Selection of the Best Supplier Criteria with the Analytical Hierarchy Process Method in the Construction Services Industry

Irfan Satriawan and Sawarni Hasibuan
Master of Industrial Engineering
Faculty of Engineering
Universitas Mercu Buana
Jl. Meruya Selatan No.1 Kembangan, Jakarta 11650, Indonesia
irfansatriawan12@gmail.com

Abstract

The progress of the industry causes a lot of competition in various industrial circles, especially in construction services. There are many types of competition in the construction service industry, this requires construction service actors to make improvements. One of the strategies in competing in the industrial world is to maintain the best quality and provide innovation in increasing the procurement of raw materials. This study aims to analyze the criteria that are the company's priorities in choosing iron plate suppliers for fabrication needs. One of the methods used in this research is the Analytical Hierarchy Process (AHP) method. The problem solved is multi-objective and multi-criteria based on the comparison of preferences of each element in the hierarchy. This research involves experts who are used as respondents to consider decisions. The results of the study show that the Price criteria is still the most important criterion with a weight of (0.352), followed by Quality criteria with a weight of (0.277), Service criteria with a weight of (0.143), Flexibility criteria with a weight of (0.114), and Delivery criteria with a weight of (0.113).

Keywords
AHP, Construction, MCDM, Supplier, Supply Chain

1. Introduction

The progress of the industry causes a lot of competition in various industrial circles, especially in construction services. Competition occurs because of the struggle for market share in Indonesia. The many types of competition in the construction service industry, this requires construction service actors to make improvements to win the competition. One of the strategies in competing in the industrial world is to maintain the best quality and provide innovation in the manufacture of a product that is desired and used by consumers (Russo & Camanho, 2015). One of the most important activities for construction service companies is inventory management. One of the activities in this inventory management is the procurement of raw materials. Raw materials are generally imported from suppliers. Suppliers are one of the important external parties for the existence and sustainability of a company. Supplier is a company or work partner that procures goods from manufacturers, agents, distributors, traders and contractors who have passed the pre-qualification and have their domestic/foreign address (Juliana et al., 2017). The concept of the supply chain, suppliers are one part of the supply chain that is very important and affects the survival of a factory. The factory as a system that carries out production activities must require raw materials which of course are imported from suppliers (Yu & Liu, 2021). If the supplier is less responsible and does not respond to demand fulfillment, it will cause problems, including the occurrence of stockouts and the length of lead time. Therefore, companies that have many alternative suppliers must be selective in choosing suppliers. To get a selective supplier, a good and objective Supplier Evaluation and Selection System is needed (Razi et al., 2020).

Industry SIKO is a contractor company that can carry out technical improvements, consulting services and environmental restoration with technology from Japan. The company was founded with the aim of developing high efficiency performance to achieve client's needs and satisfaction. The company which was founded in October 2007 is actively involved in industrial development in Indonesia and to provide sustainable quality technology & customer satisfaction as well as to survive through the competition. The company's vision and mission is to be part of an active player in contributing to industrial development in Indonesia and around the world. The method of procuring plate

iron that has been going on so far only pays attention to a few things and criteria that focus only on administration, technical and price. This illustrates how this supplier evaluation model only focuses on evaluating product aspects. The supplier evaluation and selection system in facing industrial competition currently uses various criteria other than being limited to administration, technical and price. Dickson has made a list of 23 criteria that have become a reference as criteria for evaluating suppliers (Riyanto et al., 2022). The supplier selection and evaluation system is an important element for companies to be more efficient in procuring both raw materials and spare parts as well as selecting strategic suppliers for the company. With the problem of delays in the delivery of raw materials and material delivery errors made by suppliers, researchers will try to analyze and provide suggestions regarding the problems that occur. Strategies to increase supplier selection are needed so that companies can survive in tight business competition. One strategy that can overcome this is to use the Analytical Hierarchy Process (AHP) method by determining the criteria obtained from the Vendor Performance Indicator (VPI) with criteria including Quality, Cost, Delivery, Flexibility and Responsivene (Ristono et al., 2020; Nugroho & Iskandar, 2020). By using AHP, a problem will be solved in an organized frame of mind, so that it can be expressed to make effective decisions (Hakim & Putra, 2022; Satoglu & Türkekul, 2021). Complex issues can be simplified and the decision-making process accelerated (Wahyuningsih et al., 2022; Sanny & Safitri, 2018). AHP is a functional hierarchy with the main input is human perception (Akmaludin & Badrul, 2019; Juliana et al., 2017). With a hierarchy, a complex and unstructured problem is solved into its groups. Then the groups are organized into a form of AHP hierarchy that can solve problems. The problem solved is multi-objective and multi-criteria based on the comparison of preferences of each element in the hierarchy. Previous research used the AHP method to determine priorities (Rahmi & Firman, 2019; Balubaid & Alamoudi, 2015). This model is a complex method with tangible results. This model is a comprehensive decision-making model (Etlanda & Sutawidjaya, 2022; Hazza et al., 2022).

