

Geographic Information System (GIS)-Based Road Damage Mapping in Google Earth for Village Infrastructure Planning

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ABSTRACT

The quality of village infrastructure plays a vital role in improving community welfare through economic growth. Tuban Regency, with its diverse geographical features such as coastal areas and limestone hills, frequently experiences road damage that hinders accessibility and development. To address this issue, the local government promotes sustainable development strategies, particularly through road infrastructure improvements funded by the Village Fund Allocation (ADD) program. However, feasibility studies on road damage in Sumurjalak Village remain inefficient in terms of time and cost, and lack accuracy due to the absence of supporting digital data. This study proposes a novel approach by integrating Geographic Information Systems (GIS) with Google Earth technology to map and assess road damage. Unlike conventional manual surveys or paper-based documentation, this integration provides a more efficient, accurate, and visually interactive method of spatial analysis. Using the Action Research method, which consists of five stages problem identification, data collection, planning, implementation, and evaluation this study demonstrates that GIS-based mapping significantly enhances the efficiency and accuracy of infrastructure assessments. The resulting digital documentation can serve as a decision-support tool for stakeholders and offer a scalable and replicable model for rural infrastructure planning, representing a significant advancement over previous approaches.

INTRODUCTION

The quality of public facilities and village infrastructure plays a crucial role in improving community welfare by boosting economic growth (Suja et al., 2025). Given the strong correlation between sustainable development and economic growth, the government promotes sustainable strategies for the construction and maintenance of infrastructure, particularly road infrastructure (Suja et al., 2025). To accelerate the development and maintenance of road infrastructure in Tuban Regency, the government has launched an assistance program through the Village Fund Allocation (ADD) (Rohmah & Ma'ruf, 2016)

Tuban Regency has diverse geographical conditions, ranging from coastal ecosystems to steep limestone hills (Sari et al., 2025). The hilly terrain increases the likelihood of road damage due to soil structure instability, leading to surface texture degradation and potholes (Pratama, 2020). Field observations conducted in Sumurjalak Village, Tuban Regency, indicate that the

limestone hills also pose challenges for feasibility studies on damaged roads, particularly in terms of time efficiency and accuracy of analysis. These factors significantly impact subsequent processes, such as the preparation of the Budget Plan (RAB) under the ADD program managed by Sumurjalak Village.

Time efficiency and analytical accuracy can be improved through technological adaptation, which facilitates digitalization in institutions or organizations (Shobirin, I. Muhammad, 2024). A Decision Support System can be utilized as a technological adaptation to solve problems or manage control in a specific region or area (Ratnasari et al., 2020). Field studies revealed that the Sumurjalak Village government is open to adopting the latest technologies such as smart villages (internet for all), one-day services, electronic correspondence, and utilizing websites as a communication tool. Readiness for technology adaptation is also greatly needed in the field of road feasibility studies which are a priority program of Sumurjalak Village. In the previous road feasibility study, manual methods were still used with conventional measurements and recording with the help of a field team from the village government. The road feasibility study carried out has not utilized digital products. By implementing Geographic Information System (GIS) technology on Google Earth, it can improve the planning, analysis, decision-making, and digital reporting processes for stakeholders, especially in Tuban Regency. This digital transformation can accelerate both execution and road repair processes (Mukherjee et al., 2021).

Google has developed a satellite imagery application that can be used for digital mapping, equipped with API services on Google Maps or mapping through Google Earth on Google Earth (Ratnasari et al., 2020). To improve planning, analysis, decision-making, and digital reporting for road mapping, GIS on Google Earth offers various features such as path, polygon (Oktavia et al., 2024), color coding, text, labels, measurement tools, Google Street View, and open access. This study aims to implement and analyze the role of GIS on Google Earth as a decision support tool in village infrastructure programs, specifically in mapping damaged roads to facilitate targeted and effective repair planning.

