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Application of the Analytic Hierarchy Process (AHP) in Determining Bridge Maintenance in Sekadau Regency

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Abstract
A bridge is an infrastructure structure that connects two points separated by natural and artificial obstacles. The importance of bridge maintenance lies in prioritizing the safety and smooth operation of the community, reducing construction costs, and extending the life of bridge infrastructure. The problem is that there has been an increase in mobility in several public spaces after the pandemic, so adequate facilities and infrastructure are needed. However, adding bridge infrastructure is currently not a top priority due to budget reductions. This study aims to use the Analytic Hierarchy Process (AHP) method in determining the priority of bridge maintenance in Sekadau Regency based on 4 (four) criteria and 10 (ten sub-criteria) for 3 (three) alternative steel frame bridges, where primary data is obtained based on questionnaires for 3 (three) groups of respondents. The analysis results show that the priority is given to the alternative Balai Sepuak Bridge, located in Balai Sepuak District, with a weight of 0.423. The second priority is the alternative Riam Engkayak Bridge located in Nanga Mahap District, with a weight of 0.416. The third priority is the alternative to the Ayak River Bridge, located in Belitang Hilir District, with a weight of 0.161.
Keywords: *priority determination, ahp, bridge maintenance, regency bridge*

Abstrak
Jembatan merupakan struktur infrastruktur yang dirancang untuk menghubungkan dua titik yang terpisah oleh rintangan alami maupun buatan. Pentingnya pemeliharaan jembatan untuk mengutamakan keselamatan dan kelancaran mobilsasi masyarakat serta dapat menekan biaya pembangunan dan memperpanjang umur infrastruktur jembatan. Permasalahannya saat ini pasca pandemi terjadi peningkatan mobilitas di beberapa ruang publik sehingga membutuhkan sarana dan prasarana yang memadai. Namun penambahan infrastruktur jembatan saat ini belum menjadi prioritas utama karena terdapat pengurangan jumlah anggaran. Penelitian ini bertujuan menggunakan metode Analytic Hierarchy Process (AHP) dalam mementukan prioritas pemeliharaan jembatan di Kabupaten Sekadau berdasarkan 4 (empat) kriteria dan 10 (sepuluh sub kriteria) terhadap 3 (tiga) alternatif jembatan rangka baja, dimana data primer yang diperoleh berdasarkan quisioner terhadap 3 (tiga) golongan responden. Hasil nalisis menunjukkan alternatif Jembatan Balai Sepuak yang terletak di Kecamatan Balai Sepuak dengan bobot 0,423 merupakan prioritas pertama. Alternatif Jembatan Riam Engkayak yang terletak di Kecamatan Nanga Mahap dengan bobot 0,416 merupakan prioritas kedua. Alternatif Jembatan Sungai Ayak yang terletak di Kecamatan Belitang Hilir dengan bobot 0,161 merupakan prioritas ketiga.
Kata Kunci: *penentuan prioritas, ahp, pemeliharaan jembatan, kabupaten sekadau*

1. Introduction

Bridges are important infrastructure structures that serve to connect two points separated by natural and artificial obstacles, providing safe and efficient transportation routes for vehicles, pedestrians, and goods (Billahi & Widiatmoko, 2022). A well-designed bridge can improve mobility efficiency and support people’s economic activities. Truss bridges, for example, use triangular truss elements that provide strength and efficiency for medium to long spans (Miranda et al., 2019). The quality and safety of bridges are highly dependent on the design, materials, and regular maintenance (Kurniasari & Amalia, 2022). The sustainability and maintenance of bridges are also essential, given the large Number of resources used in their construction, maintenance, and deconstruction life cycle (Balogun et al., 2019).

However, in Sekadau Regency, bridge infrastructure still faces significant challenges related to maintenance and development. The hilly and swampy topography of Sekadau Regency, as well as the river flow pattern that can cause significant flooding potential (Anonymous, 2009), can interfere with access and quality of transportation infrastructure, including bridges (Pratiwi & Adma, 2021). Corrosive environments can also accelerate damage to bridge structures (Kurniasari & Amalia, 2022), which requires special

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attention in their care and maintenance. Research shows that climate change and the increasing frequency of extreme weather phenomena are exacerbating threats to the existence of bridges and other infrastructure (Adi, 2013; Sa'dianoor et al., 2023). In addition, the limited government budget is the primary obstacle to improving and enhancing the existing bridge infrastructure.

