Jurnal Ilmiah Geomatika

*Volume 5 Nomor 2, 2025*
*ISSN 2962-651X (online)*
https://jurnal.upnyk.ac.id/index.php/imagi

# *Studi Pengadaan Jalan Tol Menggunakan Penginderaan Jauh berdasarkan SNI No.13/P/BM/2021*

# Study of Toll Road Procurement using Remote Sensing based on SNI No.13/P/BM/2021

**Ferry Rusgiyarto[1], Niswah Selmi Kaffa[2*], Sukanto Hadi[3], Muhammad Iqbal[1], Moh. Nanang Lutfian Putra[2]**

[1]Civil Engineering Department, Faculty of Engineering, Jenderal Achmad Yani University, Cimahi, Indonesia
[2]Civil Engineering Department, Faculty of Engineering, University of Jember, Jember, Indonesia
[3]Geomatics Engineering Department, Faculty of Engineering, Jenderal Achmad Yani University, Cimahi, Indonesia

*Corresponding Author: selmikaffa.teknik@unej.ac.id

**Article Info:**
Received: 08 - 09 - 2025
Accepted: 03 - 10 – 2025
Published: 31 - 10 - 2025

***Kata kunci:*** *Sistem Informasi Geografis; Penginderaan Jauh; Perencanaan Rute*

***Abstrak:*** *Perencanaan rute jalan memerlukan studi komprehensif yang perlu mempertimbangkan berbagai parameter. Hal tersebut dapat berimplikasi pada inefisiensi secara waktu dan biaya. Studi ini menggunakan Sistem Informasi Geografis (SIG) dan penginderaan jauh untuk menganalisis pengadaan jalan tol dari Kabupaten Jombang hingga ke Kota Malang (Indonesia) berdasarkan SNI No. 13/P/BM/2021. Data yang digunakan dalam penelitian ini meliputi citra satelit Sentinel-2 untuk pemetaan tutupan lahan, Digital Elevation Model (DEM) untuk klasifikasi lereng, dan peta Rupa Bumi Indonesia (RBI) sebagai basemap pemetaan. Pemetaan tutupan lahan dilakukan menggunakan algoritma NDVI, NDBI, dan NDWI menggunakan band 2, 3,4, 8, dan 11 dari citra Sentinel-2 2A yang tervalidasi oleh data ground truth. Tiga alternatif rute dihasilkan, masing-masing berdasarkan konfigurasi overlay yang berbeda-beda terhadap aspek lereng dan tutupan lahan. Konfigurasi bobot ditentukan melalui Analytical Hierarchy Process (AHP). Hasil proses tersebut menunjukkan konfigurasi overlay paling efektif adalah 0.75 untuk tutupan lahan dan bobot 0.25 untuk aspek kelerengan. Berdasarkan hasil overlay, didapatkan rute 3 muncul sebagai rute paling optimal dengan total panjang 47,75 km. Pada rute 3, hanya satu stasiun (STA) yang terletak di lereng dengan kemiringan lebih dari 50%, yang sebagian besar melintasi lahan terbukan dan area vegetasi, dengan hanya tiga STA yang terletak di dalam area terbangun. Rute ini tidak memerlukan jembatan sehingga menawarkan potensi pengurangan biaya pembebasan lahan.*

**Keywords:** Geographic Information System; Remote Sensing; Route Plan

***Abstract:*** *Road route planning requires a comprehensive study that considers various parameters. This can lead to time and cost inefficiencies. This study uses Geographic Information System (GIS) and remote sensing to analyze the procurement of a toll road from Jombang Regency to Malang City (Indonesia) based on SNI No. 13/P/BM/2021. The data used in this study are Sentinel-2 satellite imagery for land cover mapping, a Digital Elevation Model (DEM) for slope classification, and the Indonesian Topographic Map (RBI) as the mapping basemap. The land cover mapping was performed using NDVI, NDBI, and NDWI algorithms using bands 2, 3, 4, 8, and 11 from Sentinel-2 2A imagery validated by ground truth data. The alternative routes were generated, each based on a different overlay configuration regarding slope and landcover aspects. The weight configuration was determined using the Analytical Hierarchy Process (AHP). The results of the process indicate that the most effective overlay configuration is 0.75 for land cover and 0.25 for slope. Based on the overlay results, route 3 emerged as the most optimal route with a total length of 47.75 km. On route 3, only one station (STA) is located on a slope with a gradient of more than 50%, which mostly crosses open land and vegetation areas, with only three STAs located within the built-up areas. This route does not require bridges, thus offering the potential for reducing land acquisition costs.*

**How to Cite:**
Rusgiyarto, F., Kaffa, N. S., Hadi, S., Iqbal, M., Putra, M. N. L. (2025). Study of Toll Road Procurement using Remote Sensing based on SNI No.13/P/BM/2021. *Jurnal Ilmiah Geomatika*, *5*(2), 17-32. https://doi.org/10.31315/imagi.v5i2.15554.

## 1. INTRODUCTION

Highway infrastructure plays an essential role in the nation's security, economy, and society's well-being, as it expedites the secure, streamlined, and dependable movement of both humans and commodities, thus catalyzing socio-economic enhancement (Zhao et al., 2019). Highways are expected to ensure road users' safety and comfort, enable efficient traffic operations, and simultaneously require construction and minimize maintenance costs (Raji et al., 2017). Toll roads are significant to Indonesia's transportation infrastructure, especially on Java Island, where they serve as vital arteries. The Indonesian Toll Road Authority (BPJT) delineates the core objectives of toll road integration: optimizing traffic flow, fostering economic prosperity through efficient goods and services distribution, and fostering equitable development (Maria et al., 2020).

The highway planning process is the task of carefully selecting the most optimal alignment demands a multi-factor evaluation encompassing aspects like cost implications and environmental impacts (Zhao et al., 2019). The road geometric design has to be harmonized with the local environment and topography to generate an aesthetically pleasing and functional design (Bina Marga, 2021). Geometric design serves as an activity to create road designs aligned with criteria. The highways are anticipated to have fewer negative environmental impacts and exhibit an aesthetic appearance in their final form (Raji et al., 2017). In practical terms, the highway alignment planning process is limited by a web of regulatory and external constraints, prohibiting the need for optimum alternative exploration.

Road geometry design involves tasks, namely creating road alignment and depicting the alignment profile using angles or coordinates (East and North), stations, and elevation points along the proposed route; calculating sight distances, horizontal curve (and other transition elements). Specifically, curves are locations that pose a high risk of accidents due to centrifugal force imposed on vehicles, driver expectations, and other factors (Ambros & Valentová, 2016). Geometric design focuses on specific steps that provide efficient and appropriate road operations, while considering all specific details that render the road safe and aligned with the social and environmental conditions surrounding (Raji et al., 2017).

During the highway project, the vertical alignment relies upon the road's center line, which serves as the reference axis. The elevation along this center line represents the topographical feature of the entire cross-section, facilitating the equilibrium of the earthwork distribution process. The term "optimal center-line elevation) signifies a specific height along this central axis where the balance between excavation and embankment within the cross-section is achieved. The fundamental behind this approach is to optimize the earthwork operations, ensuring a harmonious balance between excavation and embankment while minimizing the overall earthwork volume required. This cut-and-fill makes up about 25% of the project's total cost. The computation for the soil volume to be excavated and added is derived from the current topographic elevation embedded within the GIS model. The objective of earthwork simulation is to minimize the earthmoving efforts, to achieve an equilibrium between excavation and embankment activities. It is also crucial to give thorough consideration to trade-off values associated with various land-use types. These values represent the proposed alignment's impact level. Consequently, the maximum allowable impact zones for the highway are established based on their prospective significance. For instance, areas like the historical district are subject to stringent restrictions compared to farmland and built-up areas. This historical district is a protected site that the proposed alignment in this study must avoid altogether. The underlying principle is to maintain a considerable distance between the highway and the historical district while permitting the alignment to traverse farmland and built-up areas, while minimizing its impact on these regions (Zhao et al., 2019).

Unfortunately, the current segmentation of highway planning and design from comprehensive geological and environmental analysis leads to delays during the planning process. Present planning methodologies focus on the isolated highway, often sidelining critical considerations such as geotechnical and environmental contexts (Zhao et al., 2019). When carried out manually, geometric planning is highly labor-intensive, time-consuming, and susceptible to costly errors. Conventional methods also rely primarily on two-dimensional (2D) analysis, which does not guarantee a satisfying design (Raji et al., 2017).

Addressing this challenge, the current study presents a synergistic solution by proposing an integrated model that unifies Building Information Modelling (BIM) and Geographic Information System (GIS), allowing seamless data exchange between these domains to expedite the highway planning process (Zhao et al., 2019). Working with a Geographic Information System (GIS) is the most efficient method both in time and cost efficiency, especially when dealing with large datasets (Bartin et al., 2022).