RESEARCH METHODS

This study employs the Action Research method, which consists of five stages of analysis: a) Problem Identification; b) Data/Facts Collection; c) Action Planning; d) Action & Observation; and e) Reflection (Ratnasari et al., 2023)

Problem Identification

Comprehensive problem identification is a crucial first step to ensure that the implementation objectives are achieved effectively and efficiently. To analyze this problem, the fishbone diagram (or cause-and-effect diagram) approach is used, which allows us to identify various factors that may influence the existing issues (Franciska et al., 2025). The fishbone diagram helps in identifying the root causes of the problem in a structured and comprehensive manner, while categorizing the elements that could contribute to road damage and challenges in managing village infrastructure.

Data/Facts Collection

In the Data Collection/Facts phase, several types of data are required for Geographic Information System (GIS) analysis, including:

1. Socio Economic Data

This data pertains to the land use function along the road (residential, commercial, or agricultural areas) and the population density around the road, which can influence the intensity of road usage and its deterioration. This data is obtained through observations conducted collaboratively with the local government staff.

2. Road Condition Data

This data is gathered through direct observation of the road, focusing on surface damage. The data includes photographs or videos, accompanied by field notes detailing the road's condition during inspections conducted by the local government. Additionally, road condition data is collected through image processing via Geographic Information Systems (GIS) using Google

Earth. A Geographic Information System (GIS) is a type of geographic information system programmed to perform various input processing, storage, analysis, and geospatial functions, and it can be utilized as a decision support tool (Suhendi & Ali, 2020). The accuracy level of Google Earth enables it to serve as a decision-support application in policies related to infrastructure mapping (Sahila et al., 2024).

3. Geospatial Data Location.

This data includes information about the layout and road network connecting various key areas within the village, such as main roads, secondary roads, and access roads. It encompasses road length, width, and interconnections between roads. Geospatial data is supplemented with GPS coordinates, presented through latitude and longitude coordinate axes.

Action Planning

Action Planning utilizing a Research Flowchart is a structured and systematic planning process aimed at implementing solutions derived from the problem identification and data collection phases. The flowchart serves as a visual framework that delineates the necessary steps to achieve the objectives of the research or system implementation, ensuring that each step is clearly monitored and evaluated (Ratnasari et al., 2023).

Action & Observation

Action & Observation in this research utilizes image processing through the Geographic Information System (GIS) in Google Earth, leveraging all available Google Earth services such as path, measurement, and others (Earth, 2025).

Reflection

Evaluation and Reflection consist of the process of Analysis of Findings from Google Earth and Justification of Repair Priority Scale using Analytical Hierarchy Process (AHP) (Nababan, 2014).

RESULTS AND DISCUSSION

Problem Identification

Fishbone diagram is used to deepen the analysis of field observation results, in order to determine the priority of problems that occur in the field. Fishbone diagram can be seen in figure number 1.

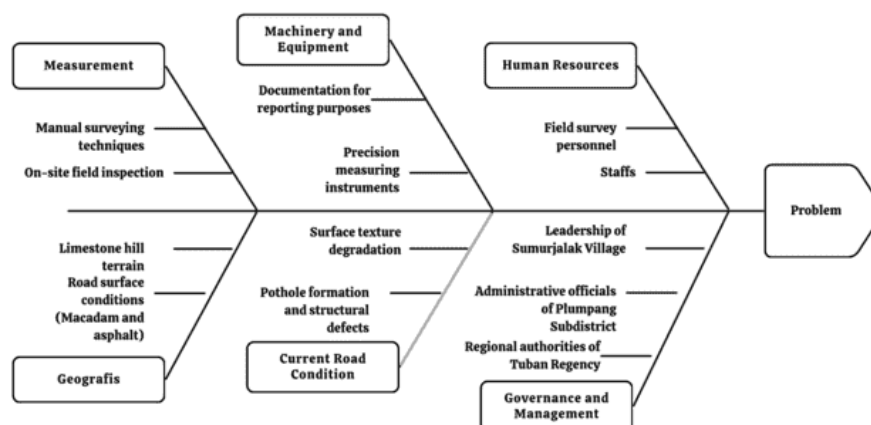


Figure 1. Fishbone Diagram Field Analysis

From the analysis of the fishbone diagram on Figure 1, the key factors influencing the issue can be categorized as follows:

