Assessment of Del Carmen Paguiruan Bridge Through DPWH Bridge Inspection Methods Type 1, 2, And 5: Implications for Public Safety and Infrastructure Maintenance: A Review

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Abstract: - This study aimed to assess the condition of a 22-year-old steel bridge through bridge inspection procedures from the DPWH manual. The purpose was to identify any damage or deterioration that may pose a safety hazard and prevent further enlargement of defects affecting its condition. The results showed that the bridge's overall condition rating is bad, with a remaining lifespan of 0–10 years. Based on the analysis, the researcher recommends comparing the cost of repairing all the defects with the cost of a new bridge design, using equipment that can detect defects not visible to the naked eye, and accomplishing all BMS types to attain a complete quality condition result. This study provides useful data for the Department of Public Ways and Highways (DPWH), Provincial Engineering Office (PEO), and civil engineers for future projects and can serve as a reference for future researchers studying bridge inspection.

Key Words: — *Del Carmen-Paguiruan Bridge, Condition Inspection, Safety, Bridge Inspection Manual.*

I. Introduction

A bridge is a horizontal structure that connects two gaps. It carries a road or railway above a river, canal, or another railway or road. So, linking infrastructure like bridges is necessary. The infrastructure of transportation plays a key role in determining each nation's prosperity and security. Its successful interaction with all economic sectors, raising population welfare, and ensuring the state's ability to defend itself depend on its continuous, reliable, and effective operation (Yavuz et al., 2017).

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However, the lack of infrastructure in many of these countries often leaves communities disconnected from the services they need. Consequently, bridge crossings could help bridge the gap, connecting these rural and underserved communities with the resources they depend on (Matthews, K., 2017).

With economic growth and an increase in the number of road and rail infrastructures, bridges are increasing dramatically. The country's transportation, trade, and economy have all improved along with the quality of life for its citizens as a result of considerable advancements in bridge design and building techniques (Kaewunruen et al., 2020). An essential component of a country's infrastructure is its bridges. This infrastructure is unfortunately prone to numerous dangers as a consequence of global climate change.

A damaged bridge decreases the load capacity and may result in a sudden collapse. Any structural problems that remain unrepaired for a very long time can pose major risks to the civilians using that particular infrastructure (Abdallah et al., 2022). Bridge collapses have the potential to cause injuries, fatalities, and property damage on an equal level to those caused by airplane crashes, terrorist acts, and natural disasters. Because of this, everyone involved in the construction of a bridge (engineers, managers, and construction workers) takes their tasks very seriously (Bridge Masters, 2017). In addition to that, the effect of the bridge collapse and destruction far outweighs the total material and monetary costs associated with the bridge construction because it also includes a variety of direct and indirect costs, such as the loss of human lives, user delays, planning for alternate routes, and greenhouse gas emissions related to detours and traffic delays (Ahmed et al., 2020).

In order to ensure proper safety and continue its service life, it is necessary to have a monthly or annual inspection. Bridge inspections allow engineers to identify small defects and potential problem areas in bridges before they develop into major issues (Abdallah et al., 2022). Bridge inspections are clearly linked to maintenance plans and can assist in managing maintenance. If a bridge problem is not identified in a responsible way, it may eventually result in a devastating incident, such as a breakdown or total collapse of the bridge, which might cause significant damage or even death. And for this reason, worldwide, laws frequently require bridge inspections (Bridge Inspections: A Complete Guide, 2022).

Developed nations are confronted with aging infrastructure and difficulty managing it. As a result, bridge management, a crucial aspect of infrastructure management, is getting more and more attention. The BMS, or bridge management systems, are instruments for managing bridges. adopted by transportation officials in numerous nations to construct bridges in the area with enough serviceability and safety in the most economical manner possible. Throughout the phases of design, building, operation, and maintenance, a BMS is integrated with every aspect of bridges (Jeong et al., 2018).

According to the DPWH Office of the Secretary under D.O. No. 43 S.2008 P 2/3, for the guidance of all concerned and to be consistent with bridge inspection procedures and to ensure that consistent inspection reports are delivered from all bridges, all BMS Accredited Bridge Inspectors and Regional Road and Bridge Information Application (RBIA) Coordinators are directed to adopt the revised BMS Manual and Guidelines (Version 6.0) in the Conduct of Bridge Condition Inspections and data encoding. To simplify the procedures, the bridge inspection types were reduced from seven (7) to five (5) types.

