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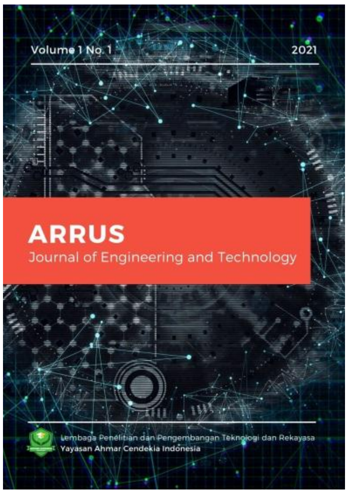

RESEARCH ARTICLE

Evaluation of the Condition and Prediction of the Remaining Life of the Old Kutai Bridge Using the Bridge Management System (BMS)

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Abstract: The Kutai Lama Bridge, which has been in operation for 15 years in Kutai Kartanegara Regency, East Kalimantan Province, is a critical infrastructure experiencing deterioration, with signs of damage in the expansion joints and corrosion on the steel structure. Evaluation using the Bridge Management System (BMS) indicates that the bridge is in severely damaged condition, with a Condition Index (NK) of 3. The remaining life of this bridge is 8.722 years. Based on these findings, this study recommends a rehabilitation program to ensure the bridge's operational sustainability, with an estimated budget of IDR 7,879,754,000.00.

Keywords: Bridge Inspection, Condition Rating, Bridge Management System (BMS)

1. Introduction

The Kutai Lama Bridge, which has been in operation for 15 years, is a vital infrastructure connecting Kutai Lama Village with the surrounding areas. Over time, this bridge is at risk of declining quality and performance due to environmental factors, traffic load, and lack of adequate maintenance. Identified damages, such as damage to the expansion joints and corrosion in the steel frame structure, indicate that the bridge requires serious attention to ensure user safety and smooth traffic flow.

In this context, a Bridge Management System (BMS) is an effective solution for managing bridges. A BMS allows stakeholders to holistically analyze the condition of the bridge and make informed decisions about maintenance or infrastructure development (Elvaria & Saputra, 2023). The bridge database should be able to visualize the current condition of a bridge as a reference for managers in determining the appropriate and optimal treatment according to their needs (Nurwijaya et al., 2023).

This study aims to determine the actual condition of the Kutai Lama Bridge based on the results of inspections using the Bridge Management System (BMS), obtain a prediction of the remaining life of the Kutai Lama Bridge based on the current Condition Value (CV), find a program to handle the damage identified on the Kutai Lama Bridge, and prepare a budget plan for the costs required for the damage handling program identified on the Kutai Lama Bridge.

Thus, this research can make a significant contribution to the effort to maintain the reliability and safety of bridge infrastructure, especially the Kutai Lama Bridge.

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2. Literature Review

2.1. Bridge Management System (BMS)

Bridge Management System (BMS) is a management system developed specifically to manage bridges. The main purpose of BMS is to organize agendas, carry out maintenance actions, and conduct regular monitoring of bridge conditions (PU, 1993).

2.2. Detailed Inspection

Detailed inspections are carried out to accurately assess the condition of the bridge. All components and elements of the bridge are inspected and major damage is identified and recorded (PUPR, 2022).

2.3. Special Examination

Special inspection is a more careful and detailed observation or test which is a follow-up to visual damage observations or when the inspector lacks the resources, training or experience to properly assess the condition of the bridge. Special inspections are carried out using special equipment to obtain more accurate data on the damage that occurs to bridge elements, especially structural elements according to their damage conditions (PUPR, 2022).

2.4. Dynamic Testing

Dynamic testing is carried out to determine the vibration characteristics of the bridge by giving it shocks. The aim is to obtain parameters such as natural frequency and mode shape structure, which are used to assess the stiffness of the bridge structure. Ideally, the frequency measured in the field should be close to the value obtained from the modeling results. The difference between these two values can be used to estimate the condition of the structure (Triyoso, 2024).

