E-ISSN: 2528-388X
P-ISSN: 0213-762X

INERSIA
Vol.20, No.2, December 2024

Bridge Maintenance Strategy: Application of Bridge Condition Index (BCI) UK to Ngawi Kertasono Toll Road Bridge

Halima Irianti Puspita Sari, Suprapto Siswosukarto*, and Akhmad Aminullah

Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

Keywords:
Bridge Maintenance Priority
Bridge Condition Index (BCI)
Toll Road Bridge

ABSTRACT

In the context of toll road infrastructure, bridges are essential for connecting two distinct sections and ensure the toll road functioning properly. Therefore, to accomplish that objective and, at the same time, optimize the allocation of limited funds for maintenance, bridges require a proper maintenance priority strategy. However, in Indonesia's Bridge Management System (BMS), the importance weight of the bridge elements has not yet been used and the final result still causes bias while assembling the rankings of handling priorities. The Bridge Condition Index (BCI), developed in the United Kingdom, offers a bridge handling priority system that is determined by the importance of each bridge element. To determine the effectiveness of the BCI UK method, an analysis was carried out using the results of a visual inspection of five river bridges located on the Ngawi Kertasono toll road. According to the handling ranking result, Kedungrejo Bridge appears to be on the first rank with the dominant defect occurred on the pier element. Sukoharjo Bridge, on the other hand, has the dominant defect happened in the carriageway surfacing and is ranked last. The outcomes itself indicate that bridges with defects in critical elements, which can affect the structural stability of the bridge, will be prioritized to be repaired prior to bridges with non-structural element damages. Moreover, suitable repair recommendations can be made based on the type and severity of the damage itself. Furthermore, this result is expected to be taken into account while developing the Indonesian bridge management system in the future.

1. Introduction

Proper maintenance of bridges within the scope of toll road infrastructure is one of the main aspects to support the achievement of optimal utilization of the toll road itself. As a result, regular bridge inspections are required to keep the bridge in optimal condition for operation. However, obtaining detailed bridge inspection results is quite expensive and takes a relatively long time. It is necessary to develop an appropriate bridge maintenance and management strategy to maximize the allocation of funds following the cruciality of the bridge. Bridge management is a method for maintaining bridges which is applied from the conception phase until the end of the bridge's service life [1]. One of the useful instruments that has been developed for enhancing the effectiveness of managing the inspection, maintenance, condition projected, and allocation of funds for bridges is the bridge management system (BMS) [2]. Indonesia itself has a bridge management method known as the Bridge Management System (BMS) of Indonesia (IBMS). However, in this method, the importance weight of the bridge elements has yet to be applied and bridge assessment is carried out hierarchically, resulting in a bias occurring in the final assessment results [3]. In the meantime, Meanwhile, developing a custom BMS requires a long-term commitment, the most sophisticated informatics expertise, and significant financial, time, and resource expenditures for both original development and ongoing maintenance because it requires frequent and ongoing modifications [4].

The United Kingdom's Bridge Condition Index (BCI UK) is an approach that uses element importance weights. Based on the value of each bridge component, this method establishes a ranking system for bridge repairs. Thus, the sequence of bridge repairs can be arranged by prioritizing elements that have an important role in bridge safety. In

*Corresponding author.
E-mail: suprapto.siswosukarto@ugm.ac.id

http://dx.doi.org/10.21831/inersia.v20i2.70211
Received January 2nd, 2024; Revised December 29th, 2024; Accepted December 30th, 2024
Available online December 31st, 2024

the past, engineers' assessments of small-scale bridges were used to determine the priority of maintenance projects, while for large and historic bridge networks, the concepts and principles of budget allocation optimization were followed. For this reason, the bridge condition index is utilized nowadays [5][6].

Many different approaches have been used to establish element importance weights. As an illustration, like weighted sum method, which is employed to assess each bridge component and how it contributes to the overall performance of the structure [7]. Moreover, other methods like the Bridge Overall Priority Indicator (BOPI), take into account variables other than element weights. Specifically, they use the parameters of bridge structural performance measures (SP), bridge functional performance measures (FP), and external factors (EF) to rank bridges on the road network system in order of the urgency of repair needs [8].

In Indonesia, the common methods studied previously such as the Maintenance Priority Number (MPN) [9], New York State Department of Transportation (NYSDOT) [10] and the Bridge Condition Rating (BCR) [11][12][13]. There hasn't been a clear explanation of how structural element weight considerations affect bridge handling priority in Indonesian research. Moreover, it is still very difficult to find the application of the BCI method to bridges in Indonesia.

Meanwhile, globally, the BCI method has been used in some research and shows the potential to be combined or become an element of development for existing methods [14][15]. Hence, this research is the latest study in order to know the efficiency of implementing the BCI method in Indonesia, and the analysis results can provide suggestions or consideration for the development of bridge management systems in Indonesia. The recommendations for bridge repair are based on the most common defects that occurred on bridges in this study.

