Applying of Global Priority Value in the Selection of Alternative Inter-Provincial Roads

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Abstract. The Salubatu – Bonehau – Kalumpang – South Sulawesi boundary is a district road which has the plan of status upgrade become a national road with the addition of new access that replaces the existing soil pavement. The proposed new access has 3 alternative sections. The purpose of this study was to determine the best alternative route for access to Kalumpang-Bonehau-Border of South Sulawesi using the analysis hierarchy process method. The most influential criteria in selecting a route based on the priority vector value is accessibility. Other criteria that influence the selection of alternatives are environment and energy sources, safety factors, land use/regional development, average speed, travel time, internal rate of return, and ease of construction. The results of the AHP, Alternative 1 can be considered with a global priority value of 88.267%. The advantages of the AHP method in this study are that it can use a variety of assessment factors, open and transparent discussions with stakeholders, criteria can be qualitative and quantitative, priority assessments are based on measurement scales and logical consistency, there is a utility value for each alternative to the criteria, and the sensitivity of the criteria. However, the weakness of this method are the evaluation process is complicated and quite long, and there are a lot of actors and data.

Keywords: inter-provincial roads, AHP, alternatives, criteria

1. Introduction

Increasing the income of a region cannot be separated from the availability of a good and interconnected road network, especially in connecting access between regions. One of the connecting accesses between South Sulawesi Province and West Sulawesi Province is the Salubatu – Bonehau – Boundary South Sulawesi section. The existing condition of the section is 89.90 km long and has various pavement conditions. For the road segment, the effective width is 4.5 m with an aggregate pavement of 50.67 km, the asphalt pavement segment is 1.9 km, and the dirt road segment is 37.23 km. Terrain conditions in the area are mountains and hills. The Salubatu - Bonehau segment has a length of 28.11 km and has damaged road surface along 24.16 km, while the Bonehau - Kalumpang segment has mild road surface damage along 28.70 km, road damage along 18.22 km is found on the link between Kalumpang – Batuisi, 44.64 km, and road damage with the category of heavy damage can be seen on the Batuisi road to the boundary of Tana Toraja Regency. This existing road is used by the surrounding community for the mobility and distribution of agricultural and plantation

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products from Bonehau to Kalumpang and vice versa. In general, this road serves mostly four and two-wheeled motorized vehicles, while some heavy vehicles pass through this segment to distribute mining products and building materials (sand, cement, iron) the average daily traffic for 2021 using the traffic growth rate of 5% traffic is 16.70 passenger cars.

The provincial road access that connects Kalumpang District with the border of South Sulawesi in West Sulawesi Province is planned to be upgraded to a national road which aims to connect and reduce travel time from Mamuju City, West Sulawesi to Masamba City in South Sulawesi, to create a transportation network that is (Decree of the Minister of PUPR No. 248 of 2015 concerning the Determination of Roads in the Primary Road Network according to their Functions as Arterial Roads and Collector Roads-1).

The plan to enhancement the status of the road section to become a national road with a width of 7m and a space belonging to the road is 14m with the addition of new access that replaces the pavement from the ground for the existing access. The proposed new access has 3 alternative sections, with details of alternative route 1 starting from sta 82+700 to sta 101+464, route 2 starting from sta 80+700 to sta 98+471, and route 3 starting from sta 82+700 to 93+329.

The purpose of this study was to determine the best alternative route for access to Kalumpang-Bonehau-Border of South Sulawesi by considering several assessment factors. The analysis hierarchy process method is used in this study, because this method can be used to deal with problems that can be viewed from various factors, another reason is that the criteria used as parameters can be quantitative or qualitative.