There are 8,131 permanent bridges in the sixteen regions of the Philippines, according to statistics provided by the Department of Public Works and Highways (DPWH) as of December 2015. These bridges provide links between barangays, cities, and regions, allowing for the transportation of goods and people, and they should remain operational, particularly during times of crisis in the area. In one of the original evaluations of bridge status, as the bridge is the key component for mobility, it must be routinely inspected and evaluated for dependability. As time went by, aging bridges became a critical problem and hugely affected our country's economy. A large portion of the existing infrastructure assets have been deteriorating due to their age, the intensity of environmental conditions, a greater amount of traffic, and a lack of space (Alejandrino et al., 2020).

One of the bridge inspection types is condition inspection (type 2). This level of inspection's aim is to monitor and analyze a bridge's condition as a foundation for determining current maintenance requirements and predicting whether future bridge intervention is necessary. Based on observed material defects and how they affect a component's capacity to carry out its role in the structural system, each structural component is given a condition rating, which is a numerical scale with numbers ranging from zero to three (Yusuf, K., & Hamid, R. 2018).

The Del Carmen-Paguiruan Bridge, a river bridge, was constructed in 2002 and is located in Guagua, Pampanga. It connects the municipalities of Guagua and Floridablanca. Its adjacent barangays are Ascomo of Guagua, Del Carmen, Benedicto, and Paguiruan. Some barangays in Porac are also using the bridge, specifically Salu and Balubad. The next nearest bridge to it is on the Floridablanca road, named Valdez Bridge; it has a distance of 3.6 km from Del Carmen-Paguiruan Bridge.

II. Methodology

The municipal and national road networks in the Philippines are lined by a substantial number of bridges. The national government is responsible for maintaining national bridges through the Department of Highways and Public Works (DPWH).

The DPWH created the Bridge Management System (BMS) to offer a computer-based system for the management of Philippine national bridges. The purpose of the BMS is to provide the DPWH with a "comprehensive and sustainable bridge inspection program to provide planners and maintenance personnel with sufficient accurate, consistent, and timely information for all bridges that are part of the national road network, using computer applications being procured by the DPWH."

A Bridge Inspection Manual (BIM) is created as part of the BMS "to give bridge inspectors and other personnel rules and procedures to execute effective bridge inspections." One of the inspections listed in the BMS Inspection Manual is the Condition Inspection, which aims to observe and assess a bridge's structural condition as a basis for determining the current state of maintenance, forecasting the need for future bridge interventions, and calculating funding needs.

The inspection of a bridge shall consist of a visual inspection of the entire bridge, including all portions above ground and water level.

2.1 Data Gathering

Different types of data are required when inspecting a bridge. The data and manuals from the Department of Public Works and Highways (DPWH) were also acquired for conducting bridge condition inspections. This also includes the photographic record or inventory photographs, front view, side view, and underside view. It must be compiled for the condition inspection report.

2.1.1 Site Visitation

The researchers did a site visit to evaluate and gather verbal, written, and visual evidence. Site visits, which often last several days, are part of the evaluation process.

2.1.2 Interview (Agency)

The researchers conducted an interview with the Department of Public Works and Highway (DPWH) and the Provincial Engineering Office (PEO) regarding the as- built information, maintenance implementation, and information about bridge inspection to assess the proper aid for bridges.

2.2 Bridge Background Information

To get a bridge's inventory data for the Road and Bridge Information Application (RBIA), use bridge inventory inspection type 5 if there’s no bridge inventory data. A bridge inventory investigation is a common collection of data points that allows for the identification and description of a bridge's geometry, construction, and function.

2.3 Condition Rating of Bridge Attributes

The BMS-Bridge Inspection Manual's 2007 revision lists and discusses common material flaws or damage to bridge members, also known as components or characteristics, with corresponding condition state requirements. Although numerous aspects affect the condition assessment state of bridge components and parts, the evaluation rating is used to produce the condition states for the bridge attributes, as shown in Table 2.3-1.

As can be seen in Table 2.3-1, the condition states are scaled from 0 to 3, with 0 representing the attribute's ideal condition state. The overall condition of the bridge will determine the proper action to implement on the bridge.