Given budget constraints and existing environmental challenges, it is critical to develop a decision-making model that can help prioritize effective and efficient bridge maintenance. One approach that can be employed is the Analytic Hierarchy Process (AHP) method, which enables decision-making based on multiple criteria and sub-criteria, as well as stakeholder participation. Using AHP, the analysis can consider factors such as the physical condition of the bridge, traffic volume, and potential damage due to a corrosive environment (Nurani et al., 2017; Shen et al., 2023). An effective maintenance strategy must also consider long-term reliability and maintenance costs (Abdelkader et al., 2023). Additionally, the development of an integrated data management system will facilitate continuous monitoring of bridge conditions, enabling faster and more accurate data-driven responses (Xiang et al., 2024).

The purpose of this study is to apply the AHP method in determining the priority of bridge maintenance in Sekadau Regency, taking into account various relevant factors and criteria. This model is expected to assist the Sekadau Regency Government in formulating more efficient policies in bridge maintenance, while optimizing limited budget allocation. Considering socio-economic factors and the lifecycle costs of bridges, this study seeks to establish a foundation for informed decision-making in the maintenance of transportation infrastructure, ultimately supporting economic growth and regional development (Alshibani et al., 2023; Hoang et al., 2020).

2. Materials and Methods

This research is focused on the maintenance of steel frame bridges using the AHP method. The AHP method, developed by Thomas L. Saaty in 1980, is a valuable tool in strategic decision-making that involves multiple factors and stakeholders. This method allows for more structured decision-making by breaking down complex problems into simpler hierarchies. Within the hierarchy, criteria and subcriteria are constructed, and alternatives are evaluated based on the predetermined weights for each criterion (BAYRAM & ÜÇÜNCÜ, 2016; Çelik, 2019). Through this approach, AHP not only facilitates better decision-making but also increases transparency and accountability, as each decision is based on a clear comparison between the available alternatives (Canhasi-Kasemi & Vardari, 2023; Stofkova et al., 2022). The length of bridges on district roads with good and moderate conditions is 4,068.46 m out of 5,553.61 m of bridges recorded, which is 73.26%. The Number of bridges on district roads with good and moderate conditions is 244 out of 375 bridges recorded, representing 65.07% (Anonymous, 2023). The data on the condition of the bridge is based on the recapitulation of the district bridge condition report. Steel frame bridges on district roads in Sekadau Regency are presented in **Table 1**.

Table 1. Names and Dimensions of Steel Truss Bridges in Sekadau Regency

No.	Bridge Name	Road Section No.	Dimension		
			Bridge Length (m)	Lane Width (m)	Bridge Span
	Sumpit - Tapang Pulau Street				
1	Sungai Ayak Bridge	30	40,50	5,00	1
	Riam Engkayak Street				
2	Riam Engkayak Bridge	304	43,00	4,00	1
	Merdeka Street				
3	Balai Sepuak Bridge	325	86,00	5,00	3

Source: Anonymous, 2023

In the context of the AHP method, two types of data are required to support decision-making: primary data and secondary data. Primary data is usually obtained through questionnaires aimed at collecting perceptions, preferences, and assessments from respondents about relevant criteria in the decision-making process (Sonia, 2021; Supriatin & Yana, 2022). Primary data was obtained by asking questions in the form of questionnaires to 3 (three) groups of respondents, namely executives, legislators, and bridge practitioners. The Sekadau Regency Bappedalitbang and the Sekadau Regency Public Works and Spatial Planning Office represented the executive. Members of the Sekadau Regency DPRD

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represented the Legislature. Universities represented bridge practitioners. This secondary data can take the form of historical data, case studies, literature, or publication information that helps establish criteria and weights in AHP (Aminah, 2020; Mahendra & Ernanda Aryanto, 2019). Secondary data is collected from various agencies related to the maintenance of the bridge. Public Works and Spatial Planning Office related to bridge condition data, population data from the Population and Civil Registration Office, and other economic data from the Sekadau Regency BPS.

The main principles in the AHP method are:

a. Decomposition is solving or dividing a whole problem into elements or criteria or sub-criteria in the form of a hierarchy of decision-making processes, where each element or criterion/sub-criterion is interrelated (Saaty, 1980). The hierarchy chart is presented in **Figure 1**.

