Jurnal Teknik Industri
Vol. 20, No. 1, February 2019, pp. 12-21

Selection of Furniture Raw Material Suppliers using Fuzzy Analytical Hierarchy Process

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ARTICLE INFO

Article history
Received October 18, 2018
Revised November 10, 2018
Accepted November 28, 2018
Available Online February 14, 2019

Keywords
MCDM
furniture
fuzzy AHP
multi-criteria decision making
supplier

ABSTRACT

The raw material is an essential aspect of ensuring smooth production. The selection of raw material suppliers needs to be done to sustain the company's production and development. Wisarka company is an export-oriented furniture company. It uses water hyacinth (Eichhornia crassipes) as the primary raw material. The company is required to maintain and improve performance. The company needs to select the right supplier. This study uses the Multi-Criteria Decision Making (MCDM) the Fuzzy Analytical Hierarchy Process (FAHP) method. It was used for selecting suppliers with criteria like price, quality, flexibility, delivery, warranty, and service. The result of the study show FAHP effective in selecting suppliers.

1. Introduction

A good company can be measured through customer loyalty. Consumers are satisfied if the order is fulfilled by the company [1]. Fulfillment of the product is an essential problem for the company. Companies need to effort in the production process to continue. One factor is to maintain the availability of raw materials. The company must have a supply chain to guarantee the supply of raw materials for production. The company must have a supply chain to guarantee the supply of raw materials. It affects the level of productivity of the company [2]. A good supply chain does not mean a high amount of raw material inventory. Excessive inventory reduces company profits. A lower inventory ratio results in a higher profit margin. Small companies receive more significant benefits from inventory efficiency [3]. Therefore, companies required an optimal inventory level. It also needs attention to the level of raw material requirements for the production process. One effort is to supplier's selection of raw materials. Companies required a strategic supplier partnership with one supplier[4].

The selection of raw material suppliers requires various criteria. The proper criteria encourage companies to select suppliers. The decision suppliers selection saw as a Multi-Criteria Decision Making (MCDM) problem. One method commonly used to solve MCDM problems is the analytical hierarchy process (AHP) [5]. The Suppliers selecting

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with AHP has been carried out by several researchers [6-8]. It is used to select sustainable supply chains in the furniture industry [9]. It also was used for another strategic decision making [10]. Although many debates in initial the AHP application concept, researchers still use AHP to studies. It has been positioned as part of complex operation research methods [11]. The AHP method has many developments from the initial concept. One of its developments is the assessment of pairwise comparisons. The assessment is considered not too precise because it uses absolute values (crisp). The same statement can have different values and have a specific range of judgments. This assessment was expressed in the fuzzy theory developed by Zadeh [12]. AHP is one of the most commonly used techniques when decision problems contain multi-criteria. Multi-criteria decision-making techniques help in making the best decisions. The decision-making uses a weighting process through pairwise comparisons. However, for uncertain, fuzzy numbers must be used to evaluate decision-making.

The fuzzy AHP (FAHP) approach is a secure method of dealing with multi-criteria decision-making problems. It is used to synthesize the opinions of decision-makers. It captures obscurity in solving research problems with a structured and straightforward process [13]. The FAHP method was used in product design selection [14]. The selected product design is based on originality, appeals, and effectiveness. In this study, FAHP show more explicit priority order differences than AHP. The FAHP model reduces the inconsistency of judgment from experts [15]. Other researchers have used the FAHP method for selecting car types in car rental companies. Tang and Beynon [16] considered five criteria: car features, driving comfort, safety, imaging, and car cost.

Supplier selection problems also occur in companies in the field of furniture. The main components of raw materials for making furniture in Indonesia are rattan, wooden, and woven material. One of the weaving materials is water hyacinth. It is a floating aquatic plant and is classified as a weed. Water hyacinth has a high growth rate. Therefore, it damages the ecology of the environment. Water hyacinth was first discovered by a scientist named Carl Friedrich Philipp von Martius. He is a German botanist. He discovered in 1824 while on an expedition on the Brazilian Amazon River [17]. Although included as a weed, it was used by humans to be used as handicrafts. It was used as a raw material for handicraft products in Central Java [18]. It was used as a raw material for various types of furniture [19]. Through specific processing processes, water hyacinth is used to make bio-degradable boards. The power level of water hyacinth is equivalent to a high-density board. It complies with American National Standard regulations for particleboards [20].

