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THE ANALYSIS OF GEOTECHNICAL AND TOPOGRAPHICAL ASPECTS BASED ON GIS AS INITIAL IDENTIFICATION OF ROAD ALIGNMENT DETERMINATION ON SWAMP AREAS

Indrayani[1*], Erika Buchari[2], Dinar D.A. Putranto[2], Edward Saleh[2]

[1] *Environmental Science, Sriwijaya University, Palembang, 30139, Indonesia,*
[2] *Polytechnic of Sriwijaya, Palembang, Indonesia*

ABSTRACT
The development of an area could not be separated from the supported road infrastructure. Therefore, a proper planning regarding the road construction is necessary. The initial step of the road planning of this study is road alignment determination by using these considerations: geotechnical and topographical aspects. The use of GIS in the initial identification of road alignment determination is expected to provide an easiness in determining the appropriate areas to be taken as a road alignment. This research was conducted in Banyuasin since this area has the largest swamp area in the South Sumatra. Furthermore, the area will be developed as a special economic zone through the government regulation No. 51 of 2014. The maps of the soil type, peat depth, and topography are taken from the secondary data while the texture of soil and CBR value are derived from the field testing and the laboratory result from the previous research. The scoring of the available data is conducted by the weight of process of geotechnical and topographical aspects with three ratios as 50 : 50, 30 : 70 and 70 : 30. The result shows that the portion of weighting ratio is more emphasized on the geotechnical aspects rather than the topographical aspects with the ratio comparison of 70: 30. The area has the depth of peat between 100 - 200 cm and 200 - 400 cm, not appropriate to taken as a road alignment.

Keywords: Geotechnical and topographical aspects; GIS; Road alignment; Swamp area

1. INTRODUCTION
The initial step in the process of planning, designing and constructing is the determination of road alignment (Dragan and Jarre, 2015). Determining the best road alignment could apply GIS and Remote Sensing technologies (Subramani and Nanda, 2012). GIS is a widely known software in spatial decision making by analyzing spatial data (maps), field data, and socio-economic data and emphasizing on data collection (input), process, analyze, and output which has managerial and decision making function (Faisal, et al, 2013; Rikalovic, et al, 2013). The most influential factors in designing the pavement thickness are the evaluation of the subgrade and traffic analysis. Mistakes in the evaluation of subgrade could lead to the differences in carrying capacity of the traffic. It is up to 10 times, which means fixing the subgrade strength is the main requirement in getting a good pavement performance (Decree of the Director General Higways No 22.2/KPTS/Db/2012). Another factor considered of land management is topography, since different topography will show different slope and characteristics of soil (Siswanto, 2006). The road alignment built on a swamp area certainly requires different road planning compared to the hilly and mountainous areas. The problems of

[*] Corresponding author's email: iiend_sumantri@yahoo.com; Postal Address : Padang Selasa Street 524, Bukit Besar Palembang, 30139, Indonesia

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swampy area are the filling and removal of the material from the sediment, whereas the problems on the hilly area are the drainage, cutting and filling (Riyadi, 2007). Indonesia has wide swamp areas, and the South Sumatra is one of the province which has quite large swamp. It is about 613,795 hectares consisting of 455,949 hectares of tidal swamp, and 157,846 hectares non tidal swamp (BWS, 2015). This swampy area is being developed by the government for agriculture, plantation and fishery areal Ismail et al, 1993). To support the development of swamp area, the infrastructure is needed. Therefore, it needs a research using GIS as a tool to get a plan regarding the sustainable road. Thus, the construction will not damage the environment (Subramani and Nanda, 2012; Yildirim and Nisanci 2010; Malczewski, 2004).

Another considered factor as an initial identification of road alignment determination on swamp area to reach sustainability is the environmental aspects (UNCED, 1992). The environmental aspects taken in this study are geotechnical and topographical aspects. Geotechnical aspect is including soil type, soil texture, peat depth and CBR value. The soil type is an important factor that influences the suitability of land use (Suryanto, 2007). Soil texture in this study is based on AASHTO the classification which is usually used by the General Highways Directorate on the roads construction in Indonesia. The peat soil area in South Sumatra was approximately 6,436,649 ha. It is 43.18% of the total of the peat land area in Indonesia (Ritung et al, 2011). The last factor is California Bearing Ratio (CBR) value which has an enormous influence on the performance of pavement to support the weight of vehicle and the existing traffic (General Higways Director, 2006; Gedafa, 2006). The topographical aspect is assessed based on the topographical maps from SRTM DEM Sumatra. Furthermore, from the two aspects of this study, the suitability of geotechnical and topography aspects as initial identification of road alignment determination based on GIS will be obtained.