Zhao et al (2019) proposed an approach to manage highway alignment within a broader context that integrates the Building Information Modelling (BIM) and Geographic Information System (GIS). By this methodology, highway projects and their surroundings can be realistically modelled in three dimensions, resulting in a comprehensive virtual environment wherein projects can be effectively planned and designed. This method can reduce design errors and communication issues, thereby mitigating project risks. Furthermore, geological and geographical analysis can assist in identifying geological hazards and environmentally sensitive areas. This approach bridges highway alignment planning from diverse disciplinary perspectives, aiming to diminish the gap between infrastructural outlooks and the geotechnical. Ambros and Valentova (2016) also utilized remote sensing to identify inconsistencies in the horizontal road alignment in the Czech Republic. This approach was chosen because it has been widely employed since 2000 and is considered a cost-effective and efficient method.

Remote sensing is an essential tool for land use and land cover map production through a process called image classification (Rwanga & Ndambuki, 2017). The image classification process can be done either manually (by visual interpretation of remote sensing data) or automatically (Fallati et al., 2017). The conventional mapping methods are based on satellite imagery or aerial observation, or digitizing (Gebrehiwot & Hashemi-Beni, 2020). The manual process takes more time to be done, but Fallati et al (2017) proved to be efficient when the analysts are familiar with the area being classified than the automation done by the computer (Fallati et al., 2017). Visual/manual interpretation can be tedious and takes more time compared to automatic classification methods. Nevertheless, calculating the validity and accuracy of the result from automatic processing is difficult, and in some cases, automatic classification methods fail to distinguish the differences in the given land surface area. Eventually, the “human insight” is essential in taking the ultimate decision on this classification (Fallati et al., 2017).

The indices of remote sensing, namely the normalized difference built-up index (NDBI), the normalized difference vegetation index (NDVI), and the normalized difference water index (NDWI), help extract vegetation, water bodies, and built-up areas. NDVI is used to assess vegetation percentage, NDBI index is used to assess the built-up areas, while NDWI index is used to assess the water bodies area. The NDWI is an approach to delineating water bodies using green and near-infrared (NIR) bands of satellite imagery based on the characteristic that a water body has strong absorbability and low radiation in the range from visible to infrared wavelengths (Gebrehiwot & Hashemi-Beni, 2020). The NDWI is an index for delineating and monitoring content changes in surface water. The NDWI is calculated using the near-infrared and green band channels formula as follows:

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)}$$

Where the Green and NIR refer to the reflection in the green and near-infrared spectrum. The NDWI pixel result will vary from -1 to +1, where water features have positive values, and soil and terrestrial vegetation features have zero or negative values, according to their characteristic in higher reflectance of Near-Infrared than green light.

This study aims to propose alternative routes using Geographic Information System (GIS) and analyze whether the proposed route is in line with the criteria and Indonesian National Standard (SNI) No. 13/P/BM/2021 regulation about road procurement. The study takes place in East Java, Indonesia, and will answer whether it is possible to establish a toll road connecting Jombang Regency to Malang City. The criteria used in this study are a topographic model to calculate the cut and fill volume, which influences 25% project's total cost, and land cover to estimate the difficulties in construction and land acquisition.

## 2. METHOD

The preliminary design in this study aims to create road alignment possibilities through an area depicted on a topographic map equipped with data, namely contours, built-up areas, and rivers, using overlay analysis in GIS using the raster calculator tool. Based on the Indonesian Public Works regulation (Permen PU) No. 19/2011, at least three alternative alignments should be considered in a geometric road design. This is intended to explore possible alignment directions and then select the best one. The three alternative alignments are created based on various comparative compositions between slope data (representing earthwork volume) and land cover gained from the analytical hierarchy process (AHP).

The corridor determination is established during the feasibility study phase, when several alignment designs are examined using available information and integrated into topographic maps containing data such as topography (contours), geology, land use (built-up areas, vegetation, water bodies), weather (rainfall and flood-prone areas), environment, culture, and population. When establishing the alignment, the engineer must consider the topography, especially the road's longitudinal slope, mountainous regions, hilly areas, and flat terrain, as well as water flow. Geological information is used to assess rock formations or soil conditions suitable for road design, areas with soft soil, and to estimate existing conditions to avoid landslides, excavations, and embankments when determining the alignment. Other factors that must be considered are the location of environmentally sensitive areas, cultural factors, population distribution, and land use (Bina Marga, 2021).

The earthwork volume can be calculated using the equation presented below (Zhao et al., 2019).

$$\sum_{i=1}^{n} \boldsymbol{V_C(i)} = \sum_{j=1}^{m} \boldsymbol{V_F(j)}$$

Where Vc(i) represents the volume of cut areas in the cross-section, Vf (j) signifies the volume of fill areas in the cross-section. In Geographic Information System software, this calculation can be done based on DEM and measured by the parameter stated in Table 1.

The construction cost is influenced by the amount of cut and fill needs to be done. The cut and fill magnitude can be assessed based on the slope gradient. According to Kang and Seo (2013), the slope gradient weight and its effect on this cut and fill volume can be described as **Table 1** follows,

**Table 1**. The Relation between Slope and Project Cost

| Slope (%) | Linguistic | Cost weight |
|---|---|---|
| < -200 | Almost impossible to fill | 10000 |
| -200 | Very expensive | 1 |
| -100 | Expensive | 0.5 |
| -50 | Quite expensive | 0.25 |
| -20 to 20 | Less expensive | 0 |
| 50 | Quite expensive | 0.25 |
| 100 | Expensive | 0.5 |
| 200 | Very expensive | 1 |
| >200 | Almost impossible to fill | 10000 |

Because Indonesia is also highly vulnerable to earthquakes, it is necessary to identify whether the corridor is located in an earthquake-prone zone, as this factor must be taken into account in the design of structural buildings, such as bridges, tunnels, and major drainage structures. The earthquake zone is identified according to data published by the Indonesian Disaster Agency (BNPB). Furthermore, when selecting the alignment, it is necessary to consider the landslide-vulnerable area. Areas crossed by fault lines must be avoided, as these are highly susceptible to land shift, especially when determining the location of structural buildings. The earthquake maps are already available on the official website of BNPB.

For highway projects, various routes could potentially be viable. For selecting the best route, the decision maker typically analyzes and evaluates multiple alternatives. Note that the shortest path may not always be the best option; a longer route could potentially be safer or more expeditious (Zhao et al., 2019). According to SNI No 13/P/BM/2021, each alignment design is assessed technically (demonstrating compliance with design criteria and construction feasibility) and economically (indicating the construction's cost-effectiveness). Based on Zhao (2019), the cut and fill plays a 25% budgeting role in road construction. The methodology flowchart can be seen in **Figure 1** below,

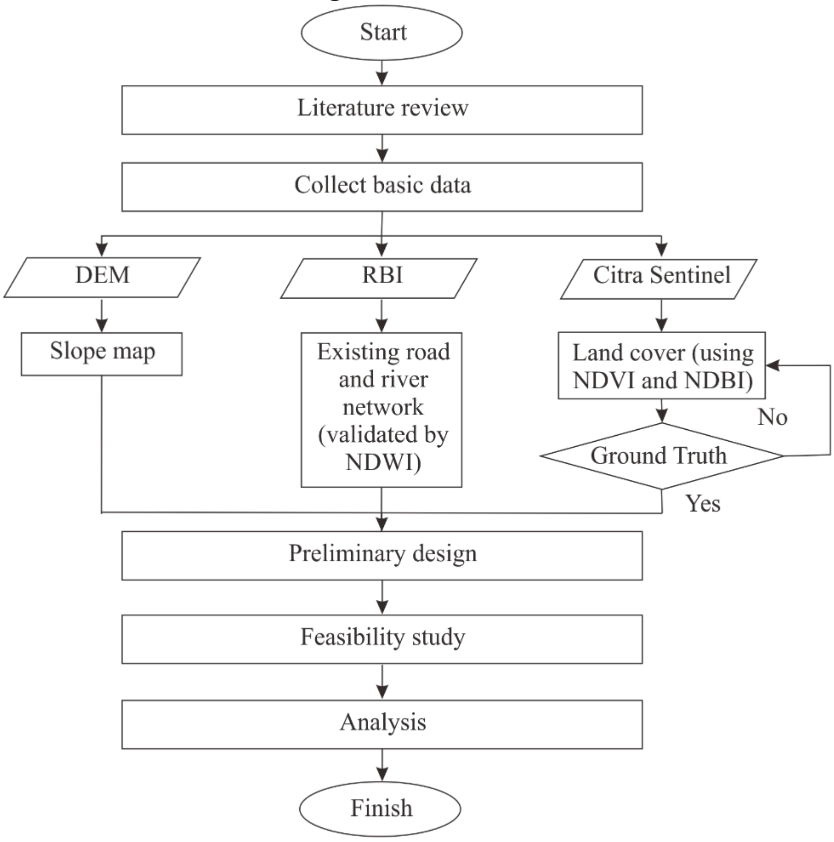


**Figure 1**. GIS-based Road Planning Flowchart

The study area takes place in East Java Province due to the need for a toll road that can connect the central part of East Java with the Southern part of East Java. Jombang regency will be the representative for the central part of East Java, while Malang City will be the representative of the Southern Part of East Java. The Jombang Regency capital is located 79 km away from Surabaya City, the capital of East Java Province. Jombang Regency is located within 07º20'48.60" S – 07º46'41.26" S and 112º03'46.57" E – 112º27'21.26" E (BPBD Kab Jombang., 2024) (Kaffa et al., 2023). The Jombang Regency alternative boundaries are as follows,

