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Range of Terrain Suitability for the Development of the Aladi Tulabolo Road Network Gorontalo Province

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Abstract:- This research aims to identify, analyze and develop a road route development model based on terrain suitability to establish a new road network connecting Aladi with Tulabolo, Bone Bolango Regency in Gorontalo Province. A GIS-based spatial approach is used to describe and measure terrain suitability. Based on the characteristics of the research object, survey methods are used; based on population characteristics, stratified proportional sampling is used as the mapping unit; and based on its relationship to analysis, scoring-based quantitative and qualitative methods are used. The research results show that (1) the characteristics of the distribution of terrain suitability for the development of the road network in the research area are based on the parameters that make up terrain units such as landform units, slope, rock type and soil type, resulting in zoning with 5 (five) levels of suitability. The five levels of suitability are S1 suitability (high suitability), S2 suitability (medium suitability), N1 suitability (temporarily not suitable), and N2 suitability (permanently not eligible). (2) The distribution of terrain suitability classes for developing the dominant road network for the Aladi-Tulabolo area is in suitability class S2 (medium suitability), covering an area of 99.25 km^2. (3) The road route development model based on the suitability of the terrain in the research area is formed with the formulation Terrain Unit (SM) = f (bl, kl, jb, jt), where bl = landform, kl = slope, jb = rock type, and jt = soil type

Keywords:- *Distribution, Gis, Road Network Development, Terrain Suitability.*

I. INTRODUCTION

Gorontalo Province is part of the economic corridor for the Master Plan for the Acceleration and Expansion of Indonesian Economic Development (MP3EI), which has many national advantages, especially in agriculture and maritime affairs. This potential is usually located in mountainous areas with limited accessibility. Administratively, Gorontalo Province is one of the regions that borders directly on the Provinces of North Sulawesi and Central Sulawesi and geographically has an area of 12,215.44 km^2. Gorontalo Province consists of 6 (six) city/district areas (one city and five districts). The area and length of roads in each district and city are shown in Table 1.

Table 1 Road Area and Length per District/City in Gorontalo Province 2023

No	Region (Regency/City)	Area (Km^2)	Wide (%)	Road Length (Km)	Long (%)	Ratio (km/km^2)
1.	Gorontalo City	64.79	0.53	262.831	4.07	4.057
2.	Gorontalo	1,846.4	15.10	1,315.180	20.38	0.712
3.	Boalemo	2,510.40	20.53	868.950	13.47	0.346
4.	Pohuwato	4,244.31	34.70	1,393.640	21.60	0.328
5.	Bone Bolango	1,984.31	16.22	2,032,970	31.51	1,025
6.	North Gorontalo	1,580.58	12.92	578.620	8.97	0.366
	Amount	12,215.44	100	6,452.191	100	0.528

Regency/City Public Works Department of Gorontalo Province (2023)

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The length of roads spread across Gorontalo Province up to 2023 is approximately 6,452.191 km. Of the total size of existing roads, the proportion of National roads is 616.24 km (9.55%), Provincial roads are 406.26 km (6.33%), and city/district roads are approximately 5,427.691 km (84.12 %). Compared with the Gorontalo Province's area, the density ratio) of the area roads is relatively small, around 0.528 kilometres per unit area (km/km^2).

In response to the problems faced and considering the urgency in the transportation sector, the government, through the Regional Spatial Planning Plan, prioritizes increasing regional development, and one of the efforts made is to improve the regional economy. This increase is accompanied by increasing regional accessibility to remote and isolated areas to support the smooth flow of investment and production between regions.

The development of the land transportation system in Gorontalo Province currently includes the national, provincial, and development routes. The main route is part of the federal and local transportation routes. From an economic perspective, this route will likely play an essential role in strengthening and accelerating the orientation of trade flows that focus on Gorontalo City. The development path is a supporting path consisting of the West route with the Kwandang – Tolinggula route and the Central route with the Isimu – Paguyaman – Marisa route. This development path is expected to shorten the distance travelled by the flow of goods and services. Another plan being implemented by the government in the future is to support the accessibility of the Paguyaman–Kwandang–Gorontalo triangle area. A shorter road access is planned to connect the three cities, passing through the ports of Anggrek and Isimu. To join the Gorontalo Province government centre in Gorontalo City with Djalaluddin Airport and other areas, to facilitate the movement of goods and residents around the area, a by-pass road from Gorontalo City to Jalaludin Airport (*Gorontalo By-Pass*), Talumolo has been built. Telaga Roundabout, Telaga – Airport Roundabout (Airport Access), and the Limboto – Isimu Road Section.