2. Method

2.1 Objectives and Research Methodology

Five river bridges with type I girders made of precast concrete material become the objectives of this research, as listed in Table 1. The selection of river bridges is based on a higher damage rate due to the influence of river environmental factors. These factors are related to water behavior that damages the bridge structure, including scouring, degradation, and flow narrowing. Figure 1 shows the location of each bridge along the Ngawi Kertasono toll road.

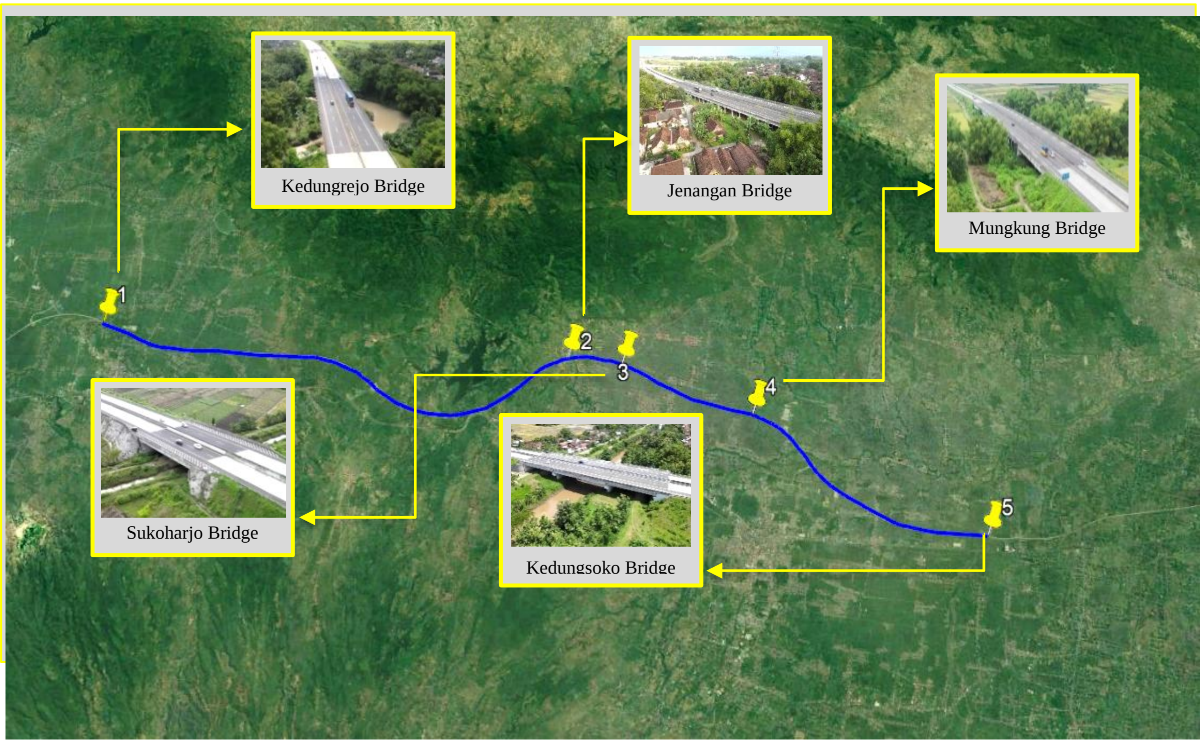

Figure 1. Research Location along Ngawi Kertasono Toll Road

The data used in this research is secondary data, which includes bridge inventory and detailed visual inspection reports obtained by PT. Jasa Marga in 2022. The data was then analyzed further using the BCI UK method through the report of each damaged element, which includes the damage volume.

2.2 BCI UK Calculation Procedure

Currently, the United Kingdom relies heavily on visual inspection data to make decisions [16]. According to the extent and severity of defect elements, the bridge's condition is evaluated. The area, length, or number (as applicable) of the bridge element impacted by the damage is known as the extent, which described in Table 2 [17]. According to Table 3, the severity indicates how much the defect interferes with the element's or other elements' capacity to function [17].

A bridge's elements are chosen one at a time, and an element condition score (ECS) is calculated for each element based on its condition data [17]. Table 4 shows the permissible combinations of extent and severity. The rating values imply that the extent of the defect is more essential than its extent.

It should be noticed that an extent cannot be assigned a severity level of 2–5 if it receives a code A. This is due to the fact that a severity value that indicates damage cannot be assigned to an element (the extent code A) that has no discernible damage [14].

Table 1. Research objectives

Bridge Name	Width (m)	Length (m)	Location (km)
Kedungrejo	25.2	116	614+395
Jenangan	32.4	188.7	635+550
Sukoharjo	32.4	40	637+895
Mungkung	32.4	200	643+675
Kedungsoko	32.4	112	654+745

* PT. Jasa Marga Ngawi Kertasono Kediri

Table 2. The extent description [17]

Code	Extent Decription
A	No significant damage
B	Slight, not more than 5% surface area/length/trunk
C	Moderate, 5% - 20% of surface area/length/amount
D	Width, 20% - 50% of surface area/length/quantity
E	Extensive, more than 50% of surface area/length/ number

Table 3. The severity description [17]

Code	Severity Decription
1	As new condition or defect has no significant effect on the element (visually or functionally)
2	Early signs of deterioration, minor defect/damage, no reduction in functionality of element
3	Moderate defect/damage, some loss of functionality could be expected
4	Severe defect/damage, significant loss of functionality and/or element is close to failure/collapse
5	The element is non-functional/failed

Table 4. Permissible combinations of extent and severity

Extent	Severity				
	1	2	3	4	5
A	1.0				
B		2.0	3.0	4.0	5.0
C		2.1	3.1	4.1	
D		2.3	3.3	4.3	
E		2.7	3.7	4.7	

The element condition factor (ECF) is later evaluated using equations in Table 5 and by taking the element importance (EI) into consideration. The element importance factor (EIF) attributes a figure for each element depending on the structural importance of the individual element [18], shown in Table 6.