1.1 Objectives

This study aims to analyze what criteria are the company's priorities in selecting plate iron suppliers for fabrication needs.

2. Methods

This research belongs to the type of quantitative research. This research was conducted in a construction industry located in Jakarta. Primary data is obtained through observation to observe and record all activities related to supplier selection. While secondary data is obtained through the documents used in the form of company reports, articles in journals and other documents related to technical studies and supplier management. A number of experts were involved in this study to provide an assessment point of view based on their expertise in the field of procuring iron plates needed by the company. Primary data was also obtained through a questionnaire. The questionnaire submitted to the experts, as many as 6 experts provided feedback, which means that 100% of the experts gave their responses. These experts consist of 1 company SCM Director, 1 Procurement Manager, 3 Procurement Leads and 1 company Marketing & Proposal Manager. This research was also carried out using systematic stages to be able to solve problems in a measurable manner. The following stages of the research can be seen in Figure 1.

The steps for applying the AHP evaluation model in supplier selection are as follows:
1. Supplier selection criteria and structure hierarchy
3. Compiling a Pairwise Comparison Matrix
4. Partial Weighting
5. Determine the overall priority weight and test the consistency index

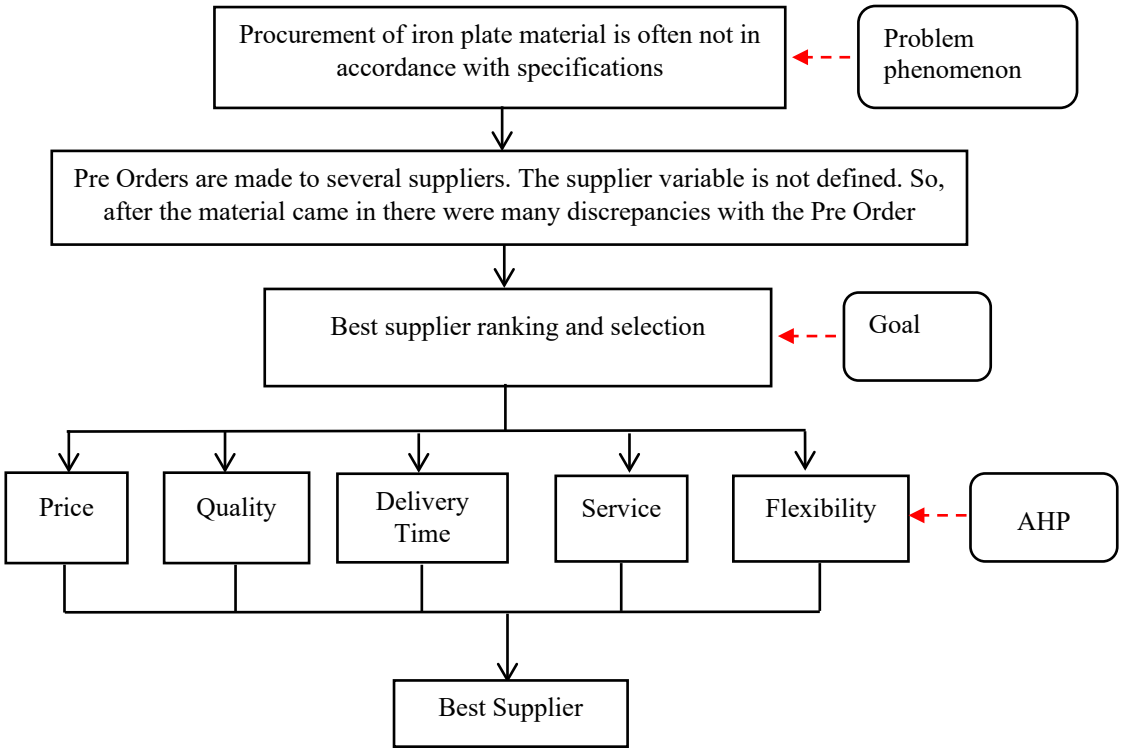

Figure 1. Research Framework

3. Analysis and Result

3.1. Supplier Criteria Selection Data

The data used in the selection of priority criteria for supplier selection consists of five main criteria and fifteen sub-criteria. The criteria and sub-criteria were obtained from the results of several literature sources and the results of interviews with several experts from the company. The selection of supplier criteria is expected to obtain a sequence of priority criteria and sub-criteria in the selection of suppliers needed by construction companies to provide iron plates. Furthermore, data processing analysis is carried out for each criterion and alternative. Then a pairwise comparison was performed (Figure 2). Qualitative criteria and quantitative criteria can be compared according to predetermined assessments to produce rankings and priorities.

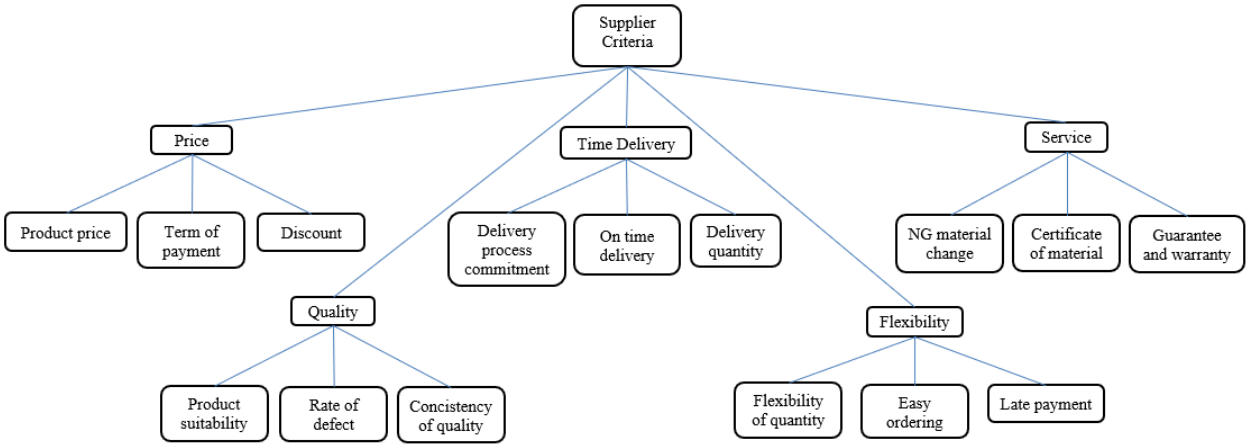

Figure 2. Hierarchy of Structure

3.2. Compiling a Pairwise Comparison Matrix

Pairwise comparisons are carried out with an assessment by decision makers by determining the level of importance of a component against other components which will be followed by calculating the geometric mean which is the input value of the comparison between elements in this study. Paired matrices consist of paired matrices between criteria and paired matrices of sub-criteria for each criterion. The results of this matrix are generated from the answers of the selected experts. The paired matrix between criteria can be seen in Table 1.

