MULTI-CRITERIA DECISION MODEL FOR MATERIAL SUPPLIER SELECTION FLEXIBLE PAVEMENT USING THE ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

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Abstract:*This research was conducted on construction workers / contractors in the field of roads and bridges in the province of West Sumatra. This study aims to provide consideration for construction companies in choosing the rightsupplier by considering various criteria, determine the priority scale of supplier selection activities for construction actors/contractors, provide suggestions or solutions for selecting flexible pavement suppliers for construction actors in the province of West Sumatra by using the Analytic Hierarchy Process (AHP) method. Theresults showed that the criteria and sub-criteria can be used as suggestions orsolutions, namely supplier profiles consisting of certificates and business licenses, not blacklisted, clear company name and address, capital, company age, performance over the last 5 years and this year, total and quality of employees, and the number of clients in a year safety records consist of taking materials with eco-friendly designations, availability of training for new employees, the importance of applying OSH in the work environment, and the number of accidents in the last 5 years and delivery consisting of timely delivery, delivery distance, delivery of materials according to the order, and the type and amount of shipping transportation. With the supplier profile factor weighing 49.70% safety record factor 21.90% delivery factor 11.70% quality factor 6.80% cost factor 5.80% service factor 4.10%.*
Keywords: *Flexible Pavement, Material Supplier, Multi Criteria Decision Making, Analytical Hierarchy Process (AHP)*

A. Introduction

The construction industry is one of the most important industries in the economy that can interact with other business fields. The complexity, uncertainty and dynamics of most construction projects create challenges for clients, consultants and contractors in determining construction project costs. Studies on the accuracy of construction costs show that the level of accuracy is very dependent on the available historical cost data (Jumas et al., 2018; Riquelme and Serpell, 2013; Moon et al., 2007). The current situation for players in the industrial world, especially construction, is faced with two choices, namely how to determine the cost approach and selecting material suppliers (*material supplier*) is appropriate (Solov'ev and Korchagin, 2014). Construction materials are the main cost component in every construction project. The total costs for installed construction materials can reach 50% to 60% of the total construction costs (Jumas, 2020; Cengiz, et al, 2017; Duiyong et al, 2014; Patil and Pataskar, 2013). For this reason, the use of similar types of materials with different properties and different prices must be considered.

In West Sumatra Province, there are 5969 construction companies from 8 types of construction company qualification classifications originating from 19 Regencies/Cities (West Sumatra Central Statistics Agency 2022). The largest number of construction companies are in Padang City, followed by Pesisir Selatan, West Pasaman, Solok City, Kab. Solok and Dharmasraya. Construction project actors really need related information *supplier* to supply material needs in the construction projects they manage. Election *supplier* has become *issues* important in building an effective supply chain (O.Pal and Garg, 2013; Mokhlesian, 2014; Thiruchelvam and Tookey, 2011) and is the most important part in the field of supply chain management (Stevic et al., 2017; Patil and Pataskar, 2013). Election *supplier* is a process of discovery supplier the right one who is able to provide the right product to buyers at the right price, quantity and time (Cengiz et al, 2017).

According to (Bima Fardika et al, 2022), there were two service providers who were found to have not been optimal in determining suppliers of flexible pavement materials, the first was the road preservation work package for the Kiliran Jao section - Jambi provincial boundary and Kiliran Jao - Riau provincial boundary at the Commitment Making Official (PPK).) 2.2 West Sumatra province, the author encountered a problem, in more detail on the aggregate material supplier for asphalt, in this package the author identified that the service provider did not think about the distance of material delivery from the quary location/material supplier to the warehouse location or asphalt *mixing plant* (AMP) service provider A, for location asphalt *mixing plant* (AMP) is in the dry trunk area of Sijunjung district while the location*quary*/ material supplier is in Alahan Panjang, Solok district. When carrying out road widening work on asphalt work in front of the Dharmasraya Grand Mosque on the Kiliran Jao - BTS Jambi section, precisely in April 2022, there was a delay in the work. Based on the author's analysis, this delay was caused by a lack of aggregate in the asphalt mixture at the location asphalt *mixing plant* (AMP)/service provider A's warehouse, so the distance between the location of the aggregate material supplier and the service provider's warehouse means that the material does not arrive on time. According to the author, distance and time need to be taken into account when selecting a supplier, that is, if at any time there is urgent work, this aggregate material will already be available asphalt *mixing plant* (AMP) service provider A. The author also received information from the laboratory service provider, service provider A chose the material supplier in the Alahan Panjang location based on a cheap price and could be paid after the project was completed, but according to the author's observations we must use the right cost method , right quality and on time.

