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Analysis of Route Selection Using the Analytical Hierarchy Process (AHP) in Mahakam Ulu Regency

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Abstract – Roads are essential infrastructure for improving the economy of the community and regional development. Good road infrastructure certainly impacts the progress of an area. As the region develops and the complexity of the district government's tasks increases, which affects the increase in vehicle traffic, new road access is needed to facilitate the mobility of officials. The Analytical Hierarchy Process (AHP) method is one of the methods used for decision-making in project feasibility studies. In this study, there are four criteria used, namely 1. Distance 2. Efficiency, and; 3. Spatial Planning Integration and aesthetics. Each of these three criteria is broken down into two sub-criteria. Questionnaires were distributed to two respondents selected proportionally, consisting of one person from the Public Works Department of Mahakam Ulu Regency and one person from the Planning Consultant of PT. TEMA KARYA MANDIRI KSO. The questionnaire results were analyzed using the Analytical Hierarchy Process (AHP) method to assess four alternative road sections to be selected. Based on the AHP analysis of the main entrance road planning in the office area of Mahakam Ulu Regency, alternative location 1 was chosen with an AHP score of 0.473, which is higher than the other three alternatives. Therefore, alternative location 1 is recommended to proceed to the next study stage (Detail Engineering Design).

Keywords: Analytics Hierarchy Process; Mahakam Ulu Regency; Road Construction

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1. Introduction

Roads play a crucial role in facilitating the movement of people and goods, thereby contributing significantly to economic growth and social development. They connect urban centers with rural areas, enabling the distribution of resources and services. This connectivity is particularly important for remote and isolated regions, where access to markets, healthcare, and education can be limited. By improving road infrastructure, these areas can be integrated into the broader economy, fostering development and reducing regional disparities.

Moreover, the geometric design of roads is a critical factor in their functionality. Proper geometric standards ensure that roads are safe and comfortable for users. This includes considerations such as road width, curvature, gradient, and sight distance. Adhering to these standards helps prevent accidents, reduces travel time, and enhances the overall efficiency of the transportation network. In essence, well-designed roads not only facilitate mobility but also contribute to the well-being and safety of the community [1].

To support the construction of provincial roads and strengthen inter-city connectivity, the East Kalimantan Provincial Government plans to procure the Main Entrance Road Construction Project for the Office Area through the Mahakam Ulu Regency Regional Budget (APBD) for the 2024 fiscal year [2].

Effective transportation systems are fundamental to regional development, as they facilitate the movement of goods and people, thereby enhancing trade and commerce. Well-maintained roads reduce travel time and vehicle operating costs, leading to increased productivity and economic efficiency. Moreover, reliable road infrastructure is essential for emergency services, ensuring that medical, fire, and police services can respond promptly to incidents. In addition to economic benefits, good road infrastructure also promotes social cohesion by connecting communities. It enables easier access to education, healthcare, and recreational activities, improving the overall quality of life. Cultural exchanges and social interactions are also enhanced, fostering a sense of unity and shared identity among residents.

Investing in road infrastructure is, therefore, not just about building roads but about building the future of the region. It requires a comprehensive approach that includes regular maintenance, upgrades, and expansions to meet the growing demands of the population and the economy [3].

Roads are not just physical structures; they are vital assets that facilitate economic activities and social interactions. They enable the efficient movement of goods and services, which is essential for trade and commerce. Without a robust road network, businesses would struggle to operate efficiently, leading to higher costs and reduced competitiveness. Moreover, roads contribute to the social capital of a community by connecting people and places. They provide access to essential services such as healthcare, education, and employment opportunities, thereby improving the quality of life. In rural and remote areas, roads are particularly crucial as they link these regions to urban centers, fostering inclusive growth and reducing regional disparities. The process of development involves continuous improvements and upgrades to infrastructure, ensuring that it meets the evolving needs of the population. This dynamic process helps create a balanced and sustainable environment where economic activities can thrive, and social well-being is enhanced. Investing in road infrastructure is, therefore, a strategic priority for any region aiming to achieve long-term economic prosperity and social cohesion [4].

