ASTONJADRO

pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 2, June 2025, pp.0661-0670
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17828 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Substitution of LRT Jabodebek Carbody Material Based on Safety Factor and Price using SPK, SAW, WP and WASPAS

Resi Sabanta Belanusa, Bi Asngali, Sukoroto Sukoroto

Applied Bachelor of Rolling Stock Engineering, Madiun State Polytechnic, Madiun, INDONESIA

E-mail: resisabanta@gmail.com, biasngalimt@pnm.ac.id, sukoroto@gmail.com

| Submitted: September 26, 2024 | Revised: September 30, 2024 | Accepted: December 30, 2024 |

| Published: May 14, 2025 |

ABSTRACT

This research raises the issue of substituting Jabodebek LRT carbody materials by considering safety factors and prices using three Decision Support Systems (SPK), namely Simple Additive Weighting (SAW), Weighted Product (WP), and Weighted Aggregated Sum Product Assessment (WASPAS). The results showed that it is necessary to consider the ranking of the results from the SPK against the safety factor, and price in choosing the right aluminium material for the carbody. The three GMS used gave similar rankings for aluminium materials, which shows that these methods are consistent in measuring material quality. Therefore, these three methods can be considered valid. Based on the rankings given by the three CBMS, 7034-T6 aluminium material has the highest quality, followed by 7001-T6 and 7178-T6. Lower-ranked materials include 6061-T6, 6063-T6, and 6066-T6. If budget is not an issue, it is best to choose materials with the highest quality ratings, such as 7034-T6, 7001-T6, or 7178-T6. However, if price is a priority, you should choose a material with a lower quality rating but a more economical price, such as 6061-T6, 6063-T6, or 6066-T6.

Keywords: meterial price; LRT; safety factor; SAW; WP; WASPAS.

INTRODUCTION

PT Industri Kereta Api (Persero) as a manufacturing company for railway facilities has produced several types of railway products and electric buses. One of the products of PT INKA is Jabodebek LRT. The production process is carried out using advanced technology and based on high quality in order to produce safe and reliable vehicles. Light Rail Transit (LRT) is a mass transportation that is still unfamiliar to the people of Indonesia, so design and configuration are important components for the operation of this transportation (Putra & Windharto, 2017).

Carbody on LRT has an important role in performing the function of efficient and safe mass transportation (Nurfadillah, 2018). In addition to protecting passengers from weather and other hazards, the carbody also serves to improve the aerodynamics and stability of the train during travel (Syaifudin et al., 2021). An attractive and modern carbody design can also increase the attractiveness and positive image of Jabodebek LRT as a mode of public transportation. In addition to having an important role in the transportation function, the carbody on the Jabodebek LRT also plays an important role in maintaining the strength and durability of the train structure. A carbody designed to support high weights and speeds can help reduce the load on other parts of the train, such as bogies or traction engines (Harak et al., 2014). In addition, proper material selection and construction techniques in carbody manufacturing can ensure that the train has optimal strength and durability.

In interviews with PT INKA (Persero) employees conducted on June 4, 2023, material selection is carried out by determining criteria as a standard for the feasibility of a material to be used, but in the selection of these materials there is no method that can provide the best material assessment based on the specified criteria, so this research proposes a method that can be used to provide the best material assessment of several material options that are compared.

Material selection in this study was carried out using the SAW, WP, and WASPAS SPK methods for ranking material substitutions by considering the importance of selecting the right material in the manufacturing process. This research was conducted based on safety factors and prices which were then ranked to determine the best material. The three Decision Support Systems (SPK) have been used in several studies such as research Amalia et al (2019) which uses three methods of SAW, WP, and WASPAS to determine PMDK scholarship recipients. Research Yanto (2020) using the SAW and WASPAS methods to select PPK election members, and Siregar et al., (2022) which uses WASPAS to determine applications on smartphones that are good to use for children at the elementary level. From some previous literature, the SPK SAW, WP, and WASPAS methods have been used in decision making, but research that discusses the context of selecting Aluminum Alloy materials using these three methods has not been found.

Aluminum Alloy is a carbody material that has medium strength and excellent corrosion resistance (Syaifudin et al., 2021; Zhao et al., 2023). aluminum alloy was originally used in the aviation industry, but over time this material has been used for the development of fast train projects in China in the last 20 years (Sun et al., 2021). The use of aluminum alloy as an LRT carbody material attracts the attention of researchers to analyze the differences between the three SPKs WAS, WP, and WASPAS based on safety factors and prices. Thus, the most effective and efficient method can be found in determining the best Aluminum Alloy material based on predetermined material criteria so that it can be used as a Jabodebek LRT carbody material recommendation.