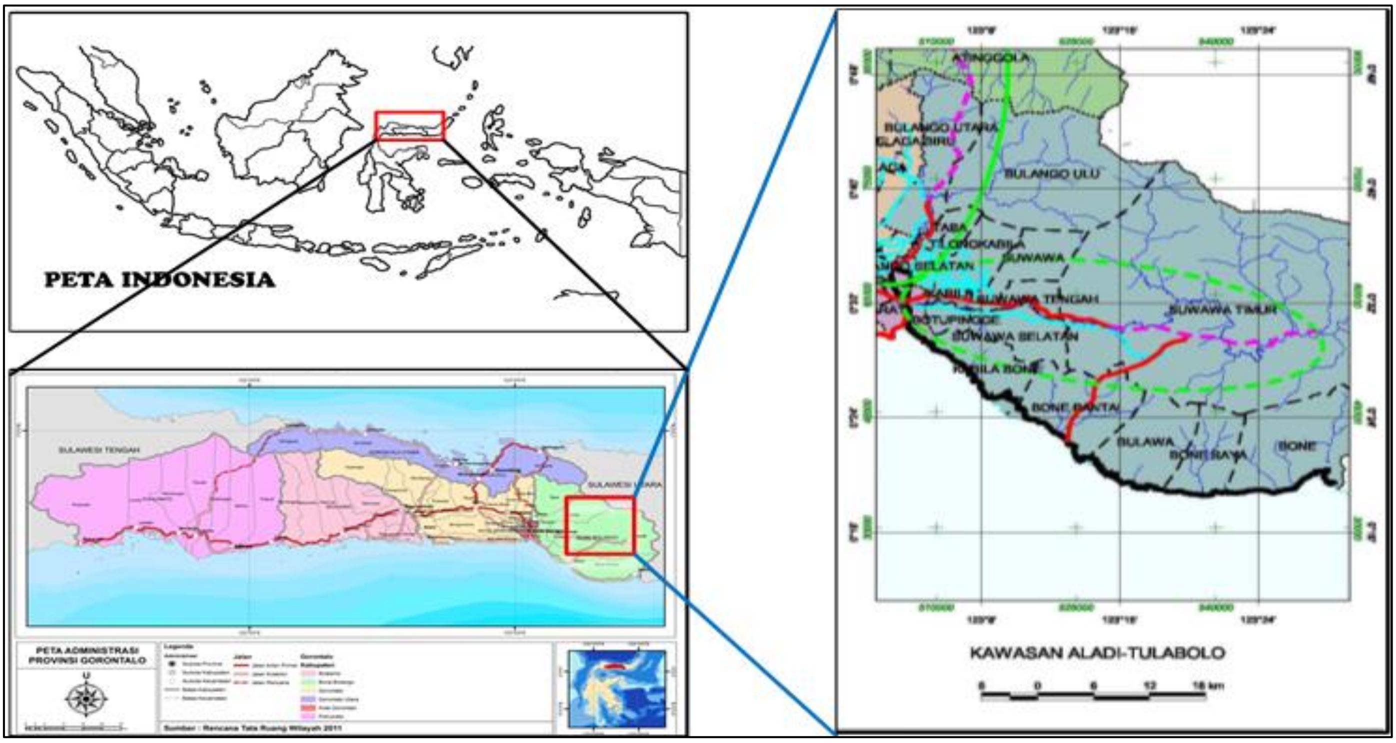

Fig 1 Research Location for the Aladi-Tulabolo Road Route

To meet the need for a road network, road construction in Gorontalo Province should be based on the results of a thorough survey. Then, when planning road construction, it is best to study the possible locations of the road network that will be built first. This is important because by building a road network based on physical studies, we will obtain road construction that is cheap, easy to maintain, easy to build and effective to use. From a physical perspective of road planning, 4 (four) factors influence the traversability of terrain for road routes, namely, land geomorphology, geology, soil, and hydrology (Sunarto & Woro, 1994). Terrain passability for road routes is the ability of a terrain unit to support the movement of land vehicles passing over it (Sunarto & Woro, 1994). The traversability of the terrain for this road route needs to be known because it is related to the various types and tonnages of land vehicles passing on a road route. Where not all road routes can be passed by these various vehicles. The inability of a road lane to support the movement of various vehicles is due to the low passability of the terrain. Therefore, in road network planning work, data regarding terrain characteristics need to be classified, analyzed and evaluated by the criteria for the planned road network.

Viewed from a technical perspective in the implementation of road construction, information on the geomorphological conditions of a region or area is beneficial in dealing with problems related to physical geomorphological conditions. This means that based on information on the

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physical conditions of the region or region, appropriate road network routes can be planned so that possible damage to the road body can be anticipated early to reduce wasted costs both in the planning aspect, construction implementation aspect and maintenance aspect. Meanwhile, on the road network that has been built, information on the geomorphological conditions of the area is still essential because it determines the level of damage and the causes of road damage. Therefore, Geomorphology as a science can be used to genetically describe landforms and the processes that result in the formation of these landforms, as well as the relationships between landforms in spatial structure (Zuidam & Cancelado, 1985).

In the context of this research, the definition of "terrain is interpreted as an area of land that is related to the physical properties of the surface and near the surface (of the earth) which are complex and essential for humans (adapted from Zuidam and Cancelado, 1985). Meanwhile, terrain suitability is interpreted as the level of suitability of a terrain for use in road network construction.

The parameters that determine the suitability of the terrain for the use of road network construction, which is a component of the terrain, are

- Topography, which includes slope slope;