Table 1. Pairwise Comparison of Level 2 Elements (Criteria)

Respondent 1					
Criteria	Price	Quality	Delivery	Flexibility	Service
Price	1	1/2	2	9	2
Quality	2	1	3	7	7
Delivery	1/2	1/3	1	4	2
Flexibility	1/9	1/7	1/4	1	1/2
Service	1/2	1/7	1/2	2	1
Respondent 2					
Criteria	Price	Quality	Delivery	Flexibility	Service
Price	1	3	9	3	5
Quality	1/3	1	5	2	3
Delivery	1/9	1/5	1	1/2	2
Flexibility	1/3	1/2	2	1	3
Service	1/5	1/3	1/2	1/3	1
Respondent 3					
Criteria	Price	Quality	Delivery	Flexibility	Service
Price	1	7	8	2	3
Quality	1/7	1	2	1/7	1/2
Delivery	1/8	1/2	1	1/3	1/3
Flexibility	1/2	7	3	1	1/2
Service	1/3	2	3	2	1
Respondent 4					
Criteria	Price	Quality	Delivery	Flexibility	Service
Price	1	1/2	4	5	2
Quality	2	1	2	5	2
Delivery	1/4	1/2	1	1/2	1/2
Flexibility	1/5	1/5	2	1	1/2
Service	1/2	1/2	2	2	1
Respondent 5					
Criteria	Price	Quality	Delivery	Flexibility	Service
Price	1	1/8	1/5	2	2
Quality	8	1	3	5	5
Delivery	5	1/3	1	5	3
Flexibility	1/2	1/5	1/5	1	1/2
Service	1/2	1/5	1/3	2	1
Respondent 6					
Criteria	Price	Quality	Delivery	Flexibility	Service
Price	1	5	8	2	2
Quality	1/5	1	2	2	1/2
Delivery	1/8	1/2	1	1/3	1/3
Flexibility	1/2	1/2	3	1	1/2
Service	1/2	2	3	2	1

The pairwise comparison matrix between criteria shows a comparison of the level of importance between criteria which will later show which criteria are the priority criteria in the selection of steel plate suppliers by the company. Furthermore, a paired matrix of sub-criteria for each criterion is also carried out, which can be seen in Table 2.

Table 2. Pairwise Comparison of Level 3 Elements (Sub-criteria)

Respondent 1			
Sub-criteria	Product price	Term of Payment	Discount
Product price	1	5	3
Term of payment	1/5	1	1/3
Discount	1/3	3	1
Respondent 2			
Sub-criteria	Product price	Term of Payment	Discount
Product price	1	3	2
Term of Payment	1/3	1	1/3
Discount	1/2	3	1
Respondent 3			
Sub-criteria	Product price	Term of Payment	Discount
Product price	1	4	5
Term of Payment	1/4	1	3
Discount	1/5	1/3	1
Respondent 4			
Sub-criteria	Product price	Term of Payment	Discount
Product price	1	5	3
Term of Payment	1/5	1	3
Discount	1/3	1/3	1
Respondent 5			
Sub-criteria	Product price	Term of Payment	Discount
Product price	1	1/5	3
Term of Payment	5	1	7
Discount	1/3	1/7	1
Respondent 6			
Sub-criteria	Product price	Term of Payment	Discount
Product price	1	1/5	3
Term of Payment	5	1	7
Discount	1/3	1/7	1

3.3. Partial Weighting

After the value of each criterion and sub-criteria is known, then normalization is carried out. The normalization of this pairwise comparison matrix has the aim of making all values equal. Normalization is done on the criteria can be seen in Table 3.

Table 3. Normalization and Partial Weight of Each Row Element Level 2 (Criteria)

Criteria	Price	Quality	Delivery	Flexibility	Service	Partial weight
Price	0.350	0.341	0.348	0.366	0.354	1.76
Quality	0.287	0.280	0.298	0.246	0.275	1.39
Delivery	0.112	0.105	0.112	0.104	0.133	0.57
Flexibility	0.109	0.130	0.123	0.114	0.096	0.57
Service	0.141	0.145	0.119	0.170	0.142	0.72
Total	1.00	1.00	1.00	1.00	1.00	5.00

Table 4. Normalization and Partial Weight of Each Row Element Level 3 (Sub-riteria)