Table 5. Equations for element condition factor [18]

EI	Element Condition Factor (ECF)
Very high	ECF = 0
High	ECF = 0.3 – [(ECS - 1) × $\frac{0.3}{4}$]
Medium	ECF = 0.6 – [(ECS - 1) × $\frac{0.6}{4}$]
Low	ECF = 1.2 – [(ECS - 1) × $\frac{1.2}{4}$]

The element condition index (ECI), which shows the element's condition on a scale from 1 (best) to 5 (worst), is derived by combining the ECS and ECF values. The element condition factor (ECF) is taken into consideration while determining the element condition index (ECI), as demonstrated by Equation (1) [19]. The ECI enables a direct comparison of how the condition of various element types affects the overall state of the bridge.

$$ECI = ECS - ECF, \text{ (the result is must be} \geq 1) \quad (1)$$

Table 6. EI and EIF description [19]

Set	Element Description	EI	EIF
Superstructure Elements	Primary deck element	Very high	2.0
	Secondary deck element(s)	Very high	2.0
	Half joints	Very high	2.0
	Tie beam/rod	Very high	2.0
	Parapet beam or cantilever	Very high	2.0
	Deck bracing	High	1.5
Load-bearing Substructure	Foundation	High	1.5
	Abutments	High	1.5
	Head wall	High	1.5
	Pier / column	Very hight	2.0
	Cross-head / capping beam	Very high	2.0
	Bearings	High	1.5
	Bearing plinth / shelf	Medium	1.2
Durability Elements	Superstructure drainage	Medium	1.2
	Substructure drainage	Medium	1.2
	Movement / expansion joints	High	1.5
	Painting: deck elements	Medium	1.2
	Painting: substructure elements	Medium	1.2
	Painting: parapet / safety fences	Medium	1.2
Safety Elements	Access / walkways / gantries	Medium	1.2
	Guardrail / handrail / safety fences	High	1.5
	Carriageway surfacing	Medium	1.2
	Footway / verge / footbridge surfacing	Low	1.0
Waterway Elements	Invert / river bed	Medium	1.2
	Aprons	Medium	1.2
	River bed upstream	Medium	1.2
	River bed downstream	Medium	1.2
	Scour	Medium	1.2
	Riverbanks	Medium	1.2
Retaining Elements	Revetment	Low	1.0
	Wing walls	High	1.5
	Retaining walls	Medium	1.2
	Embankments	Low	1.0
Others	Approach rails / barriers / walls, Approach adequacy, signs, lighting, services and appearance	Elements not used to evaluate condition indicators	

The BCSAv and BCSCrit bridge condition ratings are evaluated. The average bridge condition score, or BCSAv, is determined by applying Equation (2) [20] to evaluate a bridge while accounting for the state of each structural element. Furthermore, structural element and deck conditions hold the greatest significance among the various ratings of a bridge, as they are directly linked to the bridge's safety and serviceability [21].

$$BCS_{av} = \frac{\Sigma(\mathrm{ECIi} \times \mathrm{EIFi})}{\Sigma \mathrm{EIFi}} \tag{2}$$

Afterwards, according to Equation (3) [18], BCSCrit is the largest of the ECI values of those elements that are deemed "critical (very high based on EI)" to the bridge's integrity [18].

$$BCS_{crit} = \max ECI\ of \begin{bmatrix} primary\ deck\ elements, \\ secondary\ deck\ elements \\ seismic\ linkage\ or\ holding\ down\ bolts \\ parapet\ beam\ or\ cantilever \\ pier\ or\ column \\ crosshead\ or\ capping\ beam \end{bmatrix} \tag{3}$$

Subsequently, the BCS values are converted into the suitable bridge condition indicators (BCICrit and BCIAv). The average bridge condition index, BCIAv, is determined by applying Equation (4) [18] to a bridge evaluation that considers the state of all structural elements.

$$BCI_{AV} = 100 - 2\,[(BCS_{AV})^2 + (6.5 \times BCS_{AV}) - 7.5] \tag{4}$$

In the meantime, BCICrit, or the critical bridge condition index, is a bridge's evaluation based on the components that are considered to be highly significant and calculated using Equation (5)[18].

$$BCI_{Crit} = 100 - 2\,[(BCS_{Crit})^2 + (6.5 \times BCS_{Crit}) - 7.5] \tag{5}$$

According to Figure 2, there is a non-linear relationship between BCS and BCI. This pattern indicates that the bridge condition deteriorates gradually (BCI) at first, but more rapidly as the BCS value rises from 1 to 5 [18].

