CIVED Journal of Civil Engineering and Vocational Education

EISSN: 2622-6774
Vol. 12 No.1 March 2025
http://cived.ppj.unp.ac.id/index.php/CIVED

Bridge Condition Assessment (Case Study: Padang – Bukittinggi Route)

Amelia Masza[1*], Benny Hidayat[2], Taufika Ophiyandri[3]
[1,2,3] Civil Engineering, Faculty of Engineering, Universitas Andalas, Indonesia
*Corresponding author, e-mail: ameliamsz10@gmail.com

Received 22th January 2025; Revision 8th February 2025; Accepted 21th March 2025

ABSTRACT

Bridges are critical components of transportation infrastructure, ensuring smooth traffic flow and regional connectivity. However, their structural conditions are influenced by various factors, including traffic loads, material durability, and natural disasters such as earthquakes and floods. Despite existing bridge maintenance frameworks, a comprehensive condition assessment specifically tailored to the Padang-Bukittinggi route has not been thoroughly conducted. This study introduces a systematic evaluation using the Bridge Condition Rate (BCR) method to provide data-driven maintenance recommendations. A total of eight bridges along the Padang-Bukittinggi route were assessed through detailed and routine inspections, followed by cross-case analysis. The results indicate that 75% of the bridges (6 out of 8) require periodic maintenance (BCR=2), 12.5% (1 bridge) necessitates rehabilitation (BCR=3), and another 12.5% (1 bridge) demands immediate replacement (BCR=5) due to severe structural damage. These findings highlight the urgency of targeted maintenance strategies to enhance bridge longevity and operational safety. The study provides critical insights for policymakers and infrastructure authorities, emphasizing the need for proactive maintenance planning to ensure road network sustainability and public safety.

Keywords: *Bridge Condition Assessment; BCR Method; Infrastructure Strategy; Maintenance Strategy.*

DOI: https://doi.org/10.24036/cived.v12i1.713

INTRODUCTION

Bridges play a vital role in transportation networks by ensuring connectivity, smooth traffic flow, and economic growth[1]. However, many bridges, particularly in disaster-prone areas, are vulnerable to deterioration caused by aging, increasing traffic loads, and environmental factors such as earthquakes and floods[2]. In Indonesia, several bridges have suffered from structural failures due to inadequate maintenance and delayed inspections, leading to disruptions in transportation and potential safety hazards[3] . The Padang-Bukittinggi route, a crucial corridor in West Sumatra, has experienced similar issues, with reports indicating visible damage on multiple bridges along this route[4]. A systematic condition assessment is necessary to prevent further degradation and ensure infrastructure sustainability[5].

Figure 1. Damage to The Bridge that Connect Padang – Bukittinggi at KM 54 Kayu Tanam
Source: Detik.news

Previous studies have explored various bridge assessment methodologies, including visual inspections, structural health monitoring, and predictive maintenance strategies. However, research specifically addressing the application of the Bridge Condition Rate (BCR) method to evaluate bridges in Indonesia remains limited. Furthermore, most studies focus on individual bridges rather than conducting comparative analyses across multiple structures within a critical transportation corridor.

This study seeks to bridge this gap by applying a standardized assessment framework to multiple bridges along the Padang-Bukittinggi route, providing a more comprehensive evaluation of their condition and maintenance needs. The intercity bridge management systems (IBMS) is used to combined bridge information in the province and nationally in Indonesia [6], [7]This study aims to; (1) assess the structural condition of bridges along the Padang-Bukittinggi route using the BCR method; (2) identify bridges requiring periodic maintenance, rehabilitation, or replacement based on their condition ratings and; (3) provide actionable recommendations for policymakers to improve bridge maintenance planning and ensure long-term infrastructure reliability.

Inventory inspection is the collection of basic administrative data, material geometry and other additional data on each bridge, including the location of the bridge, the length and width, and the construction of each span and the characteristic of the river [8]. The widening data of the bridge is also included on the inventory inspection. All bridges, railway crossing, wet crossing, cruise crossing and culverts that have a length of 2 meters or more must be recorded in the inventory inspection check form.

Routine inspection aims to maintain the bridge in original condition[9], which is technically quite simple. Routine inspection is carried out every year to check whether the main components of the bridge structure are functioning properly and the bridge is in a safe, secure and comfortable condition. And whether bridge handling including the most important routine maintenance has been carried out properly or whether emergency action or repairs are needed to maintain the bridge[10].

