Design of Vendor Selection System Using FAHP and FTOPSIS in Engineering-To-Order Manufacturing Industry

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ABSTRACT

Vendor selection has an important influence in the supply chain. Therefore, choosing the wrong vendor has a bad impact on the company's activities. The absence of a vendor selection system makes it difficult for decision makers to choose the right vendor. This study solves the problem of vendor selection by using a combination of Fuzzy Analytical Hierarchy Process (FAHP) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) methods. Calculations using FAHP can identify the priority of the criteria used, while calculations using FTOPSIS are used to sort the best vendors with an assessment based on criteria. The result of this research is the design of a decision support system using the FAHP and FTOPSIS methods in selecting vendors using Microsoft Excel applications.

Keywords: FAHP, FTOPSIS, Manufacturing Industry, Vendor Selecting

1. INTRODUCTION

The development of science and technology will have an impact on industrial competition. To overcome this, every company tries to improve product quality through a production process with good raw materials [1]. One way to get raw materials for production is to buy raw materials from vendors. It is important to determine the right vendor so that it can minimize price comparisons and differences in the amount of raw materials and obtain quality raw materials and optimize supply chain management [2]. In industries related to large-scale production, raw materials and components can account for up to 70% of production costs [3].

One of the companies engaged in manufacturing is PT XYZ, which is an outsourced company with an engineer to order strategy that provides production, repair, and cleaning services for machine components. In its production activities, the procurement of raw materials is an important part for the company so that production goals can be achieved. This study focuses on the selection of vendors for raw materials for stainless steel of the type SUS 304 due to the large number of vendors for these raw materials.

At PT XYZ, the selection of vendors in the procurement of raw materials is determined by two decision makers consisting of two people, namely the procurement manager and the assistant procurement manager. In the vendor selection process, PT XYZ has not used the method and there are no fixed criteria. And also in the vendor assessment, the historical delivery data from the vendor has not been considered and only uses empirical experience.

According to one of the sources at PT XYZ, there are several cases and obstacles that occur related to the procurement of raw materials from vendors such as delays in delivery, non-conformance of specifications, price differences, less amount of raw materials and delivery errors. Inappropriate vendor selection can have a negative impact on organizational productivity, profitability, and reputation [4].

The use of a combination model of the FAHP and FTOPSIS methods can solve MCDM problems in vendor selection [2]. Calculations using FAHP can identify the priority of the criteria used. And for calculations with FTOPSIS, there are advantages in the form of weighting results with a preference recommendation scale and considering the positive ideal solution distance so as to maximize profits. The FTOPSIS method

is very flexible because it can deal with both quantitative and qualitative criteria. With the fuzzy sets in the FAHP and FTOPSIS methods, ambiguity and inconsistency in the assessment can be eliminated so that the results can be maximized [5]. In this study, a combination model of the FAHP and FTOPSIS methods is used to solve the vendor selection problem, especially for the vendor of SUS 304 stainless steel material.

2. METHODS

2.1. Vendor Selection

Vendor selection is the process of reviewing, evaluating, and selecting vendors to be part of the company's supply chain [6]. Vendor selection consists of four stages, namely determining goals, determining criteria and sub criteria for assessment, pre-qualification and make decisions [7]. Vendor selection is a typical multi-criteria decision making problem [8]. In selecting and assessing vendors, several criteria are needed that can describe the performance of vendors that add value now and in the future [9]. The criteria used can be either quantitative or qualitative criteria. In determining vendor criteria, it needs to be adjusted to the company's needs so that the company's goals can be achieved. Several vendor criteria set will then be taken into consideration for decision makers in selecting and evaluating vendors. The main purpose of vendor selection is to determine vendors who have efficiency in meeting company needs and minimize risks related to the procurement of raw materials [9]. Because it is associated with high costs and risks, choosing the wrong vendor can lead to big losses [10].

2.2. Multi Criteria Decision Making (MCDM)

Multi criteria decision making (MCDM) is an approach for compiling information and evaluating decisions on problems with several conflicting objectives [5]. MCDM has many methods to achieve efficient results in the evaluation process. MCDM can solve problems in the vendor selection process which are categorized as multi-criteria problems [11]. The goal of MCDM is to obtain an optimal choice that satisfies a set of criteria [12]. MCDM steps consist of [6]:

1. Determine the appropriate criteria to achieve the goal.
2. Identify alternatives to achieve the desired goal.
3. Evaluate each alternative with each criterion.
4. Use appropriate multi-criteria analysis tools or techniques.
5. Accept suitable alternatives to achieve goals.
6. If the final solution is not feasible or unacceptable, then choose the next iteration until a feasible solution is not reached.