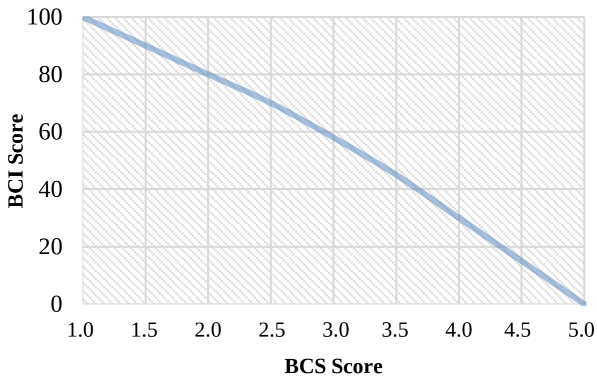

Figure 2. Relationship graph between BCI and BCS values [18].

Table 7 provides the BCI results on a scale of 100 (Best) to 0 (Worst) condition and overall condition of the bridge structure [19]. Based on the explanation above, Figure 3 is an illustration of the process used to determine the bridge condition index (BCI) [19].

Table 7. Bridge condition index range score [19]

BCI_{AV}	BCS_{AV}	Overall Condition of the Structure
100 – 95	1.0 – 1.3	No significant defects in any elements;
94 – 85	1.31 – 1.8	Mostly minor defects/ damage, but may also be some moderate defects;
84 – 65	1.81 – 2.7	Minor-to-moderate defects/ damage; One or more functions of the bridge may be significantly affected
64 – 40	2.71 – 3.7	Moderate-to-severe defects/ damage; One or more of functions of the structure may be severely affected
39 – 0	3.71 – 5.0	Severe defects/damage on a number of elements; One or more elements have failed; Structure is unserviceable

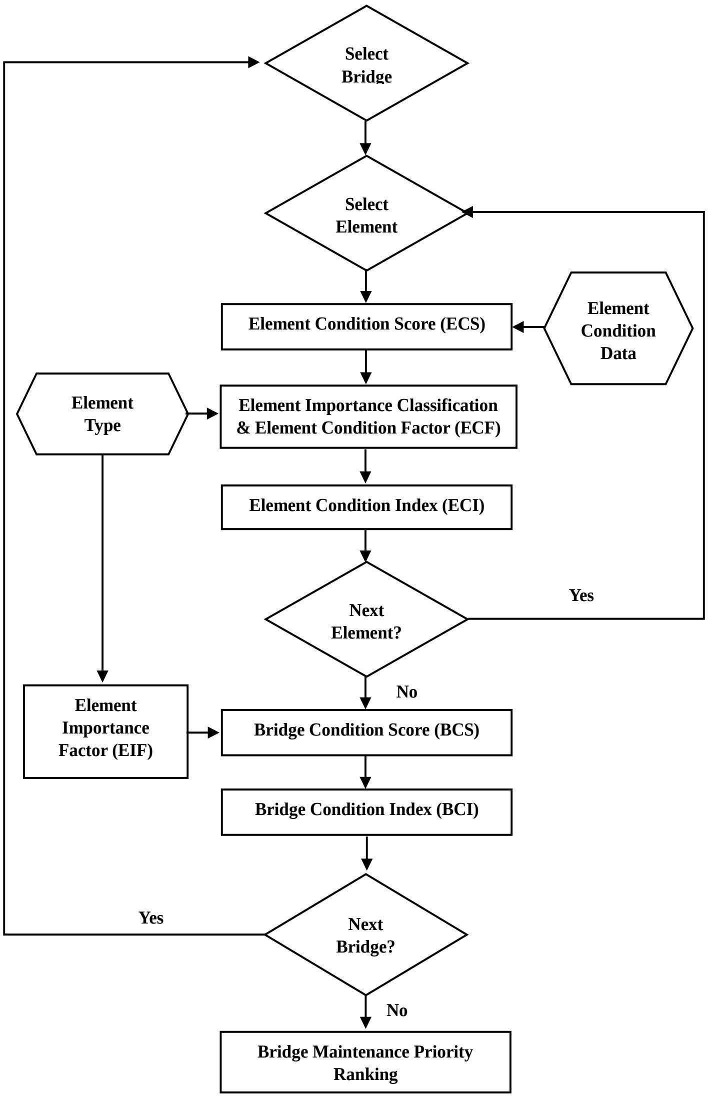

Figure 3. BCI UK calculation flow chart [19]

The values are mapped to a linear scale from 0 to 100 by the conversion from BCS to BCI. The BCI values represent a bridge's "percentage service potential" in general terms. Therefore, a bridge with a BCI value of l 00 indicates that it has maintained 100% of its service potential, a value of 60 indicates that it has lost 40% of its potential for service, and a value of 0 indicates that it is no longer in service [19].