Table 2.3 -1. Bridge Attribute Condition States

CONDITION STATE	DESCRIPTION	ACTION
0 (**Good**)	The attribute is in good condition with little or no deterioration.	No action required
1 (**Fair**)	The attribute shows deterioration of a minor nature to the primary supporting material or minor members and is showing the first signs of being affected. It requires repair.	Minor maintenance is required within 10 years
2 (**Poor**)	The attribute shows advancing deterioration and loss of protection to the supporting material; minor loss of section. If the defects are severe on the minor member, then repair is required. While the defects are on the major members, replacement should be applied.	Major maintenance is required within 10 years
3 (**Bad**)	If the attribute shows advanced deterioration, loss of effective section to the primary supporting material or major members, is acting differently from design, or is showing signs of overstress, then replacement is a must.	Immediate major maintenance is required

2.4 Sample Attribute Inspection Forms (Damage Rating)

Using this form, the bridge element and attribute, the type of material used, and the damage it has were listed, identified, and rated. The condition rating cards were used as the basis for inspecting the damage that the bridge had. All the ratings of the observed types of defects were recorded, and whatever the worst rating was, that rating was set as the attribute condition state. As shown in the sample table, the attribute condition state of the deck was then "3" or "bad.

Type of Material	Type of Damage		Severity of Defect	Affected		Damage Rating	Attrib. Cond. State
				Unit	%		
Expansion Joint							
Concrete	×	Difference in Elevation	3			Bad	3
	×	Abnormal Space/Noise	3			Bad	
	×	Water Leakage	2	m^2	42	Poor	
		Displacement					
		Cracking					

Fig.2-1. Sample attribute Form (Damage Rating)

Source: BIM 2007 The condition rating card was used to identify the damage rating.

The condition rating card was used to identify the damage rating.

ELEMENT	BRIDGE ATTRIBUTE	
	PRIMARY	SECONDARY
Superstructure	Deck Slab, Main Member (Girder, Truss, Beam)	Diaphram, Bracing, Railing
Substructure (Pier)	Main Structure, Foundation	Expansion Joint, Bearing/Restraint, Scour Protection
Substructure (Abutment)	Main Structure, Foundation	Expansion Joint, Bearing/Restraint, Scour/Bank Protection, Wingwall, Approach

Damage Rating	% Reduction in Capacity of the Component to Perform its Intended Function	
Good	0% - 5%	0% - 10%
Fair	5% - 20%	10% - 40%
Poor	20% - 30%	40% - 60%
Bad	>30%	>60%

Fig.2-2. Condition Rating Card

Source: BIM 2007

2.5 Bridge Attributes Recommended Countermeasure

Based on the findings of the condition rating of the bridge's primary components and secondary components and attributes that affected structural performance, the researcher evaluated the attribute condition of the bridge.

The following table provides guidelines for assessing the bridge's condition:

Table 2.5-1. Bridge Attributes Recommended Countermeasure

Bridge Condition	Recommended Countermeasures
Good	Routine Maintenance
Fair	Major Maintenance (Repair, Protective Works, Strengthening)
Poor	Major Maintenance or Upgrading
Bad	Upgrading or Replacement

Source: BIM 2007

The recommended action for the bridge refers to the necessary extent of restorative measures that should be taken to enhance the bridge's condition. The recommended measures for the condition of the bridge are typically determined by the table shown above.

2.6 Bridge Needs Ratio (BNR)

With the help of this process, it will be possible to rank the intervention needs for each bridge according to the parameter known as the Bridge Needs Ratio (BNR).

2.6.1 Calculation of Normalized Maintenance Priority Score (NMPS)

NMPS is the ratio of actual against worst conditions. The researchers used this formula in identifying the overall bridge condition

Formula:

$$\text{NMPS} = \frac{\Sigma(CiWi)}{\Sigma(CmWi)}$$

where:

i = attribute of an element

Ci = actual condition state of an attribute (based on the assessment of Bridge Inspector (BI))
Cm = maximum condition state = 3
Wi = weighing factor of an attribute (the greater the importance of an attribute, the higher the factor)

Table 2.6.1-1. Bridge Attribute Weighing Factors (Wi)