Problems with service provider B, the author identified an inappropriate selection of flexible pavement material suppliers, why is this the case here the author and the labor team owner Seeing that service provider B is also not correct in selecting material suppliers based on distances that are too far away, the location of this asphalt aggregate material supplier is in Solok while the location asphalt *mixing plant* (AMP) service provider B is in Dharmasraya, besides that, after the project had been running for about two months and the supplier had been appointed as service provider B, information was obtained that the material supplier/*quary*it does not have a local environmental permit. With this incident, the owner, namely the commitment making official (PPK) 2.2 of West Sumatra Province together with the consultant until *summer request* to immediately change the material supplier. With this incident the author concludes that there is a need for appropriate and good input in selecting material suppliers/*quary*.

B. Methods

Jenis penelitian yang digunakan dalam penelitian ini adalah penelitian kuantitatif dan kualitatif. Jumlah populasi adalah 39 orang pelaku konstruksi pada kontraktor jalan kelas menengah, dan tingkat kesalahan yang dikehendaki adalah 5%. Berdasarkan rumusan masalah dan tujuan penelitian yang akan dicapai, makatahapan penelitian dapat diringkas dalam bentuk diagram alir metodologi penelitian yang disampaikan pada Gambar 1 sebagai berikut:

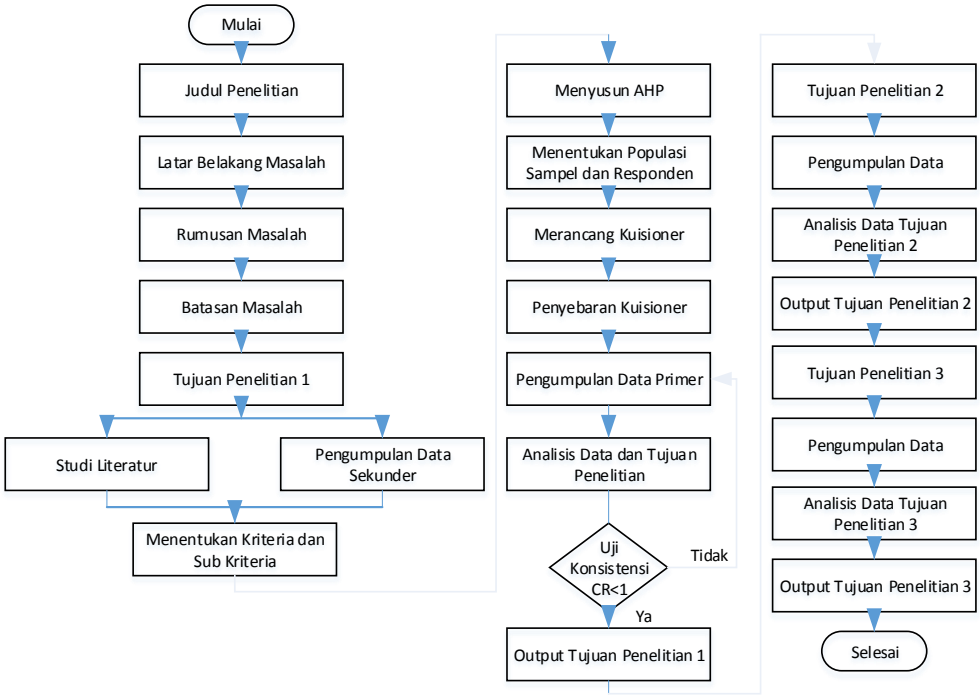

Figure 1. Diagram Alir Metodelogi Penelitian

C. Results and Discussion

First Goal Data Analysis

The data analysis for the first research objective is as follows Hierarchical structure *Analytical Hierarchy Process* (AHP)