Based on 024 / BM / 2011, Determination of Residual Capacity Value of Bridge (Bina Marga, 2011) explains the rating of the Upper Bridge structure can be determined based on:

Difference in natural frequency when loaded (fl) and when empty (fu):

(1). If the difference is between 0.1 to 0.5 Hz: Good condition
(2). If the difference is between 0.6 to 1.0 Hz: Moderate condition
(3). If the difference is > 1.0 Hz: Bad condition

3. Research Method and Materials

3.1. Study Location

The location of this research is the Old Kutai Bridge, which is located in Anggana Village - Kutai Lama Village, Anggana District, Kutai Kartanegara Regency, East Kalimantan Province. Geographically, the Old Kutai Bridge is located between 117°17'39.4" East Longitude - 117°17'47.9" East Longitude and 0°33'22.0" South Latitude - 0°33'09.3" South Latitude. The location map and aerial photos of the Old Kutai Bridge can be seen in Figure 1 and Figure 2.

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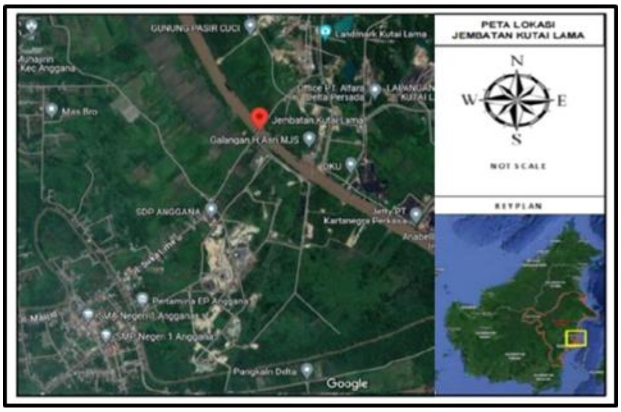

Figure 1. Map of the location of the old Kutai bridge

Figure 2. Aerial photo of the old Kutai bridge

3.2. Criteria Data Collection

This study uses two data collection techniques, namely primary data and secondary data. Primary data were collected directly through field surveys, which include visual inspection using the BMS Bridge Inspection Guide, physical measurements with measuring instruments to obtain structural data, and special inspections such as the Ultrasonic Pulse Velocity (UPV) Test to determine the condition of the concrete and the depth of cracks. Meanwhile, secondary data were obtained from existing sources, such as bridge structural information, bridge test data and inventory data from the Public Works Department of Kutai Kartanegara Regency. This secondary data plays a role in providing context and complementing the results of the field survey.

3.3. Data analysis

The collected data will be analyzed using the Bridge Management System (BMS) method. The purpose of this analysis is to determine the Condition Value (CC) of the bridge. After the damaged elements and the form of damage are recorded, a condition assessment is carried out. The assessment system for damaged elements consists of five questions related to the damage. Each question is scored 1 or 0, so as to minimize subjectivity during the inspection and allow for a more consistent assessment of the elements according to their level of damage. This assessment is applied at each level of the bridge hierarchy, starting from the lowest level, namely level 5, to the highest level, level 1, which covers the entire bridge, in this study to obtain a more accurate picture of the condition and capacity of the bridge, the results of the level 1 condition assessment are verified with the results of bridge structure testing using the dynamic test method. Each element or group of elements is given a Condition Value in the range of 0 to 5, where the number is the sum of the five scores that have been determined based on the criteria listed in Table 1.

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Table 1. Element Condition Rating System

Variable	Criteria	Condition Value
Structure (S)	Dangerous	1
	Not Dangerous	0
Damage (R)	Severe	1
	Not Severe	0
Quantity (K)	More than x %	1
	Less than x %	0
	X = 30% for structural elements and 50% for non-structural elements	
Function (F)	Element is not functioning	1
	Element is still functioning	0
Influence (P)	Affects other elements	1
	Does not affect other elements	0
Condition Value (CV)	CV = (S+R+K+F+P)	0 s/d 5

Bridge conditions are grouped into six categories based on Condition Value (CC) as explained in Table 2 below.