It is important to acknowledge that enhancing a bridge's BCS value from 2 to 1 can demand a drastically different amount of work and maintenance budget than enhancing it from 4 to 3. In the BCI scale, for example, an improvement in the BCS from 2 to 1 corresponds to an improvement of 81 to 100 (19%), whereas an improvement in the BCS from 4 to 3 corresponds to an improvement of 31 to 58 (27%) on the BCI scale [19].

3. Result

3.1 Assessment of element conditions

When conducting bridge surveys, the BCI UK approach is used. General inspection is the process of visually inspecting the elements that are above ground. Understanding the bridge's as-built drawing is the first stage in performing a bridge inspection using the BCI UK approach, which is comparable to the BMS method. However, the BCI UK approach conducts direct inspection on damaged elements (equal to level 4 in the BMS 2022 Standard), as opposed to the inspection in the BMS method, which done hierarchically.

Damaged elements are assessed based on the most dominant damage (severity) and its extent (extend), for example, on the Kedungrejo bridge, as in Table 8. where the damage to a single element is used to characterize the dominant and interacting defects. The Inspection Manual for Highway Structures: Volume 1 is used to examine damage that occurs. It does not cover every element or type of defect, but it does offer general instructions for determining the severity states [20].

The element's severity is determined by taking into account the dominant defect when one defect is found to be at least one severity category higher than all other defects on the element. In this instance, the area impacted by the dominant defect alone should be represented by the extend code [20].

3.2 Calculation of BCI Score

Estimating the BCI score for the Kedungrejo bridge starts by calculating the element condition score (ECS). The ECS value is obtained by following the result in Table 8 and adjusted accordingly to Table 4. All of the ECS, ECF, and ECI score calculations can be seen in Table 9. Looking at Figure 4, which is arranged according to the ECI value of the Kedungrejo bridge in Table 9, bridge supervisors can easily determine which elements have the highest ECI.

Table 8. Kedungrejo Bridge condition assessment using the bci uk method

Element	Multiple Defects	S/Ex	Dominant Defect	S/Ex
Abutment	There are several cracks with a width of 0.2 - 0.6 mm (S=3) and the estimated length coverage is 13.5% of the abutment width (Ex = C) At the head of the abutment, there is a part of the concrete that is broken and eroded (S=2), while the damage coverage is <5% (Ex=B)	3C 2B	Cracks become the dominant defect. Therefore, the element condition value follows the S/Ex value for the damage.	3C
Deck Bracing	There is honeycombing in several areas (< 5%, Ex=B) but only occurs on the surface and the reinforcement is not visible (S=2)	2B	Because there is no other defect, the S/Ex value does not change	2B
Girder (primary deck element)	There are cracks to spalling (S=3) with an area coverage that does not reach 5% (Ex=B) There is a cavity with a relatively small width (S=2) in the girder connection with an area < 5% (Ex=B)	3B 2B	Cracks are accompanied by spalling so that S=3. While the extent value is fixed because each damage is not more than 5%	3B
Deck	Corrosion occurs on the surface of the plate (S=2) with a coverage of less than 5% of the total plate area (Ex=B)	2B	Because there is no other defect, the S/Ex value does not change	2B
Pier	On the pillar heads, some slight – moderate honeycombing (S=2) was found which occurred with a coverage area of 1.56% (Ex=B)	2B	The dominant damage is crack. Therefore, the element condition value follows the S/Ex value for the damage	3D

Element	Multiple Defects	S/Ex	Dominant Defect	S/Ex
	There were 29 cracks with a width of 0.2 - 1.5 mm (S=3) with a total crack length reaching 47.34% (Ex=D)	3D		
Bearings	Some elastomers experienced insignificant shifts and one of them was torn so that the area coverage reached 5.56% (S=2, Ex=C)	2C	Because there is no other defect, the S/Ex value does not change	2C
Riverbanks	Minor scouring occurs (S=2) with volume not reaching 20% (Ex=C)	2C	The extend value increases because the damage that occurs reaches 20% and the severity value does not increase because the damage that occurs does not directly affect the stability of the bridge.	2D
	There are minor rubbish piles (S=2) around the river bank with coverage not reaching 20% (Ex=C)	2C		
Expansion joints	There are cracks in three expansion joints 5.2 m long (S=2) which reach 24.36% of the total length of the bridge (Ex=D)	2D	Because there is no other defect, the S/Ex value does not change	2D
Parapet / safety fences	The parapet experienced cracks with a width of 0.4 – 2.5 mm (S=2) with a coverage of 9.47% (Ex=C)	2C	Because there is no other defect, the S/Ex value does not change	2C
Superstructure drainage	There are 6 or 14.29% of the drainage (Ex=C) of the bridge's upper structure is blocked consequently reducing the element's effectiveness (S=3)	3C	Because there is no other defect, the S/Ex value does not change	3C