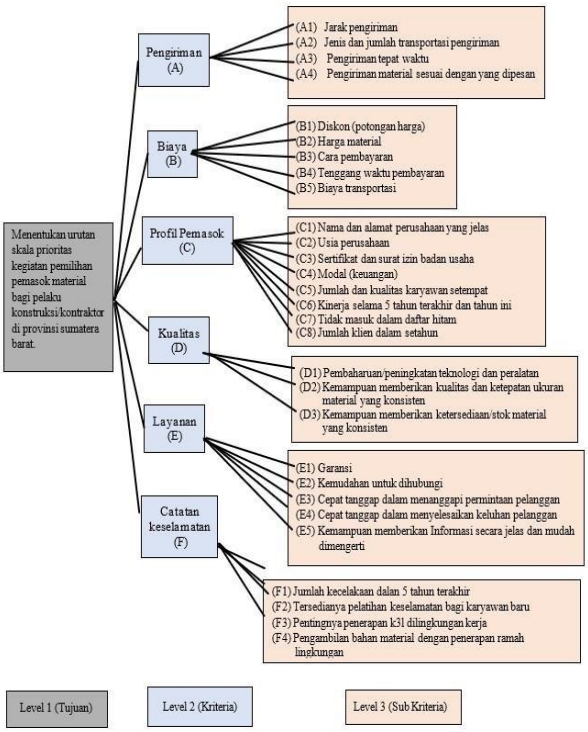

Figure 2. Hierarchical Structure*Analytical Hierarcy Process* (AHP) Research

Pair comparison and weighting criteria

Results of pair comparisons and weighting of combination results criteria for 36 respondents by paying attention to value*Consistency Ratio* shown in Table 1.

Table 1 Weights and CR Values for Pairwise Comparison Matrix between criteria

Criteria	Weight	Persentase
Delivery Factor (A)	0,117	11,7 %
Cost Factor (B)	0,058	5,8 %
Supplier Profile Factor (C)	0,497	49,7 %
Quality Factor (D)	0,068	6,8 %
Service Factor (E)	0,041	4.1 %
Safety Record Factor (F)	0,219	21,9 %
CR (Consistency Ratio)	0,03 < 0,10	3 % < 10 %

Based on the results of program analysis expert *choice* with results as shown in Table 1. The weights and consistency ratio values for the pairwise comparison matrix between the criteria were obtained consistency *ratio* (CR) 0.03, meaning that the matrix of the criteria is said to be consistent, because the value consistency *ratio* (CR) < 0.1. On the other hand, it is also known that the "Supplier Profile" criterion has the largest weight, namely 0.497 or 49.70%, so the order of weight of the criteria that influences the priority of selecting flexible pavement material suppliers in West Sumatra is (1) Supplier profile factor (49.7%) (2) Safety record factor (21.9%) (3) Delivery factor (11.7%) (4) Quality factor (6.8%) (5)Cost factor (5.8%) (6) Service factor (4.1%).

Pair comparison and weighting of sub-criteria within each criterion

The results of pair comparisons and the weighting of sub-criteria in each criterion are combined results for 36 respondents taking into account the value*Consistency Ratio* namely as follows:

A. Sub criteria in the delivery factor criteria

The results of weighting and assessment*Consistency Ratio* as in Table 2.