- To the North : Lamongan and Bojonegoro Regency
- To the East : Mojokerto Regency
- To the South : Kediri Regency and Malang Regency
- To the West : Nganjuk Regency

Malang city is a highland area located within the coordinates of 07º46'48" S – 08º46'42" S and 112º31'42" E – 112º48'48" E and elevation from 445 to 526 meters above sea level. Topographically, Malang City consists of plains surrounded by a series of hills and mountains. To the North, there is Mount Arjuno; to the East, there is Mount Semeru; to the West, there are Mount Panderman, Mount Kawi, and Mount Kelud. The Malang City is administratively surrounded by the Malang Regency as follows (BPBD Kota Malang, 2024),

- To the North : Singosari and Karangploso sub-district
- To the West : Wagir and Dau sub-district
- To the East : Pakis and Tumpang sub-district
- To the Southern : Tajinan and Pakisaji sub-district

In the route planning process from Jombang Regency to Malang City, researchers must be concerned about the area around the study locations, especially in the regions that the road route may pass through. Other areas that will also be analysed in this research are Mojokerto, Batu, and Kediri, both regencies and cities.

The areas hardly to be accessed for field survey make remote sensing technology the only viable tool to observe the land surface (Sun et al., 2016). Orthorectified Sentinel-2 2A imagery acquired on 1st August 2023, downloaded from Scihub Copernicus (http://scihub.copernicus.eu/), was used to estimate the land cover in the study area chosen. Band 2, band 3, band 4, band 8, and band 11 are composited to create NDVI and NDBI processing to detect the existence of vegetation and buildings. The best result can be achieved by extracting vegetation and field coverage from NDVI, building up our coverage from NDBI, and water from Rupa Bumi Indonesia (RBI) mapping downloaded from the Tanah Air website (https://tanahair.indonesia.go.id). NDVI is a commonly used vegetation index for observing healthy vegetation, while NDBI is an index for built-up areas analysis (Shofy & Wibowo, 2023), while NDWI is used for water analysis (Kshetri, 2018). The kappa-index is then used to identify the landcover accuracy by calculating of confusion matrix (Rwanga & Ndambuki, 2017).

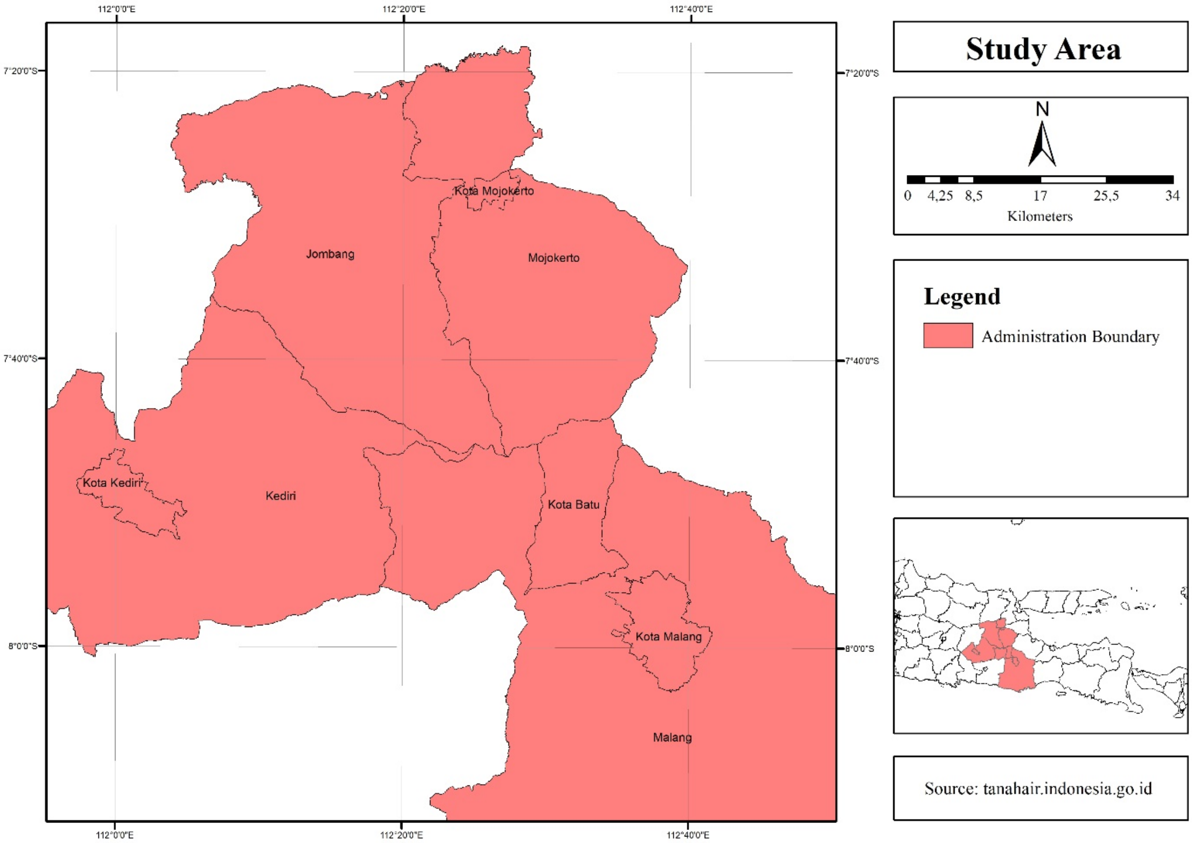


**Figure 2**. Study Areas

## 3. Result and Discussion

### 3.1 Land Cover

The landcover mapping process is identified according to NDVI, NDBI, and NDWI processing. The most used method to calculate the landcover mapping accuracy is statistical calculation using the confusion matrix (Gao et al., 2020). The overall accuracy gained by the confusion matrix calculation is 76% with the Kappa value of 69% means substantial strength of agreement (Rwanga & Ndambuki, 2017). The landcover model can be seen in **Figure 3**.