Selecting the optimal route is complex due to numerous variables. Based on research from Sameer, research aims to identify the best route by integrating various assessment criteria into a structured framework using Geographic Information System (GIS) and the Analytical Hierarchy Process (AHP). The study employs a two-stage model: the first stage involves creating design and path alternatives from different perspectives, while the second stage compares these alternatives to select the best one. Tested between Ramadi and Hit, the model proved effective, accommodating multiple criteria and generating different alignment alternatives. The model facilitates the easy identification of the suitability of each route alternative from various perspectives. By calculating the costs for each criterion separately, it enables a more precise and detailed assessment. This feature is particularly useful for decision makers who may prioritize specific criteria. For example, if a decision maker is particularly concerned with engineering considerations, the model can quickly highlight the best path from an engineering standpoint. Moreover, the model's ability to isolate and evaluate each criterion individually allows for a tailored approach to route selection. This means that if multiple criteria are important, the model can still provide a clear and accurate determination of the most suitable alternative. The efficiency of the proposed method is notable, as it not only reduces the time required for assessment but also cuts down on costs, all while maintaining a high level of accuracy. This makes the model an invaluable tool in the planning and decision-making process for route selection in road construction projects. [5]. It can be concluded that the AHP method as a decision maker for path selection is very precise and efficient.

Along with the growth of the region and the increasing complexity of government tasks, activities at the district government offices have also increased. This has led to an increase in vehicle traffic, both official vehicles and visitors. The Public Works and Spatial Planning, Housing, and Settlement Areas Department of Mahakam Ulu Regency plans to construct the main entrance road to the office area to improve accessibility, public service quality, and community satisfaction. This study was conducted to determine the selected road section using the AHP method based on several criteria determined by the researchers, namely distance, efficiency, and spatial planning integration and aesthetics.

2. Research Methods

The purposive sampling technique ensures that the selected respondents have relevant knowledge and experience, making their input valuable for the study. By using Google Forms, the researchers could efficiently collect data from a diverse group of respondents, ensuring a comprehensive analysis. The AHP method, known for its structured and systematic approach, allows for the evaluation of multiple criteria and sub-criteria, providing a clear framework for decision-making [6].

In this study, the criteria include distance, efficiency, and the integration of spatial planning and aesthetics. Each criteria is further broken down into sub-criteria to capture the nuances of each factor. The respondents' ratings on these criteria are then analyzed to determine the most suitable route. This method not only helps in making an informed decision but also ensures that the chosen route aligns with the overall objectives of improving accessibility and service quality in the office area.

The results of this study will provide valuable insights for the Public Works and Spatial Planning Department of Mahakam Ulu Regency, guiding them in the development of infrastructure that meets the needs of the community and supports regional growth. By adopting a methodical approach like AHP, the decision-making process becomes more transparent and justifiable, ultimately leading to better outcomes for the region.

2.1. Analytic Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) was created in the early 1970s by Thomas L. Saaty, a mathematician from the University of Pittsburgh. AHP is unique in its ability to gather data from one or multiple experts using a pairwise comparison scale, organize a hierarchical structure of comparisons with criteria and sub-criteria among alternatives, determine priority vectors within each group of items being compared, and compile local preferences supported by sub-criteria and criteria from all hierarchy levels to achieve global priorities among all alternatives.

According to Saaty (2008), research utilizing the AHP method does not require a large sample size but rather key individuals who are knowledgeable and play significant

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roles in the research field. In this study, the AHP was employed to create a hierarchy for selecting the optimal bonded logistics center location, drawing on the expertise and experience of several field experts. AHP was chosen for its effectiveness in quantifying qualitative knowledge by measuring intangible dimensions, which are crucial as they cannot be directly measured using an absolute scale but only through qualitative research.

This study uses the Analytical Hierarchy Process (AHP) method for analysis. The processes in the AHP method include [7]:

1. Defining the problem and determining the desired solution. This initial step involves clearly identifying the issue that needs to be addressed and outlining the objectives of the solution. It sets the foundation for the entire process by establishing what needs to be achieved.
2. Creating a hierarchical structure starting from the general goal, followed by criteria and alternatives at the lowest criteria level. In this step, a hierarchy is constructed with the overall goal at the top. Below the goal, various criteria that will influence the decision are listed. At the lowest level, the different alternatives or options are placed. This structure helps in organizing the decision-making process systematically.
3. Creating a pairwise comparison matrix that describes the relative contribution or influence of each element on the criteria at the level above it. Here, a matrix is developed to compare each element against others in pairs, based on how much they contribute to or influence the criteria at the next higher level. This helps in understanding the relative importance of each element.
4. Normalizing the data by dividing the value of each element in the pairwise comparison matrix by the total value of each column. Normalization involves adjusting the values in the pairwise comparison matrix so that they can be compared on a common scale. This is done by dividing each element's value by the sum of its column, ensuring that the comparisons are consistent and meaningful.
5. Calculating the eigenvalues and testing their consistency; if inconsistent, the data collection is repeated. Eigenvalues are calculated to determine the priority of each element. Consistency testing ensures that the comparisons made in the pairwise matrix are logically consistent. If the consistency ratio is too high, it indicates that the judgments may be unreliable, and the data collection process needs to be repeated.
6. Repeating steps 3 to 5 for each level of the hierarchy.
7. Calculating the eigenvector of each pairwise comparison matrix. The eigenvector represents the relative weights or priorities of the elements in the matrix. It is derived from the eigenvalues and provides a ranking of the elements based on their importance.
8. Checking the consistency of the hierarchy. If the value is more than 10%, the judgment values are re-evaluated. The final step involves a thorough consistency check of the entire hierarchy. If the consistency ratio exceeds 10%, it suggests that the judgments may be inconsistent, and the values need to be re-evaluated to ensure the reliability of the decision-making process.

2.2. Respondent, Criteria, Sub-Criteria, and Alternative

The questionnaire was distributed to 2 respondents selected through purposive sampling, which involves selecting respondents based on specific considerations, requiring knowledge and competence in road management. Of the 2 respondents, 1 is an official at the level of PPK in the Public Works Department of Mahakam Ulu Regency, and 1 is a practitioner from the Planning Consultant sector.

The variables used in this study consist of criteria or considerations that form the basis for prioritizing alternative routes in Mahakam Ulu Regency. These variables will be formulated into a hierarchical structure after primary and secondary data are obtained. In this study, the hierarchical levels using the AHP method consist of three levels:

1. Level I (goal): Determining the alternative route chosen to connect the main road with the office area in Mahakam Ulu Regency.
2. Level II (criteria): Consisting of several criteria for determining the priority of transportation mode selection, namely:
   - Distance
   - Efficiency
   - Integration with Spatial Planning
3. Level III (sub-criteria): Development from Level II, which includes sub-criteria such as:
   - Shortest distance and accessibility to public facilities for the Distance criteria.
   - Balance and environmental impact of the work for the Efficiency criteria.
   - Future Development Potential and Aesthetics and Beauty for the Integration with Spatial Planning and Aesthetics criteria.
4. Level IV (Alternative): These are the options offered based on the given criteria and sub-criteria. In this study, the alternatives used are route options that can be utilized to connect the main road with the office area.

The purposive sampling technique ensures that the selected respondents have relevant expertise, making their input valuable for the study. By structuring the criteria and sub-criteria hierarchically, the AHP method provides a clear framework for evaluating and prioritizing the alternative routes. This structured approach helps in making informed decisions that align with the overall objectives of improving accessibility and service quality in the office area of Mahakam Ulu Regency.

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3. Result and Discussion

Before obtaining the overall weighting of criteria, sub-criteria, and combined alternatives, the weightings for each respondent were obtained as follows.