- Rock, which includes rock type and rock strength;
- Land, which includes the type of soil;
- Disaster vulnerability includes surface erosion, inundation due to floods, landslides due to the movement of rock masses;
- Land use.

Based on the description above, the problem formulation can be expressed as follows: (1) what are the suitability characteristics of the terrain for road construction in the research area? Moreover, (2) what is the road route development model based on the suitability of the terrain in the research area?

To the problems mentioned above, the objectives to be achieved in this research are (1) to determine the characteristics of the suitability of the terrain for road construction in the research area and (2) to find out the model for road construction based on the suitability of the terrain in the research area.

It is hoped that this research activity will provide benefits, including (1) contributing to the development of science, especially geomorphology as an applied science, and (2) it is hoped that it can be used as academic information data in decision-making or local policy for regional planning and development, in particular in the field of road networks.

II. RESEARCH METHOD

The research method used is a survey method, while sampling uses a *stratified proportional sampling system*, namely sampling with proportional strata, which are *terrain units*. Apart from being a mapping and strata unit, this terrain unit is also a basis for sampling and analysis. Terrain units are obtained by delineating the area into landform units (relief, processes and constituent materials) plus information on slope class, rock type and soil type.

III. RESEARCH RESULTS AND DISCUSSION

A. Basic Physical Environmental Characteristics

➤ *Geographical Area and Location*

The location of the area that connects the Aladi-Tulabolo sub-districts, with an analysis area of 2 (two) sub-districts in Bone Bolango Regency. Geographically it is located at 123° 3'26" - 123° 27' 13" East Longitude and 0 ° 25'10" - 0 ° 34' 59" North Latitude. Based on the spatial planning directions for Bone Bolango Regency (RTRWK 2010-2029), Central Suwawa sub-district is a local activity center (PKL) with secondary service functions. East Suwawa District is dominated by areas with highland (mountainous) surfaces or located on slopes above 40% and with a rough morphological texture that is quite extensive, with an elevation of 0-1,500 meters above sea level.

Table 2 Administrative Area and Location of Road Route Plan Locations

Location	Regency	Subdistrict	Area (Ha)	Wide (%)
Aladi-Tulabolo	Bone Bolango	Central Suwawa	2342.84	6.25%
		East Suwawa	35152.45	93.75%
		Amount	37495.28	100%

Source: Results of analysis of Regional Unit Maps, 2024

Based on data obtained from the Gorontalo Province Department of Public Works and Regional Development Planning, the road network, especially the Aladi-Tulabolo section, has a planned length of 30 km, with 22 km of unopened roads. The spatial location of the research area can be shown in Figure 2.

