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

# Supplier selection for improving supply chain performance

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Article history
*Received:*
10 August 2021
*Revised:*
9 September 2021
*Accepted*:
10 September 2021

Keyword
*ANP;*
*Decision-making,*
*Fuzzy TOPSIS;*
*Supplier selection;*
*Supply Chain Management*

## ABSTRACT

*Supplier selection played a role in developing industry performance. It was one of the critical issues in supply chain management. KUD Dau Batu was one industry that needed managing operations and raw material purchase. The raw material needed, fresh milk, was a perishable product with a short lifetime. This study illustrated applying a decision-making procedure for supplier selection on KUD Dau Batu by ANP and fuzzy TOPSIS. Four suppliers (Princi, Gading Kulon, Petung Sewu, and Kucur) thought qualified for procuring milk. The first step determined the weight of criteria and sub-criteria that impacted strategic supplier selection by ANP. The result showed that supplier selection is influenced by several factors: raw material cost, shipping cost, guarantee, responsiveness, lead time, delivery time, financial health, and ability to identify needs. This approach in a KUD Dau Batu showed that cost was the top priority. The next step was to defuzzification of criteria and rank the four suppliers by fuzzy TOPSIS. The supplier from Kucur was the best milk supplier compared to another supplier. The proper supplier selection could contribute to decreasing cost production and improving industrial performance.*



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DOI 10.21107/agrointek.v16i1.11442

## INTRODUCTION

The supply chain plays a role in increasing productivity, one of which is selecting raw materials with low costs and good quality. Product flow is one of the supply chain systems (Emhar et al., 2014). This principle transports products from suppliers to customers and requires a good network of raw material providers to ensure product capacity coverage (Leng and Zailani 2012). Product flow estimates about 60% of logistics costs (Lofgren et al., 2015). Therefore, it should be considered carefully. Supplier selection is one of the factors to improve product flow performance.

Supplier selection is one of the primary keys to being competitive by managing operations and managing raw material purchases in the industry (Bai and Sarkis 2010) (Parthiban et al., 2013). Supplier selection is a way of getting the right supplier, raw material costs, delivery time, quantity, and quality (Mavi et al., 2016). Delivery time (Qian 2014), (Agarwal et al., 2007), minimum costs (Beikkhakhian et al., 2015), quality of raw materials (Amorim et al., 2015), responsive (Mwikali et al., 2012), shipping costs (Nair et al., 2015), and guarantees (Katsikeas et al., 2004) are criteria in supplier selection. It has a significant contribution to production costs. Currently, KUD Dau Batu has not established a strategic supplier for the procurement of fresh milk, occurring in a less effective procurement process. Therefore, selecting the right supplier is needed in the industry, mainly in small-scale industries. It can improve industrial performance (Xia and Wu 2007).

This study, ANP, and fuzzy TOPSIS aim to get the right supplier in KUD Dau Batu according to ranking the criteria and estimating uncertainty, ambiguity, inaccuracy, lack of information, and partial truth in a problem. The previous study has been adapted the ANP and fuzzy TOPSIS to supplier selection. Shemshadi et al. (2011) show that the supplier selection builds based on the uncertainty of internal, financial, technology, and shipment by ANP and fuzzy TOPSIS. Rezaei (2015) study shows that supplier selection uses fuzzy ANP and TOPSIS based on quality, organization, relationship, cycle time, and cost. This study uses criteria adapted to Ku et al. (2010) for supplier selection using ANP and fuzzy TOPSIS. These criteria are cost, accuracy, service, and relationship.

## METHODS

### Determining the weight of criteria using ANP

According to the interview expert, including the product, quality manager, and marketing manager, there were four qualified raw material suppliers in KUD Dau Batu. There was a breeder from Princi (A), Gading Kulon (B), Petung Sewu (C), and Kucur (D). The supplier selection used the eight sub-criteria. It was raw material cost, shipping costs, guarantee, responsiveness, lead time, delivery time, financial health, and ability to identify needs. According to Saaty methods (Chemweno et al., 2015), the five steps to measure the relative importance weight of sub-criteria were given as follows:

Step 1: The criteria were determined by literature review and data availability in KUD DAU Batu
Step 2: Model development and problem structuring was made
Step 3: Construction Pairwise comparison matrix and priority vector
Step 4: Supermatrix construction
Step 5: Limit supermatrix calculation

### Determining the fuzzy number and fuzzy TOPSIS

According to Santoso et al. (2019), suppliers evaluate and select the MCDM (Multi-Criteria Decision Making), such as TOPSIS and ANP. This method could be combined with fuzzy methods.