2. METHODOLOGY

2.1. Study area

Banyuasin has an area of 1,183,299 hectares. It is approximately 12.18 % of the total area of South Sumatra. It is situated between 1^{o}37′32.12″ up to 3°09′15.03″ LS and 104°02′21.79″ up to 105 ° 33′38.5″ BT (RTRW Banyuasin, 2011). The map of Banyuasin district is given in Figure 1.

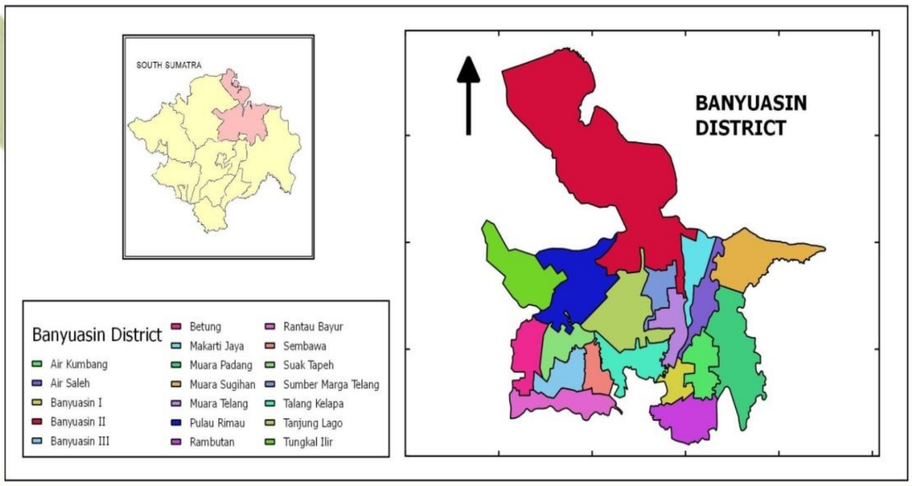

Figure 1 Area of the research study

Banyuasin was taken as a study area for several reasons, they are: (1) this area has topography consisting of 80% of wet lowland which a slope of 0 – 8 % and 1.18161 million ha wide, 8 - 15% of 1,689 hectares is the coastal area. Tidal and non-tidal swamp areas spread along the east coast to the hinterland with the topography area consisting of 20 % wavy until the undulating plateau with an elevation of 0 - 40 m above the sea level; (2) a formulation of spatial planning policies of Banyuasin has developed into hierarchical road network which connects the centers of urban services with each service area (RTRW Banyuasin, 2011); (3) The Special Economic Zone in the region of Tanjung Api-Api will be constructed according to the Government Regulation No. 51 Year 2014 about Special Economic Zones Tanjung Api-Api.

2.2. The analysis framework

Scoring and weighting techniques are performed in this study; the criteria parameter of geotechnical aspect includes the soil type, soil texture, CBR value, and the peat depth. The parameter for the topographical aspect is slope. The weighting technique is done for both of these criteria.

The initial stage of this study is collecting data including the maps of soil and topographic map which were obtained from the spatial plan (RTRW) of Banyuasin in 2011. Furthermore, the digitation of map for spatial data processing was conducted. The map of the peat depth in the form of shp was obtained from the map of International Indonesia WETLAND in 1999. The soil texture was determined based on the conversion literature of the soil type presented on the map. Afterwards, it is put into the attribute data to obtain the map of soil texture. The CBR value was obtained from the results of field and laboratory testings which were previously conducted by other researchers (Oktaviani and Sar, 2014; Prima and Pangestu, 2014). The calculation was carried out in order to obtain the map of CBR value. The results of field and laboratory testings were used as a validation for the existing map.