Table 2. Bridge Condition Value Description

Condition Value	Description
0	Good
1	Slightly Damaged
2	Moderetely Damaged
3	Severely Damaged
4	Critical
5	Collapsed

Subsequently, for the analysis of the remaining life prediction of the bridge, in the Bridge Preservation Handling Guidelines (Bina Marga, 2010), Equation (1) is used:"

$$NK = 5 - \left\{ \frac{\left(100 - \frac{Y}{N\%}\right)}{a} \right\}^{\left(\frac{1}{b}\right)} \quad (1)$$

where:

NK: Condition Value
Y: Equivalent Age of the Bridge
N: Planned Age
a: Coefficient (4.66)
b: Coefficient (1.9051)

The remaining life of the bridge is calculated based on the design age - equivalent age.

To create a damage management program, researchers refer to the damage repair guidelines contained in the Bridge Inspection Guidelines No. 01/P/BM/2022 and 2018 General Specifications for Road and Bridge Construction Work (Revision 2) (PUPR, 2020), cost calculations are carried out by referring to the 2023 Analysis of Work Unit Prices (AHSP) in the Highways Sector. The research steps are explained using the flow chart in Figure 3.

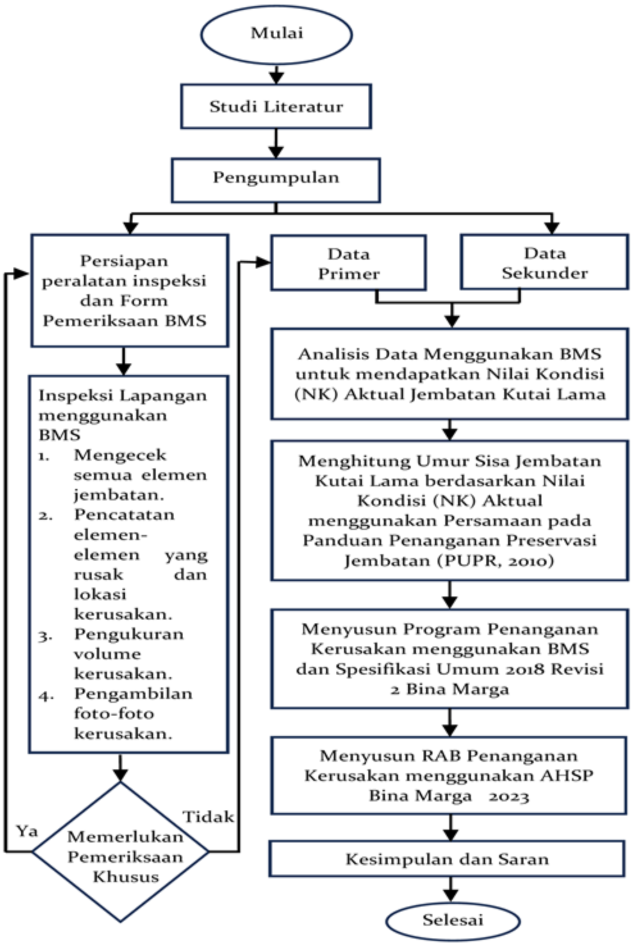

Figure 3. Research flow chart

4. Results and Discussion

4.1. Bridge Technical Data

Bridge Name	: Kutai Lama Bridge (officially named Aji Batara Agung Dewa Sakti Bridge)
Construction Year	: 2002 to 2009
Total Span Length	: 466 meters
Bridge Width	: 9 meters
Number of Spans	: 13 spans
Type of Superstructure	: Pile Slab, Composite Steel Girder, Cantilever Steel Frame
Initial Coordinates	: 0°33'22.0" S, 117°17'39.4" E
Final Coordinates	: 0°33'09.3" S, 17°17'47.9" E
Type of Crossing	: River

Longitudinal Section of the Kutai Lama Bridge is presented in Figure 4.

