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Comparison of Condition Rating and Bridge Remaining Life Based on Bridge Management System and Bridge Condition Ratio

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ABSTRACT
Bridges are a vital part of a road network that supports regional development. Bridges must be inspected regularly to convince the safety and comfort of bridge users during their service life. This paper will discuss the comparison study of condition rate and remaining life of the bridge that has been determined based on the Bridge Management System (BMS) 1992 and the Bridge Condition Ratio (BCR) code. This comparison is carried out to verify the results of field observation and calculations made on the Way Pedada Bridge in Lampung Province. The BMS 1992 guideline gives a bridge condition value of II of V for light damage with a remaining life of 18,88 years, while BCR gives a bridge condition value of 4,72 of 7,00 to overcome medium damage with a remaining life of 20,13 years. There was a difference of 6,20% between the two codes.

Keywords: *BMS 1992, BCR, Way Pedada, condition rating, the remaining life*

1. INTRODUCTION

Bridges are an important part of a road network that functions to connect between regions. Each region must be connected in order for the economy to run well. In order for the economy to run well, roads and bridges as infrastructure that support the economy must be always in good condition. Therefore, the maintenance program is carried out regularly. The type of bridge maintenance has different actions depending on the damage to the bridge. The type of bridge maintenance is determined based on the value of the bridge condition obtained after the visual bridge inspection. Visual inspection is important because most decisions relating to bridge maintenance are based on visual inspection ratings [1]. The accuracy of decisions developed by any manager or bridge engineer relies on the accuracy of the bridge condition assessment which emanates also from visual inspection [2] [3]. Among the guidelines that can be used for bridge inspection refer to the Bridge Management System (BMS) 1992 [4] and the Bridge Condition Rating (BCR) [5]. BMS is an inspection guide issued by the Ministry of Public Works and Public Housing. A project co-funded by Indonesia and Australia. Meanwhile, the Bridge Condition Ratio or Bridge Inspection Manual is a bridge inspection guideline issued by the New York State Department of Transportation (NYSDOT). The two guidelines produce the same output namely the condition value and the remaining life of the bridge, but they have different methods in calculating the condition value and the remaining life of the bridge.

Therefore, this paper aims to compare the results of the condition value and the residual life calculation of the two methods. This comparison is made to validate the results of the examinations and calculations that have been carried out. The bridge inspection was carried out on the Way Pedada Bridge in Lampung Province, as a case study.

1.1 Bridge Management System (BMS) 1992

There are several studies that discuss bridge inspection and the calculation of the remaining life of the bridge. Written research includes referring to guidelines (code) in several countries that are intended to provide comparisons and verify the results of the examinations that have been carried out. Mirza et al., (2017) conducted an examination of the Petaunan Bridge, which has a concrete structure with a span of nine meters in Banyuwangi [7]. Bridge inspection refers to BMS 1992 with a special non-destructive test in the

form of a Schmidt Hammer Test. In this guideline, each level of the bridge element is given an assessment based on five parameters, namely structure, damage, development, function and influence by giving values of 1 and 0 as shown in **Table 1**. A result, this bridge is in condition value II of V, meaning that the bridge is damaged which requires handling. immediately. The table for assessing the condition of the bridge according to BMS 1992 is as in **Table 2** below. Guidelines for Bridge Preservation Handling, Dirjen Bina Marga (2010) [6] provides **Definition 1** to calculate the remaining life of the bridge as follows:

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

with :
CR : Condition rate
Y : Age bridge
N : Age plan
a : coefficient (4,66)
b : coefficient (1,905)

Table 1 Condition Rate of Element

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

Table 2 Condition Rate of Bridge

Condition Rate	Description
0	The bridge is in a new state, without obvious damage
I	Element does not experience damage or deterioration in quality. There may be slight changes in color, spots
II	Small cracks and little clumping occur but cause corrosion of the reinforcing steel or decrease the quality of the prestressed system
III	There was a little bit of loose concrete, cracks began to appear. There is no loss of quality in prestressed systems. There may be a little corrosion on the steel reinforcement but on the non-structural parts. It does not require special analysis due to damage or degradation of elements on the bridge
IV	Separators have occurred in the concrete and chipped or cracked or corrosion in reinforcing steel. There is a decrease in the quality of prestressed systems (such as loss of adhesion, breaking of strands or wires, corrosion or destruction of anchor parts, etc.). An analysis is needed due to the damage
V	All bridge elements collapse or no longer function