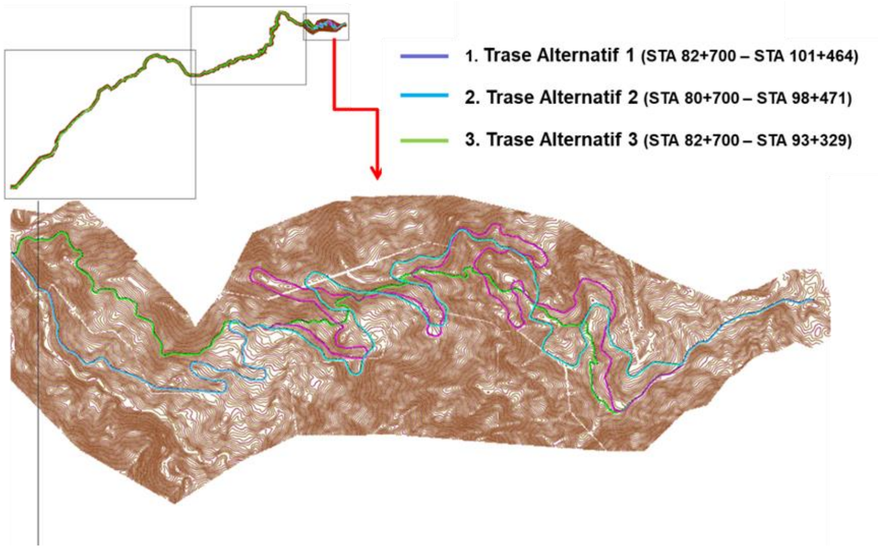

Figure 1. Alternative access route for the Salubatu-Kalumpang-Bonehau-South Sulawesi border section [1]

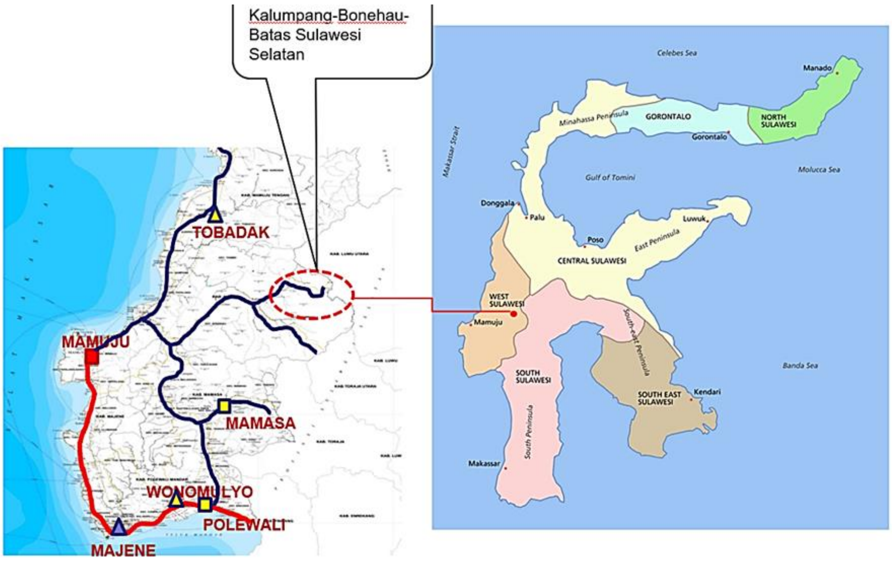

Figure 2. Access the Salubatu-Kalumpang-Bonehau-South Sulawesi Boundary section [1]

Figure 3. Existing road of Bonehau – Kalumpang – South Sulawesi Boundary [1]