1. People

The "People" entity consists of field survey personnel, including the staff of Sumurjalak Village who are responsible for conducting on-site surveys. The analysis reveals that the field surveys are conducted by the village officials currently on duty.

2. Management

The Management entity comprises the leadership at different levels, including the village-level leaders of Sumurjalak, sub-district leaders of Plumpang, and district leaders of Tuban. The presence of a multi-level leadership structure at each administrative level serves as a supervisory mechanism throughout the infrastructure development and maintenance process.

3. Management

The Management entity consists of the leadership at different levels, including the village-level leaders of Sumurjalak, sub-district leaders of Plumpang, and district-level leadership of Tuban. This multi-level leadership structure serves as a supervisory mechanism in the infrastructure development and maintenance process.

4. Current Condition

The Current Condition entity includes various types of road damage and repair needs, such as surface texture damage, potholes, newly constructed roads, and macadam roads, among others.

5. Geographical Conditions

The Geographical Conditions entity consists of the geographical characteristics of Sumurjalak Village, Plumpang Sub-district, and Tuban District. The geographical structure of Sumurjalak Village, which is hilly, increases the likelihood of road surface texture damage and pothole formation.

6. Measurement

The Measurement entity involves the current manual measurement methods, which require direct on-site surveys. These manual processes demand more time and have an accuracy level that needs to be supported by real-time data to enable stakeholders to conduct online verification without the necessity of returning to the survey location.

From the seven entities that have been identified, the primary issue is the insufficient number of survey personnel conducting road damage inspections, which results in prolonged inspection times. Additionally, the reliance on manual calculations presents a potential risk of miscalculations and inaccuracies in measurement analysis. Digital data is highly necessary to enable multi-level leadership at each administrative level to oversee the processes of planning, proposal submission, and infrastructure development effectively.

Data Collection/Facts

The results of Data Collection/Facts include several types of data required for Geographic Information System (GIS) analysis, as follows:

1. Socio-Economic and Land Use Data

Data regarding land use along the road (residential, commercial, or agricultural areas) and the population density around the road can be used for decision-making regarding the prioritization of road repairs, which will be applied in the Analytical Hierarchy Process (AHP).

2. Road Condition Data

Data obtained from direct observations of the road, such as surface damage. This data, in the form of photographs or videos, is collected by local government staff and used as validation data between image processing and field conditions.

3. Geospatial Data (Location)

Latitude and longitude coordinates are used as markers for each digital data point obtained from image processing through the Geographic Information System (GIS) in Google Earth.

Action Planning

At the Action Planning stage, all research phases are presented in the form of a research flowchart. The research flowchart is shown in the figure 2.