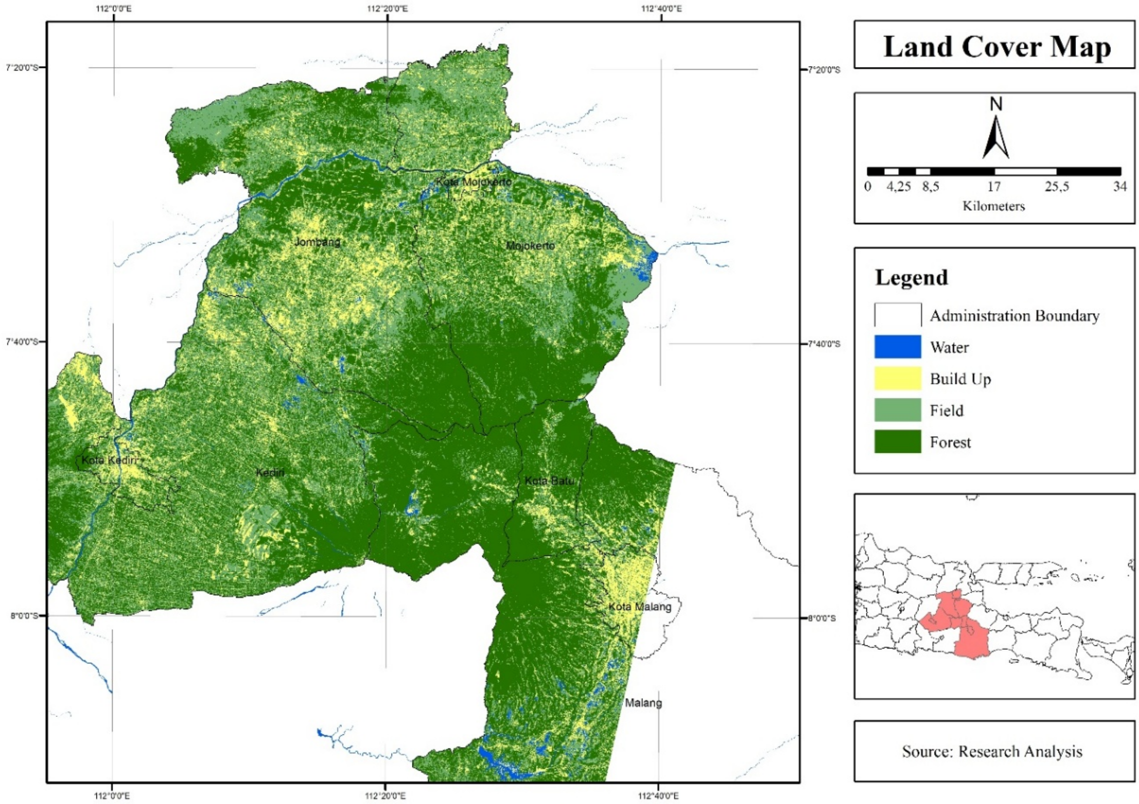


**Figure 3.** Land Cover

As shown in **Figure 3**, the Jombang Regency's Southern part is predominantly covered by vegetation. This data is correlated with the fact that Jombang Regency's Southern part, specifically Wonosalam District, is known for its mountainous terrain. The corridor determination involves a field survey process that is then integrated into the land cover mapping process. The integration is used for ensuring that the surrounding area remains clear, in proximity to existing roadways, without passing through regions with low-value indices.

The Jombang Regency corridor is located within the UTM of 49S projected coordinate system, with the latitude of 7$^o$ 40’ 11.206” and a longitude of 112$^o$ 16’ 23.572”. The corridor chosen is located in Ngoro District, where the landscape is mostly covered by built-up areas and fields. The Malang City corridor is located in Batu City, as Malang City is already densely populated (as shown in **Figure 3**). The Malang City corridor is located within the latitude of 7$^o$ 49’ 30.715” and longitude of 112$^o$ 31’ 47.176”. This corridor is located next to the T-junction to the Selecta tourist site.

### 3.2 Slope

**Figure 4** illustrates the topographical challenge within Jombang Regency to Malang City, marked by significantly high slope percentages. This segment represents terrain that demands massive earthwork or, in some cases, renders passage utterly infeasible. For optimal efficiency and cost-effectiveness, the route planned should strictly adhere to the slope percentages ranging from 0% to 50% thereby minimizing the earthwork needed.

Areas classified by slope percentages exceeding 100%, or even 200%, should be avoided due to their impracticality for passage. During the corridor selection process, the slope map plays a crucial role in ensuring that the surrounding terrain maintains a high slope index (the recommended area). This method maintains the corridor so that it does not pass through regions that have lower value indexes.

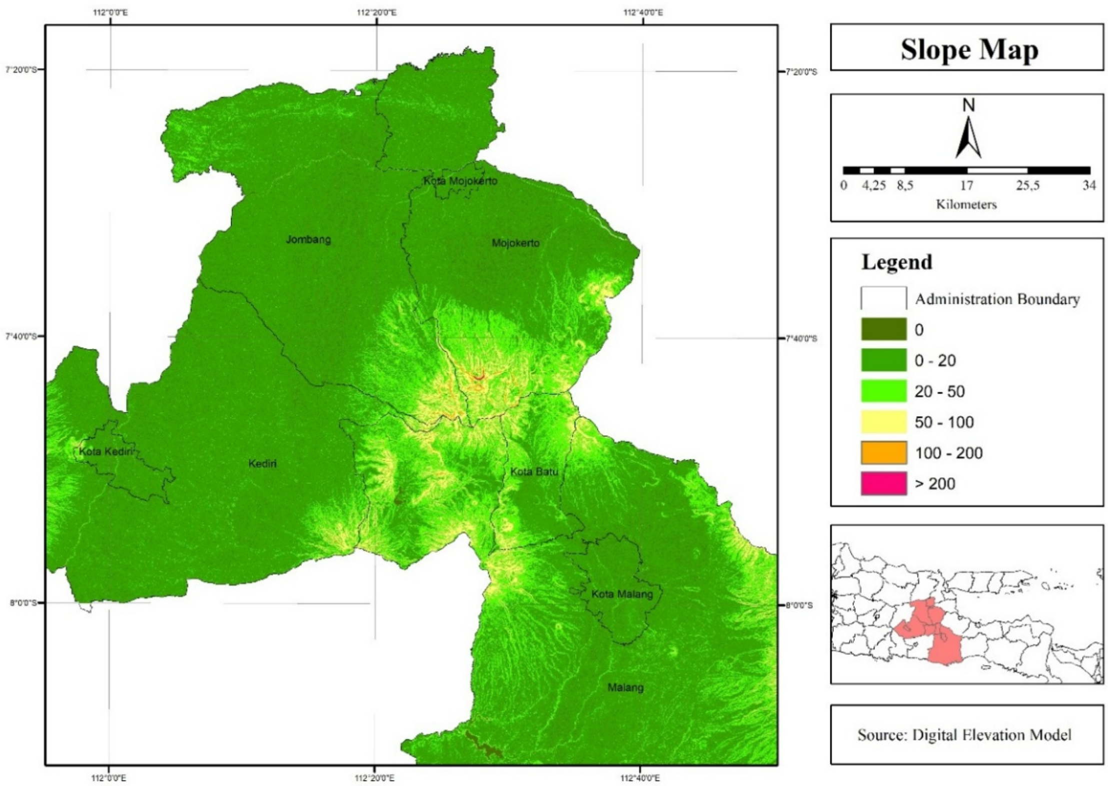


**Figure 4**. Slope Map

### 3.3 Other Factors

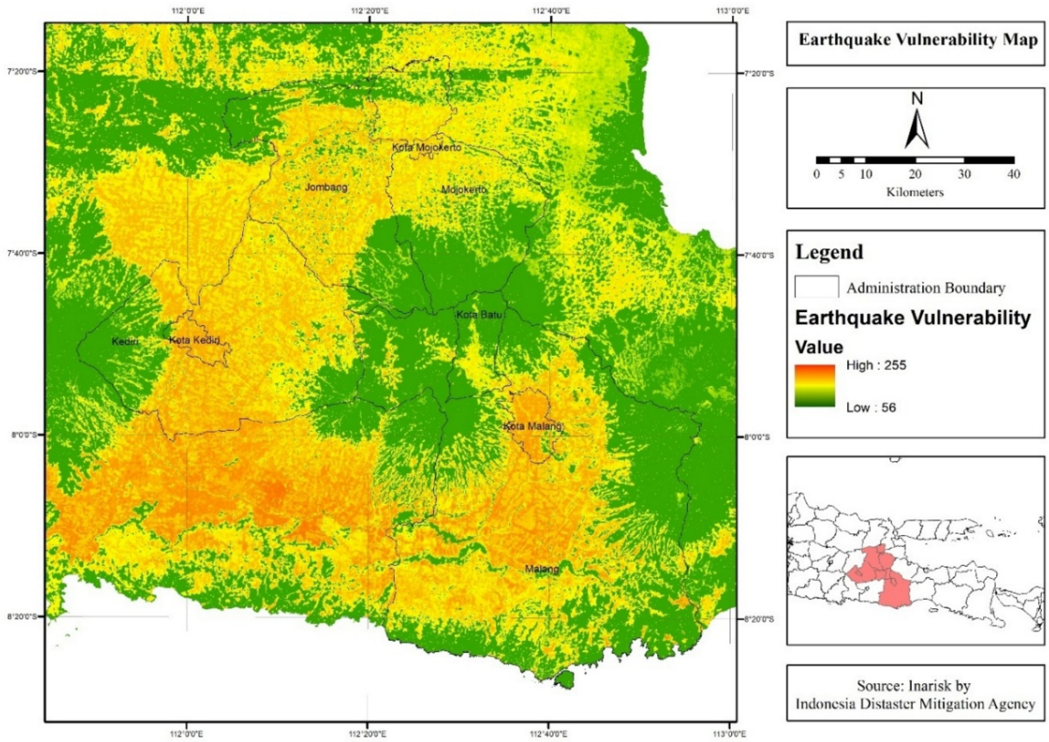


**Figure 5.** Earthquake Vulnerability Map

The earthquake vulnerability mapping above is generated from the Indonesian National Board for Disaster Management (BNPB). As shown in **Figure 5**, it is evident that earthquake-prone regions are predominantly located to the South of Malang City and Kediri Regency. These earthquake-prone areas are located outside the planned highway corridor, and as such, this criterion can be excluded from weighting consideration.