2.3. Fuzzy Sets

Fuzzy sets proposed by Zadeh (1965) which is a set that has a degree of membership. In its application, fuzzy sets enable decision makers to deal with uncertainty effectively. The fuzzy sets used in general are Triangular Fuzzy Number (TFN), trapezoidal and Gaussian fuzzy numbers [13].

2.4. Fuzzy Analytical Hierarchy Process (FAHP)

The Analytical Hierarchy Process (AHP) proposed by Saaty (1980), is a decision support model that describes complex multi-factor or multi-criteria problems into a hierarchy. A problem becomes complex because it has an unclear problem structure and the unavailability of data and information so that the input used to solve this problem is human intuition. Basically, this AHP method can break down a complex and unstructured situation into a hierarchical arrangement, assign a numerical value to subjective considerations about the relative importance of each variable or criterion, and analyze various considerations so that they can be relied upon as a decision-making tool [9]. With the arrangement of elements into a hierarchical structure, decision making is easier to understand the problem [14]. In many practical cases, human preferences tend to be uncertain and cannot assign precise and sharp values for comparative judgments [15]. By using a fuzzy approach, complex problems with inaccurate data, lacking information, and uncertainty can be handled [16]. There are several previous studies that used the FAHP method as in research [2],[7],[13] where they calculated the weights of the criteria and sub-criteria used. The following are the steps for solving multi-criteria problems using the FAHP method [13]: determine the value of the fuzzy synthetic extent, determine the degree of probability, determine the weight vector, normalize the weight vector.

2.5. Fuzzy Technique for Order Preference by Similarity to Ideal Solution TOPSIS

The technique for order preference by similarity to ideal solution (TOPSIS) proposed by Hwang and Yoon (1981), is a decision-making method with the chosen alternative having the smallest distance from the positive ideal solution (PIS) and the largest distance from the solution negative ideal or negative ideal solution (NIS) from a geometric point of view using the euclidean distance. Therefore, this method considers both the distance to the positive ideal solution and the distance to the negative ideal solution [3]. PIS is obtained by minimizing the cost criteria and maximizing the benefit criteria,

while NIS is obtained by maximizing the cost criteria and minimizing the benefit criteria [16]. TOPSIS will sort alternatives based on the priority value of the relative closeness of an alternative to a positive ideal solution which is then used as a reference for decision makers to choose the best solution in vendor selection [3]. There are several previous studies that used the FTOPSIS method as in the research [2],[13] where they ranked alternative vendors. The following are the steps for solving the problem using the FTOPSIS method [13]: forming a decision-making committee, then identifying vendor selection evaluation criteria, selecting appropriate linguistic variables for the weighting of the importance of the criteria and linguistic ratings for alternatives with respect to the criteria, determine the aggregated fuzzy rating, making a fuzzy decision matrix and a normalized fuzzy decision matrix, make a weighted normalized fuzzy decision matrix, determine the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS), calculate the distance of each alternative from FPIS and FNIS, calculate the closeness coefficient of each alternative, determine the ranking order of all vendor alternatives.

3. RESULTS AND DISCUSSION

In this study, the design of the vendor selection system in the company focused on stainless steel material vendors consisting of 5 vendors. The FAHP method is used to weight the criteria, while the FTOPSIS method is used to sort alternative vendors.

3.1. Identification of Criteria

Criteria for vendor selection are determined based on literature studies and interviews with experts and adjustments to the company's needs. There are 12 selected criteria in this study shown in Table 1.

3.2. Determination of criteria weight using FAHP

The selected criteria are then arranged in a hierarchical structure which can be seen in Figure 1. The vendor selection hierarchy is divided into 3 levels:
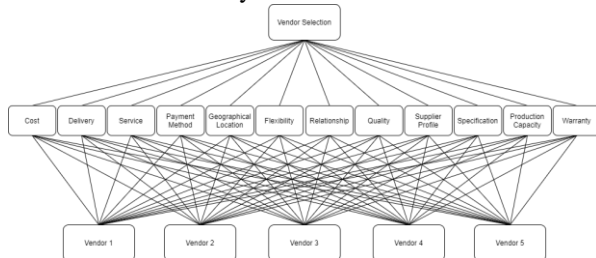

Figure 1 Hierarchical structure of the proposed model.

Table 1 Selected criteria.