ELEMENT	ATTRIBUTE (i)	FACTOR (Wi)
Span	1. Deck	3.0
	2. Main Members	8.0
	3. Secondary Members (include other members)	6.0
	4. Left Parapet	1.0
	5. Right Parapet	1.0
Pier	1. Main Structure	4.0
	2. Foundation	4.0
	3. Expansion Joint	2.0
	4. Bearings/Restraints	3.0
	5. Scour Protection	2.0
Abutment	1. Main Structure	4.0
	2. Foundation	4.0
	3. Bearings/Restraints	3.0
	4. Expansion Joint	2.0
	5. Left Wing Wall	0.5
	6. Right Wing Wall	0.5
	7. Scour/Bank Protection	2.0
	8. Bridge Approach	1.0

Source: BNR

The researcher used the table below to determine the overall condition of the bridge.

Table 2.6.1-2. Overall Condition

Intervention	Min
Good	0
Fair	0.03
Poor	0.2
Bad	0.5

Source: BNR

2.7 Estimation of Remaining Bridge Life

The period of time the bridge will still be operational is referred to as the estimated remaining bridge life. Based on the overall bridge condition, the researcher determined the remaining bridge life range using the table below.

Table 2.7-1. Estimation of Remaining Bridge Life

Overall Bridge Condition	Remaining Bridge Life Range (years)			
Principal construction material	Concrete	Steel	Timber	Demountable
Good Condition Bridge	40-50	30-40	10-15	20-30
Fair Condition Bridge	10-40	10-30	5-10	10-20
Poor Condition Bridge	5-20	5-20	2-5	5-10
Bad Condition Bridge	0-10	0-10	0-2	0-5

III. Result And Discussion

3.1 Visual Inspection (Type 1)

In this process, the researcher conducted an inspection to see if there was a visible flaw in the current condition of the bridge. It requires actual observation of the location to see if it is maintained and functioning properly. Based on the observation, the researcher found out that the actual condition of the bridge has many major flaws: it has a carriage type limitation, like heavy trucks are not allowed; the metals are very noisy, indicating a problem with the joints or the bearing; and there is a difference in elevation from the approach to the floor level of the bridge. Also, the steel of the girders and supports is exposed to rust and corrosion. And upon conversation with the townsfolk living within the area, data gathering is implied by asking for information regarding the bridge. They implied that the bridge was built around the year 2002, and from that point forward, no maintenance was applied and no changes were made. All the information acquired suggests that there is a need to conduct a further inspection.

3.2 Inventory Inspection (Type 5)

Bridge inventory data is a standardized series of data items that enable the geometry, construction, and function of a bridge to be identified and described. After completing the data and information from the initial inspection, the researcher found out that there were no documents regarding the construction of the bridges. They tried to gain information from the Provincial Engineering Office, which is responsible for the construction of the bridge, but unfortunately, there are no31
available documents. And had signed a letter to support the loss of information on the Del Carmen-Paguiruan bridge. So, the engineers of the DPWH suggest conducting the type 5 BMS, which is an inventory inspection, before proceeding to the type

2 BMS. In this kind of inspection, the researchers will need to obtain complete inventory data, a form portraying the overall structural members, types of bridges, materials used, components, and other essential information.

Department of Public Works and Highways

INVENTORY INSPECTION FORM

LOCATION

BRIDGE ID	B00001LZ
Bridge Name	DEL CARMEN-PAGUIRUAN BRIDGE
Road Name	DEL CARMEN-PAGUIRUAN
Road ID	N/A
Section ID	N/A
Location	

Region	III
Province	PAMPANGA
Congressional District	N/A
Engineering District	N/A
Municipality	GUAGUA
Barangay	
River Name	PORAC RIVER

Date of Field Inspection	March 14, 2023

Total No. of Span : 2

Total No. of Abutments : 2

Total No. of Pier : 1

Accomplished by:	Submitted by:
Ian Roy R.Corpin Angelica D. De Ausen Diether D. Montemayor John Marco M. Rio Mikka Kelcey P. Ronquillo Khatelyn Jane M. Sison Wenzen C. Valenzuela	Angelica D. De Ausen
Bridge Researcher	Leader

Fig.3.1. Inventory Inspection Form

Fig.3.2. Inventory Inspection

Fig.3.3. Inventory Inspection

3.1 Condition Inspection (Type 2)

The bridge elements are divided into three categories: the span, abutments, and pier. The bridge inspection is to be a visual inspection only and to cover all parts of the bridge above ground and water level.