1.2 Bridge Condition Ratio (BCR)

Harywijaya et al., (2020) conducted a study by examining four bridges located in the Province of Nanggroe Aceh Darussalam (NAD) [8]. The research conducted refers to the 1992 BMS and then compared with the code from the New York State Department of Transportation (NYSDOT) regarding the Bridge Condition Rating (BCR). This aims to obtain accurate results so that they can provide the right action for bridge maintenance. The BCR Guidelines have their own weighting mechanism for each element, this is of course different from BMS. The weighting and the conclusion of the bridge condition are as in **Table 3** and **Table 4**, which are then used to calculate the bridge rating as in **Definition 2** below.

$$\text{Bridge rating} = \frac{\sum \text{component rating x weigth}}{\text{weights}} \quad (2)$$

with :
CR : Condition rate of the bridge component
Weight : Component rating
Weights : Total of component rating

Table 3 Weight mechanism of component

No	Bridge Component	Weight
1	Main girder	10
2	Abutment	8
3	Bridge pier	8
4	Deck slab	8

No	Bridge Component	Weight
5	Restrain	6
6	Support	6
7	Flange wall	5
8	Flange bottom	5
9	Secondary beam	5
10	Joint	4
11	Surface	4
12	Sidewalk	2
13	Curb	1

Table 4 Condition Rate of Bridge

BCR	Condition	Type of Maintenance
1,000-3,000	Poor	Replacement
3,001-4,999	Fair	Rehabilitation
5,000-6,000	Good	Routine and periodic maintenance
6,001-7,000	Very good	

After assessing the condition of the bridge, then the equivalent age of the bridge is calculated. The equivalent age can be defined as the age of a bridge by considering the conditions of each element. Subagio et al. (2008) write **Definition 3** and **Figure 1**, namely the BMS deterioration model [9] which refers to NYSDOT (1997) to calculate the equivalent age of the bridge.

$$EA = \frac{\left(100 - a\left(5 - \left(\frac{5}{6}(7-CR)\right)\right)^{b}\right)}{100} \text{ x plan age} \qquad (3)$$

With:
EA : Equivalent age
CR : Condition rating of bridge
a = 4,66
b = 1,9051

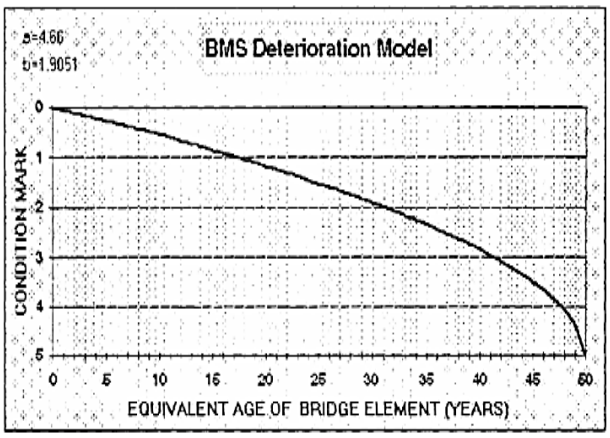

Figure 1 BMS Deterioration Model

2. BACKGROUND

2.1 Method

In general, the stages of bridge inspection are as illustrated in the flow chart in **Figure 2**. The initial data required by the inspector to inspect the bridge are technical data and administrative data for the bridge. Administrative data is in the form of the bridge operation initial year and the coordinates of the bridge location. The initial stage of the inspection begins with a literature study regarding the guidelines for the inspection of the bridge used, in this case referring to BMS and BCR. Then, it is followed by a visual inspection of the bridge. Inspectors ensure all elements of the bridge are inspected and documented. Condition rate and residual life calculation are carried out after bridge inspection by referring to the two methods previously mentioned. In the final stage, the comparative analysis of the two calculation results are carried out. Comparative analysis of the two methods was carried out on the Way Pedada Bridge in Lampung Province which is located on the road towards Punggung Tampak and Kruwi direction. **Figure 3** shows an aerial photo of the bridge.

