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Analysis of Steel Plate Raw Material Supplier Selection on Rail Using Analytical Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) Methods at PT. XYZ

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A B S T R A C T

This study aims to select the best steel plate raw material suppliers at PT XYZ using the Analytical Hierarchy Process(AHP) and Additive Ratio Assessment (ARAS) methods. This research involves the process of collecting primary andsecondary data which includes identifying criteria for selecting suppliers, collecting data for each criterion, and collecting performance data from suppliers. The results showed that the order of the best supplier of steel plate raw materials at PT XYZ with the largest value, that is, ranked 1st supplier of PT. Steel Kras with a K value of 0.195207, ranked 2nd supplier of PT. Jaraindo with a K value of 0.137696, ranked 3rd supplier of PT. Capris with a K valueof 0.135158, ranks 4th supplier of PT. Kamaseta with a K value of 0.116481, ranks 5th supplier of PT. Wima Indo witha K value of 0.106039 and ranked 6th supplier of PT. CeniaMandiri with a K value of 0.084586. Based on the AHP andARAS methods, the relative weight of each criterion has been calculated, which helps in evaluating the best or potential suppliers to be selected. In addition, supplier rankings are also determined based on the resulting priority values.

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1. INTRODUCTION

The rapid development of the industrial world at this time requires a company to have the ability to compete and this is one of the reasons for companies to develop business strategies and tactics in the best possible way. It is important for companies to determine the quality of raw materials from the best suppliers in order to manufacture products according to predetermined criteria. Consumers no longer only want quality products, but also demand good and timely service. Suppliers, as providers of raw materials, play an important role in determining product quality and the smooth running of the production process. PT. XYZ is the first integrated railway manufacturing company in Southeast Asia whose products are currently being exported to various countries such as the Philippines, Bangladesh, Malaysia, Thailand, Singapore and Australia. To support the continuity of the production process, it is necessary to have sufficient supply of raw materials according to needs, so it requires good cooperation between each supplier in supplying good quality raw materials, so that they can compete in the global market.

The company relies on several suppliers to meet its raw material needs. The company experienced problems in selecting raw material suppliers for railroad steel plates. The problem that occurs is that the supplier sends goods not following the specifications and quality requested by the company. While companies want raw materials at low prices but quality is maintained. Therefore the following factors become one of the obstacles for companies to choose the right supplier and can have an impact on hindering the production process of PT. XYZ.

Derived from this background, the company needs a method to select the best supplier of steel plate raw materials so that the company can meet customer demands appropriately and increase its competitiveness in railroad production. To solve these problems, researchers used the AHP (Analytical Hierarchy Process) and ARAS (Additive Ratio Assessment) methods. The AHP (Analytical Hierarchy Process) method has the advantage that it can be done hierarchically (order of levels) from the weighting results on each criterion so that it is easily understood by several people who want to make decisions. However, the AHP (Analytical Hierarchy Process) method has a weakness in making uncertain decisions to give values to the number of criteria with pairwise comparisons. The best selection is of course made by implementing a decision support system by applying the ARAS (Additive Ratio Assessment) method because this method is used for ranking so that problems are more focused and minimize uncertainty. The AHP (Analytical Hierarchy Process) method applies the weighting results of each criterion then proceed with the ARAS (Additive Ratio Assessment) method to produce supplier performance assessments in the form of more complex rankings based on predetermined criteria to produce more accurate decisions in selecting the best supplier in PT. XYZ

By conducting this research, it is hoped that it can provide input in the problem of selecting the best steel plate raw material supplier for PT XYZ and can improve the quality of the final product. In addition, this research can also be input for other companies that have similar needs in selecting raw material suppliers.