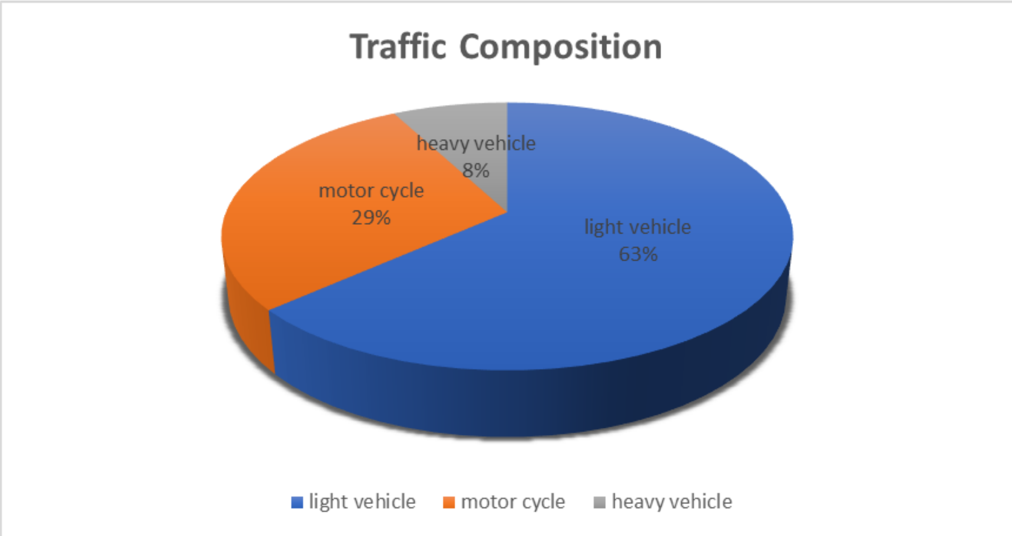

Figure 4. Traffic composition of Bonehau-Kalumpang-South Sulawesi Boundary Section [1]

The profile of the area/sub-district through which alternative access to the Salubatu-Bonehau-Kalupang-South Sulawesi Boundary access is passed, namely Bonehau and Kalumpang sub-districts. Bonehau sub-district has 15 villages with the most populous village being Bonehau Village, 819 people/km2, while the smallest population density of 39 people/km2 is Salupangkang IV Village [2]. In terms of topography, Bonehau District is a hilly area that has a slope of more than 40%. The area of Kalumpang Regency is mostly hilly, the rest is flat (coastal). The slope in most areas exceeds 12 degrees. 27 The elevation of this coastal plain is quite low, 0 to 2 m above mean sea level (MSL). In 2018, the population density of Kalumpang Regency reached 6.89 people/km2, with an average household population of 3.89 people.

According to the West Sulawesi Provincial Spatial Structure Plan for 2014-2034, several areas that will be developed into an integrated national scale area are PKNp Matabe for industrial, trade, and tourism areas, PKW in Majene City as an education area, and Pasangkayu as an agropolitan area. Meanwhile, PKWp in Polewali City is an industrial and trade area, and Tobadak City is a street vendor in an independent integrated city area. Read more on the Spatial Structure of West Sulawesi Province. Bonehau and Kalumpang sub-districts are included in the conservation area with an area of about 72,965 hectares (Gandang Dewata National Park). In addition, the Bonehau and Kalumpang sub-districts include areas prone to high ground movement and landslides, as well as earthquakes, production forest areas, food crop areas, fisheries areas, mining and energy areas, tourism areas. [2].

Several previous studies regarding the use of AHP in the selection of alternatives for road works, namely in road repairs in the Malang and Pasuruan areas, the criteria for road surface conditions are the main priority and followed by the criteria for traffic volume, land use, and economic factors [4]. The first rank in determining the main factors causing accidents is the lack of understanding in reading/understanding traffic signs [5]. Consideration of the biggest priorities of the project, the continuation of the development of the road network, and the allocation of project funds in each province are considered in the priority of road projects in the north-eastern part of Thailand [6]. Road repairs started from the main Argosari-B29 segment, then the Wonokerto-Wonosari, Senduro-Ranupane, and Kalimas segments. The factors that affect the improvement of the 4 road segments are road conditions, land use, road connectivity, traffic volume, and policies/guidelines [7]. Of the 6 alternative multimodal transportation routes for the coal industry, route 2 is the optimal route based on the results of the AHP approach. The criteria for route selection are cost, time, risk of damage to goods, infrastructure risk, operational risk, security risk, environmental risk, legal risk, financial risk [8]. The total global priority value for the selection of transportation systems in zinc and lead mining is 0.3595 (transportation system with 2 conveyor belts) [9]. By using the AHP method, the electrical municipality public bus becomes a top priority in strategic planning based on sustainability for urban transportation, while the criteria included are environmental, economic, social, and transportation. The transportation criteria became the main criteria with a CR value of 0.0941 [10]. The stages in road selection using the AHP method, namely points of interest are used to describe road characteristics indicators, create AHP models for roads with topography, geometry, and other indicators, choose roads based on interests, and maintain global connectivity from the selected network [11]. The AHP method can be used to overcome transportation problems, namely the interaction of elements on transportation safety and the evaluation of the quality of train passenger services [12]. The main technical factor in the feasibility of a road construction project is weather resistance. This is the result of calculations using the AHP method, where the weight value is 0.493 and when compared to asphalt roads, concrete roads are superior in the selection of road construction feasibility (weight value 0.667) [13]. The use of the AHPM program in the selection of asphalt and rigid pavement treatments. The advantage of the AHP method is that it can rank alternative options according to their effectiveness [14]. The risk factors for delays in road construction work along with the weight values from the AHP calculation are technical factors (0.242), natural disaster factors (0.208), economic and financial (0.186), contractual (0.125), and socio-political factors (0.105) [15]. Technical criteria (global weight 85.71%) have the most influence on-road handling compared to non-technical criteria (global weight value 14.29%) [16]. The combination of the AHP method with role-playing games for stakeholder engagement in complex transport decisions is used to select the best transit alternative that adopts a multi-stakeholder multi-criteria perspective. through consultation with key stakeholders and preference surveys [3].