Table 2. CR Weights and Values for Pairwise Comparison Matrix Sub-criteria Based on Delivery Factor Criteria

Criteria: Delivery Factor (A)		
Sub Criteria	Weight	Persentase
A1. Delivery distance	0,263	26,3 %
A2. Type and amount of shipping transportation	0,135	13,5 %
A3. Delivery on time	0,344	34,4 %
A4. Delivery of materials as ordered	0,258	25,8 %
CR (Consistency Ratio)	0,0049 < 0,10	0,5 % < 10 %

Based on the results of program analysis *expert choice* with results as shown in Table 2. Weights and values *consistency ratio* for the pairwise comparison matrix, sub-criteria based on the delivery criteria get a value *consistency ratio* (CR) 0.0049, meaning that the matrix of these criteria is said to be consistent, because the value *consistency ratio* (CR) < 0.1. On the other hand, it is also known that the "On Time Delivery" sub-criterion in the delivery factor criteria has the largest weight, namely 0.344 or 34.4%, and the lowest weight is the "Type and Amount of Delivery Transportation" sub-criterion, namely 0.135 or 13.5%.

B. sub criteria in the cost factor criteria

The results of weighting and assessment *Consistency Ratio* as in Table 3.

Table 3 CR Weights and Values for Pairwise Comparison Matrix Sub-criteria Based on Cost Factor Criteria

Criteria: Cost Factor (B)		
Sub Criteria	Weight	Persentase
B1. Discounts (discounts for orders of a certain amount)	0,319	31,9 %
B2. Material prices	0,148	14,8 %
B3. Payment method	0,161	16,1 %
B4. Payment deadline	0,259	25,9 %
B5. Transportation costs	0,113	11,3 %
CR (Consistency Ratio)	0,0045 < 0,10	0,5 % < 10 %

Based on the results of program analysis expert *choice* with results as shown in Table 3. Weights and values consistency *ratio* for the pairwise comparison matrix, the sub-criteria based on the cost criteria get a value consistency *ratio* (CR) 0.0045, meaning that the matrix of these criteria is said to be consistent, because the value consistency *ratio* (CR) < 0.1. On the other hand, it is also known that the sub-criterion "Discounts (discounts for orders in certain quantities)" in the cost factor criteria has the largest weight, namely 0.319 or 31.9%, and the lowest weight is the sub-criterion "Transportation costs" namely 0.113 or 11, 3%.

C. Sub criteria in supplier profile factor criteria

The results of weighting and assessment*Consistency Ratio* as in Table 4.

Table 4. CR Weights and Values for Pairwise Comparison Matrix Sub-criteria Based on Supplier Profile Factor Criteria

Criteria: Supplier Profile Factors (C)		
Sub Criteria	Weight	Persentase
C1. Clear company name and address	0,118	11,8 %
C2. Company age	0,083	8,3 %
C3. Business entity certificates and permits	0,247	24,7 %
C4. capital (financial)	0,087	8,7 %
C5. Number and quality of employees	0,075	7,5 %
C6. Performance over the last 5 years and this year	0,081	8,1 %
C7. Not blacklisted	0,237	23,7 %
C8. Number of clients in a year	0,072	7,2 %
C1. Clear company name and address	0,001 < 0,10	0,1 % < 10 %

Based on the results of program analysis*expert choice* with results as shown in Table 4. The weights and consistency ratio values for the sub-criteria pairwise comparison matrix based on the supplier profile criteria obtained values*consistency ratio* (CR) 0.001, meaning that the matrix of the criteria is said to be consistent, because the value*consistency ratio* (CR) < 0.1. On the other hand, it is also known that the sub-criterion "Certificates and permits for business entities" in the supplier profile

factor criteria has the largest weight, namely 0.247 or 24.7%, and the lowest weight is the sub-criterion "Number of clients in a year" namely 0.072 or 7.2 %.

D. Sub criteria in the quality factor criteria

The results of weighting and assessment*Consistency Ratio* as in Table 5.