According to Beikkhakhian et al. (2015) and Lima et al. (2014), the main steps to calculate the weight of criteria were presented as follows:

Step 1: aggregate the weights of the criteria and ratings of alternatives.

$$\widetilde{\boldsymbol{w}_j} = \frac{1}{k}\left[\widetilde{w}_j{}^1 + \widetilde{w}_j{}^2 + \cdots + \widetilde{w}_j{}^k\right] \quad (1)$$

$$\widetilde{\boldsymbol{x}_{ij}} = \frac{1}{k}\left[\tilde{x}_{ij}{}^1 + \tilde{x}_{ij}{}^r + \cdots + \tilde{x}_j{}^k\right]$$

Step 2: construct the fuzzy decision matrix of the alternatives ($\widetilde{\boldsymbol{D}}$) and the criteria ($\widetilde{\boldsymbol{W}}$)

$$\widetilde{\boldsymbol{D}} = \begin{matrix} A_1 \\ A_i \\ A_n \end{matrix}\begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1m} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \cdots & \tilde{x}_{nm} \end{bmatrix} \quad (3)$$

$$\widetilde{W} = [\widetilde{w}_1 + \widetilde{w}_2 + \cdots + \widetilde{w}_m]$$

Step 3: normalize the fuzzy decision matrix of the alternatives using linear scale transformation.

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn} \quad (5)$$

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right) \quad \text{and}$$

$$u_j^+ = max_i u_{ij} \ (benefit\ criteria) \quad (6)$$

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right) \quad \text{and}$$

$$l_j^- = max_i l_{ij} \ (cost\ criteria)$$

Step 4: calculate the weighted normalized decision matrix multiplying the weights of the evaluation criteria

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \quad (8)$$

Where

$$\tilde{v}_{ij} = \tilde{x}_{ij}\ x\ \tilde{w}_j$$

Step 5: measurement of $A^+$ and $A^-$

$$A^+ = [\tilde{V}^+_1, \tilde{V}^+_j, \ldots, \tilde{V}^+_m]$$

$$A^- = [\tilde{V}^-_1, \tilde{V}^-_j, \ldots, \tilde{V}^-_m]$$

Where

$$\tilde{V}^+_j = (1,1,1)\ and\ \tilde{V}^-_j = (0,0,0)$$

Step 6: determine the positive and negative solutions.

$$d_i^+ = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^+)$$

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-)$$

Step 7: Determine the alternatives' rate according to the closeness coefficient (CCI). The best alternative is nearest to the FPIS and farthest to the FNIS.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}$$

## RESULT AND DISCUSSION

The selection supplier is suitable for KUD Dau Batu, East Java, producing fresh and pasteurized milk. Fresh milk is an essential ingredient needed in the production at KUD Dau Batu. Milk products in KUD Dau Batu are perishable products and have a short lifetime, mainly fresh milk. It was difficult to determine the production quantity, mainly in shortage and overstock conditions. Therefore, KUD Dau Batu used a make-to-stock production system. It required accurate production planning and the proper availability of raw materials. Currently, KUD Dau Batu has not established a strategic supplier for the procurement of fresh milk, occurring in a less effective procurement process. Therefore the company wants a procurement strategy by developing a partnership with suppliers in the long term. This strategy aims to improve the quality of raw materials and reduce costs to improve the company's profits.