2. Methodology

The analytical hierarchy process (AHP) is an application of the multi-criteria analysis method that represents the problem elements in a hierarchy and uses pair comparisons in comparing alternatives. There are 4 principles in AHP, namely decomposition (solving a complex problem to a level below which has elements that can be handled), prioritization (the impact of each element), synthesis (all priorities are drawn together to get an overall assessment), and sensitivity analysis (stability of results). against changes is tested with what will happen if changes are made to the elements of the analysis) [4].

To obtain a more appropriate and fair comparison, the differences in criteria and category assumptions are made uniform. The table shows 5 categories and 8 interrelated criteria, namely network performance, service characteristics, economy and finance, system impact, and ease of construction implementation into the category section, while the average speed, travel time, accessibility, safety, internal rate of return, land use/regional development, environment and energy consumption, and ease of construction implementation are included in the criteria group. The targets of each criterion are grouped into 2, namely maximum, if performance, characteristics, economic/financial, land use, and ease of construction implementation produce the best results when maximum conditions are achieved, otherwise, the minimum conditions of travel time, environmental utilization and energy consumption will make a positive contribution to road performance and service.

To determine the consistency of the standard weight values, a consistency test was carried out. The calculation of consistency is to calculate the deviation from the consistency value, from which the deviation is called the consistency index. The substitution calculation for each sub-standard determines the weights between the alternatives. Then combined by multiplying the weights of each criterion, sub-criteria, and alternatives.