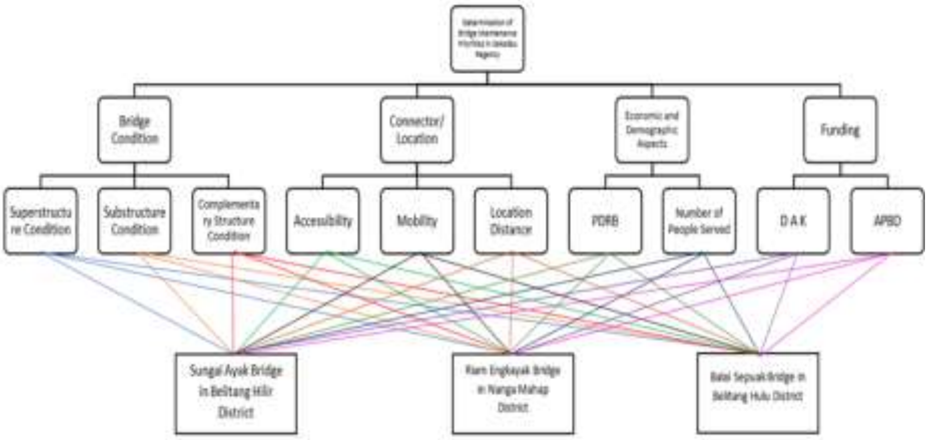

Fig. 1: The Hierarchical Structure of Bridge Maintenance Priorities

b. Comparative judgment is an assessment or comparison between elements, specifically a comparison between criteria and sub-criteria, as well as a comparison between choices for each criterion and sub-criterion (Saaty, 1994). A comparative questionnaire on the priority criteria for bridge maintenance is presented in **Table 2**.

Table 2. Bridge Maintenance Priority Questionnaire

Criteria	Difference of Interests																	Criteria
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Bridge Condition	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Connector
Bridge Condition	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Economic and Demographic Aspects
Bridge Condition	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Funding
Connector	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Economic and Demographic Aspects
Connector	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Funding
Economic and Demographic Aspects	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Funding

c. Synthesizing priorities, this principle considers each derivative of the local priority-priority ratio scale at different levels of a hierarchy and compiles a global composition of the set of priorities for the elements in the lowest hierarchy (Saaty & Vargas, 2012).

d. At this stage, logical consistency is tested to verify the level of consistency of the eigenvector value obtained by synthesizing the priority process previously conducted, with the final result in the form of a weight value to determine the priority scale (Saaty, 2008).

3. Results and Discussion

Sekadau Regency is geographically located between 0º 36’53” North Latitude and 0º 35’ 0” South Latitude and between 110º 45’43” East Longitude and 111º 11’ 0” East Longitude. Sekadau Regency is bordered to the north by Sintang Regency, to the south by Ketapang Regency, to the east by Sintang Regency, and the west by Sanggau Regency.

Paired Comparison Matrix

The paired comparison matrix is a crucial tool for collecting and mapping the value of respondents' perceptions regarding various alternatives for maintaining steel frame bridges, particularly in Sekadau Regency. The approach used to compile the value of this matrix involves collecting the opinions of several respondents and calculating the average of the geometry. The geometric averaging method is designed to yield results that not only represent individual opinions but also summarize a more holistic consensus, making its relevance in infrastructure maintenance research critical (Apriani et al., 2018). The paired comparison matrix serves not only as a data collection tool but also as an integral method in informed decision-making for the steel frame bridge maintenance sector.

Table 3. Paired Comparison Matrix Between Each Criterion

Criterion	Bridge Condition	Connector	Economic and Population Aspects	Funding
Bridge Condition	1,00	2,82	2,41	2,32
Connector	0,36	1,00	1,35	0,66
Economic and Population Aspects	0,41	0,71	1,00	0,59
Funding	0,43	1,47	1,70	1,00

Table 3 presents the results of a paired comparison between four main criteria used in assessing the priority of bridge construction or rehabilitation, namely: bridge condition, connection, economic and population aspects, and Funding. This matrix is part of the decision-making process using the AHP method, which emphasizes a structured and logical subjective assessment of the relative importance of each criterion. Each Number in the table shows how much a criterion is more important than the other. A value of 1.00 on the main diagonal reflects a comparison to oneself, which is of neutral value.