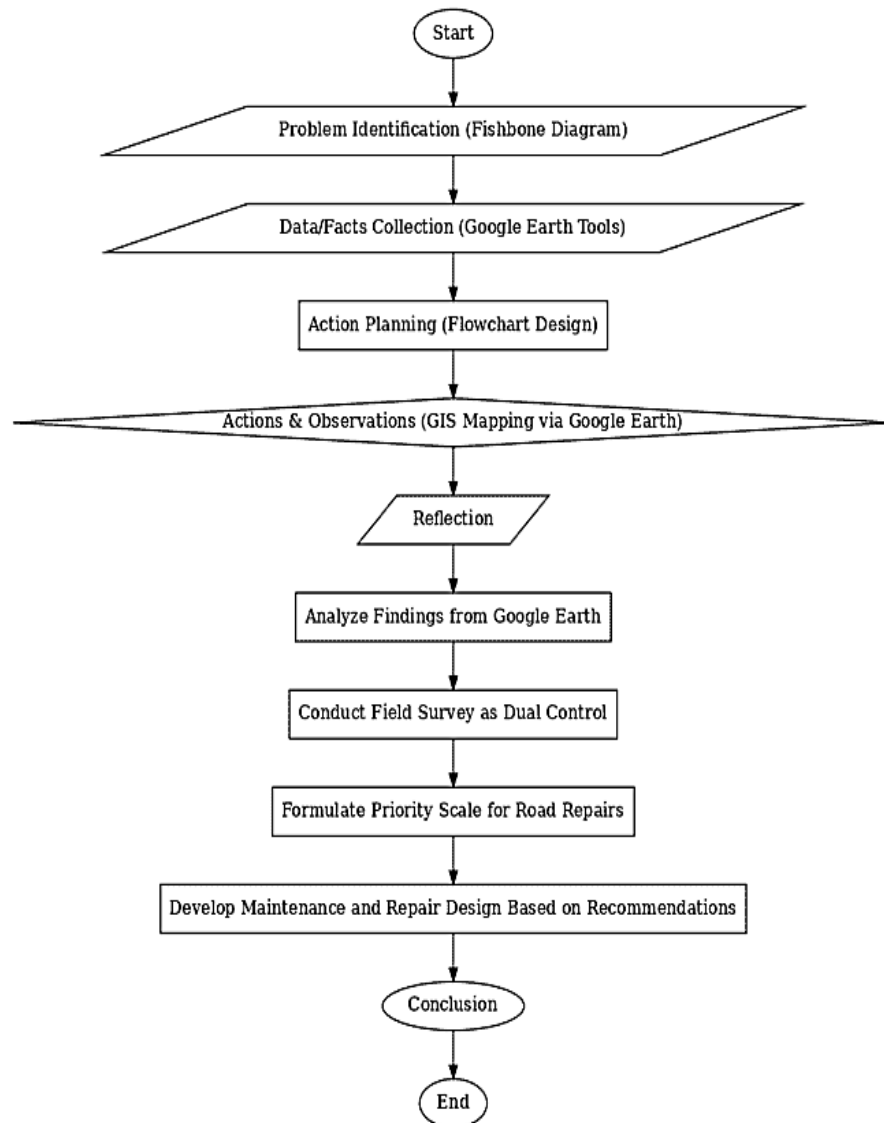


Figure 2. Research Flowchart

Action & Observation

The implementation process of the Geographic Information System (GIS) on the Google Earth application is carried out by comprehensively creating node points on several roads that were not included in the repair budget in the previous year. The following are several stages in the image processing of road damage mapping from the Google Earth Geographic Information System (GIS), presented through images 3 to 12.



Figure 3. of Sumurjalak Village Point Determination Location (Step 1)

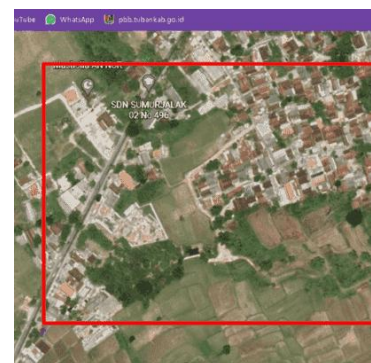


Figure 4. Detailed location mapping by zooming in on the map (Step 2)

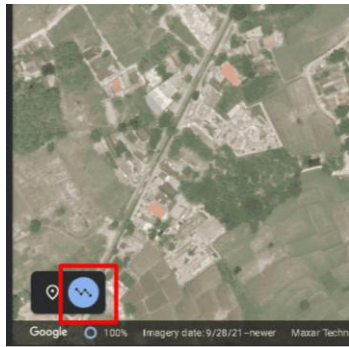


Figure 5. Path and Polygon Buttons for Marking Locations Based on Categories (Step 3)