Detailed inspection is carried out to determine the condition of the bridge and its components in order to prepare a handling strategy for each bridge and determine the priority order of bridge handling [11]. Detailed inspection is carried out a maximum once in five years or at shorter intervals depending on the bridge condition. Detailed inspection is also carried out after rehabilitation work (major repairs), bridge strengthening, construction of new bridges, in order to record new data into the Data Management System. Detailed inspection records data damage that existed on the bridge elements and sets the condition values or rate for each element, groups of elements, main elements and main component of the bridges.

Specific inspection generally recommended to be performed by a capable and competent bridge inspector using special or specific equipment when additional inspections are required to identify the severity and quantity of damage that has the potential to significantly alter the condition of the bridge for structure elements [12].

METHOD

This study employs a quantitative approach with an observational study design to assess the structural condition of bridges along the Padang-Bukittinggi route. The research process includes data collection, bridge condition evaluation, and maintenance recommendations using the Bridge Condition Rate (BCR) method. The assessment follows standardized guidelines from Indonesia's Ministry of Public Works and international best practices [13].

A purposive sampling method was applied to select eight bridges along the Padang-Bukittinggi route, each with a span of more than 9 meters. This selection was based on their strategic importance, history of reported damage, and traffic volume, ensuring that the study covers bridges with varying structural conditions. The inclusion of bridges from different locations along the route allows for a comparative cross-case analysis, providing a more comprehensive assessment of maintenance needs. To ensure data reliability and validity, bridge condition assessments were conducted by trained inspectors following standardized scoring criteria. The BCR method was applied to assess bridge conditions based on five key parameters:

Table 1. Condition Rate of Element

Parameter	Criteria	Rate
Structure (S)	Hazardous	1
	Non hazardous	0
Damage (R)	Severe damage	1
	Light damage	0
Development (K)	More than 50%	1
	Less than 50 %	0
Function (F)	Still work	1
	Does not work	0
Influence (P)	Influenced by other elements	1
	Not influenced by other elements	0
Condition Rate (CR)	CR = S + R + K+ F + P	5

Each parameter was assigned a score, and the final Bridge Condition Rate (BCR) was used to categorize maintenance needs as follows:

Table 2. Bridge Condition Rate (BCR) Interpretation

Condition Rate	Description	Recommendation Action
0	No damage	Routine maintenance
1	Light damage	Light periodic maintenance
2	Damage that requires monitoring or	Periodic maintenance

CIVED
Journal of Civil Engineering and Vocational Education

EISSN: 2622-6774
Vol. 12 No.1 March 2025
http://cived.ppj.unp.ac.id/index.php/CIVED

	maintenance in future	
3	Damage that requires a quick response	Rehabilitation and/or reinforcement
4	Critical condition	Reinforcement or replacement
5	Can not be used	Replacement

The results were analyzed using a cross-sectional comparison to identify patterns of bridge deterioration along the route. The comparison focused on differences in bridge conditions based on location, structural type, and exposure to environmental factors