Price				
Sub-criteria	Product price	Term of Payment	Discount	Partial weight
Product price	0.606	0.625	0.579	1.81
Term of Payment	0.221	0.228	0.256	0.71
Discount	0.172	0.147	0.165	0.48
Total	1.000	1.000	1.000	3.000
Quality				
Sub-criteria	Product suitability	Rate of defect	Concistency of quality	Partial weight
Product suitability	0.262	0.290	0.255	0.81
Rate of defect	0.144	0.160	0.167	0.47
Concistency of quality	0.594	0.550	0.578	1.72
Total	1.000	1.000	1.000	3.000
Delivery				
Sub-criteria	Delivery process commitment	On time delivery	Quantity of delivery	Partial weight
Delivery process commitment	0.126	0.135	0.101	0.36
On time delivery	0.629	0.675	0.701	2.01
Quantity of delivery	0.245	0.190	0.197	0.63
Total	1.000	1.000	1.000	3.000
Flexibilty				
Subcriteria	Flexibility of quantity	Easy ordering	Late of payment	Partial weight
Flexibility of quantity	0.609	0.628	0.578	1.81
Easy ordering	0.234	0.241	0.273	0.75
Late of payment	0.157	0.132	0.149	0.44
Total	1.000	1.000	1.000	3.000
Service				
Sub-criteria	NG material change	Certificate of material	Guarantee and warranty	Partial weight
NG material change	0.285	0.322	0.279	0.89
Certificate of material	0.096	0.109	0.116	0.32
Guarantee and warranty	0.619	0.569	0.606	1.79
Total	1.000	1.000	1.000	3.000

3.4. Determine the Overall Priority Weight and Test the Consistency Index

The priority weight calculation is done by finding the average of each row of the normalized matrix or the comparison of the partial weights of each criterion with the total partial weight of all criteria.

Sample Price

$$\text{Priority weight of Price criteria} = \frac{\text{Partial weight of price criteria}}{\text{total partial weight of all criteria}} = \frac{1.76}{5} = 0.35199$$

This step is carried out for all criteria so that the priority weight of each criterion is obtained as shown in Table 5.

Table 5. Partial Weight and Priority Weight of Each Row of Level 2 Elements (Criteria)

Criteria	Price	Quality	Delivery	Flexibility	Service	Partial weight	Priority weight	∑ AW	Ratio
Price	0.350	0.341	0.348	0.366	0.354	1.76	0.35199	1.77	5.018
Quality	0.287	0.280	0.298	0.246	0.275	1.39	0.27722	1.39	5.019
Delivery	0.112	0.105	0.112	0.104	0.133	0.57	0.11306	0.57	5.020
Flexibility	0.109	0.130	0.123	0.114	0.096	0.57	0.11448	0.57	5.016
Service	0.141	0.145	0.119	0.170	0.142	0.72	0.14325	0.72	5.016
Total	1.00	1.00	1.00	1.00	1.00	5.00	1.00	5.02	25.09

The steps for finding the value of the consistency ratio and the consistency of the matrix are as follows.

1. The consistency ratio is sought by the following formula
   = (Weighted Average Calculation Matrix) x (Priority Weight)

$$\underset{(X)}{\begin{pmatrix} 1.00 & 1.22 & 3.12 & 3.20 & 2.49 \\ 0.82 & 1.00 & 2.67 & 2.15 & 1.94 \\ 0.32 & 0.37 & 1.00 & 0.91 & 0.93 \\ 0.31 & 0.46 & 1.10 & 1.00 & 0.67 \\ 0.40 & 0.52 & 1.07 & 1.48 & 1.00 \end{pmatrix}} \underset{(Y)}{\begin{pmatrix} 0.35199 \\ 0.27722 \\ 0.11306 \\ 0.11448 \\ 0.14325 \end{pmatrix}} = \underset{(Z)}{\begin{pmatrix} 5.018 \\ 5.019 \\ 5.020 \\ 5.016 \\ 5.016 \end{pmatrix}}$$

2 $\lambda_{maks} = \frac{5.018+5.019+5.020+5.016+5.016}{5} = 5.0178$

3. Consistency Index

$$CI = \frac{5.0178 - 5}{5 - 1}$$
$$= 0.00445$$

4. *Random index* for n= 5 is 1.12

$$CR = \frac{CI}{RI} = \frac{0.00445}{1.12} = 0,00397 \approx 0,004$$

The CR value <0.1 means that the answers given by the respondents are interpreted as consistent. The steps above are also carried out for hierarchical elements at level 3, namely the sub-criteria for each criterion. The priority weight calculation is done by finding the average of each row of the normalized matrix or the comparison of the partial weights of each sub-criteria with the total partial weight of all sub-criteria on the dimensions of the criteria.