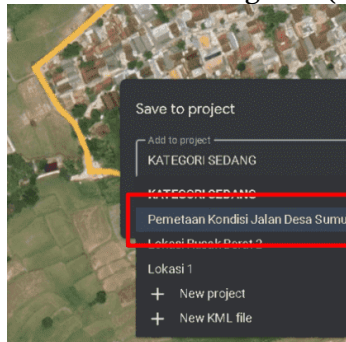


Figure 7. Point or Node Saving Process (Step 5)

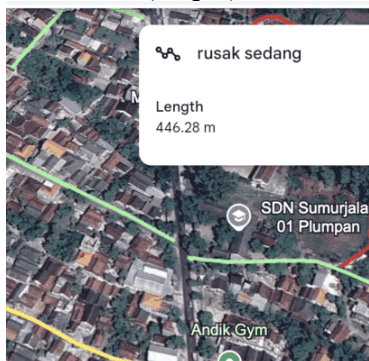


Figure 9. Rechecking the Length of Damaged Roads on Each Point or Node (Step 7)

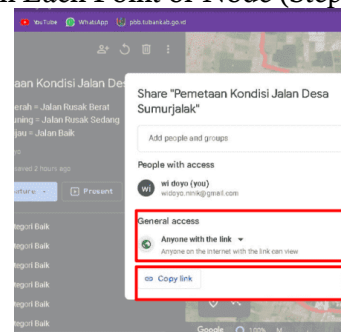


Figure 11. Sharing Session on Damaged Road Mapping Project (Step 9)



Figure 6. Drag and Drop Tombol Path and Polygon (Step 4)

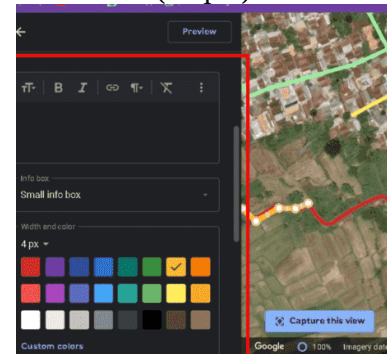


Figure 8. Category and Color Adjustment Process (Step 6)

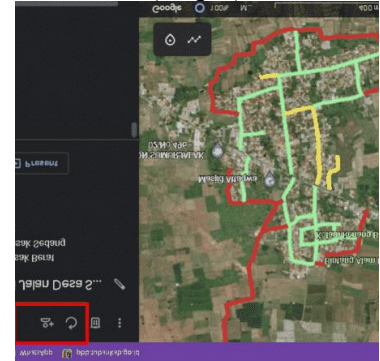


Figure 10. Mapping Results of Damaged Roads (Step 8)

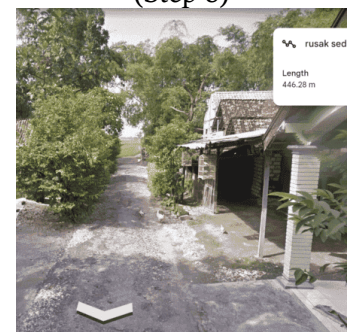


Figure 12. Google Street View Service (Step 10)

Reflection

1. Analysis of Findings from Google Earth

In the reflection process, an analysis is conducted on all findings and data obtained from road mapping in Sumurjalak Village using the Geographic Information System (GIS) on the Google Earth application.