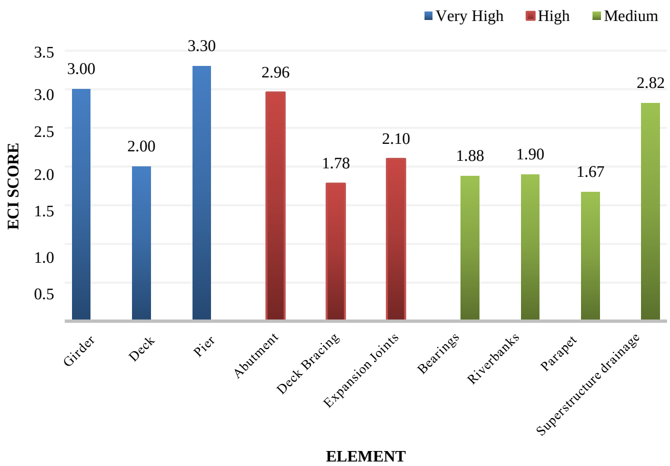

Figure 4. ECI score comparison for various elements

As an illustration, deck elements with a "very high" importance weight may be prioritized for handling than expansion joint elements. Even though it has a smaller ECI value, in the UK BCI method, the deck has a more significant influence on the overall bridge structure. This could be used to define the parts of a bridge that need maintenance and provide more information for decision-making. Therefore, the calculation of BCI score for the Kedungrejo bridge generate the following results:

$$BCS_{AV} = 37.32 / 15.6 = 2.39$$

$$BCS_{Crit} = \max \text{ ECI of (Girder / Deck / Pier)} = 3.30$$

$$BCI_{AV} = 100 - 2\,[(2.39)^2 + (6.5 \times 2.39) - 7.5] = 72.46\%$$

$$BCI_{Crit} = 100 - 2\,[(3.30)^2 + (6.5 \times 3.30) - 7.5] = 50.32\%$$

3.3 Ranking Maintenance Priority of Bridges

The systematic calculation above was then applied to four other bridges to obtain BCI score of each bridge. Therefore, all bridges are ranked based on BCIav and BCIcrit value, as shown in Figure 5 and Table 10. Where the Sukoharjo bridge with damage to nonstructural elements (Carriageway surfacing) is ranked last and the Kedungrejo bridge with structural element damage (Pier) is at the top of the priority list.

Tabel 9. ECS, ECF, ECI values of Kedungrejo Bridge

Element	EI	S/Ex	ECS	ECF	ECI	EIF	ECI * EIF
Abutment	High	3C	3.1	0.14	2.96	1.5	4.44
Deck Bracing	High	2B	2.0	0.23	1.78	1.5	2.66
Girder	Very High	3B	3.0	0.00	3.00	2.0	6.00
Deck	Very High	2B	2.0	0.00	2.00	2.0	4.00
Pier	Very High	3D	3.3	0.00	3.30	2.0	6.60
Bearings	High	2C	2.1	0.22	1.88	1.5	2.82
Riverbanks	Medium	2D	2.3	0.41	1.90	1.2	2.27
Expansion Joints	High	2D	2.3	0.20	2.10	1.5	3.15
Parapet	Medium	2C	2.1	0.44	1.67	1.2	2.00
Superstructure drainage	Medium	3C	3.1	0.39	2.82	1.2	3.38
				Total Value (Σ)		15.6	37.32

Table 10. Maintenance priority ranking

Ranking	Bridge	BCS_{AV}	BCS_{Crit}	BCI_{AV} (%)	BCI_{Crit} (%)	Dominant Defect		
						Element	EI	ECI
1	Kedungrejo	2.39	3.30	72.46	50.32	Pier	Very High	3.30
2	Jenangan	2.34	3.00	73.72	58.00	Abutment	High	3.30
3	Mungkung	1.99	2.10	81.16	78.88	Abutment	High	2.96
4	Kedungsoko	1.89	2.00	83.29	81.00	Superstructure drainage	Medium	3.05
5	Sukoharjo	1.88	2.00	83.53	81.00	Superstructure drainage	Medium	3.05

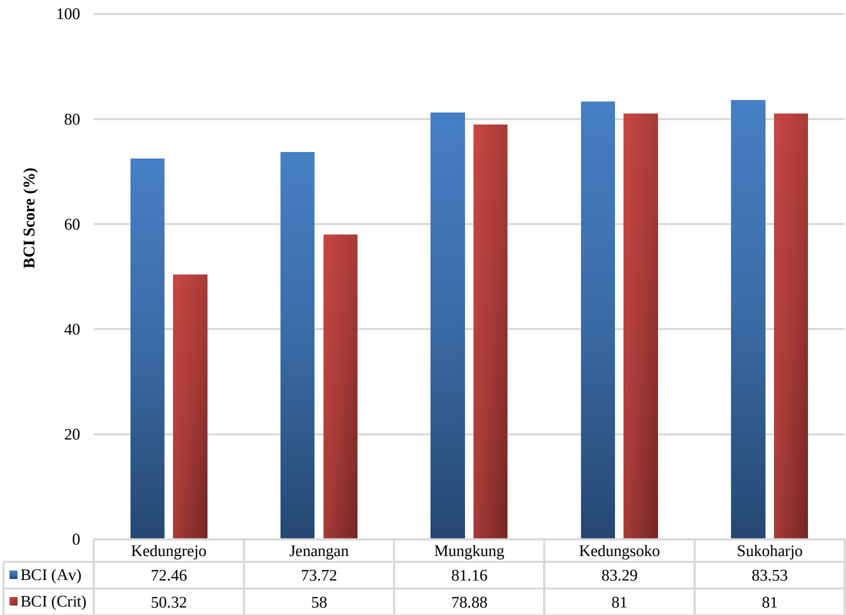

Figure 5. BCI score comparison for each bridge

3.4 Bridge Repair Recommendations

Based on the results of the bridge inspection obtained, recommendations for handling existing defects can be proposed. However, the suggested repair of action is not included in the BCI UK standards because it is dependent on the availability of maintenance funding. Overall, the most efficient type of repairment can be based on the kind of defects that occurred and a more detailed or special inspection need to be carried out.