Beyond its recreational appeal, the GAP supports local economies and promotes sustainable tourism. It encourages a slower, more immersive form of travel that allows users to appreciate the region's natural beauty and cultural heritage. Whether for a weekend getaway or a long-distance adventure, the Great Allegheny Passage stands out as a premier example of how former railway lines can be repurposed to provide safe, enjoyable, and environmentally friendly travel experiences (Kurniawan W & Rulhendri R, 2015; Sulastri D et.al, 2020; Sanjaya A, 2021).

RESEARCH METHODS

The research is designed to be useful for determining decisions on the use of Jabodetabek LRT carbody substitution materials based on safety factors and prices. The implementation of the research took place at the Madiun State Polytechnic laboratory Jl. Ring Road Barat, Winongo, Mangunharjo, Madiun City, East Java by conducting interviews with PT INKA employees.

The Simple Additive Weighting (SAW) method is known as the weighted sum method (Sukaryati & Voutama, 2022). The SAW method has the basic concept of finding the weighted sum of the performance ratings on each alternative from all attributes (Syam & Rabidin, 2019). The steps of the SAW method calculation are: a) Determine the criteria that will be used as a reference in decision making, namely b) Determine the suitability rating of each alternative on each criterion. c) Create a decision matrix based on criteria, then normalize the matrix based on equations that are adjusted to the type of attribute (profit attribute or cost attribute) so that a normalized matrix R is obtained.

$$r_{ij} \begin{cases} \dfrac{X_{IJ}}{Max^{X_{ij}}} & \text{Advantage Attributes (Benefit)} \\ \dfrac{Min^{X_{ij}}}{X_{ij}} & \text{Loss Attributes (Cost)} \end{cases}$$

Description:
Rij: Normalized performance rating value
Xij: The attribute value of each criterion
Max Xij : The largest value of each criterion i
Min Xij : The smallest value of each criterion i
Benefit: If the largest value is the best
Cost: If the smallest value is best

ASTONJADRO
pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 2, June 2025, pp.0661-0671
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17828 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The final result obtained from the ranking process is the sum of the multiplication of the normalized matrix R with the weight vector so that the largest value is selected as the best alternative (A) as a solution.

$$V_i = \sum_{j=1}^{n} W_j r_{ij}$$

Description:

Vi: Ranking for each alternative
Wj : Weight value of each criterion
Rij : Normalized performance rating value

The Weighted Product (WP) method evaluates several alternatives against a set of attributes and criteria, where each attribute is independent of the others (Abbas, 2016). This method is done with the multiplication technique to connect attribute ratings, where the rating of each attribute is multiplied by the weight of the attribute concerned. The steps of the WP method calculation are: a) Determine the criteria; b) Determine the suitability rating on each criterion; c) Normalization or weight improvement.

$$W_j = \frac{w_j}{\sum w_j}$$

Description:
Wj : Normalized weight value
wj : Attribute value of each criterion
$\sum w_j$: Normalized performance rating value

Determine the value of the vector S.

$$S_i = \sum_{j=1}^{n} X_{ij}^{W_j}$$

Description:
Si: Criterion preference
Xij : Criterion value
Wj : Normalized weight value

Determine the value of the vector V.

$$V_i = \frac{\prod_{j=1}^{n} X_{ij}^{W_j}}{\prod_{j=1}^{n} X_{ij} \times W_j} \text{ atau } V_i = \frac{S_i}{\sum S_i}$$

Description:
Vi: Ranking for each alternative
Si: Criterion preference
Xij : Criterion value
Wj : Normalized weight value

The Weighted Aggregates Sum Product Assessment method evaluates several alternatives against a set of attributes and criteria, where each attribute is independent of one another (Rizka, 2022). This method is done with the multiplication technique to connect attribute ratings, where the rating of each attribute is multiplied by the weight of the attribute concerned. The steps of the WP method calculation are: a) Determine the criteria. b) Determine the suitability rating for each criterion. c) Create a decision matrix based on criteria, then normalize the matrix based on equations that are adjusted to the type of attribute (profit attribute or cost attribute) so that a normalized matrix R is obtained.

$$R_{ij} \begin{cases} \dfrac{X_{IJ}}{Max^{X_{ij}}} & \text{Advantage Attributes (Benefit)} \\ \dfrac{Min^{X_{ij}}}{X_{ij}} & \text{Loss Attributes (Cost)} \end{cases}$$

Description:
Rij: Normalized performance rating value
Xij : The value of the attributes of each criterion
Max Xij : The largest value of each criterion i
Min Xij : The smallest value of each criterion i
Benefit : If the largest value is the best
Cost : If the smallest value is the best

Determining the Qi Value

$$Q_i = 0{,}5 \sum_{j=1}^{n} x_{ij} w + 0{,}5 \prod_{j=1}^{n} \left(x_{ij}\right)^{wj}$$