### 3.4 Weighting

The weighted overlay techniques are defined as a method to develop a map through overlays of several raster layers by giving weight to each raster layer according to its role and importance level (Basharat et al., 2016). The weights are determined according to the parameters used to distinguish the recommendation level. In this research, two key parameters are considered, namely land cover and slope. The landcover parameter is classified into four classes, namely water, built-up, field, and vegetation. According to SNI (Indonesian National Standard), water coverage is not recommended due to the necessity for bridge construction, and built-up areas are less recommended due to high land acquisition cost and potential community-related project delay. Vegetation coverage is considered a recommended area, but it's necessary to consider the environmental impact also. On the other hand, fields are deemed the most recommended areas.

The slope scores are determined based on **Table 1**, where slopes between 0% to 50% are recommended, while slopes between 100% and more than 200% should be avoided. The most recommended are given a high score of 1.00 or 0.75, gradually decreasing to less recommended areas as the score approaches 0. Detailed scores can be found in **Table 3**.

The weighting is carried out through three configurations, resulting in three alternatives. The configuration options can be found in the weight column. These weight configurations serve as the basis for overlay modelling using GIS software. The specific configuration details are presented in **Table 2** below.

Table 2. Overlaying Configuration

| Alternative | Parameter | Class | Class Value | Score | Weight |
|---|---|---|---|---|---|
| 1 | Land Cover | Water | 2 | 0.25 | 0.25 |
| | | Build Up | 3 | 0.50 | |
| | | Field | 4 | 1.00 | |
| | | Vegetation | 5 | 0.75 | |
| | Slope | Less Expensive 1 2 | 0 – 20 | 1.00 | 0.75 |
| | | Quite Expensive 3 | 20 – 50 | 0.75 | |
| | | Expensive 4 | 50 – 100 | 0.50 | |
| | | Very Expensive 5 | 100 – 200 | 0.25 | |
| | | Almost Impossible 6 | > 200 | 0 | |
| 2 | Land Cover | Water | 2 | 0.25 | 0.50 |
| | | Build Up | 3 | 0.50 | |
| | | Field | 4 | 1.00 | |
| | | Vegetation | 5 | 0.75 | |
| | Slope | Less Expensive | 0 – 20 | 1.00 | 0.50 |
| | | Quite Expensive | 20 – 50 | 0.75 | |
| | | Expensive | 50 – 100 | 0.50 | |
| | | Very Expensive | 100 – 200 | 0.25 | |
| | | Almost Impossible | > 200 | 0 | |
| 3 | Land Cover | Water | 2 | 0.25 | 0.75 |
| | | Build Up | 3 | 0.50 | |
| | | Field | 4 | 1.00 | |
| | | Vegetation | 5 | 0.75 | |
| | Slope | Less Expensive | 0 – 20 | 1.00 | 0.25 |
| | | Quite Expensive | 20 – 50 | 0.75 | |
| | | Expensive | 50 – 100 | 0.50 | |
| | | Very Expensive | 100 – 200 | 0.25 | |
| | | Almost Impossible | > 200 | 0 | |

**Table 3**. Detail Score Information.

| Score | Detail |
|---|---|
| 0 – 0.25 | Not recommended |
| 0.25 – 0.5 | Less recommended |
| 0.5 – 0.75 | Recommended |
| 0.75 – 1.00 | Very recommended |

The overlaying processing using GIS software is executed according to the data from **Table 2**. This process uses the raster calculator tools, which operate based on predetermined weights. The inputs are land cover maps (Figure 3) and slope maps (Figure 4), both in raster (.tif) format with the spatial resolution of 10 x 10 meters. The raster output is illustrated in **Figure 6**. The three alternatives are: Alternative 1 (**Figure 6a**) with the configuration of 0.25 for land cover and 0.75 for slope; Alternative 2 (**Figure 6b**) with the configuration of 0.50 for both land cover and slope; and Alternative 3 (**Figure 6c**) with the configuration of 0.75 for land cover and 0.25 for slope.

Based on the initial analysis, Alternative 1 fails to map the presence of water, particularly in the Northern parts of Jombang and Mojokerto regencies, which should be traversed by the Brantas River, East Java's largest river. Alternative 1 is unable to identify the densely populated areas of Malang City, Kediri City, and Mojokerto City. Alternative 2 and Alternative 3 exhibit similar characteristics, but Alternative 3 represents the water feature better compared to Alternative 2. This is proven by the existence of Selorejo Reservoir in Malang Regency, situated near the existing Jombang-Malang roadway. All the alternatives successfully illustrate the presence of the Anjasmoro, Welirang, and Arjuno mountains. As well as mountainous regions spanning Kediri, Jombang, Mojokerto Regencies to Malang Regency, and Batu City.

Based on qualitative judgement, Alternative 3, with the configuration of 0.75 for land cover and 0.25 for slope, emerges as the most suitable choice for route planning, because it effectively represents both land cover and slope.