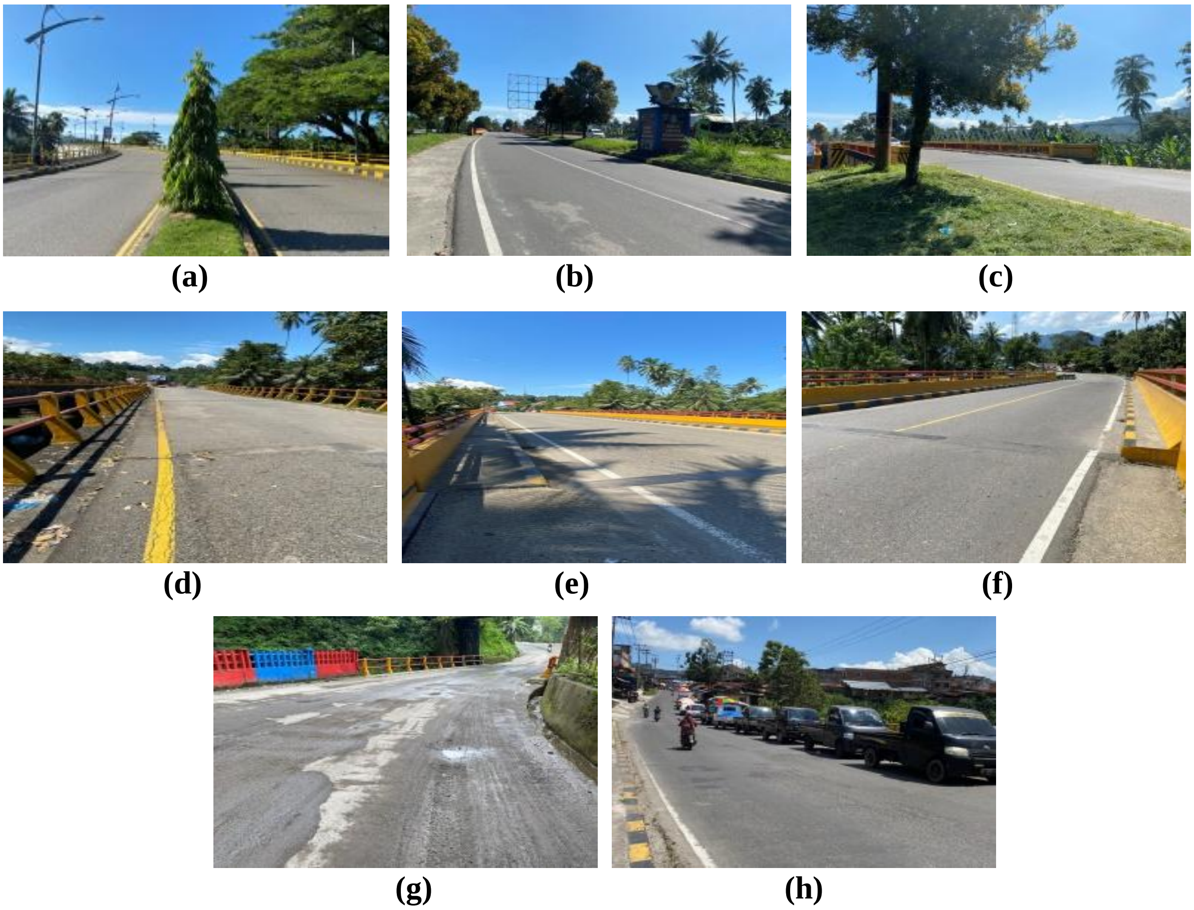

Figure 2. (a) Fly Over Duku Bridge; (b) Air Mancur Bridge; (c) Kiambang A Bridge; (d) Kiambang B Bridge; (e) Pasar Usang A Bridge; (f) Pasar Usang B Bridge; (e)Batang Kalu Bridge; (f) Tambuo Bridge.

RESULTS AND DISCUSSION

The observation was conducted through detailed inspection of 8 bridge that aimed to record all damaged to the bridges in detail.

Table 3. Results of Bridge Condition Rate

No	Bridge Name	Element			BCR	Recommendation Action
		LS	US	W		
1	Fly Over Duku	1	2	-	2	Periodic maintenance
2	Pasar Usang A	1	2	1	2	Periodic maintenance
3	Pasar Usang B	1	2	1	2	Periodic maintenance
4	Kiambang A	5	5	2	5	Replacement
5	Kiambang B	1	2	1	2	Periodic maintenance

No	Bridge Name	Element			BCR	Recommendation Action
		LS	US	W		
6	Batang Kalu	2	2	1	2	Periodic Maintenance
7	Air Mancur	-	3	2	3	Rehabilitation
8	Tambuo	-	2	2	2	Periodic maintenance

**LS: Lower structure*
US: Upper structure
W: Watershed

The Kiambang A had the highest deterioration level (BCR=5), requiring complete replacement due to severe structural failure. The Air Mancur Bridge (BCR=3) exhibited significant upper structure damage, necessitating rehabilitation. Meanwhile, six other bridges showed moderate wear and tear, requiring periodic maintenance interventions.