Description:
$x_{ij}w$: Multiplication of x_{ij} value with weight (w)
$\left(x_{ij}\right)^{wj}$: Value Departure x_{ij} with weight (w)
0,5 : Formula fixity value
Q_i : i's Q value

RESULT AND DISCUSSION
Calculation of Material Price

The calculation of the safety factor is done by using the maximum von misses stress value from the simulation result data listed in the Jabodebek LRT carbody calculation report divided by the tensile yield strength value of the material, from the data collection of the Jabodebek LRT Carbody structure calculation report by PT INKA (Persero) where each case and the results are described as follows:

Table 1. Simulation result value of LRT carbody structure calculation

Simulation result value of Jabodebek LRT carbody structure calculation			
Case 1	**Case 2**	**Case 3**	**Case 4**
28,83 MPa	66,66 MPa	70,95 MPa	75,06 MPa

Based on table 1 in case 1, namely the situation where the Jabodebek LRT Carbody is tested with a Tare Load load, namely conditions without passengers and the results obtained are 28.83 MPa. Case 2 is a situation where the Jabodebek LRT Carbody is tested with a Full Load load, which is a condition full of passengers and the result is 66.66 MPa. Case 3 is a situation where the Jabodebek LRT Carbody is tested with a Tare Load load, which is a condition without passengers and Compression Load, which is a compression load and the result is 70.95 MPa. Case 4 is a situation where the Jabodebek LRT Carbody is tested with a Full Load load, which is a condition full of passengers and Compression Load, which is a compression load and the result obtained is 75.06 MPa.

Tabel 2. Safety Factor Simulation Calculation

No	**Material**	**Case 1**	**Case 2**	**Case 3**	**Case 4**

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 2, June 2025, pp.0661-0671
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17828 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

No	Material	Case 1	Case 2	Case 3	Case 4
1	Aluminium Alloy Al 6005-T6	7,46	3,23	3,03	2,86
2	Aluminium Alloy Al 6061-T6	9,57	4,14	3,89	3,68
3	Aluminium Alloy Al 6063-T6	7,42	3,21	3,02	2,85
4	Aluminium Alloy Al 6066-T6	12,45	5,39	5,06	4,78
5	Aluminium Alloy Al 6069-T6	15,30	6,62	6,22	5,88
6	Aluminium Alloy Al 6070-T6	12,21	5,28	4,96	4,69
7	Aluminium Alloy Al 6082-T6	9,02	3,90	3,66	3,46
8	Aluminium Alloy Al 6101-T6	6,69	2,90	2,72	2,57
9	Aluminium Alloy Al 6151-T6	8,36	3,62	3,40	3,21
10	Aluminium Alloy Al 6201-T6	6,76	2,93	2,75	2,60
11	Aluminium Alloy Al 6262-T6	6,59	2,85	2,68	2,53
12	Aluminium Alloy Al 6351-T6	9,82	4,25	3,99	3,77
13	Aluminium Alloy Al 6463-T6	7,42	3,21	3,02	2,85
14	Aluminium Alloy Al 6951-T6	7,98	3,45	3,24	3,06
15	Aluminium Alloy Al 7001-T6	21,68	9,38	8,81	8,33
16	Aluminium Alloy Al 7005-T6	10,06	4,35	4,09	3,86
17	Aluminium Alloy Al 7034-T6	25,32	10,95	10,29	9,73
18	Aluminium Alloy Al 7075-T6	16,02	6,93	6,51	6,16
19	Aluminium Alloy Al 7178-T6	17,00	7,35	6,91	6,53

In table 2 is information about the safety factor of various types of aluminum alloy materials. Safety factor is a measure of safety or margin of safety, which is the ratio between the maximum load that a structure can withstand and the load actually received during its use. From the data, it can be seen that each type of material has different safety factor values in four different cases. Case 1 refers to axial load, case 2 refers to flexural load, case 3 refers to shear load, and case 4 refers to axial and flexural combination load. In general, it can be seen that materials with higher safety factor values tend to be stronger and more durable in resisting loads. The material with the highest safety factor for all four cases is Al 7034-T6, with values of 25.32, 10.95, 10.29, and 9.73, respectively. Meanwhile, the material with the lowest safety factor value is Al 6101-T6, with values of 6.69, 2.90, 2.72, and 2.57, respectively. The data table shows the Safety Factor values of 19 types of Aluminum Alloy materials in four different test cases. The safety factor values presented show how much safety factor each type of material has in each test case.

In the Case 1 to Case 4 column, each safety factor value indicates how much the Aluminum Alloy material is safe when tested under certain conditions. The higher the safety factor value, the greater the ability of the material to withstand a certain load before failure or damage. In this case, the higher the safety factor value, the better the performance of the Aluminum Alloy material. Safety factor values vary between different types of Aluminum Alloy materials. Some material types such as Al 7001-T6 and Al 7034-T6, have relatively higher safety factor values than other types, while some material types such as Al 6101-T6 and Al 6201-T6 have relatively lower safety factor values.