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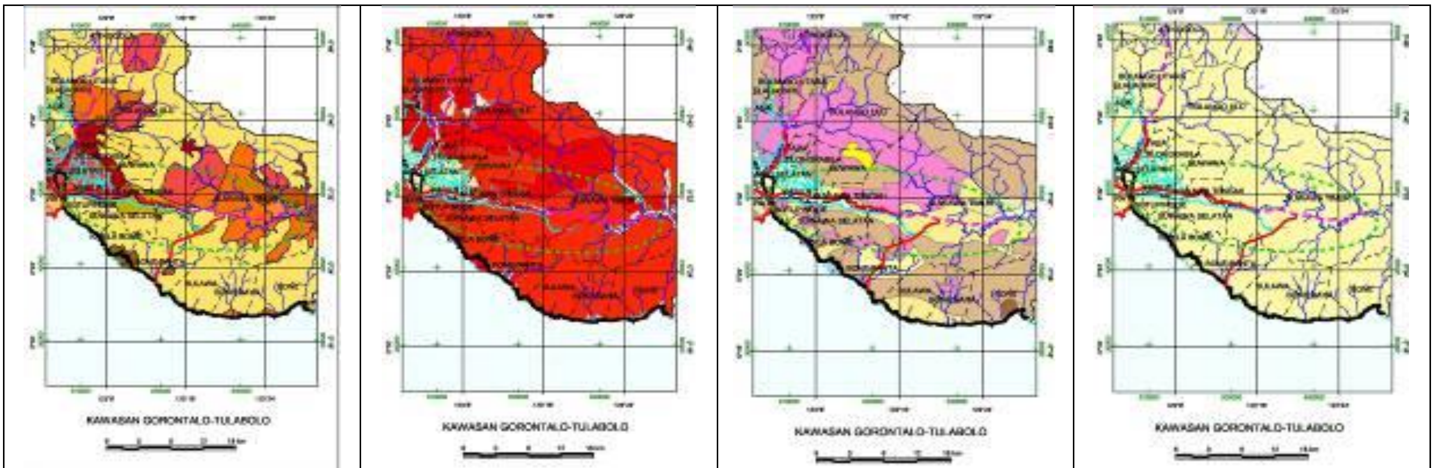
Fig 2 Location of Aladi-Tulabolo Road Route Development Research

➢ *Landform, Slope, Rock Type and Soil Type*

The research's description of landforms, slopes, rock types, and soil types is based on the results of the analysis, which can be described as follows.

- Analysis of the Alos Image Map in the 2008 recording year, the results show that the research area generally has 6 (six) types of landforms, with two dominant types of landforms, namely foothill slopes and wavy terrain (D1) spread across Central Suwawa sub-district covering an area of 730,446 ha (31.49 %).
- Indonesian Earth Map 1:50,0000, Tilamuta 1999 sheet, which is used to determine the condition of slope slopes, the results show that there are three types of slope classification, namely, class I with a slope of 0-2%, class IV with a slope of 15-40%, and class V with a slope > 40%. The largest slope class is class I, which is distributed in East Suwawa District, covering an area of 2,5730.28 ha (73.64%), followed by class IV slope (15-40%) in Central Suwawa District, covering an area of 1113.49 ha (48.01%).
- Geological Map 1:250,000, Kotamobagu sheet 2316, 2317 1997 Edition, to determine the condition of rock types, the results show that nine rock types were obtained in the research area. There is 1 (one) most significant type of rock, namely tuff, lapilli tuff, breccia and lava (TQpv) rock, spread across the Central Suwawa sub-district covering an area of 905.45 ha (39.06%), and in the East Suwawa sub-district covering an area of 14052.31 ha (40.22%).
- Soil Map, used to determine the soil type, results in only one soil type. This type of soil is the Mediterranean red and yellow (Me) type, spread across the Central Suwawa sub-district, covering an area of 2319,393 ha (100%), and in the East Suwawa sub-district covering an area of 34942,758 ha (100%).
- A map of the variables that make up the terrain unit consisting of a landform unit map, slope, rock type (geology), and soil type map can be displayed in Figure 3.