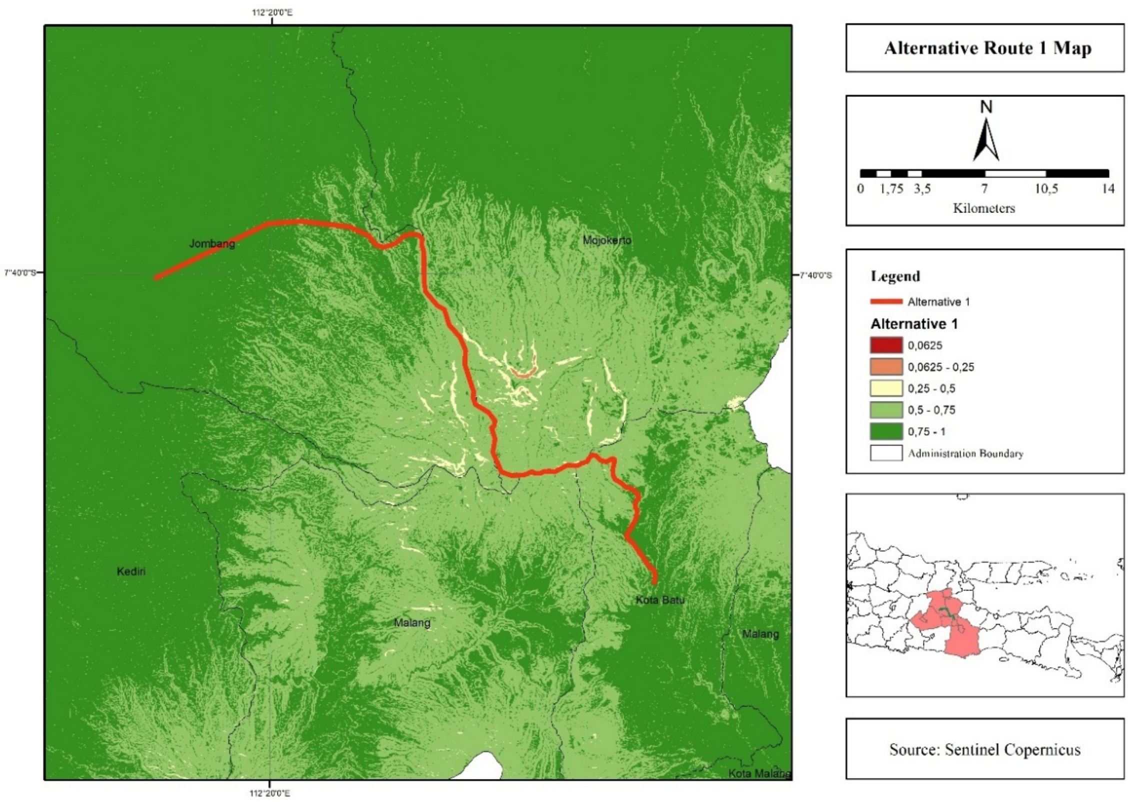


**Figure 6a**. Route Alternative based on Alternative 1 Map Configuration

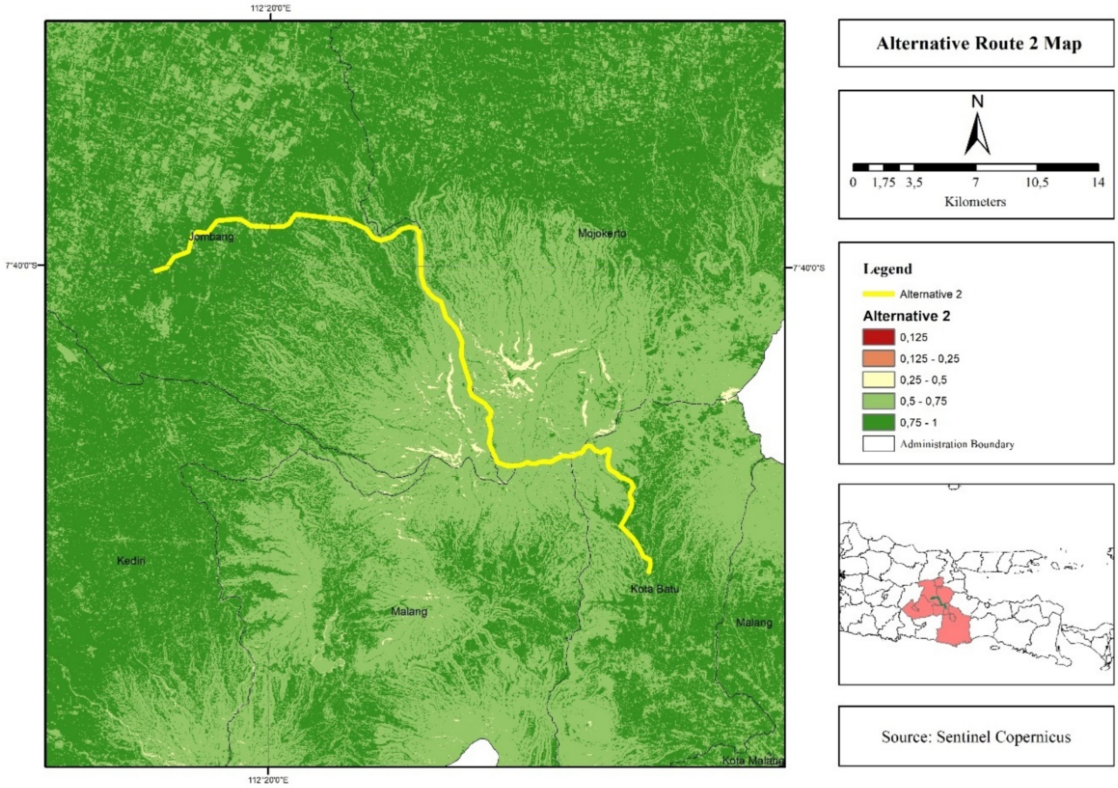


**Figure 6b**. Route Alternative based on Alternative 2 Map Configuration

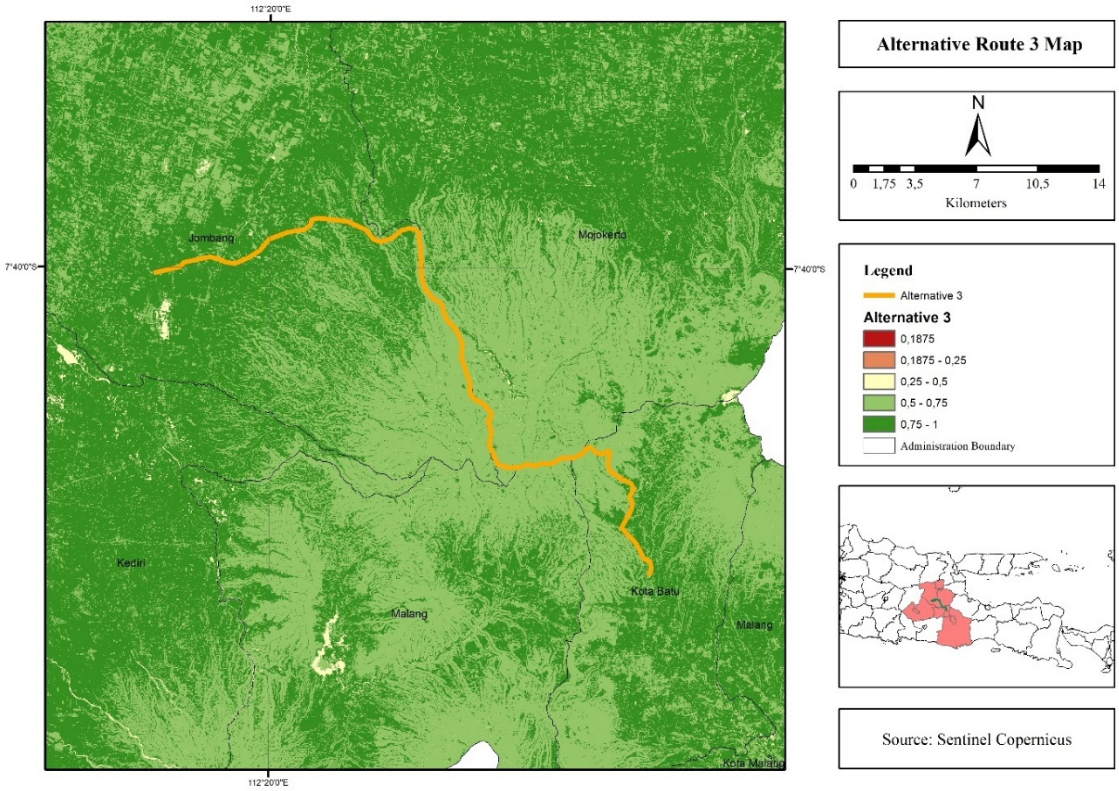


**Figure 6c**. Route Alternative based on Alternative 3 Map Configuration

### 3.6 Analysis

The route alternatives are superimposed on both the slope map and the land cover map (**Figure 7**). In **Figure 7**, the distinction among the route alternatives previously discussed can be observed. Routes 1, 2, and 3 primarily share the same route, with the variations occurring after the starting corridor in Jombang Regency. This divergence arises as alternative 1 doesn’t accurately depict land cover compared to the other configurations. Consequently, the first route tends to maintain a straighter route after the Jombang Regency corridor (red line), while Routes 2 (blue line) and 3 (black line) take slightly winding paths to avoid water coverage and built-up areas.

The land cover becomes more homogeneous at the mountain foothill, resulting in fewer discrepancies among the alternative routes. As we approach the Batu City corridor, the land cover becomes heterogeneous (as shown in **Figure 7**), causing some variance in the chosen routes, although not to the same degree as initially. Additionally, there are limited options when the route traverses mountainous terrain. **Figure 4** and **Figure 7a** illustrate that the route is covered by a high slope percentage due to the presence of Anjasmoro Mountain, which must be avoided.