The Bridge Condition Criteria received the highest relative weight compared to other criteria, which were 2.82 times more important than Connectors, 2.41 times more important than Economic and Population Aspects, and 2.32 times more important than Funding. This indicates that the physical condition of the bridge is considered the most crucial factor in prioritization, as it is directly related to the safety, technical feasibility, and continuity of the bridge's function. The connecting criteria reflect the strategic role of the bridge as a connecting access between regions. However, according to the comparison results, this criterion has a relatively lower priority than the Bridge Condition, with a ratio of only 0.36. Other values indicate that they are more important than Economic and Population Aspects (1.35 times) but less important than Funding (0.66 times). Although important, the liaison function is not considered more urgent than technical and Funding factors.

The Economic and Population Aspect Criteria include the influence of the bridge on the local economy and the Number of people served, which are lower than the other three criteria (all < values of 1), for example, 0.41 for Bridge Condition, 0.71 for Connectors, and 0.59 for Funding. Although economic and social aspects are important in the long run, the appraiser considers that technical conditions and functional aspects take precedence. The Funding Criteria is positioned in the middle of the scale of importance, ranking lower than the Bridge Condition (0.43) but higher than the Economic and Population Aspect (1.70). Moreover, it is considered 1.47 times more important than the Link. These indicate that the availability and funding scheme are considered important in policy implementation, but remain below technical urgency (bridge conditions). The condition of the bridge is the criterion with the highest priority, followed by Funding, Connections, and then economic and Population Aspects. This sequence illustrates that decision-making emphasizes technical aspects and physical feasibility, and then considers other supporting factors, such as the role of bridges as a link and socio-economic impact.

Table 4. Average Value of Alternative Paired Comparison Matrix Columns – Sub-Criteria for Building Condition on Bridge

Alternative – Condition of the Building on the Bridge	Riam Engkayak Bridge	Sungai Ayak Bridge	Balai Sepuak Bridge
Riam Engkayak Bridge	1,00	2,56	1,51
Sungai Ayak Bridge	0,39	1,00	0,53
Balai Sepuak Bridge	0,66	1,88	1,00

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Table 4 presents a comparison of the condition of the top buildings of the three bridges using the paired comparison method (AHP), where the Riam Engkayak Bridge shows the best condition because it is superior to the other two bridges, which are 2.56 times better than the Sungai Ayak Bridge and 1.51 times better than the Balai Sepuak Bridge. The Balai Sepuak Bridge is situated in the middle position, with conditions that are still below those of Riam Engkayak but 1.88 times better than those of the Sungai Ayak Bridge. The Sungai Ayak Bridge occupies the lowest position because it has the worst condition of the upper building compared to the other two bridges.

Consistency Ratio

The value of the consistency ratio for the paired comparison matrix of alternatives based on sub-criteria is presented in **Table 5**.

Table 5. The Consistency Ratio (CR) Value of the Pairwise Comparison Matrix of Alternatives Based on Sub-Criteria

Alternative	CR Value	Remarks
Superstructure Condition	0.0010	CR <0.1 (OK)
Substructure Condition	0.0017	CR <0.1 (OK)
Complementary Structure Condition	0.0013	CR <0.1 (OK)
Accessibility	0.0115	CR <0.1 (OK)
Mobility	0.0159	CR <0.1 (OK)
Distance Rental	0.0137	CR <0.1 (OK)
GDP	0.0013	CR <0.1 (OK)
Number of People Served	0.0090	CR <0.1 (OK)
DAK	0.0435	CR <0.1 (OK)
APBD	0.0000	CR <0.1 (OK)

Table 5 presents the consistency ratio (CR) values for each alternative based on the sub-criteria used in the decision-making process using the AHP method. This CR value is a crucial indicator for evaluating the level of logical consistency in the paired assessment between alternatives. Based on the AHP rules developed by Saaty, the acceptable CR value is below the threshold of 0.1 (or 10%). If the CR value exceeds this Number, then the assessment is considered inconsistent and needs to be reevaluated. According to the calculation results listed in the table, all sub-criteria exhibit a CR value that is well below the threshold of 0.1. These indicate that the paired comparison process carried out on each alternative is logically consistent and methodologically acceptable.