Form it	Slope	Geology	Land

Fig 3 Map of Variables that Make Up The Terrain Units at the Research Location

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➢ *Research Area Terrain Unit*

In this research, the variables that make up the terrain unit are as follows. Based on the analysis of terrain unit maps, the overlay of landform unit maps, slope, rock type, and soil type obtained the area and characteristics of the road route development area connecting Aladi-Tulabolo.

- Terrain Units in Formations Originating from the Denudational Process (D), a large group of landform units that occur due to degradation processes such as landslides and erosion. The landforms of Denudational origin include; 1) foothill slopes and undulating terrain (D1), forming 2 (two) terrain units, 2) rocky mountains interspersed with calcareous sediments (D3b), forming 3 (three) terrain units, 3) non-intrusive volcanic dominant rocky mountains (D3d), forming 4 (four) terrain units, spread across sub-districts.
- Terrain Units in the Origin of Fluvial Processes (F) are large landform units that occur due to river activity. This original landform only includes valleys between colluvial hills (F4c), forming 5 (five) terrain units.
- The area and characteristics of terrain units in the Aladi-Tulabolo route area in more detail can be shown in Table 3.

Table 3 Area and Characteristics of the Aladi-Tulabolo Road Route Area Based on Medan Unit Variables

Road Route Location	**Unit Variables Terrain Units**				**Road Route (Ha)**
Subdistrict	**Form it**	**Slope**	**Rock Type**	**Type of soil**	**Gorontalo-Tulabolo**
EAST SUWAWA	D1	0 - 2%	G15	Me	33,240
		15 - 40%	G3	Me	1,721,133
	D1 Total				1,754,373
	D3b	0 - 2%	G3	Me	956,122
			G9	Me	51,674
		0 - 2% Total			1,007,796
		15 - 40%	G3	Me	19,970,657
	D3b Total				20,978,453
	D3d	0 - 2%	G15	Me	65,204
			G3	Me	28,960
		0 - 2% Total			94,164
		15 - 40%	G15	Me	114,103
			G3	Me	15,874,050
		15 - 40% Total			15,988,153
	D3d Total				16,082,317
	F4c	0 - 2%	G15	Me	51,030
			G3	Me	1,487,854
			G4	Me	41,030
			G9	Me	2,470,744
		0 - 2% Total			4,050,658
		15 - 40%	G3	Me	34,866
	F4c Total				4,085,524
EAST SUWAWA Total					**42,900,667**

Source: Results of Landform Unit Map Analysis
Description: Me= Mediterranean red and yellow

Spatially (space), the distribution of terrain units in the research area can be seen in Figure 4.

