E_3\},\{E_1,E_2\},\{E_1,E_3\},\{E_2,E_3\},\{E_1,E_2,E_3\}\}$. The set of sub-criteria of $\{E_1\}$, $\{E_2\}$, $\{E_3\}$, $\{E_1,E_2\}$, $\{E_1,E_3\}$, $\{E_2,E_3\}$ and $\{E_1,E_2,E_3\}$ is $C(\{E_1\})$=$\{C_{11},C_{13},C_{14}\}$, $C(\{E_2\})$=$\{C_4\}$, $C(\{E_3\})$=$\{C_9,C_{10}\}$, $C(\{E_1,E_2\})$=$\{C_6,C_7\}$, $C(\{E_1,E_3\})$=$\{C_1,C_5,C_{15}\}$, $C(\{E_2,E_3\})$=$\{C_{12}\}$ and $C(\{E_1,E_2,E_3\})$=$\{C_2,C_3,C_8\}$, respectively.

Table 1 Assessment of supplier alternatives (Source: Research Data, 2022)

A_i	C_j														
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
A_1	7	6	7	6	7	6	7	7	6	7	6	7	7	7	7
A_2	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7
A_3	7	6	7	6	7	7	7	7	7	7	7	7	7	7	7
A_4	5	6	6	5	7	6	6	5	7	7	6	6	7	7	7
A_5	3	3	3	3	5	5	4	4	5	6	5	4	5	3	4
A_6	3	3	4	3	6	4	4	4	6	6	4	4	5	6	6
MAX	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
MIN	3	3	3	3	5	4	4	4	5	6	4	4	5	3	4

Table 2 Sub-criteria weighting of each expert (Source: Research Data, 2022)

E_k	C_j														
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
E_1	0.08	0.10	0.10	0	0.08	0.08	0.08	0.10	0	0	0.08	0	0.10	0.10	0.10
E_2	0	0.14	0.14	0.14	0	0.14	0.16	0.14	0	0	0	0.14	0	0	0
E_3	0.12	0.12	0.10	0	0.10	0	0	0.12	0.12	0.12	0	0.12	0	0	0.10
E_1,E_2	0.08	0.24	0.24	0.14	0.08	0.22	0.25	0.24	0	0	0.08	0.14	0.10	0.10	0.10
E_1,E_3	0.20	0.21	0.20	0	0.18	0.08	0.08	0.21	0.12	0.12	0.08	0.12	0.10	0.10	0.20
E_2,E_3	0.12	0.26	0.24	0.14	0.10	0.14	0.16	0.26	0.12	0.12	0	0.26	0	0	0.10
E_1, E_2,E_3	0.20	0.35	0.34	0.14	0.18	0.22	0.25	0.35	0.12	0.12	0.08	0.26	0.10	0.10	0.20

Table 3 Indicator matrix $\boldsymbol{T} = [t_{kj}]_{3\times15}$

E_k	C_j														
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
E_1	1	1	1	0	1	1	1	1	0	0	1	0	1	1	1
E_2	0	1	1	1	0	1	1	1	0	0	0	1	0	0	0
E_3	1	1	1	0	1	0	0	1	1	1	0	1	0	0	1

Table 4 Normalization of the objective matrix

A_i	C_j														
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
A_1	0	0.75	1	0.75	1	0.67	1	1	0.5	1	0.67	1	1	1	0
A_2	0.25	1	1	1	1	1	1	1	1	1	1	1	1	1	0
A_3	0	0.75	1	0.75	1	1	1	1	1	1	1	1	1	1	0
A_4	0.5	0.75	0.75	0.5	1	0.67	0.67	0.33	1	1	0.67	0.67	1	1	0
A_5	1	0	0	0	0	0.33	0	0	0	0	0.33	0	0	0	1
A_6	1	0	0.25	0	0.5	0	0	0	0.5	0	0	0	0	0.75	0.33

Table 5 The ranking value of each alternative with respect to criterion subset C($\{E1\}$)