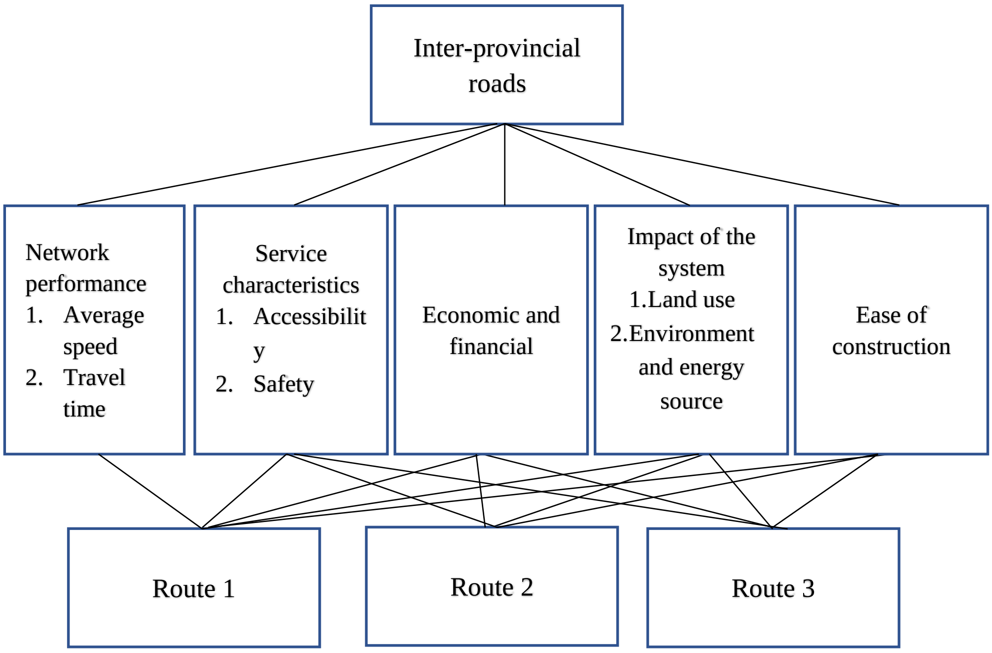

Figure 5. Hierarchy of decision making

Table 1. Selection criteria

Category	Criteria	Unit	Objective
Network performance	1. Average speed 2. Travel time	Km/hour minute	Maximal Minimal
Service characteristics	3. accessibility 4. Safety	Rank or value Rank or value	Maximal Maximal
Economic and financial	5. Internal Rate of Return (IRR)	%	Maximal
Impact of the system	6. Land use 7. Environment and energy consumption	Rank or value Rank or value	Maximal Minimal
Ease of construction	8. Ease of construction	Rank or value	Maximal

Table 2. Random consistency value

size of matrix	1	2	3	4	5	6	7	8	9	10
random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

3. Result And Discussion

The weighing scale is 1-9, the higher the weighting value, the more influential and important the element is compared to other elements. Accessibility is considered the most important and main criterion in determining alternative routes, followed by safety, environment and energy consumption, as well as land use/regional development which has an assessment weight of 8, average speed and travel time weighs 7, IRR, and ease of construction implementation have a weight assessment of 5 and 4. The weighting criteria can be seen in Table 3.

Table 3. Weighting criteria

Criteria	Type	Description	Rank	Value
Average speed	Maximum	Average road traffic speed	3	7
Travel time	Minimum	a measure of the length of time necessary to move from one place to another.	3	7
Accessibility	Maximum	ability to access	1	9
Safety	Maximum	Dependence in terms of time safety and security	2	8
IRR	Maximum	Internal rate of return	4	5
Land use	Maximum	Impact of land use/area development	2	8
Environment and energy consumption	Minimum	Impact of environment and energy source	2	8
Ease of construction	Maximum	Ease of mobility and construction	5	4

Comparison for each criterion against other criteria is carried out to determine the priority vector value of each criterion. From the comparison results for each criterion, the value of max is 8.166, the value of consistency index is 0.0234 where the number of criteria is 8, and the value of consistency random is 0.0168 (≤10%), which means that these 8 criteria can be accepted as elements in the selection of alternative routes. The most influential criteria in selecting a route based on the priority vector value are accessibility, environment and energy consumption, safety factors, land use/regional development, average speed, travel time, IRR, and ease of implementation of construction.

Table 4. Pairwise comparison matrix between criteria

Criteria	K1	K2	K3	K4	K5	K6	K7	K8	Eigen Vector	Priority Vector
K1	1.000	1.000	0.500	0.250	3.000	0.250	0.875	3.000	1.34526E-05	1.45E-25
K2	1.000	1.000	0.900	0.333	0.500	0.500	0.200	3.000	1.68151E-11	1.81E-31
K3	2.000	1.111	1.000	2.000	5.000	1.000	2.000	7.000	8.77656E+19	0.947275
K4	4.000	3.000	3.000	0.500	2.000	1.000	1.000	5.000	1.102E+18	0.011894
K5	0.200	2.000	0.750	0.500	1.000	0.333	0.200	2.000	2.56E-14	2.76E-34
K6	4.000	2.000	1.000	1.000	3.000	1.000	0.500	6.000	7.22204E+14	7.79E-06
K7	1.000	5.000	1.000	1.000	3.000	2.000	1.000	7.000	3.78229E+18	0.040823
K8	0.333	0.333	0.143	0.200	0.500	0.167	0.143	1.000	4.1618E-36	4.49E-56
Total	**13.533**	**15.444**	**8.293**	**5.783**	**18.000**	**6.250**	**5.918**	**34.000**	**9.26506E+19**	**1**

Where:
K1 : average speed (km/hour)
K2 : travel time (minute)
K3 : accessibility
K4 : safety
K5 : Internal rate of return
K6 : land use/area development
K7 : environment and energy source
K8 : ease of construction