2. LITERATURE REVIEW

The supply chain is a network of several companies that work together to create and deliver products to consumers. Some of these companies usually include suppliers, factories, distributors, shops or retail, as well as supporting companies such as logistics service companies, which are a series of mutually beneficial relationships between companies related to the distribution of goods or services from the place of origin to the final consumer. The supply chain can also be defined as a network consisting of companies that are interconnected, need and mutually benefit to make products and services that can be utilized or enjoyed by end consumers (Pujawan, 2017). From the notion of supply chain management, it can be said that all activities related to the flow of materials, information, and money along the supply chain are activities that are within the scope of supply chain management. If we look at manufacturing companies, the activities included in supply chain management are designing new products, obtaining raw materials, planning production and inventory, production, distributing products to consumers, and managing product returns. Of the six activities mentioned in a manufacturing company, it is usually divided into departments or divisions which are often called functional divisions because they are grouped according to their respective functions.

According to (Pujawan, 2017) in the supply chain there are 3 (three) types of flow, namely: (1) First is the flow of goods. Goods that were originally in the upstream (upstream) will flow to the downstream (downstream). An example of the flow of goods is the raw material for plywood sent from selected suppliers to a furniture factory. After the furniture product has been produced, the furniture product will be sent to the distributor, then proceed to sales or retail, and then to the end user, (2) Second is the flow of money. Money that was originally in the downstream (downstream) will flow towards the upstream (upstream). An example of cash flow is payment money issued by end users charged to retail which will later be used by retail to buy goods from factories. Henceforth, the factory will sell to suppliers to buy raw materials that will be used to produce goods again, (3) Third is the flow of information.

Information will be able to flow from the downstream (downstream) and will flow towards the upstream (upstream) and vice versa. An example of this flow of information is information on ordering raw materials for production from factories (downstream) flowing to suppliers (upstream), and vice versa, information on the availability of goods flowing from factories (upstream) to war (downstream). The flow of information plays an important role in producing superior supply chain management, where this information will enable the parties involved in it to make the right and best decisions. Managing the flow of information transparently and accurately will improve supply chain performance. For example, information regarding the availability of production capacity and procurement of goods owned by suppliers is often needed by factories and the status of raw material shipments is also needed by companies, where each party must be open and share information with each other for the sake of carrying out common interests and goals so that interested parties can monitoring so that planning becomes more accurate and gives managers visibility. The following is a conceptual description of the supply chain:

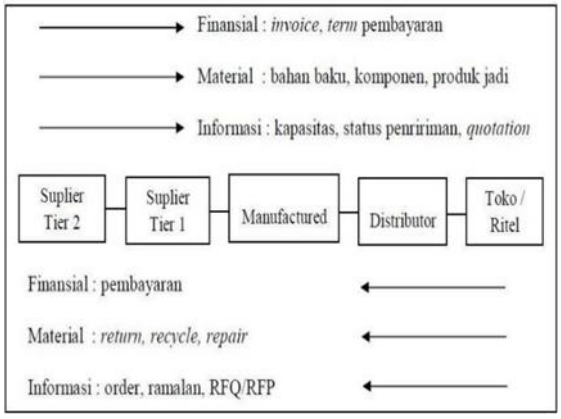

Fig. 1. Implications of 3 types of managed flow and supply chain models (Source: Pujawan, 2017)

Three kinds of flows consisting of goods, financial (money), and information flows that are managed in the supply chain must be studied efficiently and effectively where effective management can synergize supply chain management with the parties involved properly (Kindangen et al., 2018). Supply chain management is an increasingly important concept where competition is no longer only against products between products but also between supply chains. The main goal of the supply chain is to meet customer needs which in the end process is profit making (Kindangen et al., 2018).