The types of maintenance that can be carried out include, for example, rehabilitation for bridges with heavy damage and routine or periodic maintenance for bridges that experience light to moderate defects. On the other hand, the common defect that occurred on the bridges studied was as follows. This recommendation can be taken into consideration by bridges supervisor in making decisions regarding bridge maintenance.

(a) Crack

Cracks in concrete with a width below 0.3 mm (tolerable crack) still do not need epoxy injection. This is due to the fact that corrosive water from rainwater or vehicle splashes still finds it difficult to get into cracks that are less than 0.3 mm; for fractures that are larger than 0.3 mm, the injection approach is more effective. Crack widths above 0.5 mm especially require treatment. These cracks can still be tolerated (hairline cracks) and do not need any treatment.

(b) Honeycombing

Honeycombing in concrete can be caused by various things, such as the viscosity of the casting mix when it is made, which is too runny or thick, and/or the compaction process when casting is less than perfect. Most of the honeycombing that occurred on the five bridges analyzed was only on the surface and did not reveal the reinforcement of the bridge element. The porous concrete found in almost all bridges is in the form of a honeycomb so that it can be handled, among other things, by patching using suitable materials.

(c) Defects on Elastomer

On some bridges, there are torn elastomers, and special inspection is needed for those conditions. On the Kedungrejo Bridge, there is an elastomer experiencing insignificant shifts. Those conditions happen due to less attention to the elastomer position during the installation of plates or girder erection. The solution that can be done is to jack up the girders from both sides of the abutment and then support them with steel plates in the correct position.

(d) Others Minor Defects

Apart from what has been described, there is some minor damage, such as delamination, cracks in expansion joints, corrosion in small areas of reinforcement, and blockage of drainage channels. This minor damage can be handled through regular maintenance. Apart from that, other damage is not analyzed because it is not structural damage, such as the loss of lighting, reflectors, signs, defects on approach rails, and so on.

4. Conclusions

Based on the maintenance priority ranking obtained in this research, BCI UK method can rank bridge maintenance by prioritizing critical or structural elements. By relying on two main aspects (severity and extent) as well as the element importance weight used in the method, bridge condition assessment can be done directly and generate a less complicated analytical procedure. The final condition mark of the bridge expressed in a range of values makes the ranking becomes evident because each bridge has a different value.

5. Recommendation

The UK BCI method only focuses on structural elements, while in setting priorities for handling and optimizing maintenance funds there are actually other aspects that need to be considered, for example traffic and structural capacity. Moreover, assessment of the extent aspect, which is reviewed based on the total quantity of element defect, is also a challenge for surveyors to carry out direct assessments in the field. Nevertheless, this point can make it easier to prepare corrective steps that will be done in the future and suitable for planning maintenance strategy. BCI UK method also still has quite high subjectivity in the severity aspect. Hence, it should be noted that the prioritized bridges require further special inspections to determine the exact structural capacity of the bridges. In order to produce more consistent results, this method can be combined with other methods or developed further. For instance, BCI UK can be combined with Indonesia's Bridge Inspection Guidelines for 2022, which still needs weights for each bridge element.

Acknowledgement

The authors express their gratitude to PT. Jasa Marga Ngawi Kertasono Kediri Toll Road and other stakeholders for providing access to the comprehensive visual inspection reports of the bridge and giving permission for the analysis and results to be applied in this study.

References

[1] M.J., Ryall, "Bridge Management: Second Edition. Butterwoth-Heinemann," The Netherlands, 2009.

[2] R. Al-Rashed, A. Abdelfatah, and S. Yehia, "Identifying the Factors Impacting Bridge Deterioration in the Gulf Cooperation Council," Designs (Basel), vol. 7, no. 6, Dec. 2023, doi: 10.3390/designs7060126.

[3] H. Vaza, R. P. Sastrawiria, H. A. Halim, Septinurriandiani, "Identifikasi Kerusakan & Penentuan Nilai Kondisi Jembatan," Pusat Litbang Jalan dan Jembatan, Kementerian Pekerjaan Umum dan Perumahan Rakyat, Jakarta, 2017.

[4] Costa, G., Zonta, D., Caspani, V. F., Brighenti, F., Limongelli, M. P., & Giordano, P. F., "Bridge management systems: A review on current practice in a digitizing world" 2024. Engineering Structures, https://doi.org/10.1016/j.engstruct.2024.118971 .