Material Price Calculation

Material prices are obtained from data collection by submitting material catalog requests to vendors, from data collection, the following simulation results are obtained:

Table 3. Material Price Comparison

No	Material	Price ($)
1	Aluminium Alloy Al 6005-T6	$3.182
2	Aluminium Alloy Al 6061-T6	$3.182
3	Aluminium Alloy Al 6063-T6	$3.182
4	Aluminium Alloy Al 6066-T6	$3.182
5	Aluminium Alloy Al 6069-T6	$3.333
6	Aluminium Alloy Al 6070-T6	$3.333
7	Aluminium Alloy Al 6082-T6	$3.333

No	Material	Price ($)
8	Aluminium Alloy Al 6101-T6	$3.333
9	Aluminium Alloy Al 6151-T6	$3.333
10	Aluminium Alloy Al 6201-T6	$3.333
11	Aluminium Alloy Al 6262-T6	$3.333
12	Aluminium Alloy Al 6351-T6	$3.333
13	Aluminium Alloy Al 6463-T6	$3.333
14	Aluminium Alloy Al 6951-T6	$3.333
15	Aluminium Alloy Al 7001-T6	$3.485
16	Aluminium Alloy Al 7005-T6	$3.485
17	Aluminium Alloy Al 7034-T6	$3.485
18	Aluminium Alloy Al 7075-T6	$3.485
19	Aluminium Alloy Al 7178-T6	$3.485

In table 3 there is a price list of 19 types of Aluminum Alloy materials sorted by sequence number and followed by the name of the type of Aluminum Alloy material. The data in the table shows the price amount ($) per unit for each type of aluminum alloy material. Most of the materials have the same price, which is $3182 for 4 types of materials (Al 6005-T6, Al 6061-T6, Al 6063-T6, and Al 6066-T6), $3333 for 10 types of materials (Al 6069-T6, Al 6070-T6, Al 6082-T6, Al 6101-T6, Al 6151-T6, Al 6201-T6, Al 6262-T6, Al 6351-T6, Al 6463-T6, and Al 6951-T6), and $3485 for 5 material types (Al 7178-T6, Al 7001-T6, Al 7005-T6, Al 7034-T6, and Al 7075-T6).

Rating Criteria

The criteria rating is determined from the priority of the criteria used as a reference for assessment, in this study the price criteria have a higher priority than the safety factor, therefore the criteria rating is determined as follows:

Table 4. Simulation Calculation of Criteria Rating

Rating Criteria				
Safety Factor				Price
Case 1	Case 2	Case 3	Case 4	
0,125	0,125	0,125	0,125	0,5

Table 4 shows the criteria rating in selecting the type of Aluminum alloy material. There are two criteria, namely Safety Factor which is designated as Benefit and Price is designated as Cost. Each criterion is given a weight for each Case (Cases 1, 2, 3, and 4) with a value of 0.125 (total safety factor value of 0.5) and a weight for Price of 0.5 of the total overall value of 1. The weight is used to emphasize the Safety Factor and Price values so that they can be compared fairly.

Simple Additive Weighting Method

Value normalization is done to improve the comparison between values on different scales, or in other words, to transform the data on the original scale into a scale that is more comparative and can be compared more clearly. in 19 types of aluminum alloy materials in four test cases and value normalization of different prices. In this normalization technique, weights are given for each test case and the respective prices with a value of 0.125 different value ranges into the same value range so that it is easy and 0.5. This weight is used by giving a balanced value, namely a value of 0.5 (0.125 x 4) for the safety factor and a value of 0.5 for the price of the total value of 1 so that it can be compared fairly. each type of material has a different normalized safety factor value in the four different load cases. Materials with high normalized safety factor values tend to be stronger and more durable in withstanding loads. The material with the highest normalized safety factor value for all four cases is Al 7034-T6, where the value is equal to 1.00 for all load cases. While the material with the lowest normalized safety factor value is Al 6101-T6, where the value is equal to 0.26 for all four load cases.