A_i	w_{11}^k	w_{13}^k	w_{14}^k	$w_j^k\overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0.056	0.097	0.097	0.250	0.083	3
A_2	0.083	0.097	0.097	0.278	0.093	1
A_3	0.083	0.097	0.097	0.278	0.093	2
A_4	0.056	0.097	0.097	0.250	0.083	4
A_5	0.028	0	0	0.028	0.009	6
A_6	0	0	0.073	0.073	0.024	5

Indicator matrix $T=\left[t_{kj}\right]_{q\times n}$ is constructed, t_{kj} = 0 or 1, where t_{kj} = 1 if criterion C_j is in accordance to expert E_k (for example, $C_j \in C^k$); otherwise, t_{kj} = 0, $k = 1, 2, \cdots, q, j = 1, 2, \cdots, n$.

In the MCGDM problem in this study, three experts were involved in the research, namely (E_1, E_2, E_3). The three experts considered fifteen sub-criteria in selecting suppliers, namely $C = \{C_1, C_2, \ldots, C_{15}\}$. The sub-criterion referred to by each of experts E_1, E_2 and E_3 is $C^1 = \{C_1, C_2, C_3, C_5, C_6, C_7, C_8, C_{11}, C_{13}, C_{14}, C_{15}\}$, $C^2 = \{C_2, C_3, C_4, C_6, C_7, C_8, C_{12}\}$, and $C^3 = \{C_1, C_2, C_3, C_5, C_8, C_9, C_{10}, C_{12}, C_{15}\}$. Table 3 provides the indicator matrix $T=\left[t_{kj}\right]_{3\times15}$.

Based on the indicator matrix $T=\left[t_{kj}\right]_{q\times n}$, indicator vector $t_j = \left[t_{1j}, t_{2j}, \ldots, t_{qj}\right]^T$ on criterion C_j, j = 1, 2, · · ·, n can be constructed. Thus, $T=\left[t_{kj}\right]_{q\times n}$ can be represented by $T=\left[t_{kj}\right]_{q\times n} = [t_1, t_2, \ldots, t_n]$, where vector t_j is an indicator vector on criterion C_j, $j = 1, 2, \cdots, n$.

Next, the objective matrix was normalized, and the results obtained are presented in Table 4.

The value of the objective matrix is calculated based on data on the value of alternative criteria. For criteria with the benefit category, it is calculated by subtracting the criteria value from the minimum criteria value, divided by the difference between the minimum and maximum values. For criteria with the cost category, it is calculated by subtracting the maximum criteria value from the criteria value, divided by the difference between the minimum and maximum values.

The next step is to determine the ranking value of each alternative with respect to criterion subset according to the experts $\{E_1\}, \{E_2\}, \{E_3\}, \{E_1, E_2\}, \{E_1, E_3\}, \{E_2, E_3\}$, and $\{E_1, E_2, E_3\}$. The ranking value of each alternative with respect to cthe criterion subset according to expert open brace cap E sub 1 , close brace is presented in Table 5, which shows that the ranks of the alternatives are $A_2 \succ A_3 \succ A_1 \succ A_4 \succ A_6 \succ A_5$.

The ranking value is based on the VE` (A_i) value of each alternative, with the highest value occupying the earliest rank, and each alternative

only occupies one ranking position. In the case that the VE` (A_i) values are the same, the ranking value is sorted according to the order of the alternatives.

In the same way, alternative ranking values are generated with respect to a criterion subset according to the experts ($\{E_2\}$) (Table 6), ($\{E_3\}$) (Table 7), ($\{E_1, E_2\}$) (Table 8), ($\{E_1, E_3\}$) (Table 9), ($\{E_2, E_3\}$) (Table 10), and ($\{E_1, E_2, E_3\}$) (Table 11).