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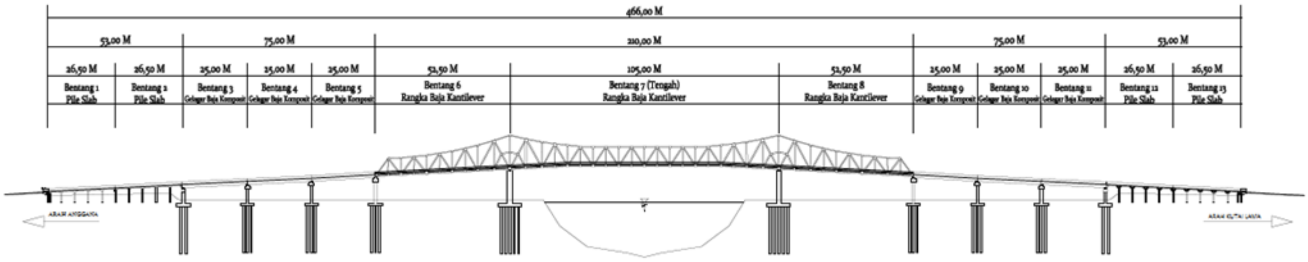

Figure 4. Longitudinal section of the Old Kutai Bridge

4.2. Special Inspection Results

Ultrasonic Pulse Velocity (UPV) testing was carried out to determine the depth of the cracks and the possibility of seepage occurring which affected the assessment of the condition of the elements and the handling program for the concrete of the bridge head beams and bridge floor slabs which were found to be cracked with the results presented in Table 3.

Table 3: UPV test results

Test Code	Time (µs)			Velocity (m/s)			Estimated Crack Depth (mm)		
	T1	T2	T3	V1	V2	V3	R1	R2	R3
Beam B1-Y3	48,5	68,0	52,0	3093	2206	2885	159,8	158,2	160,0
Average	51,16			2728			159,3		
Beam B13-Y2	49,0	51,0	49,0	3061	2941	3061	104,2	105,2	103,8
Avarage	49,66			3021			104,4		
Floor Slab B13-Y2	63,5	79,0	68,0	2362	1899	2206	115,2	116,4	115,8
Average	70,16			2155,66			115,8		

4.3. Results of Condition Assessment of the Old Kutai Bridge

Inspection Results, Condition Assessment (CA), Handling Recommendations, and Handling Costs for each Level 5 and Level 4 Element are presented in Table 4.

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Table 4. Condition Assessment level 5 and level 4

Bridge Element		Damage		Location	Damage Photo	Handing Recommendation	Damage Volume	Hamdling Fees (Rp)	NK
Code	Description	Code	Description						
4.323	Bridge Head Beam/Pillar	202	Cracks (concrete elements)	B1-Y3 B13-Y2	 	Epoxy resin injection with work items: 8.1.(1) Adhesive Liquid (Epoxy Resin), 8.1.(2) Covering Material (Sealent), 8.1.(3a) Injector Tube, preparation, 8.1.(3b) Injector Tube, use	3,15 M² / 8,12 M¹	4.107.380,68	2
4.511	Floor Structure	202	Cracks (concrete elements)	B13-Y5					3
4.412	Diaphragm	305	Damaged/missing components	B4 B10	 	8.8.(3) Replacement of Grade 345 Steel Structural Elements (Yield Strength 345 MPa)	176 Bh/ 4.178,42 Kg	249.945.849,94	3
4.453	Frame Structure	302	Rust	B6 B7 B8		8.7.(1b) Painting steel structures in dry areas 240 microns thick	10.937,77 M²	3.062.106.950,61	3
4.517	Floor Drainage	711	Blocked drain and drainage pipes	B1 s/d B13		10.2.(1) Bridge Maintenance	1,00 Ls	46.600.000,00	4

Priority for handling identified damage is based on the lowest condition value (NK) which can be seen in Figure 5.