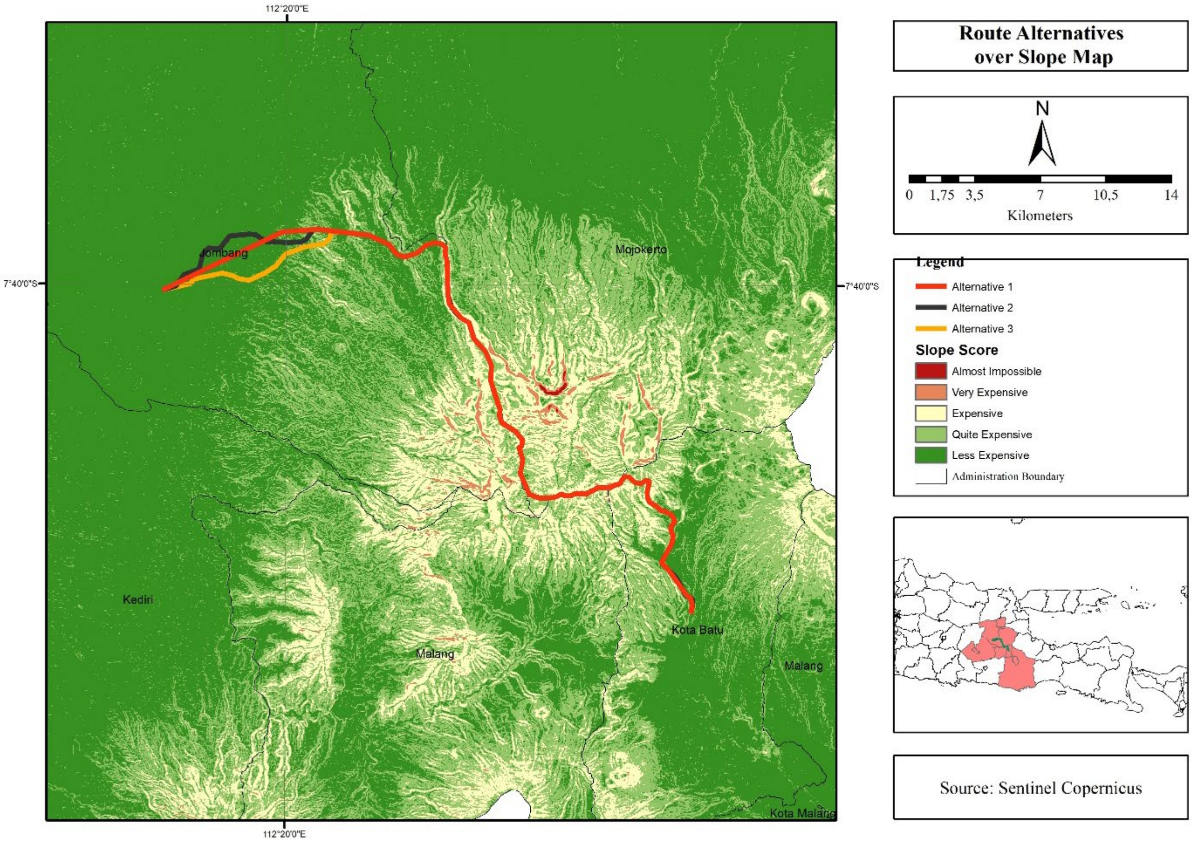


**Figure 7a**. Route Alternatives over Slope Map

The route planned lines are segmented at intervals of 500 meters and labelled as STA 0+000, STA 0+500, STA 1+000, and so forth, with each STA marked by a dot. The slope and land cover map values are extracted based on the raster using the “Extract Values to Point” tool in GIS software. The values obtained at each STA are used to generate line charts, as shown in **Figure 8**, **Figure 9**, and **Figure 10**. The left line charts (colored orange) display the slope values recorded at each STA, while the line chart (colored blue) represents the landcover values at each STA. The X axis represents the STAs, while the Y axis represents the value ranging from 0 to 1. Lowest recommended values are marked as 0, and the recommendation level increases as values approach 1.

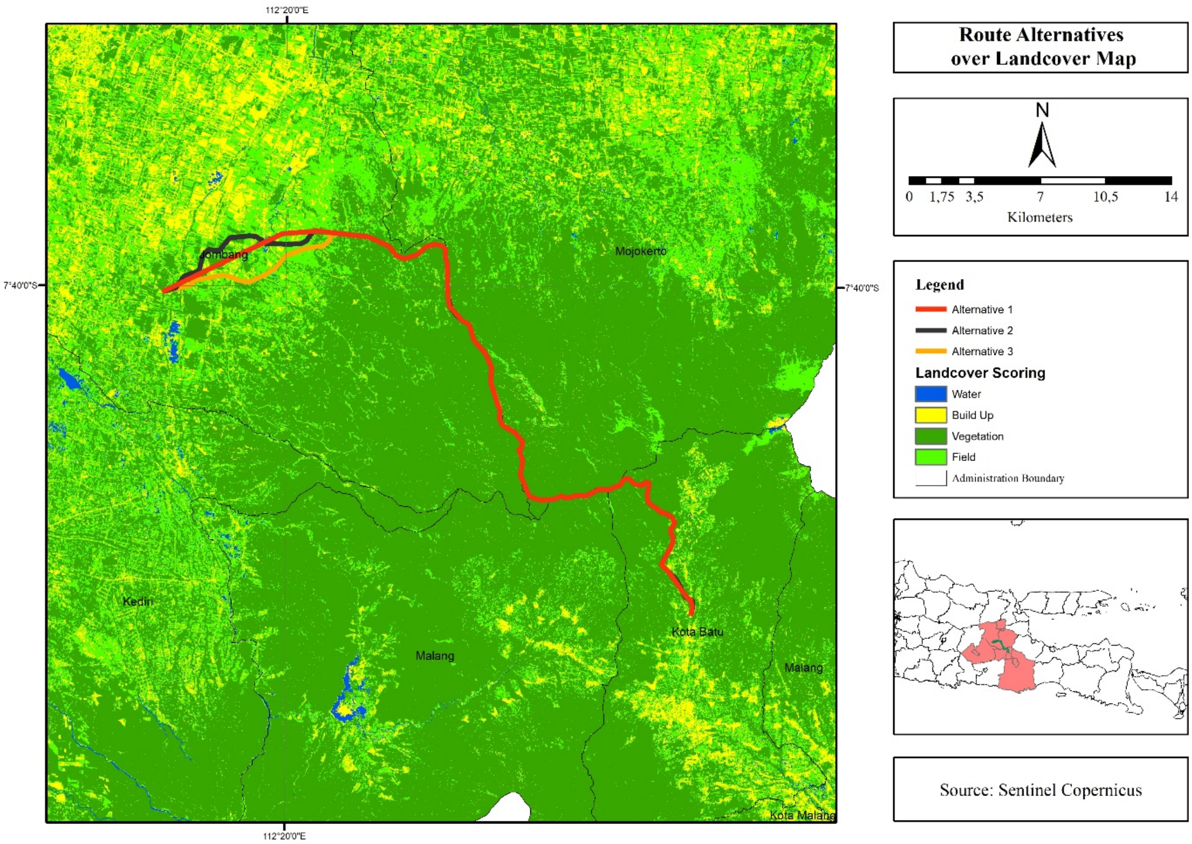


**Figure 7b**. Route Alternatives over Landcover Map

**Figure 8a** and **Figure 8b** illustrate the distribution values along Route 1 on the slope map (left) and the land cover map (right). This route traverses areas with the slope score ranging from 0.75 to 1.00, classified as less expensive to quite expensive areas for earthwork. Additionally, STA is located on a slope with a score of 0.50, which is classified as an expensive earth working area. Within this route, there are 58 STAs with the value of 1.00; 37 STAs with the value of 0.75; 1 STA with the value of 0.50; and none of them fall in the slope value below 0.50. There are 21 STAs with the value of 1.00, indicating field coverage; 67 STAs with the value of 0.75, indicating vegetation coverage; 7 STAs with the value of 0.50, indicating built-up areas; and 1 STA with the value of 0.25, indicating water bodies. Consequently, this route requires bridge construction. The total length of this route is 47.21 km.

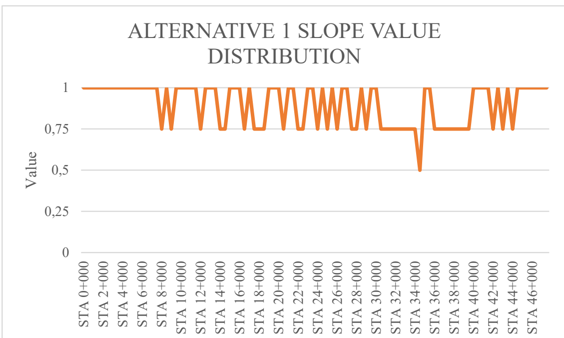


**Figure 8a.** The Route Alternative 1 Slope Values Distribution

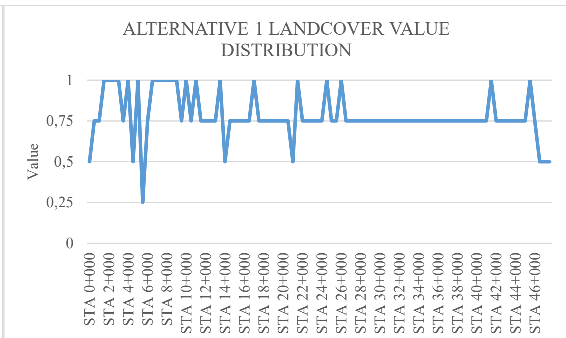


**Figure 8b.** The Route Alternative 1 Landcover Value Distribution

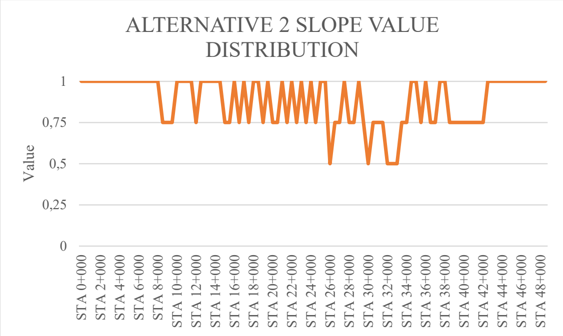


**Figure 9a**. The Route Alternative 2 Slope Value Distribution

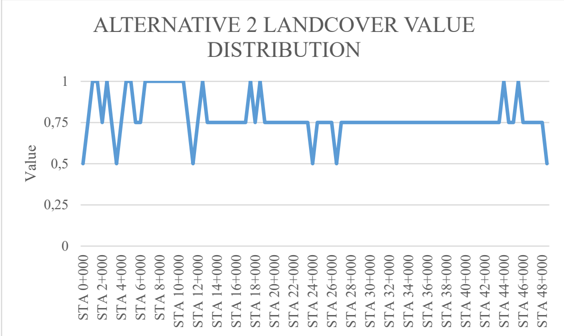


**Figure 9b**. The Route Alternative 2 Landcover Value Distribution

**Figure 9** shows the value distribution along Route 2 on the slope map (left) and land cover map (right). This route predominantly traverses areas with slope values ranging from 0.50 to 1.00, classified as the expensive and less expensive earth working criteria. Within this route, there are 57 STAs with the value of 1.00; 36 STAs with the value of 0.75; 5 STAs with the value of 0.50; and none with the value below 0.50 on the slope scale.