Data analysis and processing were conducted by dividing the two reviews. First analysis of attribute was done by giving a score for the geotechnical aspects parameter. Score ranges from 1 to 5, score 1 is given to the most suitable parameter to road alignment, while score 5 is given for the most unsuitable parameter to road alignment. Weight determination to each criterion was 25% with consideration that all geotechnical aspects criteria are important. To obtain geotechnical aspects suitability, the overlay of data attributes and weights analysis result was done. The map of the geotechnical aspects suitability was then obtained. The topographical aspect was analyzed by giving scores for the slope. Score 1 is given to the relatively flat slope and score 5 is given to the very steep slope. Thus, a map of the topographical aspect suitability can be obtained. The next step was give the weighting to both of these criteriausing three ratios namely the first ratio 50% : 50%, second 30 : 70%, and third 70 : 30%. The next step was multiplying the weighting both of aspects with those three ratios. Furthermore, the overlay process to obtain a map suitability of geotechnical and topographical aspects was conducted. The steps in this study can be seen in Figure 2.

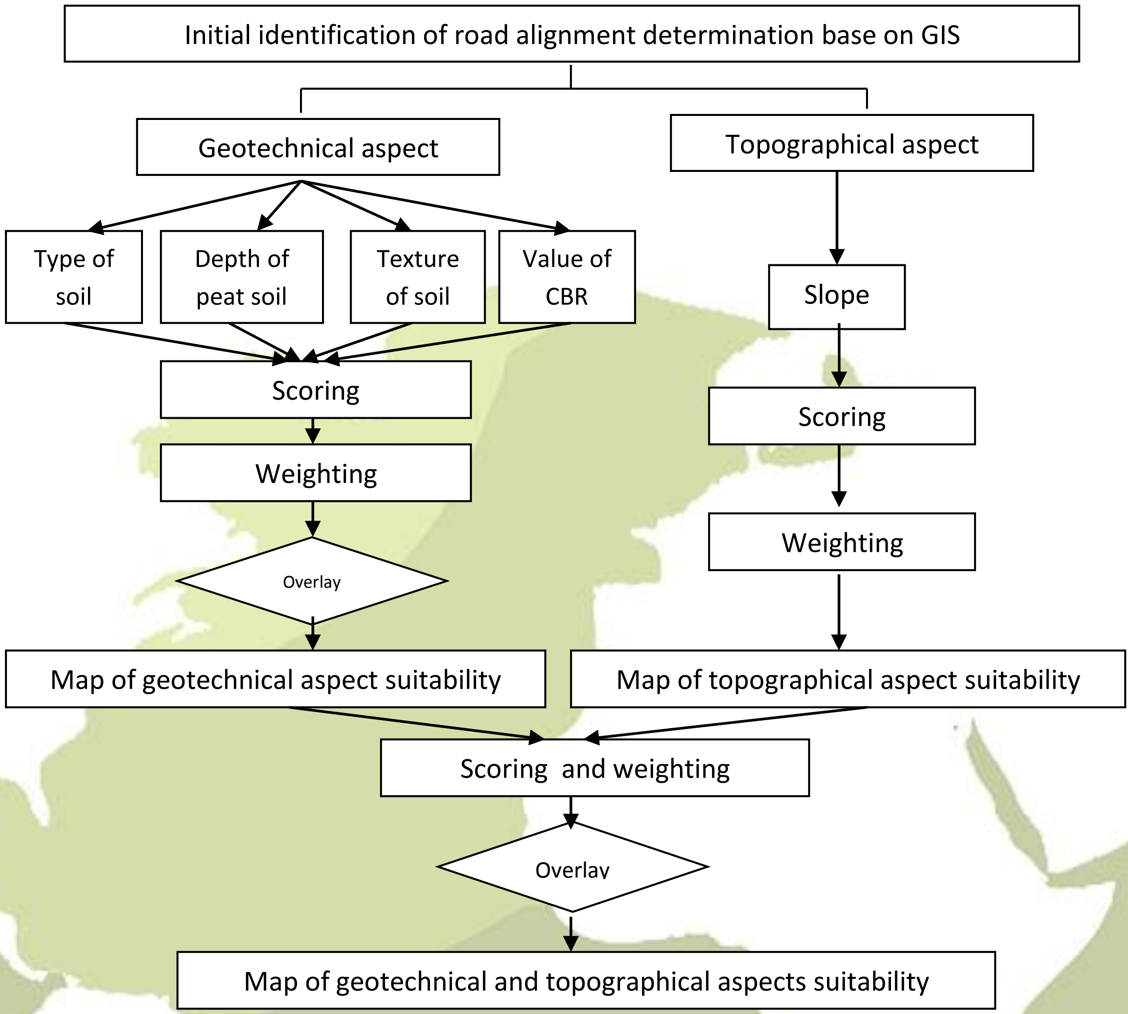

Figure 2 Flowchart of the research

3. RESULT

3.1. Geotechnical aspects

The characteristic of the soil was very important to know the feasibility of the constructions (Suryanto, 2007). In this study, the soil type parameters were taken based on the classification from the soil research center (PPT) Bogor. The scoring was based on the sensitivity level of the soil type for erosion; the highest score is given for the soil that has high sensitivity. The score and weighting of the soil type are as seen in Table 1.

Table 1 Score and weighting criteria soil type

Soil type	Sensitivity to Erosion	Score	Weighting