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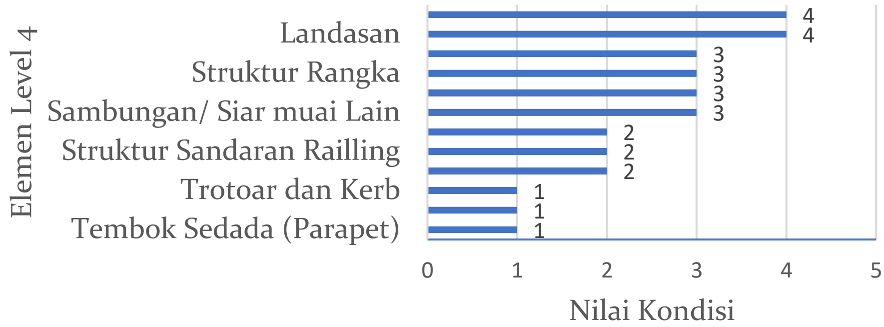

Figure 5. Order of Element Condition Values from lowest condition

The condition assessment of level 3 and level 2 as well as the percentage of damage to level 2 components can be seen in Table 5 and Figure 6.

Table 5. Level 3 and level 2 condition assessment

CODE	LEVEL 2 (COMPONENTS)	NK	CODE	LEVEL 3 (MAIN ELEMENTS)	NK
2.300	Lower Building	3	3.320	Head of Bridge/Pillar	2
2.400	Upper Building	3	3.410	Girder	3
			3.450	Steel Frame	3
			3.500	Floor System	2
			3.600	Connection/ Broadcast expansion	4
			3.610	Placement	5
			3.620	Road User Safety	1
2.700	Equipment	2	3.770	Permanent Inspection Facility	2

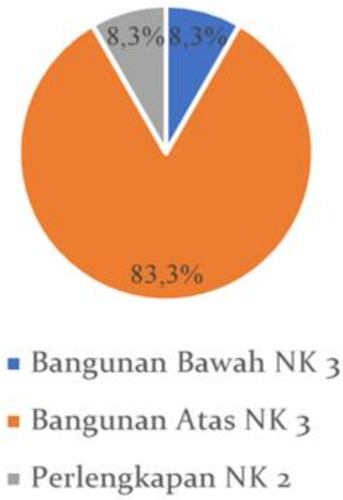

Figure 5. Percentage of Level 2 Damage

Based on the condition of the main span steel frame structural elements, the main span steel frame elements are rusty, the pot bearing elements are damaged, and the bridge steel girder diaphragm elements are missing. Level 1 condition assessment as in Table 6.

Table 6. Level 1 Condition Assessment

Element		Level 1 Condition Value					
Code	Description	S	R	K	F	P	NK
1. 00	Bridge	1	0	1	0	1	3

The Condition Value (NK) obtained from a detailed visual inspection provides an initial picture of the condition of the bridge. In this research, verification was carried out using the

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results of the Dynamic Load Test structure to validate actual conditions and identify potential performance degradation that was not detected visually. The relationship between these two results allows for a more comprehensive and accurate evaluation in determining appropriate maintenance or repair steps.

4.4. Dynamic Impulse Load Test of the Old Kutai Bridge

Vertical Mode (Impulse 1)

The location of the vertical mode impulse 1 accelerometer sensor installation is shown in Figure 6.

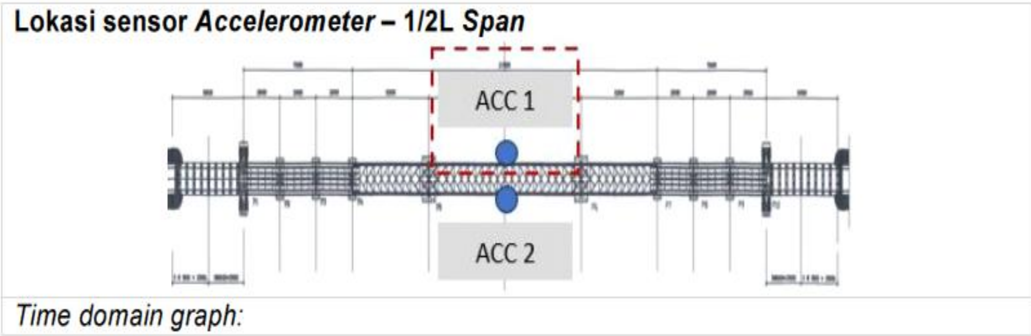

Figure 6. Installation location of impulse vertical mode sensor 1

The frequency of the vertical mode impulse 1 test results is shown in Figure 7.