Several FAHP studies have been carried out. However, FAHP is not used to extract raw materials from furniture companies. The selected raw material for furniture is water hyacinth. The research aims to the selected suppliers of water hyacinth raw materials. The selection of suppliers is intended to procure raw water hyacinth raw materials to guarantee delivery accuracy and guarantee the quality of raw materials. The selection of suppliers is made using the multi-criteria decision-making (MCDM) approach. The proposed method is FAHP.

2. Methods

The supplier's selection of water hyacinth raw material involved experts in the supply chain and production in the company. The study involved five respondents: the production department, internal order quality assurance division, woven material quality assurance division, production administrator, and warehouse administrator. The respondents were capable of assessments and decisions related to supplier selection. Focus

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group discussions (FGD) involved expert respondents in identifying factors that influence supplier selection. The questionnaires in the form of numerical values were converted into triangular fuzzy number (TFN) values. The TFN value consists of three components of value (l, m, u) using a particular membership function approach [21, 22]. The TFN value used in the calculation is shown in Table 1. Some notation was used as follows:

M	:	triangular fuzzy number
V	:	vector value
l	:	lower parameter
m	:	medium parameter
u	:	upper parameter
W	:	weight values (nonfuzzy numbers)
d	:	defuzzification ordinate value
A	:	permanent candidate
i	:	row
j	:	column
k	:	element
g	:	parameter (l, m, u)
M_{gi}^{j}	:	add up the cell values in the column starting from column 1 in each row of the matrix
$\sum_{j=1}^{m} l_j$	:	number of cells in the first column of the matrix (lower value)
$\sum_{j=1}^{m} m_j$	:	number of cells in the second column of the matrix (median value)
$\sum_{j=1}^{m} u_j$	:	number of cells in the third column of the matrix (upper value)
l_{ij}	:	a lower parameter in line i and column j
m_{ij}	:	a medium parameter in line i and column j
u_{ij}	:	an upper parameter in line i and column j
l_{ijk}	:	a lower parameter in line i, column j, and element k
m_{ijk}	:	a medium parameter in line i, column j, and element k
u_{ijk}	:	an upper parameter in line i, column j, and element k

Table 1. Triangular Fuzzy Number [21, 22]

Definition	Likert Scale	TFN	Likert Scale	TFN
Equally Important	1	(1, 1, 1) if diagonal (1, 1, 3) the other than	1/1	(1/1, 1/1,1/1) if diagonal (1/1, 1/1, 1/3) the other than
	2	(1, 2, 4)	1/2	(1/4, 1/2, 1/1)
A little more important	3	(1, 3, 5)	1/3	(1/5, 1/3, 1/1)
	4	(2, 4, 6)	1/4	(1/6, 1/4, 1/2)
More important	5	(3, 5, 7)	1/5	(1/7, 1/5, 1/3)
	6	(4, 6, 8)	1/6	(1/8, 1/6, 1/4)
The Most important	7	(5, 7, 9)	1/7	(1/9, 1/7, 1/5)
	8	(6, 8, 10)	1/8	(1/10, 1/8, 1/6)
Absolute very important	9	(7, 9, 11)	1/9	(1/11, 1/9, 1/7)

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ISSN : 1978-1431 print | 2527-4112 online

Some of the equation was used in FAHP as follows:

$$l_{ij} = \left(\prod_{k=1}^{k} l_{ijk}\right)^{1/k}, m_{ij} = \left(\prod_{k=1}^{k} m_{ijk}\right)^{1/k}, u_{ij} = \left(\prod_{k=1}^{k} u_{ijk}\right)^{1/k} \quad (1)$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad i = 1, 2, \ldots, n \quad (2)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i-1}^{n} u_i}, \frac{1}{\sum_{i-1}^{n} m_i}, \frac{1}{\sum_{i-1}^{n} l_i}\right) \quad (3)$$

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (4)$$

$$\mathrm{V}(M2 > M1) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_2)} & for\ the\ other\ condition \end{cases} \quad (5)$$

$$W^1 = (\mathrm{d}(A_1), \mathrm{d}(A_2), \ldots, \mathrm{d}(A_n))^T \quad (6)$$

Equation (1) describes the aggregation of respondents' ratings [23]; Equation (2) shows the triangular fuzzy number value to each of the criteria matrices [24]; Equation (3) shows Calculates the inverse of the sum of the triangular fuzzy number in each matrix; Equation (4) shows calculate the value of fuzzy synthetic extents (S_i) for each criterion; Equation (5) shows Calculating the degree of possibility; Equation (6) shows Calculate the weight vector and normalize the weight vector to determine the weight of the criteria.

The calculation stage ware carried out at each level appropriate to the hierarchy structure of the problem. It was also carried out for sub-factor weights calculation. In the final stages, it was calculated using the weight of suppliers based on each subfactor. Through it, the result of supplier weights was calculated for all subfactors.