Table 1. Analysis of Road Mapping Results in Sumurjalak Village

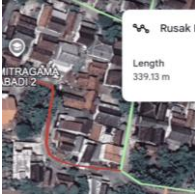
No	Path Category	Road Condition	Location	Road Length (m ²)	Repair Recommendation
1	Green	Good	-7.03380526,112.08649593	129.5 m ²	Monitoring
2	Green	Good	-7.03617246,112.09013276	750.9 m ²	Monitoring
3	Green	Good	-7.0356076,112.0872801	212.2 m ²	Monitoring
4	Green	Good	-7.03215147,112.08855061	278.5 m ²	Monitoring
5	Green	Good	-7.03046416,112.08981594	166.8 m ²	Monitoring
6	Green	Good	-7.03095818,112.08900963	114.8 m ²	Monitoring
7	Green	Good	-7.03103509,112.08950396	26.8 m ²	Monitoring
8	Green	Good	-7.03043958,112.08833552	26.8 m ²	Monitoring
9	Green	Good	-7.03043958,112.08833552	163.2 m ²	Monitoring
10	Green	Good	-7.03099643,112.08782408	163.2 m ²	Monitoring
11	Green	Good	-7.03099643,112.08782408	100.9 m ²	Monitoring
12	Green	Good	-7.03130299,112.08761094	187.7 m ²	Monitoring
13	Green	Good	-7.02967988,112.08763247	209.2 m ²	Monitoring
14	Green	Good	-7.02085982,112.09114194	501.7 m ²	Monitoring
15	Green	Good	-7.01510228,112.09709524	1417.8 m ²	Monitoring
16	Green	Good	-7.01668828,112.09592507	219.4 m ²	Monitoring
17	Green	Good	-7.02978922,112.08878181	261.7 m ²	Monitoring
18	Green	Good	-7.01635037,112.09489357	145.1 m ²	Monitoring
19	Green	Good	-7.01647918,112.09598068	197.3 m ²	Monitoring
20	Green	Good	-7.01647918,112.09598068	368.7 m ²	Monitoring
21	Green	Good	-7.01370546,112.09550657	258.4 m ²	Monitoring
22	Green	Good	-7.01489249,112.09818652	58.9 m ²	Monitoring
23	Green	Good	-7.01489249,112.09818652	177.1 m ²	Monitoring
24	Green	Good	-7.03551813,112.08941216	309.3 m ²	Monitoring
25	Green	Good	-7.03673294,112.08776127	155 m ²	Monitoring
26	Green	Good	-7.03396451,112.08666101	87.3 m ²	Monitoring
27	Green	Good	-7.02480461,112.09294329	910.2 m ²	Monitoring
28	Yellow	Moderate	-7.03431053,112.08841887	280.7 m ²	Minor Repairs
29	Yellow	Moderate	-7.03452898,112.08798769	106.8 m ²	Minor Repairs
30	Yellow	Moderate	-7.03559435,112.08797603	144.5 m ²	Minor Repairs
31	Yellow	Moderate	-7.02618571,112.08792176	446.2 m ²	Minor Repairs
32	Red	Severely Damaged	-7.02978922,112.08878181	339.1 m ²	Total Repair
33	Red	Severely Damaged	-7.02618571,112.08792176	519.1 m ²	Total Repair
34	Red	Severely Damaged	-7.02788611,112.08459787,	780.8 m ²	Total Repair
35	Red	Severely Damaged	-7.03166247,112.08757255	302 m ²	Total Repair

The analysis results from Table 1 indicate that 35 road sections were recorded in 2024 as part of the projected repair and monitoring program for damaged infrastructure in Sumurjalak Village. Among these, 27 sections fall under the good category (green), requiring maintenance and monitoring. Several recommendations for periodic maintenance include: a) Drainage Maintenance; b) Shoulder Road Maintenance; c) Bridge Structure Repair; d) Road Equipment Installation (Signs, Guardrails, Retaining Walls)(Akbaridin et al., 2021). In the moderate damage category (yellow), four locations were identified with recommendations for minor repairs. Some minor damage was caused by water seepage and road construction issues (Moruk, 2022). The analysis suggests that minor repairs should include strengthening the pavement structure, such as using rigid pavement construction and composite pavement construction (Sulaiman & Wasono, 2019). For the severely damaged category (red), four locations were prioritized for major repairs. In these cases, the road structure consists of macadam roads, newly constructed roads, or roads affected by local flooding. Macadam roads, which are composed of arranged stones and have a slippery and rocky surface, require concrete paving to ensure safety for road users (Setiawan & Jartmikowati, 2024).