In supply chain management, one of the elements that plays an important role is Procurement Management. According to Siahaya (2013). Procurement Management is a part that processes the procurement of goods and services for companies by considering quality, quantity, price, time, source and place, to meet the company's needs so that they can then carry out the production process. The main task of procurement management itself is to provide the inputs needed by the company, either in the form of goods or products or services that will be used for production activities or other activities within the company. Supplier selection is a multi-criteria decision-making problem involving qualitative and quantitative methods. Park stated that a supplier selection process is important. The decision-making process is carried out by evaluating each supplier so that the right supplier can be selected. Supplier selection is a complicated job because it involves more than one criterion, which must meet consumer needs. Therefore, supplier selection can be completed by analyzing the multiple criteria found in the company (Wardhana & Prastawa, 2018). According to Stevenson quoted by Pujotomo et al., (2018) in supplier selection there are 6 criteria, namely:

1. Price. Price is the main criterion in supplier selection. The criterion factor of the price itself can consist of the price offered to the company, giving discounts and discounts, even a reduction factor in the purchase price based on a certain purchase amount.
2. Quality. The quality of goods or services is the main consideration in choosing a supplier. This quality relates to the quality of the goods or services provided, the level of a defect in the delivered goods and the comparison of quality with the price offered.

According to (Pujawan, 2017) that choosing a supplier is important, especially if the supplier will supply defective materials or be used in the long term as an important supplier. Selection criteria is one of the important things in supplier

selection. However, supplier selection often requiresvarious other criteria that are considered equally important by the company. Research conducted by Dickson nearly 40 years ago showed that supplier selection criteria can vary widely. According to Tadeusz (2013) as cited by Ramdani (2018) the Analytical Hierarchy Process (AHP) is a decision-making method with several criteria and provides a rating or ranking of the available alternatives. In theory the AHP method will organize the available alternatives and their weights in a hierarchical arrangement, then assign numerical values based on subjective considerations regarding the level of importance of each criterion or sub-criteria variable of each alternative. After that the weighting results will then be arranged based on the highest priority ranking (Ramdani, 2018). The Additive Ratio Assessment (ARAS) method is a multi-criteria decision-making method or existing criteria based on the concept of ranking using a utility degree by comparing the overall index value of each alternative to the overall optimal alternative index value. In this study, the benchmark method was used to test data quantitatively to obtain ranking and produce weights for each criterion.

Table 1. Supplier selection criteria according to Dickson

Criteria	Score Criteria
Quality	3.5
Delivery	3.4
Performance history	3.0
Waranty and claims policy	2.8
Price	2.8
Technical ability	2.8
Financial position	2.5
Procedural compliance	2.5
Communication system	2.5
Reputation and position in theindustry	2.4
Desire for business	2.4
Management and organization	2.3
Operation control	2.2
Repair service	2.2
Attitude	2.1
Impression	2.1
Packaging capability	2.0
Labor relations records	2.0
Geographical location	1.9
Past number	1.6
Training aids	1.5
Feedback arrangement	0.6

(Source: Pujawan, 2017)

Later the results of the calculation, obtained is a result of the highest ranking to the lowest ranking. Afterthe highest to lowest ranking is completed, this ranking is used as input for decision-making (Ndruru, 2019).

3. RESEARCH METHOD

To solve problems that occur in research, a framework is created to solve these problems. The steps for solving the problem (flowchart) can be seen in the Fig. 2.