Aluvial, Gley, Planosolm, Hidromorf.	Not Sensitive	1	0.25
Laterit, Latosol	Sensitive Enough	2	0.50
Brown Soil	Less Sensitive	3	0.75
Andosol, Laterit, Grumosol, Podsol, Podsolik	Sensitive	4	1.00
Regosol, Litosol, Organosol, Renzina	Very Sensitive	5	1.25

Source : Decree of Agriculture Minister No. 837 (1980) & No. 683 (1981)

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For the peat depth criteria, the highest score shows the very deep peat soil. The score and weighting of the peat depth criteria are as seen in Table 2.

Table 2 Score and weighting criteria peat depth

Depth of peat soil (cm)	Criteria	Score	Weighting
20 – 50	Vary shallow	1	0.25
50 - 100	Shallow/ thin	2	0.50
100 - 200	Moderate	3	0.75
200 - 300	Deep/ thick	4	1.00
> 300	Very deep/ thick	5	1.25

Source : Widjja *et al*, 1992

According to the soil texture using AASHTO soil classification, the highest score of soil texture is given to clay, as shown in Table 3.

Table 3 Score and weighting criteria soil texture

Soil Texture	Category	Score	Weighting
Gravel	Excellent	1	0.25
Fine sand	Good	2	0.50
Gravel with silt and Gravel with clay	Fair	3	0.75
Silt	Poor to Fair	4	1.00
Clay	Very Poor	5	1.25

Source : AASHTO, 1998

Scores of the CBR was given based on the value of CBR, the smallest CBR value has the highest score and is unsuitable to be taken as road alignment. Therefore, the repairement of the subgrade conditions for increaing the soil carrying capacity is necessary. The score and weighting of CBR value are as shown in Table 4.

Table 4 Score and weighting criteria CBR value

CBR	General Rating	Score	Weighting
0 – 3	Very poor	5	0.25
3 – 7	Poor to fair	4	0.50
7 – 20	Fair	3	0.75
20 – 50	Good	2	1.00
> 50	Excellent	1	1.25

Source : Das, 1995

Furthermore, the score weighting of each parameter was conducted by giving equal weight to each parameter which is 25%, and the maps of the result of weighting are as shown in Figure 3.