Table 1 The Supplier Selection Criteria

| Criteria | Sub-Criteria | Ref. |
|---|---|---|
| **Cost** | Raw material | (Sura raksa and Shin 2019) |
| | Shipping cost | (Nair et al. 2015) |
| **Service** | Guarantee | (Katsikeas et al. 2004) |
| | Responsive | (Mwikali et al. 2012) |
| **Accuracy** | Lead time | (Agarwal et al. 2007) |
| | Delivery time (Speed) | (Qian 2014); (Dickson 1966) |
| **Relationship** | Financial health | (Park et al., 2011); (Ellram 1990) |
| | Ability to identify needs | (Govindaraju et al., 2015) |

Source: Adapted Ku et al., 2010

Table 2 Consistency Ratio Of Respondents

| Sub- Criteria | Consistency Ratio ($\leq 0,1$) |
|---|---|
| **Cost** | |
| Raw material cost | 0 |
| Shipping cost | 0 |
| **Service** | |
| Guarantee | 0 |
| Responsive | 0 |
| **Accuracy** | |
| Lead time | 0 |
| Delivery time | 0 |
| **Relationship** | |
| Financial health | 0 |
| Ability to identify needs | 0 |
| **Criteria** | |
| Cost | 0.05156 |
| Service | 0.04073 |
| Accuracy | 0.05156 |
| Relationship | 0.09724 |

Source: Primary Data Analysis, 2019

Table 3 Weighting Factor Of Sub-Criteria And Criteria

| Sub-Criteria | Priority Vector | Rank |
|---|---|---|
| Raw material cost | 0.45904 | 2 |
| Shipping cost | 0.54096 | 1 |
| Guarantee | 0.25697 | 2 |
| Responsive | 0.74303 | 1 |
| Lead time | 0.71430 | 1 |
| Delivery time | 0.28570 | 2 |
| Financial health | 0.84563 | 1 |
| Ability to identify needs | 0.15437 | 2 |
| **Criteria** | | |
| Cost | 0.382905 | 1 |
| Service | 0.186116 | 3 |
| Accuracy | 0.181662 | 4 |
| Relationship | 0.249356 | 2 |

Source: Primary Data Analysis, 2019

Currently, four suppliers were considered qualified for procuring milk and are still transactional. It is expected that relations within KUD Dau Batu and suppliers can reduce risk and maximize the total value of its purchases. This research had the aim to decide the best supplier based on criteria. Data of KUD was collected from study literature and interviewed the expert, including manager of product, quality manager, and marketing manager. The primary criteria were adapted from the study literature. The final criteria and sub-criteria (Table 1) were obtained from a brainstorming session with an expert by the questioner and study literature. This data was analyzed by the ANP method using a decision-support system.

Table 2 present the estimated CR of sub-criteria. CR (Consistency ratio) is used to determine the consistency level of criteria in ANP (Analytic Network Process) (Rolita et al., 2018). This study shows that the CR value ≤ of 0.1. This means, the criteria and sub-criteria used in this model are consistent and can be used for the next step. According to Lee (2014) and Rolita et al. (2018), the pair-wise comparison matrix is

consistent and can be used considering the CR value < 0.1.

Table 3 represents the priority weight of the criteria. The returns show that cost is a top priority in supplier selection compared to other criteria. According to Suraraksa & Shin (2019), cost is crucial in supplier selection. The right supplier can minimize costs and risks. In this criteria, purchasing raw materials and shipping costs is essential and spending about 70%. In this study, accuracy is the last priority. However, these criteria have a role in ensuring that suppliers achieve consumer orders (Agarwal et al. 2007).

Table 4 represents the priority weight of the sub-criteria. The results representation that financial health is the priority in supplier selection compared to other sub-criteria and was sub-criteria of the relationship. In this case, the relationship is the partnership between supplier and customer. According to Gosling et al. (2010), a good relationship can affect the strength of the business. In industry, suppliers are a crucial factor and play a role in providing raw materials. In supplier selection, financial health is one of the critical factors and can influence the sustainability of a business. Clients and suppliers will undoubtedly identify the financial condition before forming a partnership. According to Ellram (1990), suppliers with dire economic conditions will have a problem contributing to the partnership effort. Suppliers will prioritize the financial position of partners in decision-making to inquire about many benefits without consideration of partner achievement.

Table 6-8 representation the fuzzy Topsis process. In these steps, supplier selection is based on the rank of the weight of sub-criteria. The final weights from ANP are used for the defuzzification process. The study showed that a supplier from Kucur was selected as this alternative was considered the best way to maximize the expected benefits (Table 5).