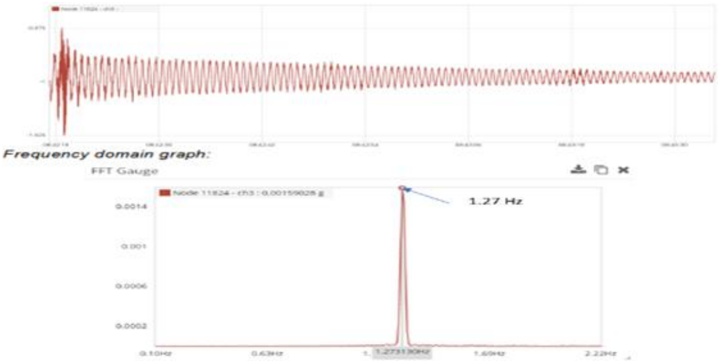

Figure 7. Impulse vertical mode frequency 1

The vertical mode dynamic test results, impulse 1 is 1.27 Hz, impulse 2 is 1.27 Hz, impulse 3 is 1.27 Hz, the results are consistent at a value of 1.27 Hz. The actual natural frequency is relatively higher compared to the empirical frequency, namely 0.95 Hz. This shows that the existing bridge structure is stiffer than the empirical theoretical limits. The natural frequency difference of 0.32 Hz shows that the bridge structural capacity is in good condition.

Remaining Age of the Old Kutai Bridge

Calculation of the Remaining Age of a Bridge with a condition value (NK) of 3 and a design age of 50 years, is calculated using Equation (2) to Equation (9) as follows:

$$NK = 5 - \left\{\frac{\left(100 - \frac{Y}{N\%}\right)}{a}\right\}^{\left(\frac{1}{b}\right)} \text{..............................} \quad (2)$$

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$$3 = 5 - \left\{\frac{\left(100 - \frac{Y}{50\%}\right)}{4,66}\right\}^{\left(\frac{1}{1,9501}\right)} \quad (3)$$

$$5 - 3 = \left\{\frac{\left(100 - \frac{Y}{50\%}\right)}{4,66}\right\}^{\left(\frac{1}{1,9501}\right)} \quad (4)$$

$$2 \ x \ 4,66^{0,525} = \left(100 - \frac{Y}{50\%}\right)^{0,525} \quad (5)$$

$$\sqrt[0,525]{4,486} = \left(100 - \frac{Y}{50\%}\right) \quad (6)$$

$$17,443 = \left(100 - \frac{Y}{50\%}\right) \quad (7)$$

$$100 - 17,443 = \frac{Y}{50\%} \quad (8)$$

Y = 41,278 Tahun .... (9)

Based on the calculations above, the current equivalent age of the bridge is estimated to be 41,278 years. The remaining life of a bridge with a condition value of 3 is 50 years – 41,278 years = 8,722 years.

A comparison of the age of the Kutai Lama Bridge can be seen in Figure 8.