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3. Result and Discussions

Based on the literature review, many criteria were used for supplier selection. Table 2 shows a summary of the results of the literature review of the supplier selection criteria.

Table 2. Literature review related to supplier selection criteria

	Warranty	Order Fulfillment	Quality	Delivery	Flexibility	Price	Service	Location
Darmawan, et al. [25]	✓	✓	✓	✓				
Limansantoso [26]			✓	✓	✓	✓		
Wardah [27]			✓	✓	✓	✓	✓	✓
Iriani and Herawan [28]		✓	✓	✓		✓		✓
Putri [7]		✓	✓	✓		✓		
Andalia and Pratiwi [29]		✓	✓	✓		✓		
Astuti [30]	✓	✓	✓	✓		✓	✓	

The criteria for selecting water hyacinth raw material suppliers were conducted through focus group discussion (FGD) and literature review. It involved five expert respondents from companies. Based on it, this research produced six criteria for selecting suppliers as (1) price, (2) quality, (3) flexibility, (4) delivery, (5) warranty, and (6) service. The price criteria are based on the low price of water hyacinth from suppliers. Companies choose suppliers that offer lower prices. Criteria for the quality are based on four sub-criteria, including dryness, color, neatness, and hardness of the webbing. Flexibility criteria are based on the ease of suppliers toward changes orders. There are two sub-criteria as the ease of changing the orders and the delivery schedule.

Shipping criteria are based on the ability of suppliers to fulfill company orders. There are three sub-criteria: the timeliness of delivery, the suitability of the number of shipments, and the capacity supplier. The warranty criteria are based on the level of guarantee of the supplier. There is three sub-criteria included ease of contact, speed of replacement, and ease of replacement. Service criteria are based on the level of company satisfaction toward suppliers. Through the criteria and sub-criteria above, the supplier selection hierarchy is shown in Fig. 1. Fig. 1 shows four potential suppliers of water hyacinth raw material. The four potential suppliers are supplier 1, supplier 2, supplier 3, and supplier 4.

Through Fig. 1, we create a paired comparison questionnaire between criteria and between sub-criteria. Pairwise comparison questionnaires are arranged based on the hierarchical structure shown in Fig. 1. Paired comparison questionnaires use linguistic variables. It is based on verbal statements used by Saaty [5]. Five respondents filled out the questionnaire. The selection of respondents was based on the involvement involved in the purchasing cycle. It starts from the purchasing order to the guarantee of the quality of the raw materials.

The TFN converts verbal statements of the respondent. The TFN value is used as shown in Table 1. The results of the pairwise comparison of each criterion can be seen in Table 3.

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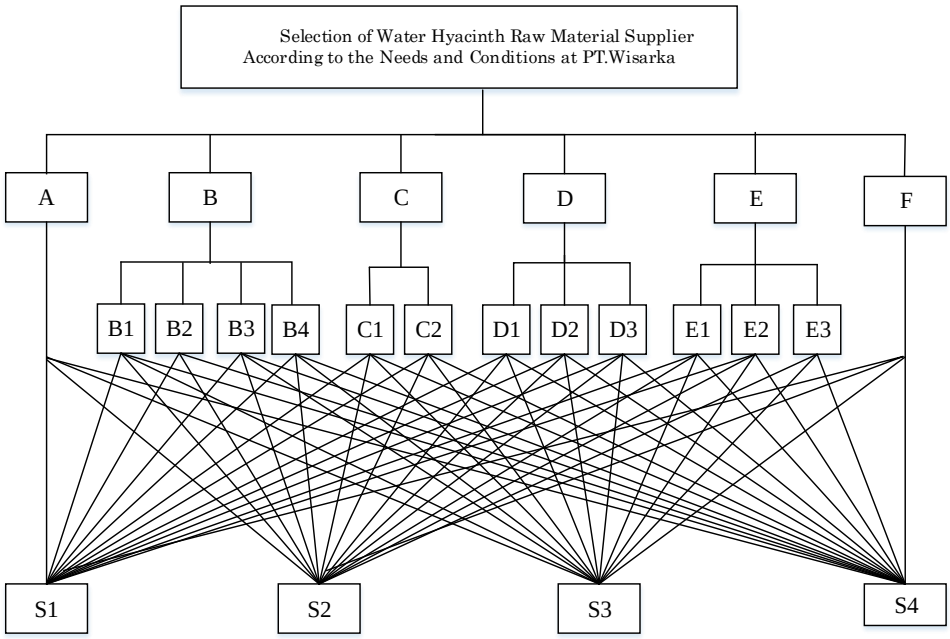