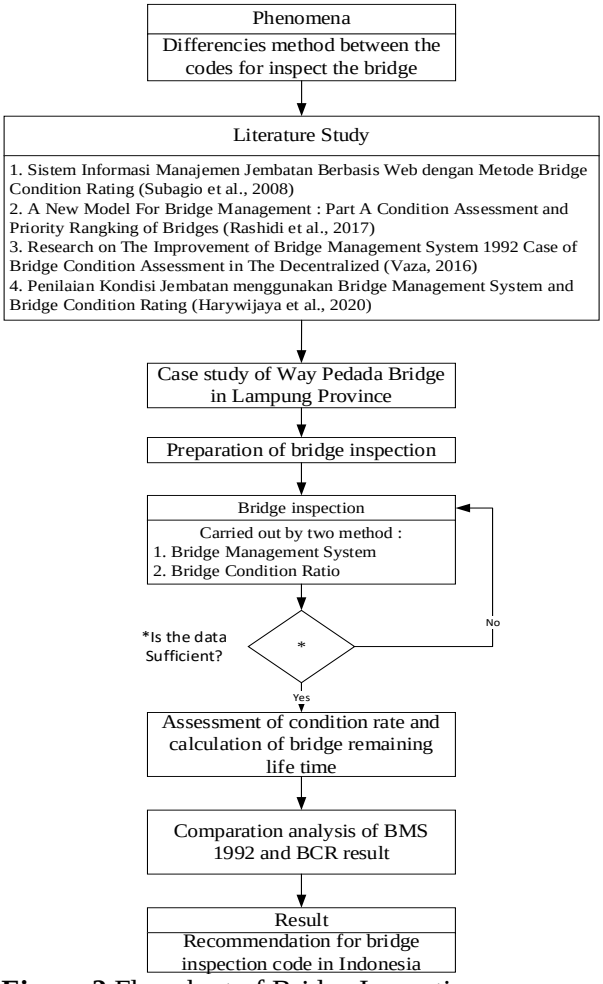

Figure 2 Flowchart of Bridge Inspection

Figure 3 Aerial Photo of Way Pedada Bridge

2.2 Result Base on BMS 1992's Code

The bridge inspection was carried out in 2017, but before the bridge inspection results were checked, the following is the administrative data for the Way Pedada Bridge:

Bridge name	: Way Pedada
Bridge number	: 017.025.001
Span	: 102,9 meter
Span number	: 3 span
Service life	: 50 years
Structure type	: Reinforcement concrete (approach bridge) and steel truss (main span)
Develop on	: 1995's
Roads	: Kruwi- Punggung Tampak
Obstacles type	: River

The following is the result of bridge assessment elements on the Way Pedada Bridge so that summarize of the level two and one level bridge element assessments are obtained like in **Table 5**. By considering the condition value of each element at level 5, then recapitulated to level 2, the Way Pedada Bridge is given a condition II of V value with information as shown in **Table 2** so that a maintenance recommendation is needed in the form of routine and periodic maintenance. Calculation of the remaining life of the bridge is done with **Definition 3**, the current age of the bridge (Y) is 31,113 years so that the remaining life of the bridge is 18.88 years.

$$2=5-\left\{\frac{\left(100-\frac{Y}{50\%}\right)}{4,66}\right\}^{1/1,905}$$

$$5-2=\left\{\frac{\left(100-\frac{Y}{50\%}\right)}{4.66}\right\}^{0.525}$$

$$3 \times 4.66^{0.525}=\left(100-\frac{Y}{50\%}\right)^{0.525}$$

$$\sqrt[0.525]{6,730}=\left(100-\frac{Y}{50\%}\right)$$

$$37,773=100-\frac{Y}{50\%}$$

$$100-37,773=\frac{Y}{50\%}$$

$$62,226=\frac{Y}{50\%}$$

$$Y=31,113 \text{ years}$$

Table 5 Condition Rate based on BMS 1992

Code	Component		CR
2,400	Superstructure	:	2
2,300	Substructure	:	0
2,200	Watershed	:	1
2,500	Slab Deck	:	2
1,000	Full Bridge	:	2

2.3 Result Base on Bridge Condition Ratio (BCR) Code

The following is the result of inspecting the elements according to BCR on the bridge elements found on the Way Pedada Bridge so that a recapitulation of level two and one bridge elements is obtained as shown in **Table 6**.