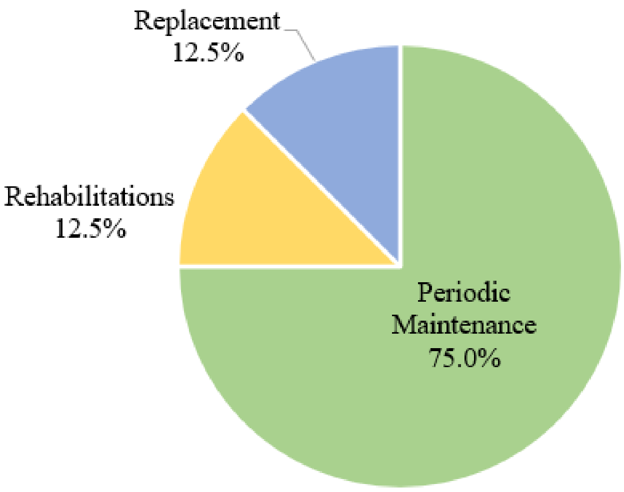

Figure 3. Percentage of Bridge Maintenance Types Based on BCR Score

The findings of this study align with previous research on bridge deterioration patterns in disaster-prone regions. Studies conducted by Zhang in 2022 found that natural disasters, material aging, and traffic load fluctuations are key contributors to structural degradation, which is consistent with the deterioration patterns observed in this study [14] [15]. However, unlike previous studies that focus on individual bridge assessments, this research provides a comparative analysis across multiple bridges within a critical transportation corridor. This broader perspective allows for better identification of maintenance priorities and resource allocation.

The assessment results confirm existing bridge maintenance theories, particularly those related to progressive structural degradation and the role of routine inspections in prolonging bridge lifespan [16]. The variation in BCR scores highlights the importance of preventive maintenance strategies to reduce long-term rehabilitation costs.

Additionally, findings support structural resilience models, which suggest that bridges with adequate periodic maintenance tend to experience slower deterioration rates [17]. The condition of the Kiambang A (BCR=5) further reinforces the principle that delayed maintenance leads to critical structural failures, resulting in costly full replacements.

Practically Implications for Bridge Management and Policy
The study's findings have significant implications for infrastructure maintenance policies:

1. **Prioritization of Maintenance Interventions**
   - Bridges with BCR=5 (Kiambang A Bridge) should be prioritized for immediate replacement to prevent structural failures and accidents.
   - Bridges with BCR=3 (Air Mancur Bridge) require urgent rehabilitation to restore functionality and extend their lifespan.
   - Bridges with BCR=2 should undergo scheduled periodic maintenance to prevent further deterioration.
2. **Implementation of a Data-Driven Inspection System**
   - Regular inspections using standardized BCR assessments can help authorities detect early-stage damage and plan maintenance schedules accordingly [18].
   - Integration of UAV photogrammetry and digital monitoring tools is recommended to enhance inspection accuracy and efficiency.
3. **Budget Allocation and Policy Development**
   - The results suggest that delayed maintenance leads to higher long-term costs, emphasizing the need for adequate government funding for routine and periodic maintenance programs[19].
   - A preventive maintenance policy framework should be developed to minimize emergency repairs and costly replacements.

CONCLUSION

This study assessed the structural condition of eight bridges along the Padang-Bukittinggi route using the Bridge Condition Rate (BCR) method. The findings indicate that:

- 75% of the bridges (6 out of 8) require periodic maintenance (BCR=2), signifying moderate structural wear.
- 12.5% of the bridges (1 bridge) require rehabilitation (BCR=3) due to significant upper structure deterioration.
- 12.5% of the bridges (1 bridge) require immediate replacement (BCR=5) as they have reached a critical failure state.

Among these, the Kiambang A Bridge (BCR=5) must be replaced, while the Air Mancur Bridge (BCR=3) requires urgent rehabilitation. The remaining bridges require preventive periodic maintenance to extend their lifespan and avoid future costly repairjs. These results highlight the urgent need for a structured and proactive maintenance strategy to enhance bridge sustainability, traffic safety, and infrastructure resilience in the region.

This study provides a comprehensive cross-sectional assessment. However, several limitations should be acknowledged. The study captures bridge conditions at a single point in time, without tracking deterioration trends over multiple years. Future studies should implement longitudinal monitoring to assess structural changes over time. Only eight bridges were analyzed, which may not fully represent all structural variations along the Padang-Bukittinggi route. Expanding the sample size to include more bridges across different geographical conditions could enhance the findings. This study relies on visual inspections and BCR assessments. Future research should integrate load capacity tests and material durability analysis to strengthen the evaluation.

REFERENCE

[1] S. A. Mitoulis, G. P. Cimellaro, M. Domaneschi, and J. R. Casas, "Bridge and transport network resilience – a perspective," *Proceedings of the Institution of Civil Engineers: Bridge Engineering*, vol. 175, no. 3, pp. 138–149, Sep. 2021, doi: 10.1680/jbren.21.00055.

[2] S. A. Argyroudis and S. A. Mitoulis, "Vulnerability of bridges to individual and multiple hazards- floods and earthquakes," *Reliab Eng Syst Saf*, vol. 210, pp. 1–18, Jun. 2021, doi: 10.1016/j.ress.2021.107564.