Code	Criteria	Reference
C1	Cost	[2],[8],[13],[17]
C2	Delivery	[2],[8],[13],[17]
C3	Service	[8]
C4	Payment Method	[13]
C5	Geographical Location	[13]
C6	Flexibility	[2],[8],[13]
C7	Relationship	[2],[8]
C8	Quality	[2],[13],[17]
C9	Supplier Profile	[2],[17]
C10	Specification	[2]
C11	Production Capacity	[17]
C12	Warranty	[17]

Level 1 includes the main objective in the hierarchy which is the optimal vendor selection, level 2 includes the criteria used in vendor assessment, level 3 includes alternative vendors.

In this study, a questionnaire was used to collect the results of the assessment of the importance of each vendor selection criteria. This questionnaire was filled out by two expert respondents who are decision makers in the selection of vendors in the company. From the results of the questionnaire data, a criterion comparison matrix was formed. The criteria comparison matrix can be seen in the Table 2. Furthermore, the comparison criteria matrix is converted into the TFN scale [2]. To integrate the results of the expert respondents' assessments, a geometric mean was calculated. The next step is to calculate the synthetic fuzzy value. After getting the fuzzy synthetic value, then the determination of the degree of possibility can be done. The weight vector is obtained by looking at the degree of possibility of each criterion. In order to get the value of the weight vector with a range between 0 and 1, the normalization process can be carried out. The results of the weighting of the criteria can be seen in Table 3.

Table 2 Criteria comparison matrix.

						Expert 1						
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1	1.00	0.25	1.00	4.00	5.00	3.00	1.00	0.33	0.33	0.20	0.33	1.00
C2	4.00	1.00	4.00	5.00	1.00	3.00	2.00	1.00	5.00	1.00	0.50	1.00
C3	1.00	0.25	1.00	3.00	3.00	3.00	0.33	0.50	2.00	0.20	4.00	1.00
C4	0.25	0.20	0.33	1.00	0.20	3.00	2.00	1.00	0.33	4.00	0.20	0.50
C5	0.20	1.00	0.33	5.00	1.00	3.00	5.00	0.20	0.33	3.00	4.00	0.33
C6	0.33	0.33	0.33	0.33	0.33	1.00	0.33	5.00	4.00	0.25	5.00	3.00
C7	1.00	0.50	3.00	0.50	0.20	3.00	1.00	0.33	3.00	0.25	0.33	1.00
C8	3.00	1.00	2.00	1.00	5.00	0.20	3.00	1.00	2.00	1.00	0.33	1.00
C9	3.00	0.20	0.50	3.00	3.00	0.25	0.33	0.50	1.00	3.00	0.50	3.00
C10	5.00	1.00	5.00	0.25	0.33	4.00	4.00	1.00	0.33	1.00	0.33	4.00
C11	3.00	2.00	0.25	5.00	0.25	0.20	3.00	3.00	2.00	3.00	1.00	6.00
C12	1.00	1.00	1.00	2.00	3.00	0.33	1.00	1.00	0.33	0.25	0.17	1.00
						Expert 2						
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
C1	1.00	0.50	2.00	5.00	3.00	4.00	5.00	0.33	0.25	0.33	3.00	0.25
C2	2.00	1.00	1.00	3.00	1.00	0.33	0.33	3.00	0.50	0.25	3.00	0.33
C3	0.50	1.00	1.00	3.00	5.00	1.00	0.33	0.33	0.33	1.00	1.00	1.00
C4	0.20	0.33	0.33	1.00	0.50	4.00	3.00	0.25	3.00	2.00	0.25	0.20
C5	0.33	1.00	0.20	2.00	1.00	5.00	0.33	0.33	3.00	3.00	0.20	0.33
C6	0.25	3.00	1.00	0.25	0.20	1.00	0.20	2.00	0.25	5.00	3.00	4.00
C7	0.20	3.00	3.00	0.33	3.00	5.00	1.00	5.00	1.00	0.33	0.33	3.00
C8	3.00	0.33	3.00	4.00	3.00	0.50	0.20	1.00	3.00	0.50	0.33	0.25
C9	4.00	2.00	3.00	0.33	0.33	4.00	1.00	0.33	1.00	5.00	4.00	4.00
C10	3.00	4.00	1.00	0.50	0.33	0.20	3.00	2.00	0.20	1.00	0.33	1.00
C11	0.33	0.33	1.00	4.00	5.00	0.33	3.00	3.00	0.25	3.00	1.00	0.33
C12	4.00	3.00	1.00	5.00	3.00	0.25	0.33	4.00	0.25	1.00	3.00	1.00

Table 3 Weight vector for each criterion.