A	: Price	C1	: Change Amount	E1	: Convenience Contacted
B	: Quality	C2	: Change Time	E2	: Speed Change
B1	: Drought Level	D	: Delivery	E3	: Ease of Replacement
B2	: Color Woven	D1	: Punctuality	F	: Service
B3	: Neatness Woven	D2	: Suitability Amount	S1	: Supplier 1
B4	: Level of Violence	D3	: Shipment Capacity	S2	: Supplier 2
C	: Flexibility	E	: Warranty	S3	: Supplier 3
				S4	: Supplier 4

Fig. 1. The supplier selection hierarchy of the water hyacinth

Table 3. Assessment of the level of importance between criteria using the TFN

Criteria	Price			Quality			Flexibility			Delivery			Warranty			Service		
	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
Price	1.00	1.00	1.00	0.52	1.40	2.60	1.80	3.80	5.80	0.51	0.97	2.07	1.40	3.40	5.40	1.40	3.40	5.40
Quality	0.68	1.53	3.00	1.00	1.00	1.00	3.00	5.00	7.00	1.40	3.00	5.00	1.80	3.80	5.80	2.20	4.20	6.20
Flexibility	0.18	0.28	0.73	0.15	0.22	0.44	1.00	1.00	1.00	0.18	0.28	0.73	0.19	0.31	0.87	0.33	0.80	1.51
Delivery	1.24	2.47	3.67	0.35	0.44	0.73	1.80	3.80	5.80	1.00	1.00	1.00	2.60	4.60	6.60	1.40	3.40	5.40
Warranty	0.19	0.31	0.87	0.18	0.28	0.73	1.40	3.40	5.40	0.15	0.23	0.47	1.00	1.00	1.00	0.17	0.25	0.60
Service	0.19	0.31	0.87	0.17	0.25	0.60	2.04	3.67	5.40	0.19	0.31	0.87	2.20	4.20	6.20	1.00	1.00	1.00

A geometric average calculation of the aggregation was carried out based on Table 3. It used fuzzy synthetic extents calculations [24]. The result of it shown in Table 4. Based on fuzzy synthetic extent values. The next step is to compare synthetic extent values to

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obtain the minimum value. The result of the minimum value is shown in Table 5. This minimum value of synthetic extent was used to weight the vector criteria. It was obtained from the results of the normalization of the vector. Results of the normalization of the vector shown in Table 6.

Table 4. Fuzzy synthetic extent

	l	m	u
Price	0.06	0.21	0.62
Quality	0.10	0.28	0.78
Flexibility	0.02	0.04	0.15
Delivery	0.08	0.24	0.64
Warranty	0.03	0.08	0.25
Service	0.06	0.15	0.41

Table 5. The results of the comparison of synthetic extent values

	S1 ≥	S2 ≥	S3 ≥	S4 ≥	S5 ≥	S6 ≥	Min
S1	0.883	1.000	0.954	1.000	1.000	1.000	0.883
S2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
S3	0.330	0.171	0.252	0.750	0.467	1.000	0.171
S4	1.000	0.928	1.000	1.000	1.000	1.000	0.928
S5	0.594	0.438	1.000	0.524	0.752	1.000	0.438
S6	0.846	0.705	1.000	0.787	1.000	1.000	0.705

Table 6. The results of the weight vector calculation and normalization

	d'(A1)	d'(A2)	d'(A3)	d'(A4)	d'(A5)	d'(A6)	Information
W'	0.883	1.000	0.171	0.928	0.438	0.705	Vector weights
W'	0.214	0.242	0.041	0.225	0.106	0.171	Normalization