The next step is to find the weight of the criterion subset. The weight is obtained by multiplying the weight of the criterion subset according to the expert by the weight of the expert. It is obtained that the weights of criterion subsets $C(\{E_1\})$, $C(\{E_2\})$, $C(\{E_3\})$, $C(\{E_1, E_2\})$, $C(\{E_1, E_3\})$, $C(\{E_2, E_3\})$ and $C(\{E_1, E_2, E_3\})$, i.e., $w_{\{E_1\}}$, $w_{\{E_1\}}$, $w_{\{E_2\}}$, $w_{\{E_3\}}$, $w_{\{E_1,\ E_2,\}}$, $w_{\{E_1,\ E_3\}}$, $w_{\{E_2,\ E_3\}}$, $w_{\{E_1,\ E_2,\ E_3\}}$, are 0.093, 0.047, 0.078, 0.156, 0.194, 0.085, 0.348, respectively.

Table 6 The ranking value of each alternative with respect to criterion subset C($\{E_2\}$)

A_i	w_4^k	$w_j^k \overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0.105	0.105	0.035	2
A_2	0.140	0.140	0.047	1
A_3	0.105	0.105	0.035	3
A_4	0.070	0.070	0.023	4
A_5	0	0	0	5
A_6	0	0	0	6

Table 7 The ranking value of each alternative with respect to criterion subset C($\{E_3\}$)

A_i	w_9^k	w_{10}^k	$w_j^k \overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0.058	0.117	0.175	0.058	4
A_2	0.117	0.117	0.233	0.078	1
A_3	0.117	0.117	0.233	0.078	2
A_4	0.117	0.117	0.233	0.078	3
A_5	0	0	0	0	6
A_6	0.058	0	0.058	0.019	5

Table 8 The ranking value of each alternative with respect to criterion subset C($\{E_1, E_2\}$)

A_i	w_6^k	w_7^k	$w_j^k \overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0.149	0.246	0.395	0.132	3
A_2	0.223	0.246	0.469	0.156	1
A_3	0.223	0.246	0.469	0.156	2
A_4	0.149	0.164	0.313	0.104	4
A_5	0.074	0	0.074	0.025	5
A_6	0	0	0	0	6

Table 9 The ranking value of each alternative with respect to criterion subset C($\{E_1, E_3\}$)

A_i	w_1^k	w_5^k	w_{15}^k	$w_j^k \overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0	0.183	0	0.183	0.061	5
A_2	0.050	0.183	0	0.233	0.078	4
A_3	0	0.183	0	0.183	0.061	6
A_4	0.100	0.183	0	0.283	0.094	3
A_5	0.200	0	0.197	0.397	0.132	1
A_6	0.200	0.092	0.066	0.357	0.119	2

Table 10 The ranking value of each alternative with respect to criterion subset C($\{E_2, E_3\}$)

A_i	w_{12}^k	$w_j^k\overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0.256	0.256	0.085	1
A_2	0.256	0.256	0.085	2
A_3	0.256	0.256	0.085	3
A_4	0.171	0.171	0.057	4
A_5	0	0	0	5
A_6	0	0	0	6

Table 11 The ranking value of each alternative with respect to criterion subset C($\{E_1, E_2, E_3\}$)

A_i	w_2^k	w_3^k	w_8^k	$w_j^k\overline{v}_{ij}$	VE` (A_i)	Rank
A_1	0.265	0.337	0.353	0.955	0.318	2
A_2	0.353	0.337	0.353	1.044	0.348	1
A_3	0.265	0.337	0.353	0.955	0.318	3
A_4	0.265	0.253	0.118	0.635	0.212	4
A_5	0	0	0	0	0	6
A_6	0	0.084	0	0.084	0.028	5

An overall ranking probability matrix, P, is constructed from the weighted results of the criterion subset that has been obtained.

$$P = \begin{bmatrix} 0.085 & 0.394 & 0.249 & 0.078 & 0.194 & 0 \\ 0.721 & 0.085 & 0 & 0.194 & 0 & 0 \\ 0 & 0.327 & 0.480 & 0 & 0 & 0.194 \\ 0 & 0 & 0.271 & 0.729 & 0 & 0 \\ 0.194 & 0 & 0 & 0 & 0.288 & 0.518 \\ 0 & 0.192 & 0 & 0 & 0.518 & 0.288 \end{bmatrix}$$