The lowest CR value was found in the APBD sub-criterion with a value of 0.0000, indicating perfect consistency in the alternative assessment based on this criterion. The sub-criteria of Building Condition Above Bridge, Underbridge, and Complementary Buildings have minimal CR values, namely 0.0010, 0.0017, and 0.0013, indicating a high level of reliability in the technical assessment of the bridge's physical structure. Non-physical sub-criteria, such as Accessibility, Mobility, and Location Distance, also have CR values within the safe range: 0.0115, 0.0159, and 0.0137, respectively. Although the score is slightly higher than the other sub-criteria, it still shows good consistency. Economic sub-criteria such as PDRB, Number of Population Served, and DAK also showed consistent CR results, with values of 0.0013, 0.0090, and 0.0435. The CR value for DAK was recorded as the highest among the others, at 0.0435, but it was still within the tolerance limit of consistency.

Overall, it can be concluded that the assessment process of alternatives in each sub-criterion has been carried out carefully and consistently. This ensures that the final results obtained from the AHP process provide a strong basis for further decision-making, such as determining the priority for developing or repairing bridge infrastructure.

Value Weight

The alternative global weight value for determining bridge maintenance in Sekadau Regency is presented in **Table 6**.

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Table 6. Global Weight Value of Alternatives

Criteria		Sub Criteria		Alternative		
				Riam Engkayak Bridge	**Sungai Ayak Bridge**	**Balai Sepuak Bridge**
Bridge Condition	0.452	Superstructure Condition	0.126	0.061	0.023	0.042
		Substructure Condition	0.291	0.162	0.047	0.083
		Complementary Structure Condition	0.035	0.02	0.006	0.01
Total Weight Value of Bridge Condition				0.242	0.075	0.135
Connector/Location	0.175	Accessibility	0.074	0.025	0.013	0.036
		Mobility	0.077	0.025	0.014	0.038
		Location Distance	0.018	0.006	0.004	0.008
Total Weight Value of Connector/Location				0.056	0.031	0.082
Economic and Demographic Aspects	0.147	PDRB	0.112	0.034	0.017	0.061
		Number of People Served	0.035	0.016	0.005	0.015
Total Weight Value of Economic and Demographic Aspects				0.049	0.022	0.076
Funding	0.226	DAK	0.155	0.046	0.022	0.087
		APBD	0.076	0.022	0.011	0.043
Total Weight Value of Funding				0.068	0.032	0.13
Global Weight Value of Alternatives				0.416	0.161	0.423

Priority Ranking

Ranking criteria, sub-criteria, and alternative rankings are presented in **Tables 7, 8, 9, 10, 11** and **12**.

Table 7. Priority Ranking of Criteria

Criteria	Weight Value	Priority Ranking
Bridge Condition	0.453	1
Connector	0.170	3
Economic and Demographic Aspects	0.147	4
Funding	0.230	2

Based on the results of the assessment in **Table 7**, the Bridge Condition criterion has the highest weight of 0.453 and ranks first, indicating that this factor is considered the most important in determining the priority of handling or selecting bridges. The Funding Criteria is in second place with a weight of 0.230, indicating that the availability and efficiency of funds are also the main concerns in the decision-making process. Meanwhile, Connector got a weight of 0.170 in third place, indicating its role as a supporting factor in regional connectivity. Finally, the criteria of Economic and Population Aspects ranked fourth with a weight of 0.147, indicating that although relevant, this aspect was considered the least urgent compared to other criteria.

Table 8. The Priority Ranking of Sub-Criteria for the Bridge Condition Criterion

Sub Criteria	Weight Value	Priority Ranking
Superstructure Condition	0.279	2
Substructure Condition	0.643	1
Complementary Structure Condition	0.078	3

Based on **Table 8**, the sub-criterion of Bridge Bottom Condition has the highest weight of 0.643 and ranks first, indicating that this aspect is considered the most important in assessing the overall condition of the bridge and followed by the Condition of the Upper Bridge with a weight of 0.279 in second place, which although significant, is considered less crucial than the bottom. Meanwhile, the Condition of the Bridge Complementary Building is in third place with the lowest weight of 0.078, indicating that this element has the least influence in determining the priority of bridge conditions.