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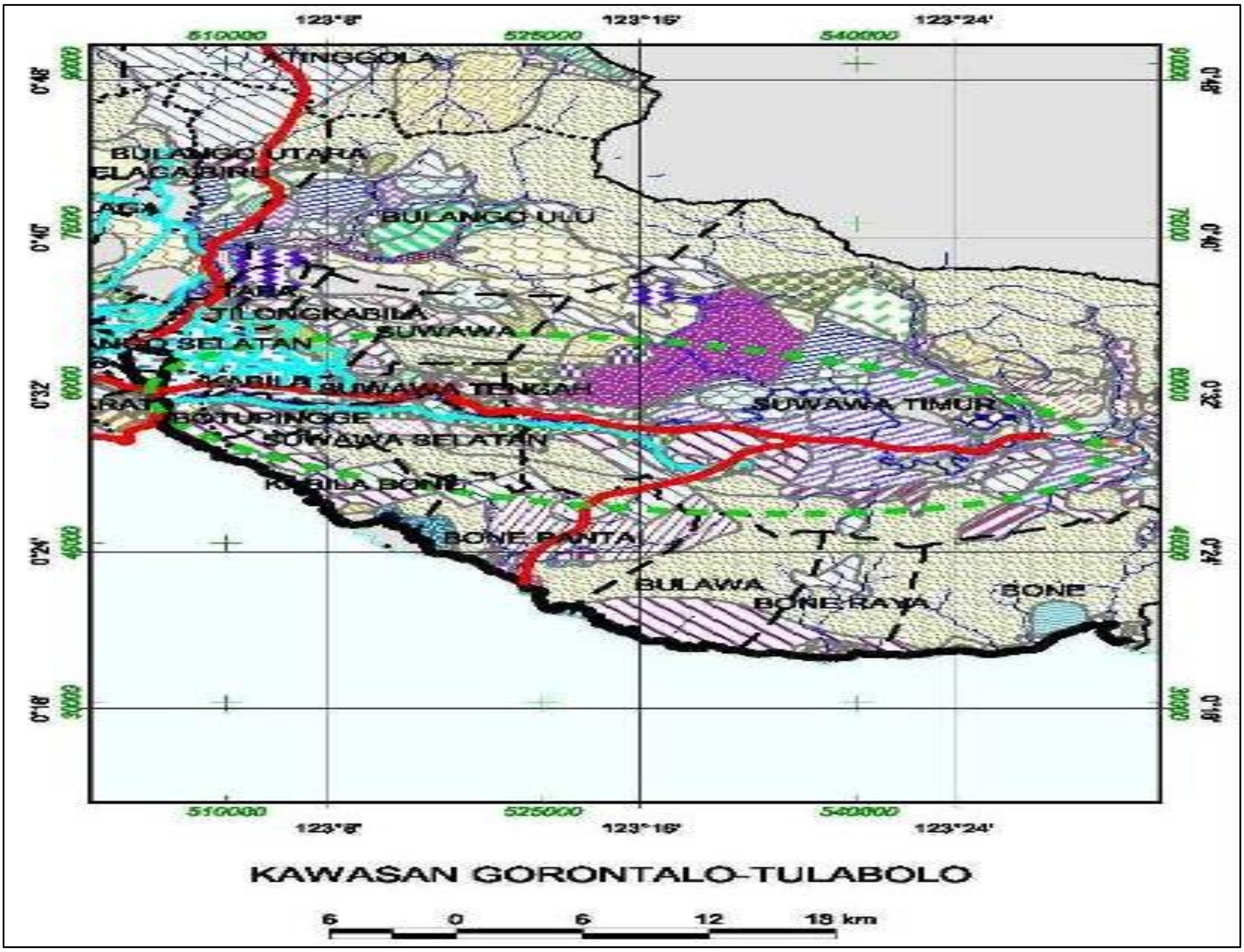

Fig 4 Map of Terrain Units at the Research Location

- *Suitability of Terrain for Road Network Development*

Based on the overlay (overlapping) results of the three factors that make up the terrain unit mentioned above, namely the slope factor, rock type factor and soil type factor, directions for the suitability of the terrain for use in developing road routes are obtained. Directions for suitability of the terrain are arranged based on a classification which can be mathematically calculated using the equation I=R/N (Effendi, 1987) where I is the desired class interval, namely five units, R is the difference between the highest and lowest values, 12 units. So the terrain suitability value interval is divided into 5 (five) suitability classes, namely, high suitability (S1), medium suitability (S2), low suitability (S3), temporarily unsuitable (N1), and permanently unsuitable (N2). The results of calculating criteria for terrain suitability values for developing road routes can be shown in Table 4.

Table 4 Description of Terrain Suitability Class Criteria for Example Locations For Road Construction

Conformity class	Interval Value	Category	Physical Description of Terrain
S1	13-15	High suitability	Very suitable for road paths
S2	11-13	Medium suitability	Suitable for road paths
S3	9-11	Marginal suitability	Suitable enough for road routes
N1	7-9	Temporarily inappropriate	Not suitable for roads
N2	3-7	Incompatible forever	Not suitable for roads

Source: Calculation Results.

Determining the terrain suitability class for the location of road routes in the Aladi-Tulabolo area is based on the results of assessing 3 (three) parameters of the physical aspects of the environment in varying terrain suitability classes with a total of 59 terrain units. The results of the analysis of terrain characteristics and score values in determining the suitability of the terrain for the location of routes in the research area can be shown in Appendix Table 1.