Table 5 CR Weights and Values for Pairwise Comparison Matrix Sub-criteria Based on Quality Factor Criteria

Criteria: Quality Factor (D)		
Sub Criteria	Weight	Persentase
D1. Renewal/improvement of technology and equipment	0,544	54,4 %
D2. Ability to provide consistent quality and accuracy of material sizes	0,272	27,2 %
D3. Ability to provide consistent material availability/stock	0,184	18,4 %
CR (Consistency Ratio)	0,02 < 0,10	2 % < 10 %

Based on the results of program analysis*expert choice* with results as shown in Table 5. The weights and consistency ratio values for the sub-criteria pairwise comparison matrix based on the quality criteria obtained values*consistency ratio* (CR) 0.02, meaning that the matrix of the criteria is said to be consistent, because the value*consistency ratio* (CR) < 0.1. On the other hand, it is also known that the sub-criterion "Renewal/improvement of technology and equipment" in the quality factor criteria has the largest weight, namely 0.544 or 54.4%, and the lowest weight is the sub-criterion "Ability to provide consistent material availability/stock" namely 0.184 or 18.4%.

E. Sub criteria in the service factor criteria

The results of weighting and assessment*Consistency Ratio* as in Table 6.

Table 6 CR Weights and Values for Pairwise Comparison Matrix Sub-criteria Based on Service Factor Criteria

Criteria: Service Factor (E)		
Sub Criteria	Weight	Persentase
E1. Warranty	0,253	25,3 %
E2. Ease of contact	0,187	18,7 %
E3. Be quick and responsive respond to customer requests	0,210	21,0 %
E4. Quickly respond in resolving customer complaints	0,193	19,3 %
E5. Ability to provide information clearly and easy to understand	0,156	15,6 %
CR (Consistency Ratio)	0,0027 < 0,10	0,5 % < 10 %

Based on the results of program analysis*expert choice* with results as shown in Table 6. The weights and consistency ratio values for the sub-criteria pairwise comparison matrix based on the service criteria obtained values*consistency ratio* (CR) 0.0027, meaning that the matrix of these criteria is said to be consistent, because the value*consistency ratio* (CR) < 0.1. On the other hand, it is also known that the "Warranty" sub-criterion in the service factor criteria has the largest weight, namely 0.253 or 25.3%, and the lowest weight is the "Ability to provide information clearly and easily understood" sub-criterion, namely 0.156 or 15.6%

F. Sub criteria in the safety record factor criteria

The results of weighting and assessment*Consistency Ratio* as in Table 7.

Table 7 CR Weights and Values for Pairwise Comparison Matrix Sub-criteria Based on Safety Note Factor Criteria.

Criteria: Safety Record Factor (F)		
Sub Criteria	Weight	Persentase
F1. Number of accidents in the last 5 years	0,125	12,5 %
F2. Availability of safety training for new employees	0,213	21,3 %
F3. The importance of implementing K3L in the workplace	0,203	20,3 %
F4. Taking materials with environmentally friendly practices	0,459	45,9 %
CR (Consistency Ratio)	0,001 < 0,10	0,5 % < 10 %

Based on the results of program analysis*expert choice* with results as shown in Table 7. The weights and consistency ratio values for the sub-criteria pairwise comparison matrix based on the safety record criteria obtained values*consistency ratio* (CR) 0.001, meaning that the matrix of the criteria is said to be consistent, because the value*consistency ratio* (CR) < 0.1. On the other hand, it is also known that the sub-criterion "Extraction of materials with environmentally friendly applications" in the service factor criteria has the largest weight, namely 0.459 or 45.9%, and the lowest weight is the sub-criterion "Number of accidents in the last 5 years" namely 0.125 or 12 .5%.

The form of criteria that needs to be considered and most influential

From the results of the analysis carried out by researchers, the criteria that need to be considered and which most influence the priority of selecting flexible pavement material suppliers in the West Sumatra region are as shown in Table 8.

Table 8 Criteria that need to be considered and which influence the most in determining priorities for selecting flexible pavement material suppliers.