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Table 9. Priority Ranking of Sub-Criteria of the Connector Aspect Criteria

Sub Criteria	Weight Value	Priority Ranking
Accessibility	0.439	2
Mobility	0.456	1
Distance Rental	0.106	3

Based on **Table 9**, the Mobility sub-criterion has the highest weight of 0.456 and ranks first, which shows that the smooth movement of people and goods is the most important aspect in the assessment. Accessibility is second, with a weight of 0.439, reflecting the importance of ease of reaching the bridge location, even if it requires slightly reduced mobility. Meanwhile, Location Distance is third with the lowest weight of 0.106, indicating that the relative distance between locations is considered to have the least influence in decision-making related to the bridge connecting function.

Table 10. Priority Ranking of Sub-Criteria from the Economic and Demographic Aspect Criteria

Sub Criteria	Weight Value	Priority Ranking
PDRB	0.759	1
Number of People Served	0.241	2

Based on the table above, the PDRB sub-criterion has the highest weight of 0.759 and ranks first, indicating that the regional economic contribution is the primary factor in assessing both economic and population aspects. Meanwhile, the Number of people served is in second place with a weight of 0.241, indicating that although it is also important, its role is considered smaller than the economic impact represented by the GDP.

Table 11. Priority Ranking of Sub-Criteria of Funding Criteria

Sub Criteria	Weight Value	Priority Ranking
DAK	0.671	1
APBD	0.329	2

Based on **Table 11**, the DAK (Special Allocation Fund) sub-criterion has the highest weight of 0.671 and ranks first, indicating that Funding from the central government is considered the most important source in supporting the implementation of bridge projects. Meanwhile, the APBD (Regional Revenue and Expenditure Budget) ranks second with a weight of 0.329, indicating that although it continues to play a role, its contribution to Funding is considered less dominant than that of the DAK.

Table 12. Alternative Priorities

Criteria	Weight Value	Priority Ranking
Riam Engkayak Bridge	0.416	2
Sungai Siak Bridge	0.161	3
Balai Sepuak Bridge	0.423	1

Based on **Table 12** of the alternative priority order, the Balai Sepuak Bridge ranks first, with the highest weight of 0.423, indicating that this bridge is considered the highest priority alternative based on the overall criteria analyzed. The Riam Engkayak Bridge is in second place with a weight of 0.416, just a little below Balai Sepuak, indicating that the two have a relatively close value. Meanwhile, the Ayak River Bridge is in third place, with a weight of 0.161, indicating that it has the lowest level of urgency and feasibility compared to the other two alternatives.

4. Conclusion

This study demonstrates that decision-making related to bridge maintenance can be conducted systematically and based on various criteria using the Analytic Hierarchy Process (AHP) approach. In this study, four main criteria—namely the physical condition of the bridge, the connecting function, the socio-economic impact, and the source of Funding—were used to evaluate three alternatives to steel frame bridges in Sekadau Regency.

The results of the analysis revealed that the Balai Sepuak Bridge had the highest priority (weight of 0.423), followed by the Riam Engkayak Bridge (0.416), and the Ayak River Bridge (0.161). Although the Riam Engkayak Bridge has the best top-building condition, the overall weight composite shows that Balai

Sepuak is superior when all aspects are considered thoroughly. These findings demonstrate how a hierarchy-based approach can objectively and measurably capture the complexity of both technical and social realities.

The model used also suggests that the right decision in infrastructure management is not solely determined by one dominant aspect, but rather the result of a balance between technical reliability, public service functions, and resource allocation efficiency. Such an approach allows for policy formulation that is more responsive to the actual conditions and needs of the community.

Furthermore, these findings present opportunities for applying similar approaches to manage other infrastructure assets in various regions with distinct geographical conditions and budgetary challenges. By combining empirical data and multicriteria considerations, decision-making can be improved in a more strategic and sustainable direction. Therefore, the preparation of maintenance priorities is no longer just a technical effort, but part of regional development that is directed and long-term insightful.

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6. Abbreviations

D.C.	Regional House of Representatives
BPS	Central Bureau of Statistics
m	Meter
%	Percentage
GDP	Gross Regional Domestic Product
DAK	Special Allocation Fund
APBD	Regional Revenue and Expenditure Budget

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