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 2, June 2025, pp.0661-0671
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17828 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The highest price normalization value in Aluminum Alloy Al 6005-T6, Aluminum Alloy Al 6061-T6, Aluminum Alloy Al 6063-T6, and Aluminum Alloy Al 6066-T6 material is 1. While the lowest price normalization value in Aluminum Alloy Al 7001-T6, Aluminum Alloy Al 7005-T6, Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7075-T6, and Aluminum Alloy Al 7178-T6 material is 0.91. Each type of material has a different ranking based on its V value. The highest ranking material is Al 7034-T6 with a V value of 0.96 and the lowest ranking material is Al 6101-T6 with a V value of 0.61. Aluminum Alloy Al 7034-T6 material type gets the first rank with the highest V value of 0.96. While Aluminum Alloy Al 6262-T6, Al 6101-T6, and Al 6201-T6 material types get the last rank because they have the smallest V value. This ranking is used to assist in the process of selecting the most appropriate type of Aluminum Alloy material according to needs. Materials with a price of $3485 have a ranking of 1, 2, 3, 5, and 11 with materials Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7001-T6, Aluminum Alloy Al 7178-T6, Aluminum Alloy Al 7075-T6, and Aluminum Alloy Al 7005-T6. Furthermore, the material with a price of $3333 has ranks 4, 7, 9, 10, 14, 15, 16, 17, 18, and 19 with materials Aluminum Alloy Al 6069-T6, Aluminum Alloy Al 6070-T6, Aluminum Alloy Al 6351-T6, Aluminum Alloy Al 6082-T6, Aluminum Alloy Al 6151-T6, Aluminum Alloy Al 6951-T6, Aluminum Alloy Al 6463-T6, Aluminum Alloy Al 6201-T6, Aluminum Alloy Al 6101-T6, and Aluminum Alloy Al 6262-T6. Then, the material with a price of $3182 has a ranking of 6, 8, 12, and 13 with materials Aluminum Alloy Al 6066-T6, Aluminum Alloy Al 6061-T6, Aluminum Alloy Al 6005-T6, Aluminum Alloy Al 6063-T6.

Weighted Product Method

The weight in the WP SPK is used to raise a value from the criteria with the condition that it is positive if it is beneficial (benefit) and negative if it is detrimental (cost). This weight is used by giving a balanced value, namely a value of 0.5 (0.125 x 4) for the safety factor and a value of 0.5 for the price of the total value of 1 so that it can be compared fairly. From the results of normalizing the value, the S value is then calculated which is used for the calculation of the V value for ranking.

The calculation results of each type of material have different normalized safety factor values in the four different load cases. Materials with high normalized safety factor values tend to be stronger and more durable in withstanding loads. The material with the highest normalized safety factor value for all four cases is Al 7034-T6, where the values are 1.50, 1.35, 1.34, and 1.33 respectively for all load cases. While the material with the lowest normalized safety factor value for cases 1, 2, and 3 is Aluminum Alloy Al 6101-T6, Aluminum Alloy Al 6201-T6, and Aluminum Alloy Al 6262-T6 with values of 1.27, 1.14, and 1.13, and case 4 is Aluminum Al 6262-T6 with a value of 1.12. In addition, the data also informs the price normalization value for each type of material. It can be seen that the highest price normalization value in Aluminum Alloy Al 6005-T6, Aluminum Alloy Al 6061-T6, Aluminum Alloy Al 6063-T6, and Aluminum Alloy Al 6066-T6 materials is 0.018. While the lowest price normalization value in the material Aluminum Alloy Al 6069-T6, Aluminum Alloy Al 6070-T6, Aluminum Alloy Al 6082-T6, Aluminum Alloy Al 6101-T6, Aluminum Alloy Al 6151-T6, Aluminum Alloy Al 6201-T6, Aluminum Alloy Al 6262-T6, Aluminum Alloy Al 6351-T6, Aluminum Alloy Al 6463-T6, Aluminum Alloy Al 6951-T6, Aluminum Alloy Al 7001-T6, Aluminum Alloy Al 7005-T6, Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7075-T6, and Aluminum Alloy Al 7178-T6 by 0.017.

Ranking results from 19 types of Aluminum Alloy materials show the highest ranking material is Al 7034-T6 with a V value of 0.079 and the lowest ranking material is Aluminum Alloy Al 6101-T6, and Aluminum Alloy Al 6262-T6 with a V value of 0.041. While Aluminum Alloy Al 6262-T6, and Al 6101-T6 material types get the last rank because they have the smallest V value of 0.041. This ranking is used to assist in the process of selecting the most appropriate type of Aluminum Alloy material according to needs.

Materials with a price of $3485 have rankings 1, 2, 3, 4, and 10 with materials Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7001-T6, Aluminum Alloy Al 7005-T6, Aluminum Alloy Al 7178-T6, Aluminum Alloy Al 7075-T6, and Aluminum Alloy Al 7034-T6. Furthermore, the material with a price of $3333 has a ranking of 5, 7, 9, 11, 12, 13, 16, 17, 18, and 19 with materials

Aluminum Alloy Al 6069-T6, Aluminum Alloy Al 6070-T6, Aluminum Alloy Al 6351-T6, Aluminum Alloy Al 6082-T6, Aluminum Alloy Al 6151-T6, Aluminum Alloy Al 6951-T6, Aluminum Alloy Al 6463-ST6, Aluminum Alloy Al 6201-T6, Aluminum Alloy Al 6101-T6, and Aluminum Alloy Al 6262-T6. Then, the material with a price of $3182 has ranks 6, 8, 14, and 15 with materials Aluminum Alloy Al 6066-T6, Aluminum Alloy Al 6061-T6, Aluminum Alloy Al 6005-T6, Aluminum Alloy Al 6063-T6.