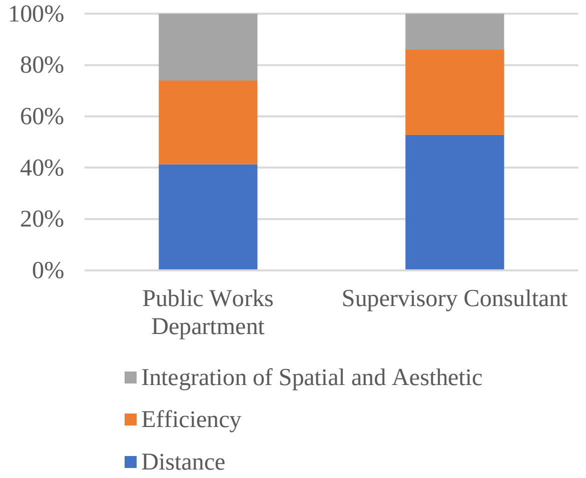

Figure 1. Weight of Each Respondent for the Criteria Used

Based on the image, it is known that both respondents support distance criteria as the main consideration in determining the route that will be used as a connection between the main road and the office area. However, the Public Works Department tends to balance the three criteria more evenly compared to the supervising consultant. The supervising consultant places a strong emphasis on distance and work efficiency as the main references in building a project. This indicates a shared understanding of the importance of proximity in planning infrastructure. However, there is a notable difference in approach between the Public Works Department and the supervising consultant. The Public Works Department appears to consider all three criteria—distance, cost, and environmental impact—more equally. In contrast, the supervising consultant places a significant emphasis on distance and work efficiency, suggesting a focus on optimizing project timelines and reducing travel time. This divergence in priorities highlights the varying perspectives and methodologies that different stakeholders bring to infrastructure planning and development.

After getting the weighting of each respondent on the criteria used, the weighting for each respondent on the selected alternative is also obtained. The following is a graph of alternative weights for each respondent.

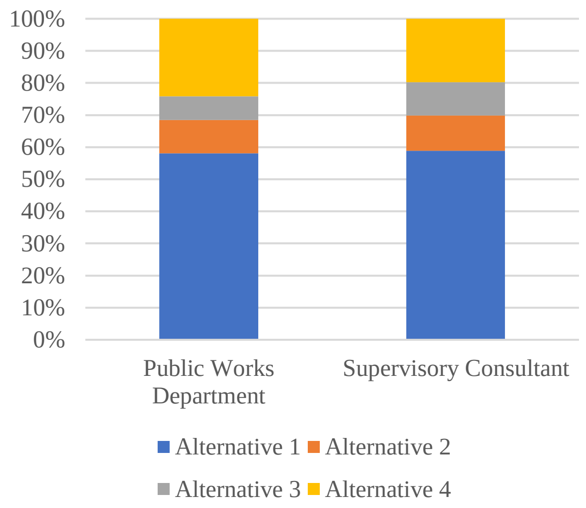

Figure 2. Weight of Each Respondent for the Alternative Choosed

Based on figure 2, it is known that both respondents chose alternative 1 as the route option that meets the three previously given criteria: distance, efficiency, and integration with spatial planning and aesthetics. The image also confirms that both respondents agree on the selection of the route that will connect the main road with the office area. This alignment suggests a shared understanding of the importance of these factors in infrastructure planning. Additionally, the image confirms that both respondents are in agreement regarding the route that will link the main road to the office area. This consensus highlights a collaborative approach to decision-making, ensuring that the chosen route not only meets practical requirements but also aligns with broader urban planning and aesthetic considerations.

After obtaining the weightings for each respondent, the combined weightings of both respondents were calculated. The following are the weightings for each criteria and sub-criteria in this study based can be seen on table 1.

Table 1
Weighting of Level 2 Criteria against the goal

Criteria	Weight
Distance	0.473
Efficiency	0.334
Integration with Spatial Planning and Aesthetics Factor	0.193
Total	1

Based on the weighting of criteria against the goal, it is known that the distance factor has the highest weight in determining the alternative route connecting the main road with the office area. This indicates that distance is the most critical factor in the decision-making process for selecting the optimal route. The emphasis on distance suggests that minimizing travel time and ensuring efficient connectivity are top priorities. A shorter route not only reduces travel time but also lowers transportation costs and enhances accessibility for both employees and visitors.

In addition to distance, other factors such as efficiency

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and integration with spatial planning also play significant roles, but their impact is secondary compared to the distance. By prioritizing the distance factor, the study aims to identify the most practical and effective route that meets the needs of the office area while supporting overall regional development.

This approach ensures that the selected route will provide the best possible balance between accessibility, cost-effectiveness, and integration with existing infrastructure, ultimately contributing to improved public service delivery and community satisfaction. For more details, the weighting of level 3 sub-criteria against the goal based on each criteria can be seen on table 2.