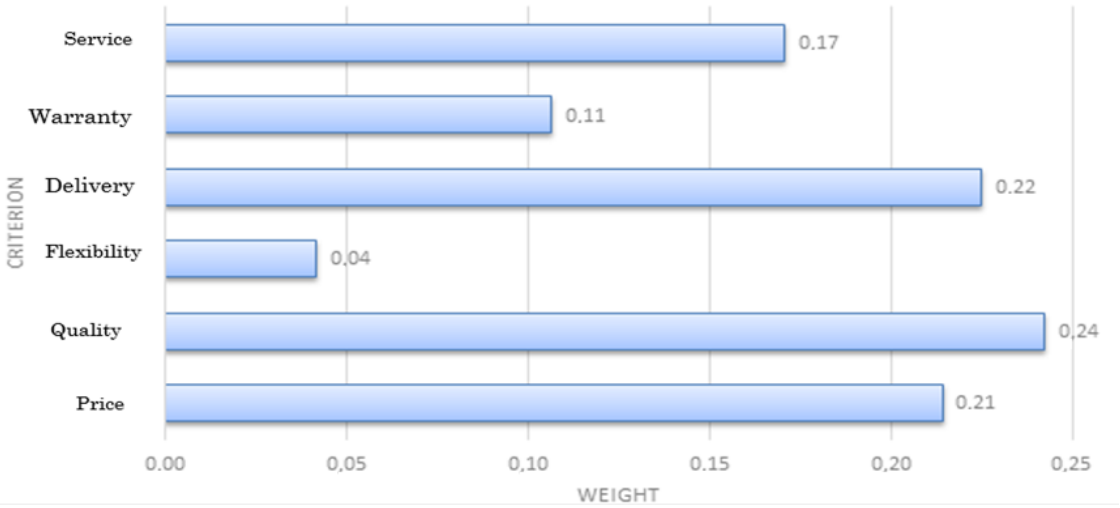

Fig. 2. The weighting of criteria

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Fig. 2 shows the result of the weight of the criteria. Based on Fig. 2, the priority for supplier selection is quality, price, service, warranty, and flexibility. Quality has the highest weight among several other criteria. Quality is needed for the sustainability of the company. The results of this study are by the research conducted by Darmawan, et al. [25], Limansantoso [26], Wardah [27], and Iriani and Herawan [28]. Furthermore, the delivery has the next most significant weight. The company requires the delivery according to the agreement. This research is by the research conducted by Putri [7], Andalia and Pratiwi [29], and Astuti [30].

Through the same steps, the sub-criteria weights are calculated on each of the criteria. The global weight value was produced by multiplying the value of each criterion's weights and sub-criteria. It is shown in Table 7. Based on Table 7, the results of supplier selection have obtained the weight of each supplier. Supplier 1 has several advantages: neat woven, suitability in quantity, delivery capacity, ease of contact, ease of replacement, and service. Supplier 4 has several advantages: price, dryness, woven color, hardness, timeliness, and replacement speed. Supplier 3 has an advantage in the sub-criteria, changing the quantity and changing the time. Suppliers 2 are considered not to have an advantage of sub-criteria. Supplier 1 is considered the most superior, followed by supplier 4, supplier 3, and supplier 2.

Table 7. Result of supplier weights

Criteria	Weight	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Price	0.210	0.215	0.249	0.230	0.306
Drought Level	0.053	0.355	0.216	0.024	0.405
Woven colour	0.084	0.313	0.184	0.173	0.330
Neatness Woven	0.091	0.332	0.209	0.163	0.296
Level of Violence	0.012	0.345	0.202	0.027	0.426
Change the Quantity	0.023	0.238	0.272	0.278	0.212
Change Time	0.017	0.071	0.383	0.440	0.107
Punctuality	0.106	0.396	0.061	0.127	0.416
Suitability Amount	0.088	0.449	0.154	0.036	0.361
Shipment Capacity	0.026	0.477	0.129	0.191	0.202
Convenience Contacted	0.055	0.287	0.203	0.278	0.232
Speed Change	0.017	0.349	0.212	0.047	0.392
Ease of Replacement	0.019	0.274	0.229	0.272	0.225
Service	0.170	0.483	0.181	0.145	0.190
Total		0.334	0.187	0.161	0.289

4. Conclusion

The supply of raw materials is essential in production. Therefore, the suppliers are needed to guarantee the availability of raw materials. The supplier selection must use criteria that are not ambiguous value. Hence, It is carried out with a fuzzy approach. The primary criteria for supplier selection include price, quality, flexibility, delivery, warranty, and service. Results of supplier selection used fuzzy analytical hierarchy process (FAHP) show supplier 4 has several advantages, including price, dryness, woven color, hardness,

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timeliness, and speed of replacement. Supplier 3 has an advantage in the sub-criteria, changing the quantity and changing the time. Suppliers 2 are considered not to have an advantage of sub-criteria. Supplier 1 is considered the most superior, followed by supplier 4, supplier 3, and supplier 2.

In this study, FGD involved were still limited to companies. There is a possibility of subjectivity in give an assessment. Therefore, future research can involve external parties in the assessment. In addition, research can also be continued by using other MCDM tools.

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Please cite this article as: Djunaidi, M., Utami, C., Alghofari, A., & Munawir, H. (2019). Selection of Furniture Raw Material Suppliers using Fuzzy Analytical Hierarchy Process. Jurnal Teknik Industri, 20(1), 12-21. doi:https://doi.org/10.22219/JTIUMM.Vol20.No1.12-21