Table 6 Condition and Maintenance Recommendation

Compo-nent	Weight	CR	Wei-ght x CR	Con-dition	Recommen-dation
Main structure	10	5	50	Good	Routine and Periodic Maintenance
Abutment	8	5	40	Good	Routine and Periodic Maintenance
Deck slab	8	4	32	Fair	Rehabilita-tion
Pier	8	4	32	Fair	Rehabilita-tion
Restrain	6	5	30	Good	Routine and Periodic Maintenance
Support	6	5	30	Good	Routine and Periodic Maintenance
Bottom flange	5	5	25	Good	Routine and Periodic Maintenance
Flange wall	5	5	25	Good	Routine and Periodic Maintenance
Secondary beam	5	5	25	Good	Routine and Periodic Maintenance
Joint	4	4	16	Fair	Rehabilita-tion
Surface	4	5	20	Good	Routine and

Compo-nent	Weight	CR	Wei-ght x CR	Con-dition	Recommen-dation
					Periodic Maintenance
Sidewalk	2	5	10	Good	Routine and Periodic Maintenance
Curb	1	5	5	Good	Routine and Periodic Maintenance
Total weight	72				
Total weight x CR	340				
Bridge condition rating	4,72				
Condition	Fair				
Recom-endation	Rehabilitation				
Equivale-nt of age	29,86' years				
Remaini-ng bridge life	20,13' years				

Based on the description of the examinations and calculations that have been carried out, with reference to the BMS guidelines, the value of condition II of V is obtained, which means damage that requires monitoring or maintenance in the future with a remaining age of 18.88 years. Meanwhile, with the BCR guidelines, the condition value is 4.72 of 7,00, meaning that the damage is moderate with a remaining life of 20.13 years. Based on the comparisons that have been made, there is a difference in the value of the remaining life of 6.20%. It happens because there are different calculation methods between BMS and BCR. In the 1992 BMS guidelines, there is no mention of a systematic equation for assessing the overall condition of the bridge (1,000) based on the assessment of the level elements below it, so it causes the results of the assessment to be subjective. This is supported by Vaza (2016) in his dissertation which states that reducing the level elements that are checked during field inspection will provide more objective examination data. In addition, to increase the level of confidence in the results of field inspections, inspectors from local government requires sufficient competency to deliver good bridge inspection data [10]. But on the other hand, the BCR method also does not contain all bridge elements such as river basins, pedestrians, bridge signage and so on, so that if the element is in a damaged condition, it does not affect the assessment of the bridge condition. In addition, in order to obtain a more valid comparison result, it is recommended to take more than one bridge as a case study, as was done by Harywijaya et al. (2020) on four bridges in Banda Aceh Province. In addition, the BMS 1992 and BCR methods have their respective advantages and disadvantages. However, the most suitable method to be applied to bridge conditions in Indonesia is the BMS method, but with a note that this method needs to be updated to meet the dynamic advance of information technology and current of bridge structural knowledge, including the decentralization of government.

3. CONCLUSION

The value of the Way Pedada Bridge condition refers to BMS 1992 and BCR respectively, namely II of V (damage requiring monitoring) and 4,72 of 7,00 (moderate damage). Meanwhile, the remaining life of the bridge is 18.88 and 20.13 years. There is a difference in the remaining life of the bridge by 6.20% for the reasons mentioned in the previous description. The BMS 1992 and BCR have their respective advantages and disadvantages, but BMS 1992 more suitable to applied on bridges condition in Indonesia if there's the improvement of the code that have described before.

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