The supplier selected based on an ideal solution was measured. Table 9 and Table 10 presented the distances of the category of each alternative from A+ and A-, respectively. A+ or the positive ideal solution meant the excellent alternative, while A- or the negative perfect solution meant the most insignificant preferable option. Then, the relative closeness (**Ci***) of each criterion was determined.

According to the estimation, alternative D has a CCi value 0.503 higher than alternatives A, B, C, 0.500, 0.498, 0.497, respectively. Therefore, supplier D is the best supplier based on raw material cost, shipping cost, guarantee, responsiveness, lead time, delivery time, financial health, and ability to identify needs.

Table 4 Priority Weight Of The Sub-Criteria

| Criteria | Sub-Criteria | Priority Vector | Rank |
|---|---|---|---|
| **Cost** | Raw material cost | 0.175768 | 2 |
| | Shipping cost | 0.138290 | 3 |
| **Service** | Guarantee | 0.047826 | 6 |
| | Responsive | 0.138290 | 3 |
| **Accuracy** | Lead time | 0.129732 | 4 |
| | Delivery time | 0.051890 | 5 |
| **Relationship** | Financial health | 0.210863 | 1 |
| | Ability to identify needs | 0.038493 | 7 |

Source: Primary data analysis, 2019

Table 5 The Distance Of The Ratings Of Each Alternative From $A^-$ To Each Criterion

| Alternative | $S^*$ | $S^-$ | CCI | Priority |
|---|---|---|---|---|
| A | 7.826 | 7.823 | 0.500 | 2 |
| B | 7.843 | 7.793 | 0.498 | 3 |
| C | 7.872 | 7.769 | 0.497 | 4 |
| D | 7.780 | 7.869 | 0.503 | 1 |

source: Primary Data Analysis, 2019

Table 6 Fuzzy Number Of The Aggregated Ratings Of The Alternatives Suppliers

| Alternative | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A | (3.979, 6.082, 7.612) | (3.557, 5.593, 7.612) | (0.000, 2.759, 5.130) | (4.718, 6.804, 8.277) | (2.924, 5.278, 7.399) | (4.718, 6.804, 8.277) | (3.000, 5.000, 7.000) | (4.217, 6.257, 8.277 |
| B | (5.000, 7.000, 9.000) | (4.217, 6.257, 8.277) | (1.442, 3.557, 5.593) | (3.557, 5.593, 7.612) | (3.557, 5.593, 7.612) | (4.217, 6.257, 8.277) | (3.557, 5.593, 7.612) | (3.557, 5.593, 7.612 |
| C | (3.979, 6.082, 7.612) | (3.557, 5.593, 7.612) | (1.442, 3.557, 5.593) | (3.557, 5.593, 7.612) | (4.718, 6.804, 8.277) | (3.557, 5.593, 7.612) | (3.557, 5.593, 7.612) | (4.217, 6.257, 8.277 |
| D | (3.557, 5.593, 7.612) | (4.217, 6.257, 8.277) | (2.466, 4.718, 6.804) | (3.557, 5.593, 7.612) | (3.557, 5.593, 7.612) | (3.000, 5.000, 7.000) | (1.442, 3.557, 5.593) | (3.000, 5.000, 7.000 |
| Weight | (0.200, 0.167, 0.143) | (0.250, 0.200, 0.167) | (1.000, 0.500, 0.333) | (0.250, 0.200, 0.167) | (0.333, 0.250,0.200) | (0.500, 0.333, 0.250) | (0.167, 0.143, 0.143) | (1.000, 1.000, 1.000 |