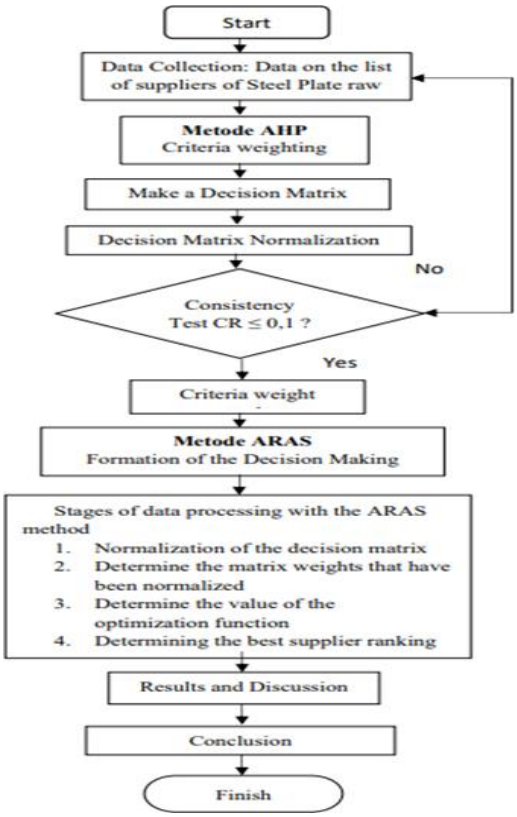

Fig. 2. Research framework

This case study aims to analyze the selection of steel plate raw material suppliers using a combination of the Analytic Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) methods. This method is used for decision-making and ranking the results of the criteria weight of each supplier. According to (Ndruru, 2019; Diana 2018), decision support systems are implementations of decision-making theories that have been introduced by sciences such as operations research and management science. The only difference is that in the past, to find a solution to the problem at hand, it had to be manually calculated iteratively (usually to

find the minimum, maximum, or optimum value). Currently the computer has offered its ability to solve the same problem in a relatively short time. Decision support systems provide support to a manager or to a group of managers in solving semi-structured problems by providing information or advice regarding certain decisions, this information can be provided in the form of periodic reports, special reports or mathematical models. The model also has the ability to provide advice to varying degrees. This decision support system is the development of an information system in decision-making, which is focused on supporting management. The existence of this decision support system is not to replace the tasks of managers, but to become a means of support for them (Diana, 2018). The selection of steel plate raw material suppliers is important for the company. This is because the quality of the availability of these raw materials is very important in the production process. The AHP and ARAS methods are used to identify the importance of the weight of the criteria and to rank each supplier that has worked with the company.

AHP is often used as a problem-solving method compared to other methods because: (1) A hierarchical structure as a consequence of the selected criteria, down to the deepest sub-criteria, (2) Take into account the validity up to the tolerance limit for inconsistency of various criteria and alternatives chosen by decision-makers, (3) Taking into account the durability of the sensitivity analysis output decision-making (Limbong, 2020). The ARAS method is used to quantitatively test data to obtain ranking and produce weights for each criterion. Later the results of the calculation, obtained is a result of the highest ranking to the lowest ranking. After the highest to lowest ranking is completed, the ranking is used as input for decision making (Ndruru, 2019). Researchers collect information and data needed from companies to solve a problem that will be studied, by conducting interviews and distributing questionnaires to obtain data that needs to be processed so that it can facilitate analysis.

The ARAS method is also the method used for ranking criteria. Conceptually, the ARAS method is used in conjunction with other methods that use the ranking concept. ARAS rating helps companies get information about supplier recommendations. To calculate supplements in a comprehensive decision support system and consider qualitative and quantitative aspects, this method uses the criteria for purchasing supplements for poor families, profession, income, number of families, type and age of house, usually very different, so their income is different (Hutagalung et al., 2022).

This method was originally introduced in 2010 by Zavadskas and Turkis from Vilvinus Gediminas Technical University. This Additive Ratio Assessment (ARAS) method is a utility value function that determines the relative efficiency of the complex of feasible alternatives and is proportional to the relative effect of the value and weight of the criteria considered. The Additive Ratio Assessment (ARAS) method is used for data management and several computerized criteria starting from alternative adjustments, calculating weighting, calculating dominance values, calculating preferences, and calculating index values (Halimah et al., 2020).

4. RESULT AND DISCUSSION

For this study, data collection was taken from the results of interviews and questionnaires at PT. XYZ. In this study requires two questionnaires. The first is a questionnaire on the level of importance (weight) of the criteria, and the second is a supplier assessment questionnaire where the filling out the questionnaire must be carried out sequentially. When making a decision regarding the best steel plate raw material supplier at PT. XYZ, it requires the following criteria to support decision-making. The use of this method is suggested as an alternative method in organized decision- making. It is necessary to carry out interviews and data collection on decision making at PT. XYZ, namely that criteria are considered in choosing the best supplier.