[5] S. Darban, H. G. Tehrani, and N. Karballaeezadeh, "Presentation a new method for determining of bridge condition index by using analytical hierarchy process," 2020, doi: 10.20944/preprints 202003.0420.v1.

[6] S. Darban, H. G. Tehrani, N. Karballaeezadeh, and A. Mosavi, "Application of analytical hierarchy process for structural health monitoring and prioritizing concrete bridges in iran," *Applied Sciences (Switzerland)*, vol. 11, no. 17, Sep. 2021, doi: 10.3390/app11178060.

[7] A. Chen, D. Wang, R. Ma, and Z. Pan, "Standardization of life-cycle performance evaluation and application to suspension bridge with multiple pylons," Structure and Infrastructure Engineering, vol. 16, no. 4, pp. 567–582, Apr. 2020, doi: 10.1080/15732479.2019.1662065.

[8] D. M. Mohamed Mansour, I. M. Moustafa, A. H. Khalil, and H. A. Mahdi, "An assessment model for identifying maintenance priorities strategy for bridges," Ain Shams Engineering Journal, vol. 10, no. 4, pp. 695–704, Dec. 2019, doi: 10.1016/j.asej.2019.06.003.

[9] A. S. Wijaya, A. Aminullah, dan A. S. B. Nugroho, "Prioritas Pemeliharaan Jembatan Pada Ruas Jalan Nasional Daerah Istimewa Yogyakarta," Prosiding CEEDRiMS 2021, ISBN: 978-602-361-385-4, available: https://publikasiilmiah.ums.ac.id/xmlui/handle/11617/12684

[10] M. A. Toib, H. A. Syarif, dan P. Lumba, "Penilaian Kondisi Visual Sisa Usia Jembatan Sei Kumu dengan Metode Bridge Conditional Rating," 2024, urnal Taxiway Vol. 3 No. 2 - Juli 2024, e-ISSN :2685-7464

[11] A. Y. Pratiwi, N. Chairunnisa, I. Prasetia, I. F. Radam, R. Nurwidayati., "Bridge Management System dan Bridge Condition Rating pada Evaluasi Kondisi Jembatan Girder Baja Komposit di Kabupaten Tapin," 2023, Buletin Profesi Insinyur 6(1) (2023) 026–031. ISSN 2654-5926.

[12] K. Utami, A. Triwiyono, dan A. Aminullah., "Aplikasi Nilai Kondisi Overpass dengan Metode BCR pada Evaluasi Ekonomi di Ruas Tol Solo - Ngawi - Kertosono KM 503+900 - KM 645+400," 2024, Simposium Nasional Teknologi Infrastruktur

[13] Sumargo, & A.L. Ramdhani, "Comparison of Condition Rating and Bridge Remaining Life Based on Bridge Management System and Bridge Condition Ratio," International Seminar of Science and Applied Technology (ISSAT 2020), 191–196, doi: 10.2991/aer.k.201221.033

[14] Stevens, Nicola-Ann., L. Myra, Cambell, Kristopher, Neeson, Thomas., A.H. Marshall., S.E. Taylor, "Conversion of legacy inspection data to Bridge Condition Index (BCI) to establish baseline deterioration condition history for predictive maintenance models," Civil Engineering Research ibbn Ireland 2020, Pg. 71-76 Available: https://pure.qub.ac.uk/en/publications/conversion-of-legacy-inspection-data-to-bridge-condition-index-bc

[15] M. Taghaddos, Y. Mohamed, "Predicting Bridge Conditions in Ontario: A Case Study," Proceedings of the 36th ISARC, 2019, Pg 166-171, Banff, Canada, ISBN 978-952-69524-0-6, doi: https://doi.org/10.22260/ISARC2019/0023

[16] J. Bennetts, S. R. Denton, G. T. Webb, D. T. Nepomuceno, and P. J. Vardanega, "Looking to the future of bridge inspection and management in the UK," in Bridge Maintenance, Safety, Management, Life-Cycle Sustainability and Innovations - Proceedings of the 10th International Conference on Bridge Maintenance, Safety and Management, IABMAS 2020, CRC Press/Balkema, 2021, pp. 3858–3866. doi: 10.1201/9780429279119-526.

[17] Highway Agency, CSS Bridges Group, "Inspection Manual for Highway Structures, Volume 1:

Reference Manual," London: TSO, 2007, ISBN 978-0 11-5528975.

[18] CSS Bridges Group,"Bridge Condition Indicators: Volume 1: Commission Report," 2002, WSA CJ0089-Vol 1/Issue 3.

[19] CSS Bridges Group, "Bridge Condition Indicators: Volume 3: Evaluation of Bridge Condition Indicators," 2002, WSA CJ0089-Vol. 3/Issue 4.

[20] CSS Bridges Group, "Bridge Condition Indicators: Volume 2: Bridge Inspection Reporting," 2002, WSA CJ0089-Vol. 2/Issue

[21] J. Fang, J. Hu, H. Elzarka, H. Zhao, and C. Gao, "An Improved Inspection Process and Machine-Learning-Assisted Bridge Condition Prediction Model," Buildings, vol. 13, no. 10, Oct. 2023, doi: 10.3390/buildings13102459.