Weighted Aggregates Sum Product Assessment Method

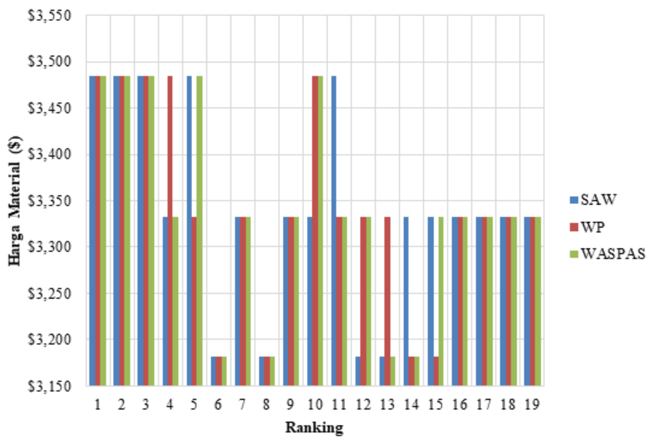
The material with the highest normalized safety factor value for all four cases is Aluminum Alloy Al 7034-T6, where the value is equal to 1.00 for all load cases. While the material with the lowest normalized safety factor value is Aluminum Alloy Al 6101-T6 and Aluminum Alloy Al 6262-T6, where the value is equal to 0.26 for all four cases. The highest price normalization value in the material Aluminum Alloy Al 6005-T6, Aluminum Alloy Al 6061-T6, Aluminum Alloy Al 6063-T6, and Aluminum Alloy Al 6066-T6 is 1. While the lowest price normalization value in the material Aluminum Alloy Al 7001-T6, Aluminum Alloy Al 7005-T6, Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7075-T6, and Aluminum Alloy Al 7178-T6 is 0.91.

The ranking results of 19 types of Aluminum Alloy materials calculated using data normalization and criteria ratings that have been done before, the type of Aluminum Alloy Al 7034-T6 material is ranked first with the highest Q value of 0.96. While the type of material Aluminum Alloy Al 6262-T6, get the last rank because it has the smallest Q value of 0.55. This ranking is used to assist in the process of selecting the most appropriate type of Aluminum Alloy material according to your needs.

SPK WASPAS ranking results obtained material at a price of $3485 has a ranking of 1, 2, 3, 5, and 10 with materials Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7001-T6, Aluminum Alloy Al 7178-T6, Aluminum Alloy Al 7075-T6, and Aluminum Alloy Al 7005-T6. Furthermore, the material with a price of $3333 has a ranking of 4, 7, 9, 11, 12, 15, 16, 17, 18, and 19 with materials Aluminum Alloy Al 6069-T6, Aluminum Alloy Al 6070-T6, Aluminum Alloy Al 6351-T6, Aluminum Alloy Al 6082-T6, Aluminum Alloy Al 6151-T6, Aluminum Alloy Al 6951-T6, Aluminum Alloy Al 6463-T6, Aluminum Alloy Al 6201-T6, Aluminum Alloy Al 6101-T6, and Aluminum Alloy Al 6262-T6. Then, the material with a price of $3182 has a ranking of 6, 8, 13, and 14 with materials Aluminum Alloy Al 6066-T6, Aluminum Alloy Al 6061-T6, Aluminum Alloy Al 6005-T6, Aluminum Alloy Al 6063-T6.

Comparison of SAW, WP, and WASPAS Methods for Material Substitution based on Safety Factor and Price

Comparison of the results of SAW, WP, and WASPAS SPK is done because each method has a different approach in providing rankings, so the comparison between the three methods can help to choose which method is most suitable for the characteristics and needs of the case at hand. The results of the comparison between the three methods are described in Figure 1 below:



pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 2, June 2025, pp.0661-0671
DOI: http://dx.doi.org/10.32832/astonjadro.v14i2.17828 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Figure 1. Comparison of Material Ranking based on SAW, WP, and WASPAS SPK

SAW, WP, and WASPAS SPK ranking data from 19 aluminum alloy materials with the same highest and lowest ranking results, namely the highest material ranking on Aluminum Alloy Al 7034-T6 obtained ranking in SPK SAW with rank 1 with a V value of 0.96, SPK WP with rank 1 with a V value of 0.079, and SPK WASPAS with rank 1 with a Q value of 0.96, and has a price of $ 3485. In Figure 1 SPK SAW, WP, and WASPAS ranking data from 19 aluminum alloy materials with the same highest and lowest ranking results, namely the highest ranking material on Aluminum Alloy Al 7034-T6 obtained ranking in SPK SAW with a ranking of 1 with a V value of 0.96, SPK WP with a ranking of 1 with a V value of 0.079, and SPK WASPAS with a ranking of 1 with a Q value of 0.96 and has a price of $ 3485. The lowest material ranking on Aluminum Alloy Al 6262-T6 material is obtained in SPK SAW with a ranking of 19 with a V value of 0.61, SPK WP with a ranking of 19 with a V value of 0.041, and SPK WASPAS with a ranking of 19 with a Q value of 0.55, and has a price of $3333.