Criteria	Weight (%)
Delivery (A)	11,70 %
Cost (B)	5,80 %
Supplier Profile (C)	49,70 %
Quality (D)	6,80 %
Service (E)	4,10 %
Safety Notes (F)	21,90 %

Based on Table 8, the criteria that need to be considered and which influence the priority determination of aggregate material suppliers for asphalt mixtures in the West Sumatra region are: The "Supplier Profile Factor (C)" criterion.

Second Objective Data Analysis

Analysis of the second research objective was carried out after knowing the weighting and testing the consistency of form between criteria and sub-criteria, also the criteria considered and influencing were known with the results as in Table 8, then the priority alternative weighting was carried out from the final summation results using the application*expert choice* by paying attention to the criteria and sub-

criteria with conditions*consistency ratio*must not exceed the predetermined threshold, namely in accordance with equation 2.5.*consistency ratio* (CR) < 0,1.

Determination and order of priority scale for selecting flexible pavement material suppliers

Table 9 Calculation of priority scale weights for criteria and sub-criteria for selecting flexible pavement material suppliers.

Criteria	Criteria Weight	Sub Criteria	CR	Sub Weight Criteria	Final Weight	Priority Ranking
Delivery (A)	0,117	A1	0,0049	0,263	0,027	13
		A2		0,135	0,014	19
		A3		0,344	0,035	10
		A4		0,258	0,027	14
Cost (B)	0,058	B1	0,0045	0,319	0,018	17
		B2		0,148	0,008	26
		B3		0,161	0,009	25
		B4		0,259	0,014	18
		B5		0,113	0,006	29
Supplier Profile (C)	0,497	C1	0,001	0,118	0,072	3
		C2		0,083	0,051	6
		C3		0,247	0,151	1
		C4		0,087	0,053	5
		C5		0,075	0,045	8
		C6		0,081	0,049	7
		C7		0,237	0,145	2
		C8		0,072	0,044	9
Quality (D)	0,068	D1	0,02	0,544	0,020	15
		D2		0,272	0,010	22
		D3		0,184	0,007	28
Service (E)	0,041	E1	0,0027	0,253	0,013	20
		E2		0,187	0,009	24
		E3		0,210	0,010	21
		E4		0,193	0,010	23
		E5		0,156	0,008	27
Safety Notes (F)	0,219	F1	0,01	0,125	0,018	16
		F2		0,213	0,031	11
		F3		0,203	0,029	12
		F4		0,459	0,066	4

Table 10 Description of sub-criteria column codes in table 9

Code	Information
A1	Delivery distance
A2	Type and amount of shipping transportation
A3	Delivery on time
A4	Delivery of materials as ordered
B1	Discounts (discounts for orders of a certain amount)
B2	Material prices

B3	Methods of payment
B4	Payment deadline
B5	Transportation costs
C1	Clear company name and address
C2	Company age
C3	Business entity certificates and permits
C4	Capital (finance)
C5	Number and quality of employees
C6	Performance over the last 5 years and this year
C7	Not blacklisted
C8	Number of clients in a year
D1	Renewal/improvement of technology and equipment
D2	Ability to provide consistent quality and accuracy of material sizes
D3	Ability to provide consistent material availability/stock
E1	Warranty
E2	Ease of contact
E3	Quickly respond to customer requests
E4	Quickly respond in resolving customer complaints
E5	Ability to provide information clearly and easily understood
F1	Number of accidents in the last 5 years
F2	Availability of safety training for new employees
F3	The importance of implementing K3L in the work environment
F4	Taking materials with environmentally friendly practices

Based on table 9, the calculation of priority scale weights and priority order of criteria and sub-criteria for selecting flexible pavement material suppliers in West Sumatra province, the author carries out calculations in the application *expert choice*, therefore from the results of this priority scale calculation the author gets the final final weight. After the final weight is obtained, the author can create a priority weight ranking in selecting flexible pavement material suppliers from priority ranking 1 to 29.

Third Objective Data Analysis

Analysis of the third research objective was carried out after knowing the priority scale and priority order of criteria and sub-criteria for selecting flexible pavement material suppliers.