Sample Price

$$\text{Priority weight of Price criteria} = \frac{\text{Partial weight of price criteria}}{\text{total partial weight of all criteria}} = \frac{1.81}{3} = 0.603$$

This step is carried out for all sub-criteria for each criterion so that the priority weight of each sub-criteria is obtained as shown in Table 6.

Table 6. Partial Weight and Priority Weight of Each Row of Level 3 Elements (Sub-Criteria) on Price Criteria

Price							
Sub-criteria	Product price	Term of Payment	Discount	Partial weight	Priority weight	∑ AW	Ratio
Product price	0.606	0.625	0.579	1.81	0.603	1.81	3.007
Term of payment	0.221	0.228	0.256	0.71	0.235	0.71	3.003
Discount	0.172	0.147	0.165	0.48	0.161	0.48	3.002
Total	1.00	1.00	1.00	3.00	1.00	3.01	9.01

Quality							
Sub-criteria	Product suitability	Rate of defect	Concistency of quality	Partial weight	Priority weight	∑ AW	Ratio
Product suitability	0.262	0.290	0.255	0.81	0.269	0.81	3.003
Rate of defect	0.144	0.160	0.167	0.47	0.157	0.47	3.002
Concistency of quality	0.594	0.550	0.578	1.72	0.574	1.72	3.006
Total	1.00	1.00	1.00	3.00	1.00	3.00	9.01
Delivery							
Sub-criteria	Delivery process commitment	On time delivery	Quantity of delivery	Partial weight	Priority weight	∑ AW	Ratio
Delivery process commitment	0.126	0.135	0.101	0.36	0.121	0.36	3.00
On time delivery	0.629	0.675	0.701	2.01	0.668	2.02	3.02
Quantity of delivery	0.245	0.190	0.197	0.63	0.211	0.63	3.01
Total	1.00	1.00	1.00	3.00	1.00	3.02	9.04
Flexibility							
Sub-criteria	Flexibility of quantity	Easy ordering	Late of payment	Partial weight	Priority weight	∑ AW	Ratio
Flexibility of quantity	0.609	0.628	0.578	1.81	0.605	1.82	3.01
Easy ordering	0.234	0.241	0.273	0.75	0.249	0.75	3.00
Late of payment	0.157	0.132	0.149	0.44	0.146	0.44	3.00
Total	1.00	1.00	1.00	3.00	1.00	3.01	9.01
Service							
Sub-criteria	NG material change	Certificate of material	Guarantee and warranty	Bobot Parsial	Partial weight	Priority weight	Ratio
NG material change	0.285	0.322	0.279	0.89	0.295	0.89	3.004
Certificate of material	0.096	0.109	0.116	0.32	0.107	0.32	3.001
Guarantee and warranty	0.619	0.569	0.606	1.79	0.598	1.80	3.008
Total	1.00	1.00	1.00	3.00	1.00	3.01	9.01

The steps for finding the value of the consistency ratio and the consistency of the matrix are as follows.

1. The consistency ratio is sought by the following formula
   = (Weighted Average Calculation Matrix) x (Priority Weight)

$$\underset{(X)}{\begin{pmatrix} 1.00 & 2.74 & 3.52 \\ 0.37 & 1.00 & 1.55 \\ 0.28 & 0.64 & 1.00 \end{pmatrix}} \underset{(Y)}{\begin{pmatrix} 0.603 \\ 0.235 \\ 0.161 \end{pmatrix}} = \underset{(Z)}{\begin{pmatrix} 3.007 \\ 3.003 \\ 3.002 \end{pmatrix}}$$