Table 2
Weighting of Level 3 Sub-Criteria against the Criteria

Criteria	Sub-Criteria	Weight
Distance Factor	Shortest Distance	0.833
	Accessibilities to Public Facilities	0.167
	Total	1
Efficiency Factor	Balancing	0.667
	Environmental Impact	0.333
	Total	1
Integration with Spatial Planning and Aesthetics Factors	Development Potential	0.500
	Aesthetic and Beauty	0.500
	Total	1

This analysis highlights the importance of different factors in the decision-making process. The emphasis on the shortest distance indicates that minimizing travel time and ensuring direct routes are crucial for the overall efficiency of the transportation network. A shorter distance not only reduces travel time but also lowers fuel consumption and operational costs, making it a highly prioritized sub-criteria.

For the efficiency factor, the high weight given to balance suggests that maintaining a harmonious and sustainable development is essential. This includes considering the environmental impact and ensuring that the road construction does not disrupt the natural and built environment. A balanced approach helps in achieving long-term sustainability and operational efficiency.

In terms of integration with spatial planning and aesthetics, the equal weighting of both sub-factors indicates that both the potential for future development and the aesthetic appeal of the road are equally important. This balance ensures that the road infrastructure not only meets current needs but also supports future growth and enhances the visual and functional quality of the area. After obtaining the weights of the criteria and sub-criteria, a sensitivity analysis is conducted to determine the best alternative based on the criteria and sub-criteria used as follows.

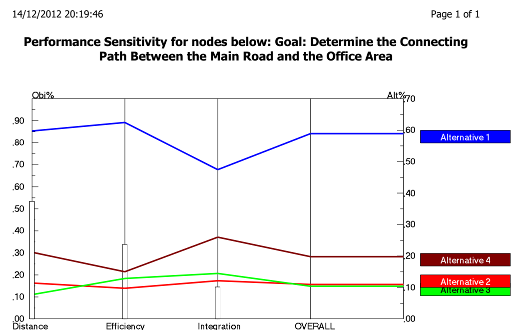

Figure 3. Sensitivity Analysis

Based on figure 3, The sensitivity analysis clearly demonstrates the superiority of alternative 1 across multiple dimensions. This alternative excels not only in minimizing distance, which is crucial for reducing travel time and costs, but also in maximizing efficiency, ensuring that the route is practical and sustainable. The integration with spatial planning and aesthetics further highlights its suitability, as it aligns well with the existing infrastructure and enhances the visual appeal of the area.

Moreover, the combination of criteria and sub-criteria underscores the comprehensive advantages of alternative 1. This holistic approach ensures that all relevant factors are considered, providing a balanced and well-rounded evaluation. The high score across various metrics indicates that alternative 1 is not only the most efficient and practical option but also the most aesthetically pleasing and future-proof choice.

In conclusion, the sensitivity analysis reaffirms that alternative 1 is the optimal route, offering the best balance of distance, efficiency, and integration with spatial planning and aesthetics. This makes it the most viable option for connecting the main road with the office area, ensuring improved accessibility and service quality for the community.

4. Conclusion

This analysis highlights the effectiveness of the AHP method in evaluating and prioritizing different route options. By considering various criteria such as distance, efficiency, and integration with spatial planning and aesthetics, the study ensures a comprehensive assessment of each alternative. The high AHP score of 0.473 for alternative route 1 indicates its superiority in meeting the established criteria, making it the most suitable choice for the project.

The selected route not only provides a direct and efficient connection between the office area and the main road but also supports the overall development goals of Mahakam Ulu Regency. With a total length of 1365.8 meters, this route is designed to enhance accessibility, reduce travel time, and improve the quality of public

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services.

Furthermore, the implementation of this route is expected to have positive impacts on the local economy and community well-being. By facilitating smoother transportation and better connectivity, the new road will contribute to the region's growth and development, making it a valuable investment for the future.

5. Recommendation

Given the limitation of respondents to only the Public Works and Spatial Planning Department of Mahakam Ulu Regency and the organizing consultant from the Tender Winner, further analysis related to the environment and community perceptions is needed. The next step after selecting the route for the connecting road between the office area and the main road in Mahakam Ulu Regency is to ensure its immediate realization, as it will significantly increase productivity.

Considering that the score of alternative 1 is much higher than the other alternatives, alternative 1 becomes the only best solution for connecting the main road with the office area. The results of this work should be promptly followed up by the relevant authorities, considering the potential hazards that may occur, such as the road body breaking on the Main Entrance Road Construction to the Office Area.

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