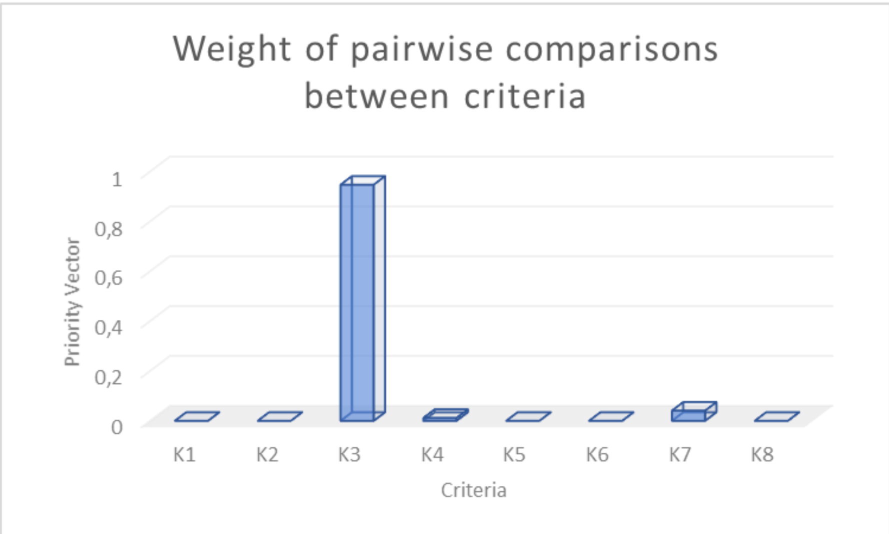

Figure 6. Weight of pairwise comparisons between criteria

Value of λ_{max} of each criteria1,2,3,4,5,6,7, and 8 are 3.116; 3.118; 3.062; 3.117; 3.115; 3.056; 3.116; and 3.116. Random consistency values for all criteria are below or equal to 10%, thus all criteria can be used. The random consistency values of criteria 1,2,3,4,5,6, 7, and 8 are 9.89%, 10%, 5.34%, 9.89%, 10%, 4.81%, 9.67 %, and 9.56%.

Table 5. Sub-criteria pairwise comparison matrix of quality criteria, criteria 1

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.500	9.000	91.125	0.989
Route 2	2.000	1.000	0.500	1.000	0.011
Route 3	0.111	2.000	1.000	0.011	0.000
Total	3.111	3.500	10.500	92.136	1.000

Table 6. Sub-criteria pairwise comparison matrix of quality criteria, criteria 2

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.500	9.000	91.125	0.996
Route 2	2.000	1.000	0.333	0.296	0.003
Route 3	0.111	3.000	1.000	0.037	0.000
Total	3.111	4.500	10.333	91.458	1.000

Table 7. Sub-criteria pairwise comparison matrix of quality criteria, criteria 3

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	9.000	0.500	91.125	0.919
Route 2	0.111	1.000	1.000	0.001	0.000
Route 3	2.000	1.000	1.000	8.000	0.081
Total	3.111	11.000	2.500	99.126	1.000

Table 8. Sub-criteria pairwise comparison matrix of quality criteria, criteria 4

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.500	9.000	91.125	0.996
Route 2	2.000	1.000	0.333	0.296	0.003
Route 3	0.111	3.000	1.000	0.037	0.000
Total	3.111	4.500	10.333	91.458	1.000

Table 9. Sub-criteria pairwise comparison matrix of quality criteria, criteria 5

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.500	9.000	91.125	0.989
Route 2	2.000	1.000	0.500	1.000	0.011
Route 3	0.111	2.000	1.000	0.011	0.000
Total	3.111	3.500	10.500	92.136	1.000

Table 10. Sub-criteria pairwise comparison matrix of quality criteria, criteria 6

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.500	8.000	64.000	0.889
Route 2	2.000	1.000	1.000	8.000	0.111
Route 3	0.125	1.000	1.000	0.002	0.000
Total	3.125	2.500	10.000	72.002	1.000

Table 11. Sub-criteria pairwise comparison matrix of quality criteria, criteria 7

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.111	2.000	0.011	0.000
Route 2	9.000	1.000	0.500	91.125	0.989
Route 3	0.500	2.000	1.000	1.000	0.011
Total	10.500	3.111	3.500	92.136	1.000