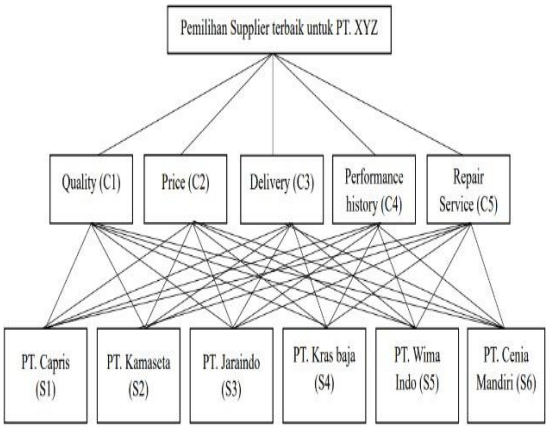

Fig. 3. Hierarchy structure

Based on the results of observations of conducting research and interviews with the company, several criteria were obtained to determine which criteria were considered important for the company in assessing the company's performance based on the references in Table 1. Then several criteria for selecting the best steel plate raw material. Material supplier. The criteria referred to are quality, price, delivery, performance history, and repair services. The following is a table of several supplier selection criteria.

Table 2. Supplier selection criteria

Indicator	Criteria
C1	Quality
C2	Price
C3	Delivery
C4	Performance history
C5	Repair service

(Source: expert interview)

In this study, the results of interviews that have been carried out with the company obtained supplier data which is an alternative to selecting the best supplier. There are several suppliers trusted by the company to work together in supplying steel plate raw materials. The following is a list of its suppliers.

Table 3. Data on supplier list of steel plate raw materials

No	Supplier
1	PT. Capris
2	PT. Kamaseta
3	PT. Jaraindo
4	PT. Kras baja
5	PT. Wima indo
6	PT. Cenia mandiri

(Source: PT. XYZ)

After filling in the data on the questionnaire, the next step is to recapitulate the results on the questionnaire on the level of importance between the criteria and supplier evaluation. From the results of the assessment in the questionnaire, data processing will then be carried out. Later the data obtained will be further processed in stages until the final results are obtained accordingly.

There are results of a comparison questionnaire from each criterion, namely in the form of a number 1-9 by showing a comparison of the importance level of the criteria. The assessment was carried out by 5 respondents namely Senior Manager, Manager Purchasing, Purchasing, Quality control, and warehouse.

Table 4. Recapitulation of interest level questionnaire result between criteria

Comparison Criteria	Senior Manager	Purchasing	Purchasing	Quality	Warehouse	Geometric Mean
Quality - Price	5	0.333	3	1	1	1
Quality - Delivery	8	5	5	8	3	5
Quality - Performance history	3	1	2	0.333	0.333	1
Quality - Repair service	3	3	1	7	0.2	2
Price - Delivery	3	5	2	3	5	3
Price - Performance history	1	0.333	2	1	3	1
Price - Repair Service	2	3	2	4	3	3
Delivery - Performance history	0.333	0.2	0.2	3	1	1
Delivery - Repair Service	1	0.333	0.5	2	1	1
Performance history - Repair service	0.333	3	1	3	2	1

(Source: processed data)

Then these results are averaged with the geometric mean. This calculation was made because the Analytical Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) methods only require one answer for the pairwise comparison matrix. The results are obtained as follows:

Geometric Mean: $\sqrt{(X1)(X2) \dots (Xn)}$ (1)

Information:

X1 : Assessment of the 1st respondent
X2 : Assessment of the 2nd respondent
Xn : Assessment of the 3rd respondent
n : Number of respondents

After getting the results from the geometric mean, they will then be entered in the pairwise comparison matrix between criteria. Furthermore, the criteria are determined, followed by the weighting of the criteria in the selection of suppliers using the Analytical Hierarchy Process (AHP) method. Then a pairwise comparison matrix is made which can be seen in the matrix below.

