International
Journal
Of Advanced Research in Engineering & Management (IJAREM)
ISSN: 2456-2033 || PP. 06-13

Road Network Analysis and Determining the Best Route based on Geographic Information Systems

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Abstract: Roads are transportation infrastructure that functions as a route for the movement of people, goods and services to and from certain locations. Apart from being a transportation facility, roads have a role as a tool for regional development and connectivity, and also have an environmental function. Of course, with the complexity of this role, a road must have a good level of comfort, safety and travel effectiveness for all its users. Nowadays, road users tend to look for the best alternative routes to get the best accessibility with the aim of reducing travel time and avoiding traffic jams. This research aims to find out the best route and ideal travel distance based on several supporting parameters. The method used is the weighting/scoring method for each criterion and then data processing is carried out based on a geographic information system so that a route map can be obtained. From the results of the analysis that has been carried out, 2 routes have been obtained that can be used as alternative routes. The results of the analysis of the most effective and efficient route based on geological structure, lithology, soil type, road geometry, traffic conditions, land cover, forest environment, slope and rainfall, it was found that route 1 with a distance of 17 km, with a total land suitability of553352613.002664 m2, is the most effective and efficient route, although with a longer distance duration compared to route 2 which only has a distance of 13 km, with a land suitability level of100543589.17874 m2.
Keywords: Transportation, Roads, Geographic Information Systems, Scoring

Introduction

Nowadays, roads and tourist attractions are very closely tied together and have interrelated roles. As it has become a psychological need for various elements of society, tourist attractions are always a target to visit. In an effort to visit a tourist attraction, roads are of course the main support in terms of transportation infrastructure. The growth rate of tourist attractions can be more rapid with the availability of good roads, in various ways. Both in terms of the level of service, as well as the construction design which is related to the safety and comfort parameters of road users. The cities of Batu and Malang are examples used as case studies in this study. These two cities are tourism destinations in East Java, and are even among the favorite tourism destinations in Indonesia. This can also be seen from the surge in the number of tourists (from outside the city) which has reached 4,958,841 throughout 2022. With such a large number of tourists recorded, of course this has an impact on the performance of the roads that connect to the city of Batu. Congestion is one of the real impacts and always occurs along the roads that provide access to the tourist city of Batu. The large number of alternative roads has become a target for tourists, causing traffic jams to pile up on various roads, especially on roads in the Malang City administrative area, during weekends and peak seasons. Several articles on the results of similar research, at different study locations, include:

1. Road Network Route Analysis (Case Study: Suramadu Bridge – Juanda Airport) (Boy Dian Anugra Sandy, Proceedings of SNPPM, 2019). The data analysis method is based on primary data from survey results and secondary data in the form of data regarding the road chosen as the route for analysis. From the results of a survey conducted using two-wheeled vehicles. Data obtained from the three routes took the value of the fastest travel time. It was found that route 2, which is a type of secondary arterial road, has the fastest travel time among other routes with a travel time of 2929 seconds and a distance of 22.97 km.
2. Shortest Route Discovery in Map-Based Applications (Putu WiraBuana, Lontar Computer Journal). To develop the shortest route tracing application, this can be done by creating shape files, especially for roads, including weighting the distance and standard speed for each road segment, preparing a network dataset to ensure network connectivity by determining one of the fields in the road attribute as

impedance, tracing routes with Network Analyst. . The output of this application is a sequence of routes and estimated travel time. The test results by making several routes and comparing calculations have shown that the route results are appropriate according to conditions in the field.

3. Pontianak Regency Road Geographic Information System (IdySafriadi, AGRIFOR Journal Vol. XV No. 01, 2016). The results obtained from this research are that the condition of primary local roads still does not meet the minimum road width requirements, the pavement condition is good for 32 sections, the type of damage that is most often cracks is 76%, the geometric condition is in good condition for 7 sections, the social condition is good for 76%. 15 sections. This research has produced a Geographic Information System-based database program which contains information on primary local road conditions in the Pontianak Regency IKK.
4. Evaluation of City Freight Transportation Routes Using Geographic Information Systems (GhinaFadilah, Jupri, Lili Somantri, Geography Education Journal vol. 18 No. 02 October 2018). The research results show that city transport routes in Bogor City have a circuit network, the factors that most influence driver route selection are cost and income. For passengers, route selection is influenced by fares, safety, comfort, punctuality. This research recommends the four most effective routes for city transportation 01, city transportation 03, city transportation 08, and city transportation 15.