2. $\lambda_{maks} = \frac{3.007+3.003+3.002}{3} = 3.004$

3. *Consistency Index*

$$CI = \frac{3.004-3}{3-1} = 0.0020$$

4. *Random index* for n= 3 is 0,58

$$CR = \frac{CI}{RI} = \frac{0.0020}{0.58} = 0,003448 \approx 0,0035$$

The CR value <0.1 means that the answers given by the respondents are interpreted as consistent

AHP provides the results of supplier selection criteria and sub-criteria relevant to construction companies. AHP also provides an analysis of the importance of each of these criteria and sub-criteria. These sub-criteria become the basis for evaluating the selection of iron plate suppliers for companies. The results of the complete selection sub-criteria with their importance weighting scores are shown in Table 7.

Table 7. Results of the selection of sub-criteria ranking

No.	Sub-criteria	Weight of sub-criteria
1	Product price	0.2124
2	Consistency of quality	0.1591
3	Guarantee and warranty	0.0856
4	Term of Payment	0.0828
5	On time delivery	0.0756
6	Product suitability	0.0746
7	Flexibility of quantity	0.0693
8	Discount	0.0568
9	Rate of quality	0.0436
10	NG material change	0.0423
11	Easy ordering	0.0285
12	Quantity delivery	0.0238
13	Late of payment	0.0167
14	Certificate of material	0.0153
15	Delivery process commitment	0.0137

5. Discussion

The order of evaluation results with AHP shows that the product price criterion is the criterion that has the highest weight. This is because the price of the product from the supply of goods must be in accordance with the demand from the user. This is understandable because the procurement system requires all potential suppliers to offer appropriate prices (Yu & Liu, 2021). If the price offered is below the funds provided, it will be disqualified as a potential supplier. Therefore, the findings of this study will have a significant influence on the selection of suppliers, the weighting results make the price criteria as a determinant of the winner and the selection of plate iron suppliers for the company.

The results of the evaluation with AHP also show that the sub-criteria for the consistency of material quality is the criterion that has the second highest weight. This is because the quality of the supply goods must be in accordance with the demand from the user (Nugroho & Iskandar, 2020). The quality factor of service is the company's big target. Thus, it is necessary to have quality plate support for the construction process to be carried out. Material quality consistency can be defined as the supplier's ability to consistently meet product specifications such as material, dimension, design, or durability issues, thereby preventing product rejection due to quality problems.

5.1. Implication

The positive impact if this evaluation method is applied consistently will produce suppliers who have better capability and quality from the point of view of price, quality, delivery, flexibility and service criteria. Suppliers generated from this evaluation model can meet the expectations of the procurement unit in the form of supply of goods at appropriate prices and guaranteed quality, so that they can support and expedite the timeline and quality of projects being carried out by construction companies.

6. Conclusion

The conclusions in this study were obtained, among others, as many as 5 criteria and 15 sub-criteria have been validated that are relevant to construction companies, especially those related to the procurement of plate iron. Price criteria is still the most important criterion with a weight of (0.352), followed by Quality criteria with a weight of (0.277), Service criteria with a weight of (0.143), Flexibility criteria with a weight of (0.114), and Delivery criteria with a weight of (0.113). Meanwhile, the five most important sub-criteria are Product Price sub-criteria with a weight of (0.212), Consistency of quality (0.159), Guarantee and warranty (0.086), Term of payment (0.0826) and on time delivery (0.076). The limitation of this study is that it does not consider the uncertainty factor and the reliability of the information in the judgment of the experts. In future research can consider the uncertainty factor and for method validation can be compared with other multi-criteria decision-making methods.

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Biographies

Irfan Satriawan is a postgraduate student in Industrial Engineering at Universitas Mercu Buana, Jakarta, Indonesia. He is interested in supply chain management, transportation design system and logistic supply chain. He works in the procurement department at a contractor company in Jakarta

Sawarni Hasibuan is an associate professor in the Industrial Engineering Department at Universitas Mercu Buana, Jakarta, Indonesia. She completed his master's in industrial engineering at the Bandung Institute of Technology and obtained a Doctorate in Agro-industrial Technology, at Bogor Agricultural University. She has carried out several research and publications in operational management, green & sustainable manufacturing, supply chain management, and renewable energy