At rank 1, 2, and 3 have no price difference of $3485 with Aluminum Alloy Al 7034-T6, Aluminum Alloy Al 7001-T6, and Aluminum Alloy Al 7178-T6 materials. It can also be seen in rank 4, and 5 have a price difference of $3333 and $3485 with Aluminum Alloy Al 7075-T6 material ($3485) from SPK WP for rank 4 and SPK SAW and WASPAS for rank 5. Furthermore, Aluminum Alloy Al 6069-T6 ($3333) from SPK SAW and WASPAS for rank 4 and SPK WP for rank 5. Furthermore, at rank 6, and 8 have no price difference of $3182 with Aluminum Alloy Al 6066-T6, and Aluminum Alloy Al 6061-T6 materials. After that at rank 7, 9, 16, 17, 18, and 19 have no price difference of $3333 with Aluminum Alloy Al 6070-T6 material, and Aluminum Alloy Al 6351-T6, Aluminum Alloy Al 6463-T6, Aluminum Alloy Al 6201-T6, Aluminum Alloy Al 6101-T6, and Aluminum Alloy Al 6262-T6.

Also seen at rank 10 has a price difference of $3333 and $3485 with Aluminum Alloy Al 6082-T6 material ($3333) from SPK SAW for rank 10 and SPK WP and WASPAS for rank 11 and Aluminum Alloy Al 7005-T6 ($3485) from SPK WP and WASPAS for rank 10 and SPK SAW for rank 11. Then at rank 12 has a price difference of $3182 and $3333 with Aluminum Alloy Al 6005-T6 ($3182) from SPK SAW and Aluminum Alloy Al 6151-T6 ($3333) from SPK WP and WASPAS. At rank 13, and 14 have a price difference of $3182 and $3333 with Aluminum Alloy Al 6005-T6 material ($3182) from SPK SAW for rank 13 and SPK WP for rank 14, Aluminum Alloy Al 6063-T6 ($3182) from SPK WP for rank 13 and SPK WASPAS for rank 14 and Aluminum Alloy Al 6951-T6 ($333333) from SPK WASPAS for rank 13 and SPK SAW for rank 14. Finally, at rank 15 has a price difference of $3182 and $3333 with Aluminum Alloy Al 6063-T6 material ($3182) from SPK WP and Aluminum Alloy Al 6951-T6 ($333333) from SPK SAW and WASPAS.

From the data exposure, it can be seen that the type of material Aluminum Alloy Al 7034-T6 gets the first rank in each SPK with the highest V value in SAW which is 0.96, the highest V value in WP is 0.079, and the highest Q value in WASPAS is 0.96. While the material type Aluminum Alloy Al 6262-T6, gets the last rank because it has the smallest V value in SAW which is 0.61, the smallest V in WP which is 0.041, and the smallest Q in WASPAS which is 0.55.

CONCLUSION

Based on the analysis and discussion, it can be concluded that based on the ranking using the SAW, WP, and WASPAS Decision Support System methods, it is found that Aluminum Alloy Al 7034-T6 is the best ranked material while Aluminum Alloy Al 6262-T6 gets the lowest rank. In addition, high-ranked materials tend to have higher prices than low-ranked materials in all three methods. The compared decision support systems SAW, WP, and WASPAS have similar ranking results. This shows that the three methods are consistent in ranking and valid in making decisions. From the three methods, the best material is Aluminum Alloy Al 7034-T6 so it can be used as a recommendation. However, if price is a priority then Aluminum Alloy Al 6061-T6 material can be a recommendation for Jabodebek LRT Carbody material.. As for some things that are suggested for further research, FEM simulations can be carried out for the Carbody structure so that the results of the study include images of the simulation results of each material. In addition, development and improvement of ranking methods can be carried out and adding other criteria that can be considered according to industry needs.

REFERENCES

Abbas, I. (2016). Penerapan Metode Weighted Product (WP) Berbasis Sistem Pengambilan Keputusan Untuk Pemberian Dana Bantuan Mandiri Desa Wisata pada Dinas Perhubungan Pariwisata Kabupaten Bone Bolango. *Jurnal Informatika UPGRIS*, *2*(1).