From the pairwise comparison matrix, the criteria are obtained from the assessment of each existing criterion. Based on the results of the questionnaire for the importance level of the criteria, a value of 1 was obtained, which means that there is a relationship between criteria where the value of the importance level is comparable. Relationship criteria that have a value of 1 are quality - performance history, price - performance history, delivery - performance history, delivery - repair service, performance history - quality, performance history - price, performance history - delivery, performance history - repair service, repair service – Performance history.

Meanwhile, the criteria with a value of 1/2 are price - quality, repair service - quality, repair service - price, and vice versa with a value of 2, namely quality - price, quality - repair service which means that it is closer to a little more important. Then the criteria that have a value of 1/3, namely delivery - price, repair service - delivery, and vice versa also have a value of 3, namely price - delivery, price-repair service which has a slightly more important meaning. In addition, there is also a value of 1/5, namely on the delivery criteria – quality, and vice versa with a value of 5, namely quality - delivery which has a more important meaning.

Table 5. Criteria pairwise comparison matrix

	Quality	Price	*Delivery*	P. History	R. Service
Quality	1	1	5	1	2
Price	1	1	3	1	3
Delivery	1/5	1/3	1	1	1
P. History	1	1	1	1	1
R. Service	1/2	1/3	1	1	1

(Source: processed data)

In the Analytical Hierarchy Process (AHP) method, the nature of the hierarchy is defined as a representation of a complex problem at a level where the first level is the goal, the next level is the criteria, and so on until the last level is an alternative. The existence of a hierarchy in a problem that is complex can be broken down into groups which are then arranged into a supplier ranking hierarchy. At the first level is the goal, namely the selection of the best supplier. The second level is the criteria used in supplier selection, there are 5 criteria, namely quality, price, delivery, performance history, and repair

services. Furthermore, the third or last level in the hierarchy is an alternative supplier that will be chosen, namely PT. Capris, PT. Kamaseta, PT. Jaraindo, PT. Steel Kras PT. Wima Indo, and PT. Cenia Mandiri.

The next step is to create a pairwise comparison matrix. Then the results of the comparison of each criterion are in the form numbers 1 to 9 which show the comparison of the level of importance of a criterion. The assessment was carried out by senior managers, purchasing managers, purchasing quality, control, and warehouses as competent people in the field of suppliers at PT. XYZ (Repair service) is its 0.135. The calculation is as follows:

1. Total in the first column: =1+1+0.2+1+0.5 = 3.7
2. Total in the second colum =1+1+0.333+1+0.333 = 3.666

The following is the result of the sum of each column of the pairwise comparison matrix between criteria.

Table 6. The sum of the pairwise comparison matrices between criteria

	C1	C2	C3	C4	C5
C1	1	1	5	1	2
C2	1	1	3	1	3
C3	0.2	0.333	1	1	1
C4	1	1	1	1	1
C5	0.5	0.333	1	1	1
Total	**3.7**	**3.666**	**11**	**5**	**8**

(Source: processed data)

➢ C1-C1 = 1/3,7 = 0.270
➢ C2-C1 = 1/3,7 = 0.270

Table 7. Normalization of pairwise comparison matrix between criteria

	C1	**C2**	**C3**	**C4**	**C5**	**Average**
C1	0.270	0.272	0.455	0.200	0.256	0.291
C2	0.270	0.272	0.273	0.200	0.384	0.280
C3	0.054	0.090	0.091	0.200	0.103	0.108
C4	0.270	0.272	0.091	0.200	0.128	0.192
C5	0.135	0.090	0.091	0.200	0.128	0.129
Tot.	**1**	**1**	**1**	**1**	**1**	**1**

(Source: processed data)

It can be seen from the matrix above that theaverage of each row will be the weight value of these criteria. The weight of the C1 feature(Quality) is 0.270, the C2 feature weight (Price) is 0.270, the C3 (Delivery) feature weight is 0.054, the C4 feature weight (performance history) is 0.270, and the C5 feature weight 0.135.