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➢ *Road Network Development Scenario*

Determining the suitability class of terrain units for the location of road routes in the research area is based on the results of assessing 3 (three) biogeophysical engineering aspect parameters, in variations in terrain suitability (class IV), with the number of selected terrain units in the Aladi-Tulabolo area being 10 units. Terrain from a total of 59 evaluated terrain units. The distribution of terrain units in determining the suitability of terrain to support each road route scenario in the research area can be shown in Table 5.

Table 5 Distribution of Selected Terrain Suitability Classes in Aladi-Tulabolo Road Route Layout Scenario

No	SPM No	Terrain Unit	Subdistrict	Area (ha)	Conformity Class
1	13	D3bG3MeL1	East Suwawa	361,614	S2
2	14	D3bG3MeL4	East Suwawa	6,211.203	S2
4	20	D3bG9MeL1	East Suwawa	25,837	S1
5	27	D3dG15MeL1	East Suwawa	16,301	S1
6	28	D3dG15MeL4	East Suwawa	114.103	N1
7	31	D3dG3MeL1	East Suwawa	14.48	S2
8	32	D3dG3MeL4	East Suwawa	2,229.475	S2
9	46	F4cG4MeL1	East Suwawa	20,515	S1
10	50	F4cG9MeL1	East Suwawa	617,686	N1

Source: Analysis results

Several considerations in determining the number of each terrain unit in the research area are, firstly, to support the scenario (alternative 1) of road route location based on terrain suitability classes in the intervals S1, S2, S3, and N1 by taking into account the contour conditions (minimum slope) that there is, the second is to support the scenario (alternative 2) of road route location based on terrain suitability classes in the intervals S1, S2, S3, and N1 taking into account the closest (shortest) distance, and the third is to support the scenario (alternative 3) of road route location based on terrain suitability classes in the intervals S1, S2, S3, and N1 taking into account the plans of the Public Works Department/Kimpraswil of Gorontalo Province.

The development of the road route in the Aladi-Tulabolo area is located in a mountainous area with non-intrusive volcanic rock and intrusive rock, with a structure of lava basalt (Teot), Granodiorite (Tpb) and dacite (Tppv) rock types. And on the Red and Yellow Podzolic soil type (Pok).

On a macro scale, the Aladi-Tulabolo road network scenario will connect the Tulabolo Farming Business access route (Gorontalo-Suwawa-Tulabolo). On a micro-scale scenario, this road network will connect fairly dense residential areas from the centre of Kabila City, Tilongkabila, Suwawa sub-district, to Tulabolo village, East Tulabolo, which connects with Pinogu Village. The results of the analysis of road route lengths from each alternative scenario, the Aladi-Atinggola area, are shown in Table 6.

Table 6 Route Length of the Aladi-Tulabolo Road Based on Alternative Road Network Scenarios

SCENARIO Alternative Road Network	Suitability Symbol	Line Route Length	
		Meters	Percent
Conformity and Contour (alternative 1)	N1	-	0.00%
	N2	-	0.00%
	S1	2,090.43	8.03%
	S2	23,952.25	91.97%
	S3	-	0.00%
Total Fit and Contour		**26,042.68**	**100**
Suitability and Shortest Distance	N1	-	0.00%
(alternative 2)	N2	-	0.00%
	S1	3,632.91	15.55%
	S2	19,728.47	84.45%
	S3	-	0.00%
Suitability and Total Shortest Distance		**23,361.38**	**100**
PU Suitability and Plans	N1	1,848.89	8.08%
(alternative 3)	N2	-	0.00%
	S1	669.92	2.93%
	S2	20,352.40	88.99%
	S3	-	0.00%
Suitability and Total PU Plan		**22,871.2**	**100**