Concerning land cover, route 2 passes through areas with the values varying from 0.50 to 1.00. There are 19 STAs with the value of 1.00, which indicates field coverage; 73 STAs with the value of 0.75, which indicates vegetation coverage; 6 STAs with the value of 0.50, which indicates built-up coverage; and none with the value of 0, which indicates the water bodies coverage. This route's total length is 48.5 km.

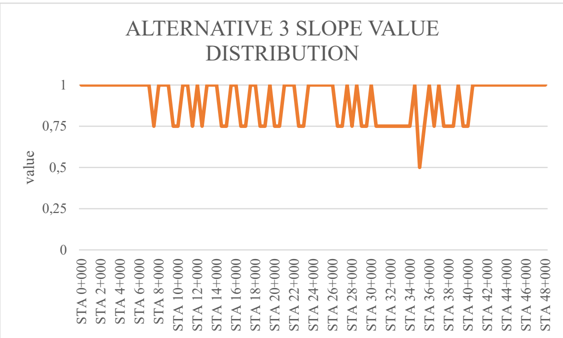


**Figure 10a**. The Route Alternative 3 Slope Value

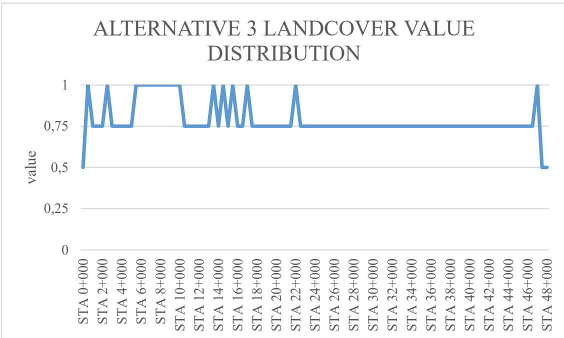


**Figure 10b**. The Route Alternative 3 Landcover Value Distribution

**Figure 10** shows the value distribution along Route 3 on the slope map (left) and land cover map (right). This route predominantly traverses areas with slope values ranging from 0.50 to 1.00, classified as expensive to less expensive areas for earthwork. Within this route, there are 61 STAs with the value of 1.00; 35 STAs with the value of 0.75; 1 STA with the value of 0.50; and none with the value less than 0.50 on the slope scale. Regarding the landcover map, Route 3 traverses areas with the value varying from 0.50 to 1.00. There are 18 STAs with the value of 1.00, which indicates the field coverage; 76 STAs with the value of 0.75, which indicates the vegetation coverage; 3 STAs with the value of 0.50, which indicates built-up coverages; and none with the value of 0.25, which indicates water bodies. The total length of Route 3 is 47.75 km.

From **Figure 8**, **Figure 9**, and **Figure 10**, it is evident that route 3 exhibits the most favorable slope value distribution, with only 1 STA located on a slope greater than 50%. Furthermore, Route 3 boasts the best landcover value distribution, primarily passing through fields and vegetation coverage areas, with only 3 STAs situated within the built-up coverage. This route doesn't require bridge construction and is predicted to have less land acquisition cost. Route 3 has a total length of 47.75 km, differing by 0.54 km from Route 1, which is the shortest route, with a total length of 47.21 km.

## 4. CONCLUSION

This study employs Geographic Information System (GIS) and remote sensing for the route planning process according to parameters mentioned in the Indonesian National Standard (SNI) No. 13/P/BM/2021, specifically slope and land cover coverage. The result indicates that the optimum configuration is 0.75 for the land cover map and 0.25 for the slope map. The most favorable route based on the weighting configuration is Route 3 with a total length of 47.75 km. Route 3 stands out as it has less slope exceeding 50%, and its predominant path through field and vegetation coverage areas, with merely three STAs located within the built-up coverage. This route doesn't require any bridge construction and is predicted to have lower land acquisition costs.

## References

Ambros, J., & Valentová, V. (2016). Teetrassi plaanielementide ebakõlade määramine – Pilootuuring Tšehhi Vabariigist. *Baltic Journal of Road and Bridge Engineering*, *11*(1), 62–69. https://doi.org/10.3846/bjrbe.2016.07

Bartin, B., Demiroluk, S., Ozbay, K., & Jami, M. (2022). Automatic Identification of Roadway Horizontal Alignment Information Using Geographic Information System Data: CurvS Tool. *Transportation Research Record*, *2676*(1), 532–543. https://doi.org/10.1177/03611981211036364

Basharat, M., Shah, H. R., & Hameed, N. (2016). Landslide susceptibility mapping using GIS and weighted overlay method: a case study from NW Himalayas, Pakistan. *Arabian Journal of Geosciences*, *9*(4). https://doi.org/10.1007/s12517-016-2308-y

Fallati, L., Savini, A., Sterlacchini, S., & Galli, P. (2017). Land use and land cover (LULC) of the Republic of the Maldives: first national map and LULC change analysis using remote-sensing data. *Environmental Monitoring and Assessment*, *189*(8). https://doi.org/10.1007/s10661-017-6120-2

Gao, Y., Liu, L., Zhang, X., Chen, X., Mi, J., & Xie, S. (2020). Consistency analysis and accuracy assessment of three global 30-m land-cover products over the european union using the lucas dataset. *Remote Sensing*, *12*(21), 1–23. https://doi.org/10.3390/rs12213479

Gebrehiwot, A., & Hashemi-Beni, L. (2020). Automated Indunation Mapping: Comparison of Methods. *International Geoscience and Remote Sensing Symposium (IGARSS)*, 3265–3268. https://doi.org/10.1109/IGARSS39084.2020.9323702

Kshetri, T. B. (2018). Volume II Geomatics for Sustainable Development NDVI, NDBI AND NDWI CALCULATION USING LANDSAT 7 AND 8. *GeoWorld*, *Volume II*(September 2018). https://www.researchgate.net/publication/327971920

Marga, D. J. B. (2015). Pdgj 2021. *Etika Jurnalisme Pada Koran Kuning : Sebuah Studi Mengenai Koran Lampu Hijau*, *16*(2), 39–55.

Maria, T., Amelia, M., & Vembrie, S. (2020). Evaluation of Toll Road Pavement Performance Based on the 2013 Bina Marga Method (Case Study: Serpong-Pondok Aren Toll Road). *IOP Conference Series: Earth and Environmental Science*, *498*(1). https://doi.org/10.1088/1755-1315/498/1/012024

Niswah Selmi Kaffa, Muchammad Masykur, & Yoga Kencana Nugraha. (2023). Perbandingan Nilai Kedalaman Relatif Sungai Brantas Kabupaten Jombang dengan Perhitungan Algoritma Van Hengel and Spitzer Citra Sentinel-2 dan Digital Elevation Model (DEM). *Jurnal Teknik: Media Pengembangan Ilmu Dan Aplikasi Teknik*, *21*(2), 172–180. https://doi.org/10.55893/jt.vol21no2.475

Pembangunan, B. P., Provinsi, D., & Barat, J. (2018). *Perubahan Rencana Strategis (RENSTRA)*.

Raji, S. A., Zava, A., Jirgba, K., & Osunkunle, A. B. (2017). Geometric Design of a Highway Using Autocad Civil 3d. *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, *4*(6), 2458–9403. www.jmest.org

Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy Assessment of Land Use/Land Cover Classification Using Remote Sensing and GIS. *International Journal of Geosciences*, *08*(04), 611–622. https://doi.org/10.4236/ijg.2017.84033

Shofy, Y. F., & Wibowo, A. (2023). The Impact of the Trans-Java Toll Road Development on Spatial

Planning in the Northern Region of Java Island: A Study Utilizing NDBI and Google Earth Images. *Indonesian Journal of Earth Sciences*, *3*(1), A611. https://doi.org/10.52562/injoes.2023.611

Sun, G., Chen, X., Jia, X., Yao, Y., & Wang, Z. (2016). Combinational Build-Up Index (CBI) for Effective Impervious Surface Mapping in Urban Areas. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *9*(5), 2081–2092. https://doi.org/10.1109/JSTARS.2015.2478914

Zhao, L., Liu, Z., & Mbachu, J. (2019). Highway alignment optimization: An integrated BIM and GIS approach. *ISPRS International Journal of Geo-Information*, *8*(4). https://doi.org/10.3390/ijgi8040172