Source: Primary Data Analysis, 2019

Table 7 Normalized Fuzzy Decision Matrix

| Alternative | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A | (0.442, 0.676, 0.848) | (0.395, 0.621, 0.846) | (0.000, 0.307, 0.570) | (0.524, 0.756, 0.920) | (0.325, 0.586, 0.822) | (0.524, 0.756, 0.920) | (0.333, 0.556, 0.778) | (0.469, 0.695, 0.920 |
| B | (0.556, 0.778, 1.000) | (0.469, 0.695, 0.920) | (0.160, 0.395, 0.621) | (0.395, 0.621, 0.846) | (0.395, 0.621, 0.846) | (0.469, 0.695, 0.920) | (0.395, 0.621, 0.846) | (0.395, 0.621, 0.846 |
| C | (0.442, 0.676, 0.846) | (0.395, 0.621, 0.846) | (0.160, 0.395, 0.621) | (0.395, 0.621, 0.846) | (0.524, 0.756, 0.920) | (0.395, 0.621, 0.846) | (0.395, 0.621, 0.846) | (0.469, 0.695, 0.920 |
| D | (0.395, 0.621, 0.846) | (0.469, 0.695, 0.920) | (0.274, 0.524, 0.756) | (0.395, 0.621, 0.846) | (0.395, 0.621, 0.846) | (0.333, 0.556, 0.778) | (0.160, 0.395, 0.621) | (0.333, 0.556, 0.778 |

Source: Primary Data Analysis, 2019

Table 8 Weighted Normalized Fuzzy Decision Matrix

| Alternative | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A | (0.088, 0.113, 0.121) | (0.099, 0.124, 0.141) | (0.000, 0.153, 0.190) | (0.131, 0.151, 0.153) | (0.108, 0.147, 0.164) | ().262, 0.252, 0.230) | (0.056, 0.079, 0.111) | (0.469, 0.695, 0.920) |
| B | (0.111, 0.130, 0.143) | (0.117, 0.139, 0.153) | (0.160, 0.198, 0.207) | (0.009, 0.124, 0.141) | (0.132, 0.155, 0.169) | (0.234, 0.232, 0.230) | (0.066, 0.089, 0.121) | (0.395, 0.621, 0.846) |
| C | (0.008, 0.113, 0.121) | (0.099, 0.124, 0.141) | (0.160, 0.198, 0.207) | (0.009, 0.124, 0.141) | (0.175, 0.189, 0.184) | (0.198, 0.207, 0.211) | (0.066, 0.089, 0.121) | (0.469, 0.695, 0.920) |
| D | (0.079, 0.104, 0.121) | (0.117, 0.139, 0.153) | (0.274, 0.262, 0.252) | (0.009, 0.124, 0.141) | (0.132, 0.155, 0.169) | (0.167, 0.185, 0.194) | (0.027, 0.056, 0.089) | (0.333, 0.556, 0.778) |

Source: Primary Data Analysis, 201

Table 9 Distances Of The Ratings Of Each Alternative From $A^+$ To Each Criterion

| Alternative | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A | 0.986 | 0.989 | 0.890 | 1.000 | 0.968 | 1.000 | 0.993 | 1.000 |
| B | 1.000 | 1.000 | 0.947 | 0.982 | 0.977 | 0.986 | 1.000 | 0.950 |
| C | 0.986 | 0.989 | 0.947 | 0.982 | 1.000 | 0.968 | 1.000 | 1.000 |
| D | 0.981 | 1.000 | 1.000 | 0.982 | 0.977 | 0.953 | 0.976 | 0.911 |

Source: Primary Data Analysis, 2018

Table 10 The Distance Of The Ratings Of Each Alternative From $A^-$ To Each Criterion

| Alternative | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A | 0.955 | 1.000 | 1.000 | 0.982 | 1.000 | 0.953 | 0.983 | 0.911 |
| B | 0.981 | 0.989 | 0.936 | 1.000 | 0.990 | 0.965 | 0.976 | 0.956 |
| C | 0.995 | 1.000 | 0.936 | 1.000 | 0.968 | 0.983 | 0.976 | 0.911 |
| D | 1.000 | 0.989 | 0.980 | 1.000 | 0.990 | 1.000 | 1.000 | 1.000 |

Source: Primary Data Analysis, 2018

## CONCLUSIONS

This study was performed in the decision-making model using ANP and fuzzy TOPSIS. The research was conducted with a literature study and brainstorming session with experts and business people. The results showed that supplier D (Kucur) was the best supplier based on raw material cost, shipping cost, guarantee, responsiveness, lead time, delivery time, financial health, and ability to identify needs. Therefore, t**his supplier was recommended**. Combining qualitative and quantitative criteria, the future study could have been applied for developing supplier selection.

## ACKNOWLEDGMENT

The authors gratefully acknowledge KUD Dau Batu, East Java, Indonesia, for supporting facilities to carry out this research.

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