3.1.1 Damage Rating

The attributes of the bridge were rated as good, fair, poor, and bad.

3.1.1.1 Summary of Damage Rating

ELEMENT	ATTRIBUTE	Condition State	
		A1	A2
Abutment	Main structure	3	3
	Bearings/restraints	3	3
	Expansion Joint	3	3
		S1	S2
Span	Deck	2	2
	Main member	3	3
	Secondary/other	3	3
		P1	
Pier	Main structure	3	
	Bearings/restraints	2	

3.1.2 Overall Condition

The bridge inspector shall determine the overall condition of the bridge based on the result of the condition rating of the bridge's primary components and attributes and secondary components and attributes that affect structural performance, such as bearings and restraints. For the computation of the overall condition shown below using BNR:

Element	Attributes	Wi	Condition State S1	Condition State S2	Total Ci	Ci Wi	Cm	No.	Total Cm	Cm Wi
SPAN	Deck	3.0	2	2	4	12	3	2	6	18
	Main member	8.0	3	3	6	48	3	2	6	48
	Secondary/other	6.0	3	3	6	36	3	2	6	36
	Left Railing	1.0	0	0	0	0	3	2	6	6
	Right Railing	1.0	0	0	0	0	3	2	6	6
			P1							
PIER	Main structure	4.0	3		3	12	3	1	3	12
	Foundation	4.0	0		0	0	3	1	3	12
	Exapansion joint	2.0	0		0	0	3	1	3	6
	Bearings/restraints	3.0	2		2	6	3	1	3	9
	Scour Protection	2.0	0		0	0	3	1	3	6
			A1	A2						
ABUTMENT	Main structure	4.0	3	3	6	24	3	2	6	24
	Foundation	4.0	0	0	0	0	3	2	6	24
	Bearings/restraints	3.0	3	3	6	18	3	2	6	18
	Expansion Joint	2.0	3	3	6	12	3	2	6	12
	Scour/bank protection	2.0	0	0	0	0	3	2	6	12
	Approach	1.0	0	0	0	0	3	2	6	6

$\Sigma(Ci\,Wi) =$ 168 $\Sigma(CmWi) =$ 255

NMPS = $\Sigma(CiWi)/\Sigma(CmWi)$ = 0.658823529

NMPS = 0.66

BNR options for intervention	Min
GOOD	0
FAIR	0.03
POOR	0.2
BAD	0.5

OVERALL CONDITION = 0.66 (BAD)

3.1.3 Estimated Bridge Remaining Life

It refers to the remaining length of time for which the bridge will remain serviceable. Guidelines for the estimation of remaining bridge life are shown below:

Overall Bridge Condition	Remaining Bridge Life Range (years)			
Principal construction material	Concrete	Steel	Timber	Demountable
Good Condition Bridge	40-50	30-40	10-15	20-30
Fair Condition Bridge	10-40	10-30	5-10	10-20
Poor Condition Bridge	5-20	5-20	2-5	5-10
Bad Condition Bridge	0-10	0-10	0-2	0-5

Since the overall condition of the bridge falls under "bad condition," the estimated remaining life will range from 0 to 10 years.

IV. Conclusion

4.1 Conclusion

The researchers conducted a bridge inspection of a 22-year-old steel deck bridge. Data are gathered solely on the chosen Del Carmen-Paguiruan bridge using the procedures from the bridge inspection manual from the DPWH.

The purpose is to enable the assessment of a bridge's condition and the early detection of any damage or deterioration that may pose a safety hazard. Prevent further enlargement of the defects affecting its condition.

Based on the assessment of the bridge components, the abutments A and B, span 1 and 2 main/secondary members, as well as the main structure of the pier, all require upgrading or replacement due to their bad condition rating. Additionally, the bearings, restraints, and deck of the bridge require major maintenance or upgrading.

The overall condition of the bridge is bad, with a bridge condition rating of 0.66. According to the Bridge Management System (BMS) of the Department of Public Works and Highways (DPWH), the remaining lifespan of the bridge is estimated to be 0–10 years.

In conclusion, immediate action is necessary to address the maintenance, upgrading, or replacement needs of the bridge to ensure the safety of its users.

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