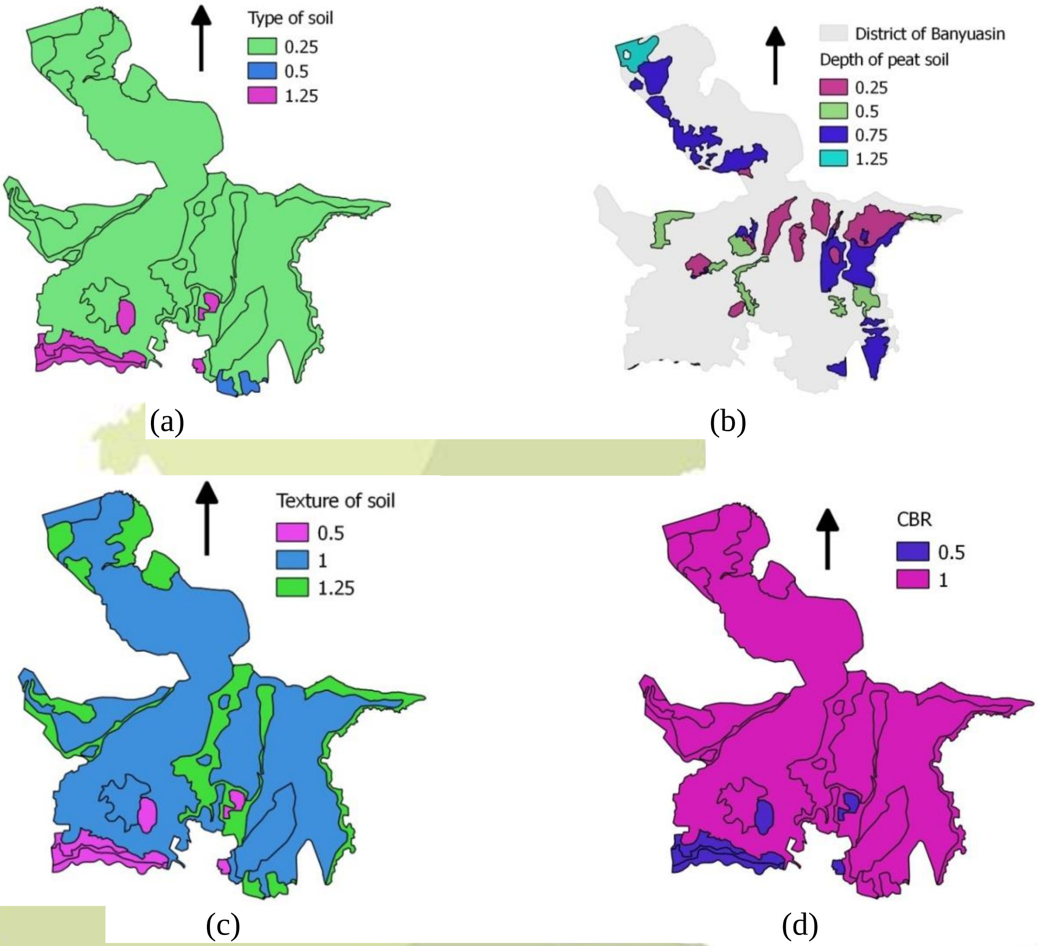


Figure 3 Weighting of geotechnical aspects (a) type of soil; (b) depth of peat soil; (c) texture of soil; (d) value of CBR

3.2.Topographical aspect

The topographical score was given based on the slope of the land. The lowest score indicates the flat slopewhich means that this area has suitability to road alignment. The score and weighting of the topographical aspect are as shown in Table 5.

Table 5 Score and weightening of topography criteria

Slope	Criteria	Score/weightening
0 % - 8 %	Flat	1
8 % - 15 %	Sloping	2
15 % - 25 %	Rather steep	3
25 % - 40 %	Steep	4
> 40 %	Very steep	5

Source : Decree of Agriculture Minister No. 837 (1980)

Topographical aspect map as seen in Figure 4.

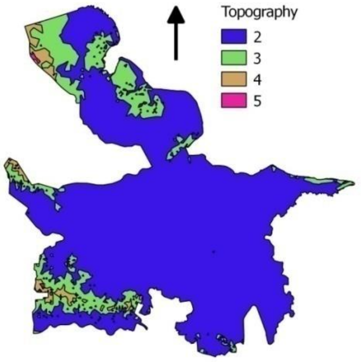


Figure 4 Topographical aspect score/weighting

3.3. The Analysis of geotechnical and topographical aspects suitability

The analysis was conducted by overlaying all maps that consist of the geotechnical and topographic maps. The equation used to combine the score and weighting is :