Based on the matrix P, it is necessary to carry out a linear model solution to find the final ranking results for alternative suppliers. The solution to the linear model can be seen in the following X matrix.

$$X=[X_{is}]_{6\times6}= \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

From the X matrix, it is clear that the final rank of the suppliers is $A_2 \succ A_1 \succ A_3 \succ A_4 \succ A_6 \succ A_5$. Thus, the selected alternative suppliers based on the Multi-Criteria Group Decision Making approach method, from highest to lowest order, are A_2 or Terong Mas, A_1 or SPM, A_3 or Agro Mas, A_4 or Pringsewu, A_6 or Gunungkidul, and A_5 or Wonogiri. Terong Mas, SPM, Agro Mas, and Pringsewu are suppliers positioned in Lampung, whereas Gunungkidul and Wonogiri are suppliers located in Java Island. The selection of Terong Mas, SPM, Agro Mas, and Pringsewu as the four best suppliers is in line with the practice that Tiga Hati Mutiara has been doing, namely choosing sago flour suppliers from the Lampung area.

Based on data processing, it was found that in the first ranking, A_2 is preferred over A_1, indicated by the weight value of $A_2 = 0.721$ and $A_1 = 0.085$. This shows that Tiga Hati Mutiara's preference for Terong Mas is far above the same company's preference for SPM. Meanwhile, A_1 is more preferred than A_3 as indicated by the weight values $A_1 = 0.394$ and $A_3 = 0.327$. In this case, the company's preferences for SPM and Agro Mas are actually not that different. The weight values of $A_3 = 0.480$ and of $A_4 = 0.271$ indicate that Agro Mas is preferred over Pringsewu. In fourth place, Pringsewu is absolutely preferred over Gunungkidul, as indicated by the weight values of $A_4 = 0.729$ and of $A_6 = 0$. In the fifth rank, Gunungkidul is more preferred than Wonogiri, as indicated by the weight values of $A_6 = 0.518$ and of $A_5 = 0.288$. In sixth place is Wonogiri with a weighted value of 0.518. By looking at these figures, it can be said that the company's preference for Terong Mas is very high, and in general, it can be concluded that wheat flour suppliers located in the Lampung region are absolutely preferred over wheat flour suppliers located in Java Island. Given these preferences, choosing suppliers from the

Lampung region over suppliers from other regions appears to be the most realistic option for Tiga Hati Mutiara in the near future.

CONCLUSION

Based on the research conducted in Tiga Hati Mutiara, the following conclusions can be drawn. First, the criteria for sago flour suppliers selected for use in supplier selection are the criteria of price, quality, location, flexibility, delivery, response, warranty or service, and payment. Second, the selected criteria are further detailed into fifteen sub-criteria, namely price suitability, white flour quality, dry flour quality, easy to process flour, easy to reach suppliers, able to respond to changes in demand, punctuality of delivery, accuracy of delivery quantity, security during delivery, neatness of packaging, responsiveness when responding to problems, responsiveness when there are sudden requests, provision of warranty, good communication, and payment can be made in installments. Third, of the six alternatives included in this research, the best supplier of sago flour for Tiga Hati Mutiara is Terong Mas. Fourth, as a whole, wheat flour suppliers located in the Lampung region are regarded as markedly more preferable than their counterparts in other regions. Strengthening the relationship and establishing a long-term contract with the suppliers from Lampung could serve as effective follow-up measures.

This research is not yet completely perfect due to time constraints and the information obtained, so the researcher suggests that further research can be improved by exploring deeper information, especially information regarding alternative suppliers from other regions in Indonesia.

ACKNOWLEDGMENT

We would like to thank the Tiga Hati Mutiara company for providing researchers with the opportunity to conduct research.

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