The results of the data analysis for the third objective are suggestions and solutions for road and bridge construction actors. In selecting flexible pavement material suppliers, several criteria and sub-criteria need to be considered. The author made a table containing several solutions and suggestions for selecting flexible pavement material suppliers along with explanations and the author made these suggestions and solutions totaling three suggestions with the highest percentage weight values from the six criteria.

Table 10 Suggestions and solutions for criteria and sub-criteria for selecting flexible pavement material suppliers.

Criteria and Sub Criteria	Weight (%)
Supplier Profile	**49,70 %**
Business entity certificates and permits	15,10 %
Not blacklisted	14,50 %
Clear company name and address	7,20 %

Capital (finance)	5,30 %
Company age	5,10 %
Performance over the last 5 years and this year	4,90 %
Number and quality of employees	4,50 %
Number of clients in a year	4,40 %
Safety Notes	**21,90 %**
Material collection with friendly application Environment	6,60 %
Availability of training for new employees	3,10 %
The importance of implementing K3L in the work environment	2,90 %
Number of accidents in the last 5 years	1,80 %
Delivery	**11,70 %**
Delivery on time	3,50 %
Delivery distance	2,70 %
Delivery of materials as ordered	2,70 %
Type and amount of shipping transportation	1,40 %

Based on the results that the author has obtained in Table 10 above, there are three criteria and sixteen sub-criteria that are characteristic in the province of West Sumatra for road and bridge construction actors in selecting flexible pavement material suppliers.

C. Conclusions

The conclusions from this research are:

1. There are six main criteria that need to be considered in determining priorities for selecting flexible pavement material suppliers in West Sumatra province. These criteria are: supplier profile criteria with a weight of 49.70%, safety record criteria 21.90%, delivery criteria 11.70%, quality criteria 6.80%, cost criteria 5.80%, service criteria 4.10%.
2. From calculating the weight of the results from the data for the first objective, the priority order for selecting suppliers of flexible pavement materials in West Sumatra province is obtained as follows:
   a) Order of priority scale according to criteria: 1. Supplier profile, 2. Safety records, 3. Delivery, 4. Quality, 5. Cost, 6. Service.
   b) Order of priority scale in sub-criteria: 1. Certificate and business entity permit, 2. not included in the black list, 3. Clear company name and address, 4. Material collection with environmentally friendly practices, 5. Capital (finance), 6. Company age, 7. Performance over the last 5 years and this year, 8. Number and quality of employees, 9. Number of clients in a year, 10. Timely delivery, 11. Availability of training for new employees, 12. The importance of implementing K3L in the environment work, 13. Delivery distance, 14. Delivery of materials as ordered, 15. Renewal/improvement of technology and equipment, 16. Number of accidents in the last 5 years, 17. Discounts (price discounts for orders of a certain amount), 18. Payment grace period, 19. Type and quantity of delivery transportation, 20. Guarantee, 21. Fast responsive in responding to customer requests, 22. Ability to provide consistent quality and accuracy of material sizes, 23. Quick response in resolving customer complaints, 24. Ease of contact, 25. Method of payment, 26. Material prices, 27. Ability to provide information clearly and easily understood, 28. Ability to provide consistent material availability/stock, 29. Transportation costs.
3. From the author's analysis, the criteria and sub-criteria used as suggestions or solutions in selecting flexible pavement material suppliers in West Sumatra province are as follows:

a) Supplier profile: 1. Business entity certificate and permit, 2. not blacklisted, 3. Clear company name and address, 4. Capital (finance), 5. Company age, 6. Performance over the last 5 years and this year, 7. Number and quality of employees, 8. Number of clients in a year.
b) Safety notes: 1. Material collection with environmentally friendly practices, 2. Availability of training for new employees, 3. the importance of implementing K3L in the work environment, 4. Number of accidents in the last 5 years.
c) Delivery: 1. Delivery on time, 2. Delivery distance, 3. Delivery of materials according to order, 4. Type and quantity of delivery transportation.

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