Table 8. Weight of each criterion

Criteria	**Weight**
Quality (C1)	0.291
Price (C2)	0.280
Delivery (C3)	0.108
Performance History (C4)	0.192
Repair Service (C5)	0.129

(Source: Processed data)

After that the consistency ratio (Consistency Ratio) is obtained from a comparison of the consistency index with the value of the random number (RI). The RI value for n = 5 = 1.12

Table 9. Consistency ratio

Matrix size	RI
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

(Source: Suryani, 2020)

CR : Consistency Ratio
CI : Consistency Index
RI : Average random consistency
CR : CI / RI
CR : 0.057684 / 1.12 = 0.05150415

The consistency value of the pairwise comparison matrix between alternatives has a CR value ≤ 0.1 = 0.0515 ≤ 0.1, so it can be saidto be consistent or it can be said to have met therequirements.

Table 10. Matrix Weighting Results

Supplier	C1	C2	C3	C4	C5
A0	0.063261	0.05833	0.028421	0.04571424	0.03225
A1	0.037956	0.035	0.011368	0.02742854	0.01935
A2	0.037956	0.023333	0.011368	0.02742857	0.0129
A3	0.004951	0.058333	0.017053	0.02742857	0.0258
A4	0.063261	0.046666	0.017053	0.03657143	0.0258
A5	0.025304	0.035	0.011368	0.01828571	0.0129
A6	0.025304	0.023333	0.011368	0.00914286	0.0129

Source: processed data

Next is to determine the value of the optimization function (Si), then the overall index value for each alternative is calculated by adding up the weighted normalized decisionmatrix elements for each alternative with the following formula:

$$Si = \sum_{j=1} dij \ (i = 1,2,\ldots m: j= 1,2,\ldots,n)$$

Information:
Si : The value of the optimization function
dij : weight value in row i column j

The following can be seen below is the result ofcalculating the value in the optimization function.

Table 11. Optimization function

Supplier	Optimization function
S0	0.227979
S1	0.131103
S2	0.112987
S3	0.133565
S4	0.189351
S5	0.102858
S6	0.082049
Total	**0.97**

Source: processed data

The next step is to determine the highest-ranking level of the alternative (utility degree). Later the utility degree value is calculated by dividing the overall index value in the i-th alternative by the overall index value in the optimal alternative. Here's the ranking formula:

$$Ki = Si / So$$

Information:
Ki: utility degree
Si: The value of the optimization function
So: The sum of the optimization function values

The following can be seen below are the results of the utility degree calculation:

Table 12. The sum utility degree

No	Supplier name	Ki	Rank.
1	PT. Kras Baja	0.195207	1
2	PT. Jaraindo	0.137696	2
3	PT. Capris	0.135158	3
4	PT. Kamaseta	0.116481	4
5	PT. Wima Indo	0.106039	5
6	PT. CeniaMandiri	0.084586	6

Source: processed data

As can be seen in Table 12, the value obtained in the supplier ranking with the largest value is rank 1 supplier PT. Steel Kras with a K value of 0.195207, ranked 2nd supplier of PT. Jaraindo with a K value of 0.137696, ranked 3rd supplier of PT. Capris with a K value of 0.135158, ranks 4th supplier of PT. Kamaseta with a K value of 0.116481, ranks 5th supplier of PT. Wima Indo with a K value of 0.106039 and ranked 6th supplier of PT. Cenia Mandiri with a K value of 0.084586.

5. CONCLUSIONS

The conclusions resulting from research and data processing using the AHP (Analytical Hierarchy Process) Method and the ARAS (Addidtive Ratio Assessment) Method, the best supplier sequence of steel plate raw materials at PT. XYZ is obtained with the largest value, namely, rank 1 supplier PT. Steel Kras with a K value of 0.195207, ranked 2nd supplier of PT. Jaraindo with a K value of 0.137696, ranked 3rd supplier of PT. Capris with a K value of 0.135158, ranked 4th supplier of PT. Kamaseta with a K value of 0.116481, ranked 5th supplier of PT. Wima Indo with a K value of 0.106039 and ranked 6th supplier of PT. Cenia Mandiri with a K value of 0.084586.

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