Amalia, V., Syamsuar, D., & Atika, L. (2019). Komparasi Metode WP SAW dan WASPAS dalam Penentuan Penerima Beasiswa Penelusuran Minat dan Kemampuan. *Jurnal Informatika*, *06*(01).

Harak, S. S., Sharma, S. C., & Harsha, S. P. (2014). Structural Dynamic Analysis of Freight Railway Wagon Using Finite Element Method. *Procedia Materials Science*, *6*, 1891–1898. https://doi.org/10.1016/j.mspro.2014.07.221

Nurfadillah, E. M. (2018). *Analisis Struktur Statis pada Carbody Kereta LRT Palembang dengan Menggunakan Metode Elemen Hingga*. Istitut Teknologi Sepuluh November.

Putra, I. M., & Windharto, A. (2017). Desain Carbody Eksterior-Interior Light Rail Transit untuk Kota Palembang dengan Konsep Iconic dan Modern. *Jurnal Sains Dan Seni ITS*, *6*(2).

Rizka, A. (2022). Penerapan Metode Weighted Product Model dan Weighted Sum Model dalam Penentuan Produk yang akan Dipasarkan. *LOFIAN: Jurnal Teknologi Informasi Dan Komunikasi*, *1*(2).

Siregar, E. Y., Khairani, S., & Rismayanti, R. (2022). Analisis Perbandingan Menggunakan Metode Waspas (Weight Aggregated Sum Product Assesment) dan AHP(Analitycal Hierarchy Process) Pemilihan Aplikasi Smartphone Untuk Anak Tingkat SD. *JurnalIlmu Komputer Dan Sistem Informasi (JIRSI)*, *1*(2), 63–69.

Sukaryati, L. N., & Voutama, A. (2022). Penerapan Metode Simple Additive Weighting Pada Sistem Pendukung Keputusan Untuk Memilih Karyawan Terbaik. *Jurnal Ilmiah Matrik*, *24*(03). https://doi.org/https://doi.org/10.33557/jurnalmatrik.v24i3.2029

Sun, X., Han, X., Dong, C., & Li, X. (2021). Applications of Aluminum Alloys in Rail Transportation. In *Aluminium Alloys [Working Title]*. IntechOpen. https://doi.org/10.5772/intechopen.96442

Syaifudin, A., Nurfadillah, E. M., Farid, A. R., & Windharto, Ag. (2021). Strength consideration on car body of light rail transit making from aluminum extrusion. *IOP Conf. Series: Materials Science and Engineering*. https://doi.org/10.1088/1757-899X/1034/1/012025

Syam, S., & Rabidin, M. (2019). Metode Simple Additive Weighting dalam Sistem Pendukung Keputusan Pemilihan Karyawan Berprestasi (Studi Kasus : PT. Indomarco Prismatama cabang Tangerang 1). *UNISTEK*, *6*(1), 14–18. https://doi.org/10.33592/unistek.v6i1.168

Yanto, R. (2020). Analisis Perbandingan Keputusan Seleksi Anggota PPK Pilkada Menggunakan Metode SAW dan WASPAS. *CogITo Smart Journal*, *6*(1), 83–96. https://doi.org/10.31154/cogito.v6i1.224.83-96

Zhao, H., Ye, L., Cheng, Q., Kang, Y., & Zhang, W. (2023). Enhanced mechanical properties and corrosion resistance of 7055 aluminum alloy through variable-rate non-isothermal aging. *Journal of Alloys and Compounds*, *943*, 169198. https://doi.org/10.1016/j.jallcom.2023.169198

Kurniawan, W., & Rulhendri, R. (2015). TINJAUAN VOLUME PEMELIHARAAN TAHUNAN JALAN REL BERDASARKAN HASIL TRACK QUALITY INDEX (TQI) (Studi kasus: Lintas Manggarai - Bogor). ASTONJADRO, 4(2), 1–17. https://doi.org/10.32832/astonjadro.v4i2.823

Sulastri, D., Wahyuni, A., & Mudjanarko, S. W. (2020). GUBENG STATION RAILWAY INFRASTRUCTURE PERFORMANCE ACCORDING TO USER PERCEPTION. ASTONJADRO, 9(2), 107–116. https://doi.org/10.32832/astonjadro.v9i2.3154

Sanjaya, A. (2021). KAJIAN PERBANDINGAN BIAYA DAN WAKTU PEKERJAAN

PERAWATAN JALAN REL MENGGUNAKAN MEKANISASI DAN NON MEKANISASI (Studi Kasus: Petak Jalan Rel Antara Bojonggede - Bogor). ASTONJADRO, 6(1), 28–35. https://doi.org/10.32832/astonjadro.v6i1.2259