The aim of carrying out this study is to analyze the existence of the road network that connects the Malang area with the city of Batu, so that later it can provide priority results for the best routes that can be selected to reduce/avoid traffic jams and shorten travel time, using several main parameters in performance assessment. road sections, scoring parameters, and combined with the results of Geographic Information System-based analysis.

Research Methods

The method used in this research is a quantitative method and the data analysis process continues using a weighting/scoring method. The research stages generally start from problem formulation, literature review, creating research design, instrument development, data collection, data analysis, and data interpretation. Then in the data processing process using the scoring methodIn principle, this method is a way of assessing land potential by giving a score or value to each land characteristic/parameter so that the land capability class can be determined based on calculating the value of each of these parameters. In this method there are 2 (two) scoring techniques, namely the addition or subtraction technique and the multiplication or division technique (index system). The addition or subtraction technique is done by adding or subtracting the value/value of each land parameter, while the multiplication or division technique is done by multiplying or dividing the value/value of each land parameter. Determining the assessment method for determining regional development requires classification for each parameter.There are several stages, namely identifying criteria and weights, determining the assessment scale, providing a range of scores, calculating the total score, determining thresholds and classification, and interpreting the results in a research result.

Results and Discussion

Based on the research flow, it is first necessary to map several factors that are the main influence in determining the optimal road network route, several related factors, namely road width, road capacity, city size factors, road space dimensions, so that it will lead to a segment analysis each road along the route studied. As in the following image:

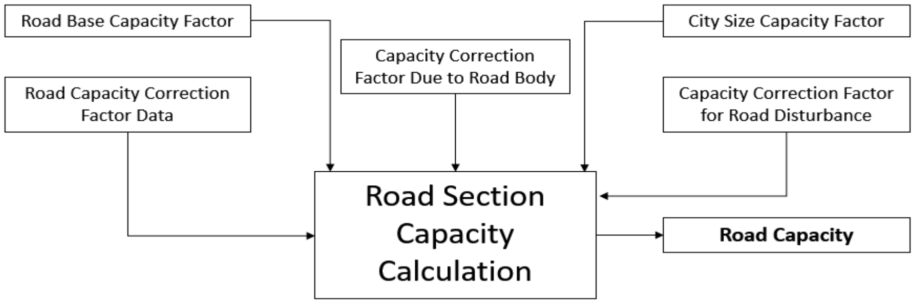

Figure 1 Hierarchical Pattern of Factors Determining Road Capacity

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The level of road service is calculated by comparing vehicle volume with road capacity so that it will produce a road service level index which can be used to determine the characteristics of the service level of a road.

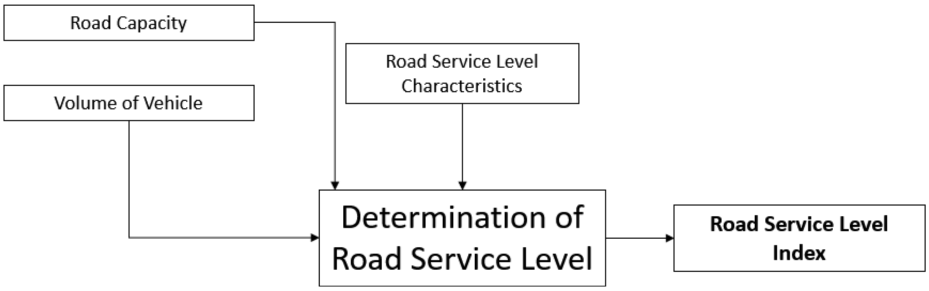

Figure 2 Determination of Road Service Levels

To obtain the ratio value, road capacity and vehicle volume are calculated. The ratio value is then converted to obtain the road service index value. This road service index value is needed for the process of determining the type of travel used on the road section being studied. Travel time on a road section is divided into two, namely travel time under normal conditions (t0) and travel time under congested conditions (tc).