[3] W. Harywijaya, M. Afifuddin, and M. Isya, "Penilaian Kondisi Jembatan Menggunakan Bridge Management System (BMS) dan Bridge Condition Rating (BCR)," *Jurnal Arsip Rekayasa Sipil dan Perencanaan*, vol. 3, no. 1, pp. 443–451, 2020, doi: 10.24815/jarsp.v2i2.16462.

[4] M. S. Nasution, "Jembatan rusak timbulkan kemacetan panjang di jalur Padang-Bukittinggi," Antara News.

[5] A. Agredo Chávez, J. Gonzalez-Libreros, C. Wang, and G. Sas, "Bridge condition index: A review of methodologies used in Bridge Management Systems," in *Bridge Maintenance, Safety, Management, Digitalization and Sustainability - Proceedings of the 12th International Conference on Bridge Maintenance, Safety and Management, IABMAS 2024*, Sweden: CRC Press/Balkema, 2024, pp. 1130–1137. doi: 10.1201/9781003483755-131.

[6] T. S. Lee, D. W. Lee, Y. H. Kim, and J. H. Kim, "Enhancement of Bridge Management System (BMS) with Mobile Communication Technology," in *First International Conference on Semantics, Knowledge, and Grid*, Semantic Scholar, 2006. doi: DOI:10.1109/SKG.2005.70.

[7] Sabdin, R. Karlinasari, and Antonius, "Penilaian Jembatan Menggunakan Bridge Management System (BMS) Berbasis Android," *Rang Teknik Journal*, vol. 7, no. 1, pp. 139–146, Jan. 2024, doi: http://dx.doi.org/10.31869/rtj.v7i1.4200.

[8] U.S Department of Transportation, *Spesifications for The National Bridge Inventory*. United State: Federal Highway Administration, 2022.

[9] B. Hidayat and I. Kamil, "Penilaian Kondisi Jembatan di Kabupaten Sijunjung," *Jurnal Bangunan: Konstruksi dan Desain*, vol. 1, no. 2, pp. 99–108, 2023, doi: E-ISSN: 3021-7547.

[10] T. Arshad, R. A. Karim, and A. D. Rarasati, "Factors Influencing Bridge Inspections in Developing Countries, Challenges and Future Directions: A Systematic Literature Review," *SmartCity: Sustainability in Smart Urbanism*, vol. 4, no. 1, pp. 1–22, 2024, doi: 10.56940/sc.v4.i1.12.

[11] US DOT, *Fundamentals of the Bridge Inspection Process*. United States: Bridge Inspector's Reference Manual: Section 3, Fundamentals of Bridge Inspection, 2006.

[12] Kementerian PUPR, *Prosedur Pemeriksaan Jembatan - Modul 3*. Bandung: Kementerian PUPR dan BPSDM, 2022.

[13] Ditjen Bina Marga, *Pedoman Pemeriksaan Jembatan No. 005-01/P/BM/2011*. Jakarta, 2011.

[14] G. Zhang, Y. Liu, J. Liu, S. Lan, and J. Yang, "Causes and statistical characteristics of bridge failures: A review," Jun. 01, 2022, *Chang'an University*. doi: 10.1016/j.jtte.2021.12.003.

[15] A. Ö. Çiftçioğlu and M. Z. Naser, "Identifying and estimating causal effects of bridge failures from observational data," *Journal of Infrastructure Intelligence and Resilience*,

vol. 3, no. 1, Mar. 2024, doi: 10.1016/j.iintel.2023.100068.

[16] G. Xu and F. Azhari, “Data-driven optimization of repair schemes and inspection intervals for highway bridges,” *Reliab Eng Syst Saf*, vol. 228, Dec. 2022.

[17] J. Peng, Y. Yang, H. Biang, J. Zhang, and L. Wang, “Optimisation of maintenance strategy of deteriorating bridges considering sustainability criteria,” *Structure and Infrastructure Engineering*, vol. 18, no. 3, pp. 395–411, 2020.

[18] J. R. Casas, D. M. Frangopol, J. Turmo, and Y. Tsompanakis, “Bridge safety assessment, maintenance, monitoring, and life-cycle performance,” *Structure and Infrastructure Engineering*, vol. 20, no. 7–8, pp. 957–959, 2024.

[19] Y. Wang, Y. Wang, J. Ni, and H. Zhang, “Reliability-Centric Maintenance Planning for Bridge Infrastructure: A Novel Method Based on Improved Electric Fish Optimization,” *Buildings*, vol. 14, no. 11, Nov. 2024, doi: 10.3390/buildings14113583.