Table 12. Sub-criteria pairwise comparison matrix of quality criteria, criteria 8

Alternative	Route 1	Route 2	Route 3	Eigen Vector	Priority Vector
Route 1	1.000	0.500	9.000	91.125	0.989
Route 2	2.000	1.000	0.500	1.000	0.011
Route 3	0.111	2.000	1.000	0.011	0.000
Total	3.111	3.500	10.500	92.136	1.000

From the results of comparisons between criteria and between alternatives, then the global priority value is obtained which becomes a reference for alternative rankings. The highest global priority value is for alternative route 1, which is 88.3%, followed by alternative route 3, which is 7.6%, and ranked 3, namely alternative route 2 with a global priority value of 0.05%. Route 1 has a travel time of 137 minutes, the average land use traversed by plantation land, the average cut and fill work is 3-5m, there are no landslide points on the route, the maximum slope is 10%, and the amount of land acquisition (including housing, forest, rice fields, and plantations) is147.94 ha. Route 2 has a travel time of 146 minutes, the land use is residential and forest, cut and fill is above 10m, there are landslide points on the route, the maximum slope is 10% but there is a critical incline of 300m, and the average land acquisition area is 152.23 ha. Travel time on route 3 is 163 minutes, cut and fill above 10m, there is a landslide point, a maximum slope of 24% but there is no critical incline, the land acquisition area is 153.24 ha.

Table 13. Criteria weight matrix of quality

Alternative	K1	K2	K3	K4	K5	K6	K7	K8	Global Priority
	1.45E-25	1.81E-31	9.47E-01	1.19E-02	2.76E-34	7.79E-06	4.08E-02	4.49E-56	
Route 1	9.89E-01	9.96E-01	9.19E-01	9.96E-01	9.89E-01	8.89E-01	1.19E-04	9.89E-01	8.83E-01
Route 2	1.09E-02	3.24E-03	1.38E-05	3.24E-03	1.09E-02	1.11E-01	9.89E-01	1.09E-02	5.25E-05

Route 3	1.11E-01	4.05E-04	8.07E-02	4.05E-04	1.19E-04	2.71E-05	1.09E-02	1.19E-04	7.65E-02

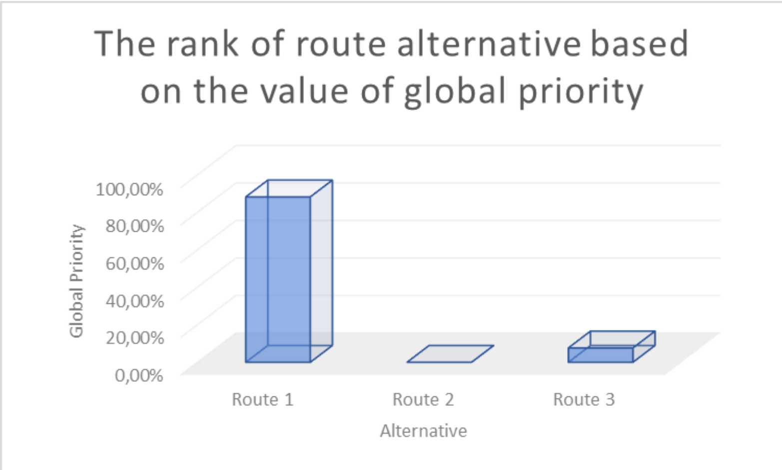

Figure 7. The rank of route alternative based on the value of global priority

4. Conclusion

The most influential criteria in selecting a route based on the priority vector value are accessibility, environment and energy consumption, safety factors, land use/regional development, average speed, travel time, IRR, and ease of construction. The results of the AHP, Alternative Route 1 (Sta 82+700 to sta 101+464) can be considered in the selection of additional access for the Salubatu-Kalumpang-Bonehau-South Sulawesi Boundary section with a global priority value of 88.267%. The advantages of the AHP method in this study are that it can use a variety of assessment factors, open and transparent discussions with stakeholders, criteria can be qualitative and quantitative, priority assessments are based on measurement scales and logical consistency, there is a utility value for each alternative to the criteria, and the sensitivity of the criteria. election results. However, the weakness of this method are the evaluation process is complicated and quite long, and there are a lot of actors and data.

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