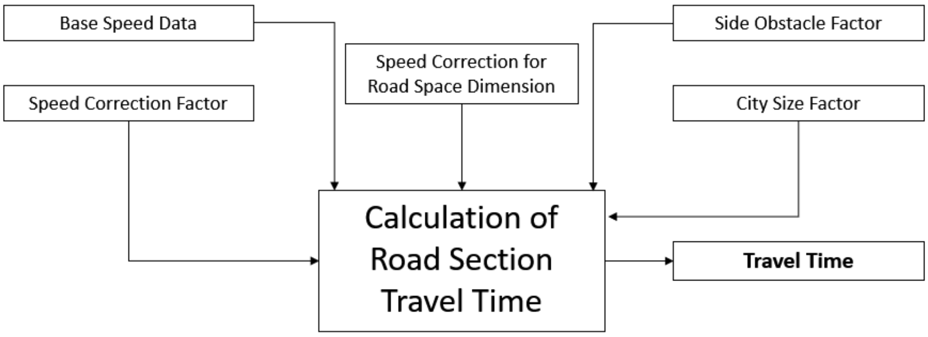

Figure 3 Calculation of Travel Time for the Road Section Studied

Then an analysis is carried out regarding the division of daily time periods which is based on working hours, work hours, school and market activities and community generation. This process produces a grouping of density characteristics based on time groups.

The soil type map shows the soil types that form the Malang-Batu tract area. This soil type map is used as a basis for creating a map of the contribution of soil carrying capacity to road construction. Next, GIS applications and quantitative indicators are used to process this soil type map, which produces a raster map with an assessment of soil type and its bearing capacity. The bearing capacity for road construction becomes weaker with clayier soil types.

Table 1 Scoring Based on Soil Type

Skor	Tingkat Daya Dukung Tanah	Jenis Tanah	Indikator Kualitatif *)
1	Sangat kuat	Litosol, Umbrisol, Renzina, Aluvial, Entisol, Vertisol, Regosol, Grumusol, Arenosol	Lanau
2	Kuat	Andosol, Latosol, Molisol	Lanau Kepasiran
3	Lemah	Kambisol, Ultisol, Inseptisol,Gleisol, Nitosol, Podsolik, Mediteran, Alfisols, Planosol	Lanau Lempungan, Lempung Kelanauan
4	Sangat lemah	Podsol, Oksisol, Lateritik, Orgonosol	Lempung

As shown in Table 1 according to Hardjowigeno (2003), technical indicators of soil type values are based on soil characteristics and classification based on geology and geotechnical science. The closer to the properties of clay, the more difficult the soil type becomes and the more expensive it is to treat road pavement. Clay soil properties have the greatest score, meaning that choosing a route will avoid basic soil which has clay properties.

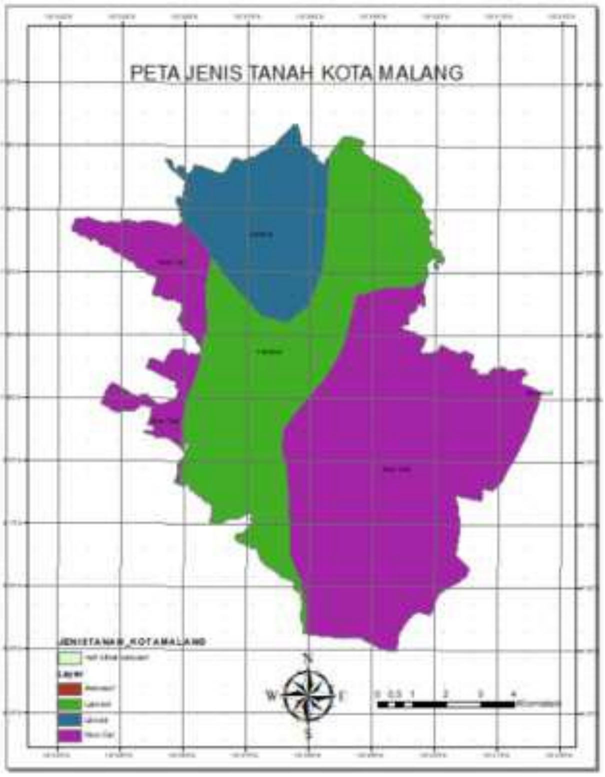

Figure 4 Soil Type Map of Malang City

The road status map functions as a basis for creating a map of the contribution of vehicle volume to increasing road capacity because it shows the distribution of road status and road capacity in the Malang-Batu route area. Road capacity is needed due to increasing traffic volumes. As shown in Table 2, the technical indicators of traffic volume values are based on the average number of vehicles. According to Handayani et al. (2017), if the average number of vehicles on one of the route alternatives is greater, then the level of handling priority will be higher.