Code	Criteria	Weight Vector
C1	Cost	0.094
C2	Delivery	0.089
C3	Service	0.075
C4	Payment Method	0.060
C5	Geographical Location	0.080
C6	Flexibility	0.079
C7	Relationship	0.078
C8	Quality	0.088
C9	Supplier Profile	0.093
C10	Specification	0.088
C11	Production Capacity	0.099
C12	Warranty	0.077

3.3. Sort Alternative Vendors Using FTOPSIS

After collecting the questionnaire data for the assessment of alternative vendors by expert respondents, then it is converted into a fuzzy aggregate rating using the TFN scale [18]. The vendor alternative assessment data can be seen in Table 4. The next step is to change the results of the alternative vendor assessment into the form of a fuzzy decision matrix. The fuzzy decision matrix is then normalized and each criterion is classified into a benefit criterion or a cost criterion. Included in the type of cost criterion are cost, delivery, and geographic location. Included in the type of benefit criterion are service, payment method, flexibility, relationship, quality, supplier profile, specification, production capacity, and warranty.

Table 4 Vendor assessment results.

Expert 1												
Vendor	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
Vendor 1	G	F	F	G	G	MP	F	F	MG	F	G	G
Vendor 2	MG	MP	G	VG	G	F	G	MG	G	MG	G	F
Vendor 3	F	F	G	VG	G	MG	F	F	F	F	F	MG
Vendor 4	MG	F	F	G	MG	F	G	MG	G	F	MG	MP
Vendor 5	G	MP	F	G	MG	F	MP	F	F	G	F	F
Expert 2												
Vendor	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
Vendor 1	MG	G	G	G	G	F	F	MG	F	F	G	MG
Vendor 2	F	MG	F	G	G	MG	MG	MG	MG	G	MG	MG
Vendor 3	MP	G	MG	G	G	F	MG	MG	G	F	G	G
Vendor 4	MG	F	MG	G	F	MG	F	MG	F	G	G	F
Vendor 5	MG	MP	F	G	F	F	F	MG	G	G	F	MG

Making a weighted normalized fuzzy decision matrix is done by multiplying the results of the weighted criteria using the FAHP with the normalized fuzzy decision matrix. Next is to determine FPIS and FNIS, then calculate the distance for each alternative vendor from FPIS and FNIS. After knowing the distance of each alternative from FPIS and FNIS, the closeness coefficient of each alternative is calculated

Vendor alternative ratings can be sorted from first to last by looking at the closeness coefficient value from the largest to the smallest. The closeness coefficient for each alternative vendor can be seen in Table 5.

Table 5 Closeness coefficient for each vendor.

Vendor	d^*	d^-	Closeness Coefficient
Vendor 1	0.112	0.198	0.639
Vendor 2	0.089	0.231	0.721
Vendor 3	0.140	0.175	0.556
Vendor 4	0.133	0.192	0.591
Vendor 5	0.200	0.111	0.356

Figure 2 Input field on decision support system.