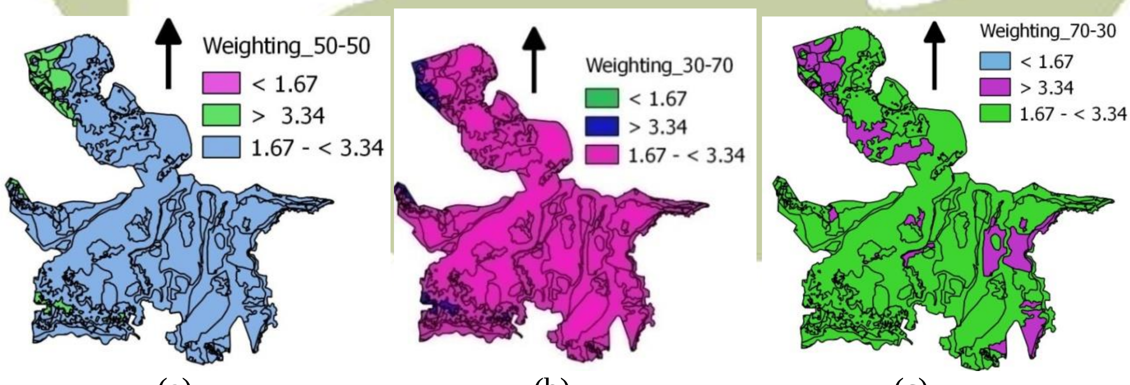
$$X = \sum_{i=1}^{n}(Wi \; x \; Xi) \tag{1}$$

Where: X is value of the suitability of geotechnical and topographical aspects; Wi is weighting parameter to- i; and Xi is the score of the class parameter to-i.

Weighting of geotechnical and topographical was multiplied with three ratio namely 50% : 50%, 30 : 70%, and 70 : 30%, Thus, a map of geotechnical and topographical aspects suitability as initial identification of road alignment determination in swamp areas was obtained. An assessment of suitability based on ranking of the weighting is shown in Table 6. The map overlay result of each weighting comparison is shown in Figure 5.

Table 6 Suitability weighting of geotechnical and topographical aspect

Rank	Geotechnical and topographic aspects appropriate	Weighting
1	Very Appropriate	< 1.67
2	Appropriate	≥ 1.67 - < 3.34
3	Not Appropriate	≥ 3.34



(a) (b) (c)

Figure 5 Weighting comparison of geotechnical and topographic aspects (a) 50 : 50; (b) 30 : 70; (c) 70 : 30

Figure 5 shows that among all comparison ratio, no area is appropriate to be taken as road alignment since all weighting > 1,67. At geotechnical and topographical aspects comparison ratio, 50: 50 and 30: 70 ratios indicate that some areas with peat depth of over 100 m was declared eligible to be taken as road alignment although this condition is dangerous for the road construction. This is happened since the topographical aspect has a quite large ratio. In addition, the swamp area generally has a flat contour area, so the topographical aspect ratio is not always equal to the geotechnical aspects Thus, this ratio can not be used. While at the ratio of 70 : 30, it is shown that the regions with depth of peat > 100 m are not appropriate to be taken as road alignment. This is according to the review of the literature. The depth of peat > 100 m is dangerous for road construction. The comparison ratio of geotechnical and topographical aspects taken was 70 : 30 since in the swampy area, in average, has a flat slope.

4. DISCUSSION

Banyuasin has the lagerst swampy areas in South Sumatra; thus it has a carrying capacity of weak subgrade. The results showed that the average value of CBR ranged from < 5% up to 10%, with the soil texture is silt up to clay. The topography has a slope average of 0 - 8%. Some areas in Banyuasin has peat soil with a depth of 50 up to 200 cm, even on a particular region has very deep peat soil that is 200 - 400 cm and should be avoided in the determination of road alignment.

Banyuasin region is an area with huge potential to be developed in various sectors such as plantation, agriculture, and industry. The road infrastructure was needed to support these development. Road alignment determinations in swamp area certainly require different road planning of hilly and mountainous areas which have a good stability subgrade. Even though the result showed that several areas in Banyuasin were appropriate as road alignment, a special calculation in determination the type and thickness of the pavement is needed since generally Banyuasin has a poor stability subgrade.

5. CONCLUSION

Geotechnical and topographical aspects must be considered in the initial identification of road alignment determination. However more emphasis is on the geotechnical aspects rather than the topographical aspects with the comparison ratio of 70 : 30. Areas having the peat depth of 200 - 400 cm are not appropriate to be taken as road alignment.

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