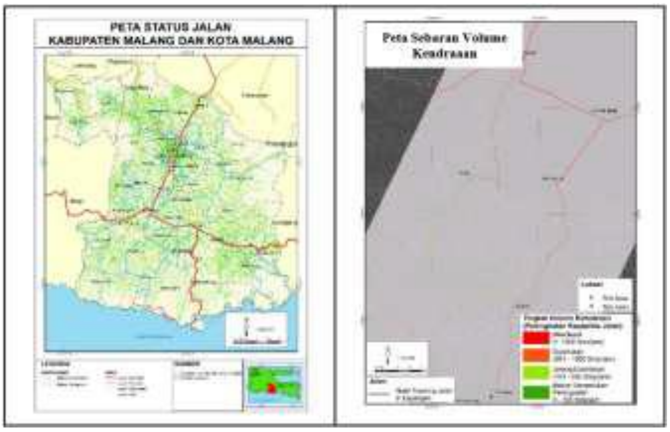

Figure 5 Road Status Map and Vehicle Volume Distribution

Table 2 Vehicle Volume Level Scoring

Skor	Tingkat Volume Kendaraan	Indikator Kuantitatif *)
1	Peningkatan kapasitas jalan mendesak	Jumlah kendaraan rata-rata > 1.000,0
2	Peningkatan kapasitas jalan diperlukan	Jumlah kendaraan rata-rata 501,0 – 1.000,0
3	Peningkatan kapasitas jalan jarang diperlukan	Jumlah kendaraan rata-rata 101,0 – 500,0
4	Belum memerlukan peningkatan kapasitas jalan	Jumlah kendaraan rata-rata 0,0 –100,0

Furthermore, the contribution map of land use to land acquisition is based on this land cover map, processed using GIS applications and quantitative indicators. The result is a raster map containing land cover assessments.

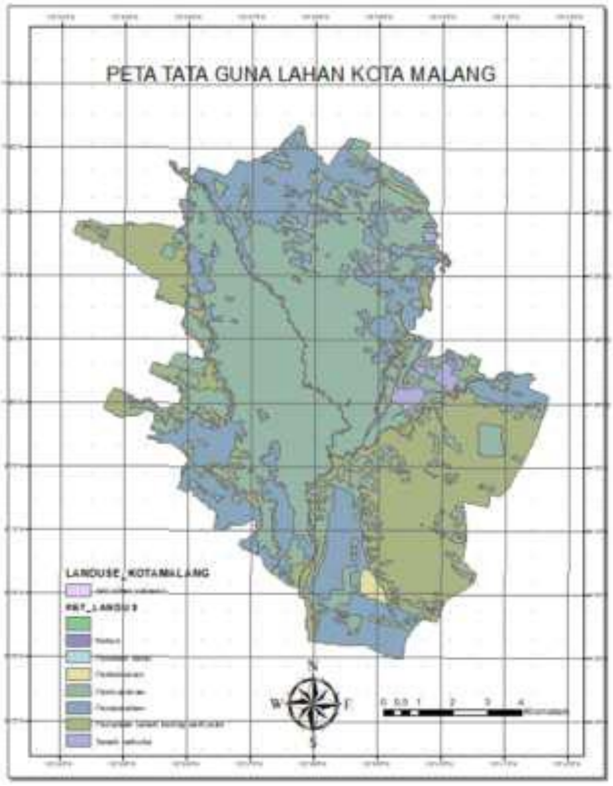

Figure 6 Land Use Map of Malang City

Table 3 Scoring for the Level of Ease of Land Acquisition

Skor	Tingkat Kemudahan Pembebasan Lahan	Indikator Kuantitatif *)	
1	Tidak memerlukan biaya dan administrasi	- Jalan	
2	Biaya murah, administrasi mudah	- Tanah Terbuka - Belukar - Sawah	- Pertanian Lahan Kering - Perkebunan
3	Biaya mahal, administrasi sukar	- Hutan	
4	Biaya mahal, administrasi sukar	- Permukiman - Pertambangan - Lokasi Latihan Marinir	- Lokasi Bersejarah - Perairan (danau/situ, rawa, sungai, Tambak, kolam)

As shown in Table 3, technical indicators of land cover value are based on land ownership and functionality. Based on Hermawan et al. (2011), research shows that as land ownership gets closer to restricted areas or conservation areas, road infrastructure becomes more expensive and more difficult to acquire, which suggests that roads are a better option for avoiding land that is difficult to acquire.