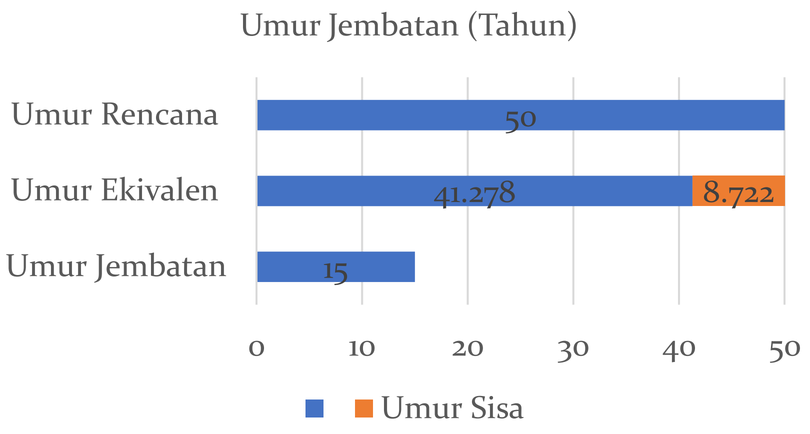

Figure 8. Comparison of the age of the old kutai bridge

5. Conclusion

(1). Based on the results of the inspection and analysis using the Bridge Management System (BMS), the Kutai Lama Bridge is in a severely damaged condition with a Condition Rating (CR) of 3. The largest percentage of damage is in the superstructure, which is 83.3%, which is a priority for rehabilitation.

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(2). The current equivalent age of the bridge is 41.278 years out of a planned 50 years. The remaining life of the bridge is 8.722 years, indicating the need for immediate repairs to extend its service life.

(3). The recommended treatment program includes: a. Epoxy Resin Injection: To repair cracks in concrete elements. b. Replacement of Steel Components: Including missing or damaged steel diaphragms. c. Repainting of Steel Structures: As protection against corrosion. d. Bridge Maintenance: Addressing clogged drainage issues. e. Replacement of Pot Bearings and Expansion Joints: To improve structural stability and user comfort.

(4). The total budget required to implement the Kutai Lama Bridge damage treatment program is Rp 7,879,754,000.00 (Seven billion eight hundred seventy-nine million seven hundred fifty-four thousand rupiah). This cost includes Division 1 General (Mobilization, Traffic Management and Safety, Occupational Safety and Health, Quality Management) of Rp 242,225,000.00, Division 8 Bridge Rehabilitation of Rp 6,810,052,687.58, Division 10 Bridge Maintenance of Rp 46,600,000.00, and Value Added Tax (VAT) of Rp 780,876,545.63.

References

Bina Marga. (2010). Panduan Penanganan Preservasi Jembatan.

Bina Marga. (2011). Pedoman Penentuan Nilai Sisa Kapasitas Jembatan (024/BM/2011).

Dinas Pekerjaan Umum Kabupaten Kutai Kartanegara. (2019). Gambar Rencana Peningkatan Jembatan Kutai Lama 2019.

Elvaria, A., & Saputra, R. H. (2023). Evaluasi Kondisi Jembatan Cipamokolan 1 Dengan Menggunakan Metode Bridge Management System (BMS). Jurnal Teslink : Teknik Sipil Dan Lingkungan, 5(2), 186–195. https://doi.org/10.52005/teslink.v5i2.297

Nurwijaya, R., Saputra Budiarso, D., Catur, N., Yuliati, E., Susanto, H., Kunci, K., Jembatan, I., & Bridge, ; (2023). Studi Inventarisasi Jembatan Menggunakan Metode Bridge Management System dan Bridge Condition Rating. Composite:JournalOfCivilEngineering, 02, 87–93.

PT. Sadhya Grahacara. (2023). Laporan Akhir Kajian Kondisi Jembatan Kutai Lama.

PU. (1993). Panduan Pemeriksaan Jembatan Bridge Management System (BMS) 1993. Direktorat Jenderal Bina Marga Departemen Pekerjaan Umum Republik Indonesia.

PUPR. (2020). Spesifikasi Umum 2018 untuk Pekerjaan Konstruksi Jalan dan Jembatan (Revisi 2). Kementerian Pekerjaan Umum dan Perumahan Rakyat Direktorat Jenderal Bina Marga.

PUPR. (2022). Pedoman Pemeriksaan Jembatan No. 01/P/BM/2022. Kementerian Pekerjaan Umum dan Perumahan Rakyat Direktorat Jenderal Bina Marga.

Sucofindo. (2024). Laporan Pengujian UPV Jembatan Kutai Lama.

Triyoso, dkk. (2024). Perbandingan Getaran Alami Struktur Jembatan Rangka Baja Belanda dengan Pengujian Ambien. Simposium Nasional Teknologi Infrastruktur.