2. Justification of Repair Priority Scale

Based on the mapping analysis using the Geographic Information System (GIS) on the Google Earth application, several repair recommendations were identified across three categories: good, with a recommendation for monitoring; moderate, with a recommendation for minor repairs; and severely damaged, with a recommendation for total repair. The analysis and recommendations serve as a decision-making support tool for government stakeholders in planning road infrastructure repairs in Sumurjalak Village. In the severely damaged category, four locations were identified as requiring total repair. The data is presented in Table 2.

Table 2. Justification of Repair Priority Scale

No.	Category	Location	Road Length (m ²)	Google Street View	Google Earth View
1	Severely Damaged	7.02978922 112.088781 81	339.1 m ²		
2	Severely Damaged	7.02618571 112.087921 76	519.1 m ²		
3	Severely Damaged	7.02788611 112.084597 8	780.8 m ²		
4	Severely Damaged	7.03166247 112.087572 55	302 m ²		

Among the four severely damaged categories, it was found that all road conditions are still in the form of macadam roads or limestone rock arrangements, which pose a risk to road users

(Setiawan & Jartmikowati, 2024). The priority scale is determined using the Analytical Hierarchy Process (AHP) method (Nababan, 2014) with several formulation alternatives based on field conditions. Analytical Hierarchy Process (AHP) it is a decision-making method that involves pairwise comparisons between selection criteria as well as pairwise comparisons among the available alternatives (Wijaya et al., 2022). The AHP diagram is presented in Figure 13.

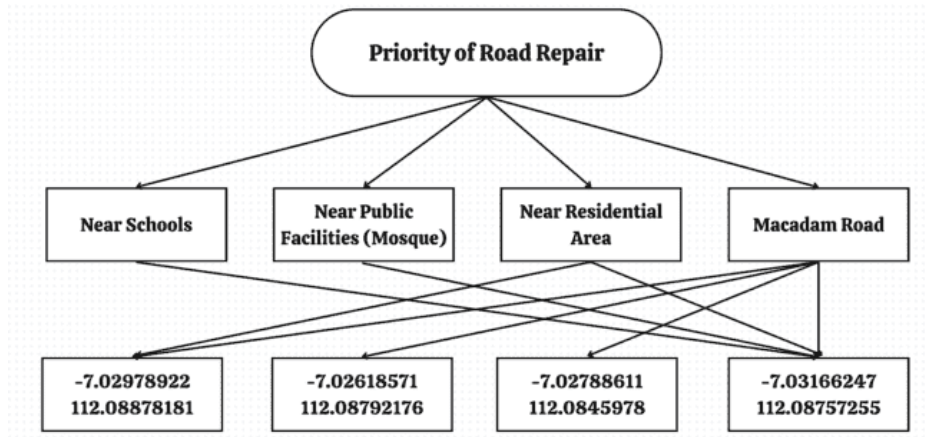


Figure 13. Priority of Road Repair

From Figure 13, the priority scale calculation results are as follows: a) Criteria 1, location 7.02978922, 112.08878181, falls into two main priorities, namely macadam road conditions and proximity to residential areas; b) Criteria 2, location -7.02618571, 112.08792176, falls into one main priority, which is macadam road conditions; c) Criteria 3, location -7.02788611, 112.0845978, falls into one main priority, which is macadam road conditions; and d) Criteria 4, location -7.03166247, 112.08757255, falls into four main priorities, namely proximity to schools, public facilities (mosques), residential areas, and macadam road conditions. Based on the AHP diagram analysis, it can be concluded that the highest repair priority is assigned to Criteria 4, location -7.03166247, 112.08757255.