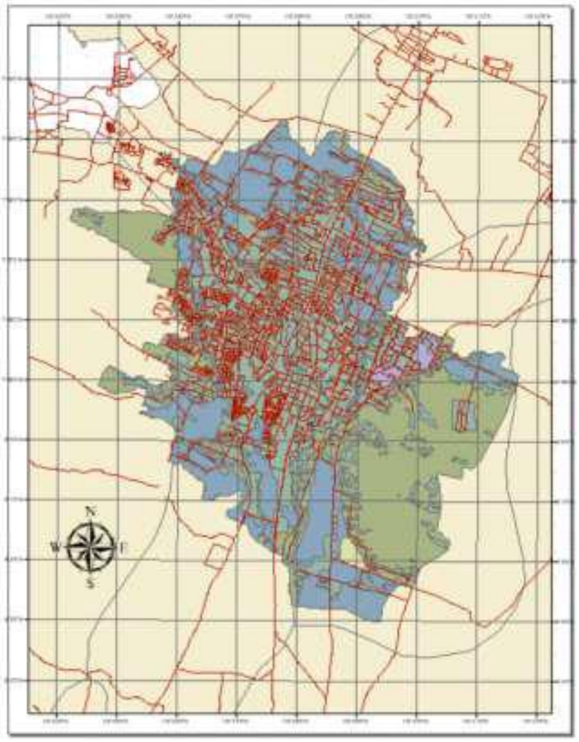

Figure 7 Road Network Map of Malang City

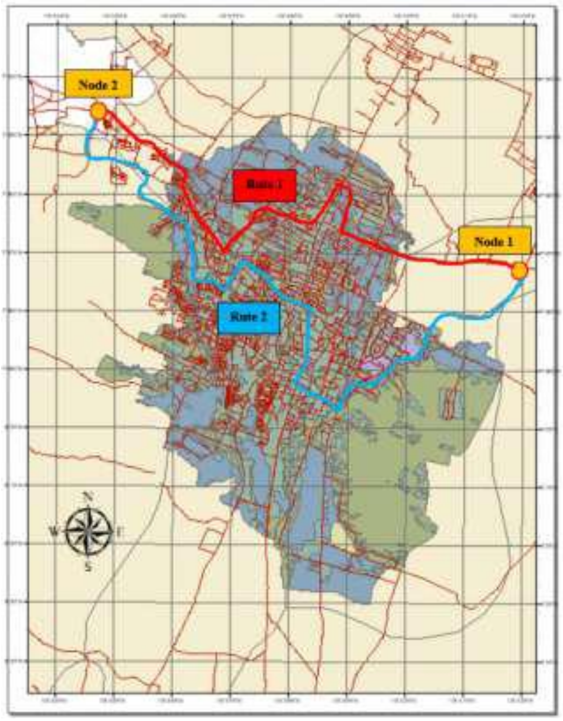

Figure 8 Malang-Batu connecting route

Furthermore, from the results of the analysis based on each parameter and each weight value, 5 land classification results were obtained to assess the suitability of existing routes, which connect the Malang area with Batu City, as shown in the following table:

Table 4 Regional Calcification Results on Route 1 (17 Km)

No.	Land Suitability Classification	Area (m2)
1	It is not in accordance with	51527891,626459
2	Not Appropriate	157458741,421914
3	Suitable enough	305175752,520083
4	In accordance	488621745,894453
5	Very suitable	553352613,002664

Table 5 Regional Calcification Results on Route 2 (13 km)

No.	Land Suitability Classification	Area (m2)
1	It is not in accordance with	141352786,119139
2	Not Appropriate	362370037,400999
3	Suitable enough	554636623,259732
4	In accordance	397233708,385965
5	Very suitable	100543589,17874

Conclusion

The geological and deep rock bearing capacity contribution map is produced from the lithological map. The bearing strength level of route 1 is greater than that of route 2, according to both contribution maps. Today's road geometries are very diverse, as shown by road grade observations. The road grade contribution map to road geometry shows that route 1 has a relatively flatter slope compared to route 2. Looking at the road status map shows the distribution of road status in the Malang Regency and City areas, which determines the number of vehicles crossing each road section. The results of the vehicle volume contribution map show that route 2 requires urgent road quality improvements compared to route 1. The land use contribution map shows that on route 1 it is easier to carry out land acquisition compared to route 2. On the DEM map, the surface elevation in the study area shows that the surface of route 1 is sloping compared to the surface of route 2. The landscape conditions of the two routes are different, according to GIS observations. The results of the analysis of the most effective and efficient route based on geological structure, lithology, soil type, road geometry, traffic conditions, land cover, forest environment, slope and rainfall, it was found that route 1 with a distance of 17 km, with a total land suitability of553352613.002664 m2, is the most effective and efficient route, although with a longer distance duration compared to route 2 which only has a distance of 13 km, with a land suitability level of100543589.17874 m2.

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