3.4. Decision Support System Design

In this study, Microsoft Excel is used to create a decision support system in vendor selection. The purpose of making this decision support system is to facilitate decision makers in conducting vendor assessments using FAHP and FTOPSIS calculations so that the vendor selection process becomes faster. In this decision support system, users can enter input data such as the number of decision makers, the criteria used, and alternative vendors.
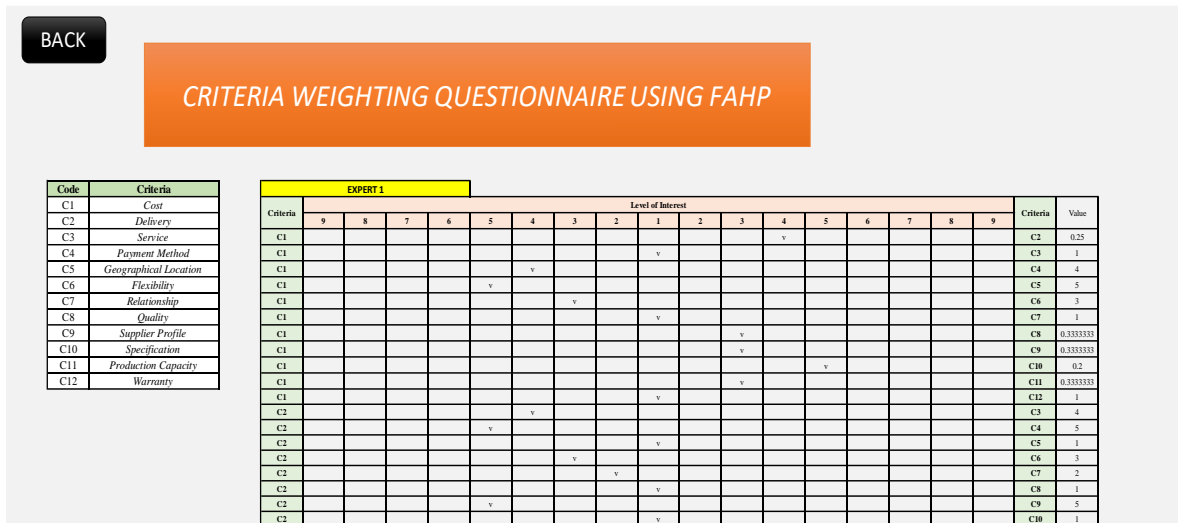
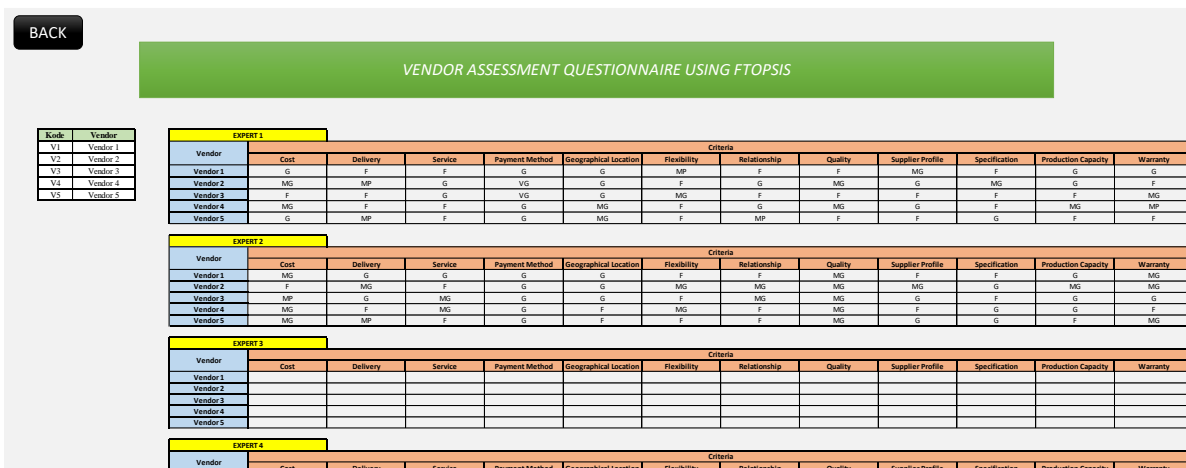**Figure 3** Criteria weighting questionnaire display on decision support system.

Figure 4 Vendor assessment questionnaire display on decision support system.

Figure 5 Decision support system dashboard view for

However, this decision support system has several limitations for the input data, such as the maximum number of decision makers is four people, the number of criteria entered must be twelve, and the number of alternative vendors entered must be five. These data can be entered in the input field as shown in Figure 2.

In this input field there is also a "criteria weighting" button which will direct the user to the criteria weighting sheet as shown in Figure 3. The "vendor assessment" button will direct the user to the vendor assessment sheet as shown in Figure 4.

After processing the data using FAHP and FTOPSIS, the output results in the form of weighting criteria and vendor ratings will be automatically displayed on the dashboard page. The dashboard display of the decision support system can be seen in Figure 5.

4. CONCLUSION

From the results of the weighting of the criteria using FAHP, the cost criteria are 9.4%, the delivery criteria are 8.9%, the service criteria are 7.5%, the payment method criteria are 6.0%, the geographical location criteria are 8.0%, and the flexibility criteria are 7.9. %, the weight of the relationship criteria is 7.8%, the quality criteria is 8.8%, the supplier profile criteria is 9.3%, the specification criteria is 8.8%, the production capacity criteria is 9.9%, and the warranty criteria is 7.7%. After performing calculations with FTOPSIS, the order of vendor rankings can be determined by looking at the largest closeness coefficient value, so that the vendor order obtained is V2, V1, V4, V3, and V5. Based on the research results obtained, the use of a combination model of the FAHP and FTOPSIS methods can solve the problem of vendor selection. FAHP can determine the priority of vendor selection criteria well. Then with the consideration of the fuzzy positive ideal solution for each alternative vendor, FTOPSIS can provide results with maximum profits. With the use of fuzzy sets, ambiguity in the assessment by decision makers can be eliminated so that the results of vendor selection are more precise. Suggestions for further research is to combine this method with other methods so that it can determine the weight of decision makers in the selection of vendors. With the weight of decision makers, the results of vendor selection may be different.

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