3. Field Survey as Dual Control

After the identification process, a control process is carried out by government staff through direct on-site surveys. By utilizing mapping selection through the Geographic Information System (GIS) on the Google Earth application, the Sumurjalak Village Government can conduct mapping more efficiently and determine the priority scale for road repairs. The field survey implementation process is illustrated in Figure 14.



Figure 14. Field Survey as Dual Control
Source : Budget Plan Document for Sumurjalak Village

The field survey process is conducted to ensure the accuracy of digital data management results as an initial stage in the road repair process, which has been prioritized using the AHP diagram (Awaliani et al., 2024).

4. Development of Maintenance and Repair Design

After the digital mapping process and priority scale determination, the development of the maintenance and repair design is carried out, as illustrated in Figure 15.

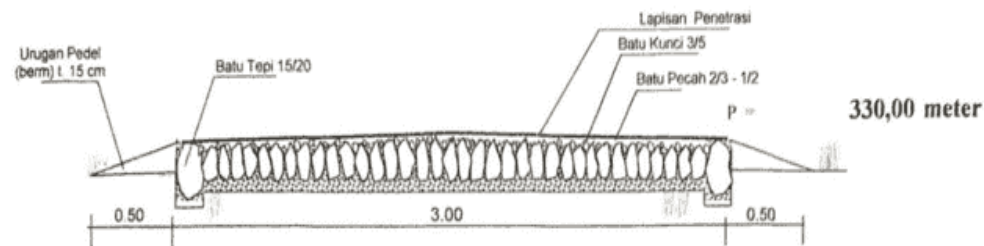


Figure 15. Prototype of Cross-Section of Concrete Pavement Road

In Figure 15, it is shown that for Criterion 4 at location -7.03166247, 112.08757255, the initial repair length of 302 m² was extended to 330 m² based on field conditions. In Figure xx, several design criteria for the maintenance and repair prototype are outlined as follows: a) Road length: 330.00 meters; b) Road width: 3.00 meters; c) Base layer using crushed stone (2/3 – 1/2 inch); d) Additional layer using river stone (15/20 cm); e) Pedel fill (sand and small stones) with a thickness of approximately 15 cm; f) Spreading of primary aggregate with a thickness of 3–5 m²/m²; g) Spreading of secondary aggregate with a thickness of 2–3 m²/m² followed by compaction; h) First asphalt application of 2 kg/m²; i) Spreading of locking aggregate with a thickness of 1–2 m²/m³ followed by compaction; and j) Final asphalt layer application of 1.5 kg/m².

CONCLUSION

The Geographic Information System (GIS) on the Google Earth application can be utilized as a decision support tool for the Sumurjalak Village infrastructure program, particularly in mapping damaged roads to facilitate targeted repair planning. Its implementation enables a more efficient and streamlined mapping process when applied comprehensively and simultaneously to assess road damage. The accuracy level of GIS on Google Earth aligns with actual field conditions, as verified through re-evaluation of prioritized roads selected for repairs.

GIS on Google Earth is user-friendly and equipped with various features such as path, polygon, color coding, text, labels, measurement tools, Google Street View, and open access for non-commercial activities. The road mapping results using GIS on Google Earth can also be shared as digital documents that can be read, analyzed, and used as a decision-making reference by stakeholders and authorities. Additionally, the Google Street View feature in GIS on Google Earth enables real-time verification by stakeholders, allowing online assessments to be conducted anytime and anywhere.

For broader implementation, it is recommended to conduct training programs to improve the digital literacy of village officials and community members. The development of standardized GIS-based mapping templates by local governments can also facilitate replication in other villages facing similar infrastructure issues. These templates can serve as accurate documents to be attached as digital evidence in road repair proposals submitted to local governments or higher-level stakeholders. Furthermore, integrating GIS data with the village information system or regional planning databases can strengthen coordination and long-term monitoring of infrastructure projects.

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