Source: Analysis results

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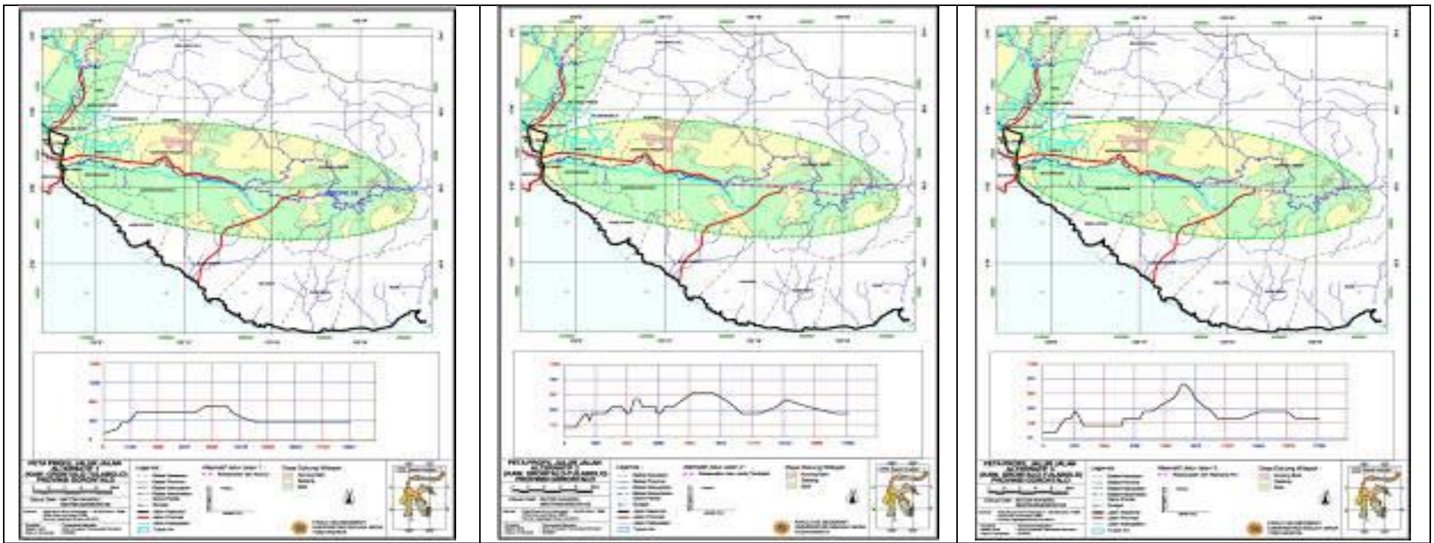
Based on Table 6, the length of each alternative road route is obtained. In the first alternative scenario with a length of 26,042.68 meters (26.04 km), the number of contours crossed is six contour lines. This first alternative route is a route that passes through terrain with a slope of 15-40% (steep) at an average height of 404 m above sea level. In the second alternative scenario with a length of 23,361.38 meters (23.36 km), the number of contour lines crossed is six contour lines. This second alternative route is a route that passes through terrain with a slope of 15-40% (steep) at an average height of 390 m above sea level. Meanwhile, in the third alternative scenario, a length of 22,871.20 meters (22.87 km) is obtained, and the number of contour lines crossed is eight contour lines. This third alternative route is a route that passes through terrain with a slope of 15-40% (steep) at an average height of 360 m above sea level.

The road network for the Aladi-Tulabolo area scenario will pass through (cross) 3 (three) villages in Central Suwawa sub-district, namely Duano village, Tolomato village and Lompotoo village, 2 (two) villages in East Suwawa sub-district, namely Tulabolo Village and Tulabolo Village. East Tulabolo. The results of the analysis of alternative road network scenarios in the Marisa-Tolinggula, Tapa-Atinggola and Aladi-Tulabolo areas can be shown in Figure 5.



Alternative 1	Alternative 2	Alternative 3

Fig 5 Alternative Scenario Map of Road Routes at the Research Location

IV. CONCLUSION

Based on the results of the analysis and discussion, it can be concluded that (a) the suitability characteristics of the terrain for the development of the road network in the research area refer to the analysis of terrain units with the parameters that make up the terrain units in the form of landform units, slope, rock type and soil type, has zoning or area with 5 (five) levels of suitability, namely, S1 suitability (high suitability), S2 suitability (medium suitability), N1 suitability (temporarily not suitable), and N2 suitability (permanently not suitable). The suitability class for developing the dominant road network for the Aladi-Tulabolo area is in suitability class S2, amounting to 99.25. (b) a road route development model based on the suitability of the terrain in the research area can use the formulation Terrain Units (SM) = f (bl, cl, jb, jt), where bl = landform, kl = slope, jb = rock type, and jt = soil type.

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