The river flow regime assessment model of bridge condition rating for preventive maintenance program

Juliastuti¹, Oki Setyandito¹, Made Suangga¹, and Djoko Sulistyono²

¹Civil Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480
²Directorate of Bridges, Directorate General of Bina Marga, Ministry of Public Works and Housings, Jakarta, Indonesia

Corresponding author: juliastuti@binus.ac.id; osetyandito@binus.edu

Abstract. Multitude numbers of bridges and barrages are being constructed across innumerous rivers in Indonesia to serve different purposes for the benefit of people. However, some of these bridges are failed due to channel bed degradation and scouring. Bridge scour is one of the main causes of bridge failure. To prevent this condition, it is very crucial to thoroughly understanding the river behavior changes at the upstream and downstream area of bridge and barrage constructions. After that, the proper operation and preventive maintenance of bridges and barrages can be formulated. In this study, we identified the indicator parameters that are associated with hydraulic channel and potentially scour the bridge. The objective of this study is to develop a scouring assessment based on the river flow regime. In the assessment, the structures is the indicators status and the performance of the bridge component which will be measured in order to assess the bridge failures performance, and recommendations are proposed to obtain the results by using visual inspection method. The assessment models is an evaluation of the river regime condition using inspection and other direct measures to determine the effect of river condition related with deterioration. The study result shows that the main component to assess the performance of bridge are hydraulic channel, riverbank, and floodplain. The assessment is conducted at the upstream and downstream area of the bridge.

Keywords: scouring, river flow regime, bridge, deterioration

1. Introduction

Large numbers of bridges and barrages are being constructed across many rivers in Indonesia. However some of them are under poor condition and failed. These failures can be caused by load factors, environmental or natural disaster. The Bridge failure can be resulted from a scour of riverbed sediment near the bridge abutments or piers as shown in Figure 1. To prevent this, we need to analyze the river characters (upstream and downstream area of the bridge construction) and barrages for their proper operation and preventive maintenance. Routine monitoring system for the river condition is a crucial tools to reduce the risk failure. River is a natural water flow or a place to storage the form of water drainage network along with water in it, from upstream to estuary, with restricted right and left by a line of separation [1]. River is the combination of river stream and water flow [2].
The assessment in this study is specifically to assess the river flow regime. This assessment river regime is considered to be a tool to evaluate the bridge performance related with its safety. The development of the river flow regime assessment and monitoring has been described in The Element Hierarchy and Bridge Failure Related with River Flow Regime Assessment [10]. The research of assessment resulted in water condition and water depth surrounding floodplain, riverbank and bridge structure is the main component for survey and inspection [2].

The objective of the research is to prepare the assessment model to evaluate the river condition that related with the deterioration of bridge structure. Several methods of assessing the river have been conducted based on Indonesian regulations. The goal of this research is to develop an inspection manual for bridge managers to measure and assess the performance of a river at the upstream and downstream of the bridge structure.

Assessment of river condition is powerful tool to evaluate the initial condition before the river restoration [1]. The bridge components that were being assessed in this study are refer to the Standard of Bridge Component in the Bridge Management System (BMS) which published by Directorate of Bridges, Directorate General of Bina Marga, Ministry of Public Works and Housings, Jakarta, Indonesia. This study is conducted through field investigation to get the main component of river regime in order to assess its performance.

2. Methods
2.1. Parameters in River Flow Assessment

Bridge scour is the removal of soil around the foundation of bridge due to the flowing water, may happen around the foundation of bridge at pier or abutment. These conditions can be identified mainly in three forms: long-term aggradations and degradation which includes long-term changes in the streambed elevation of river caused by erosion and deposition of material, general scour which is due to the removal of material from bed and banks of the channel, and finally local scour which involves the removal of material from around piers and abutments [6]. Another research mentioned that, one of the main natural risks to river crossings is scour of the riverbed. Scour may expose the foundations of bridges or other infrastructure, or buried assets, making them vulnerable to failure causing undesirable social, operational and environmental impacts. Tafarojnoruz et. al. [8], applied the framework and methods to develop a probabilistic scour risk assessment using fragility curves to account for uncertainty in input variables, prediction methods and performance of structures. Understanding the risks associated with possible movements of the riverbed, both in the vertical and lateral directions, is fundamental to provide an evidence base to define future management actions and strategies. The analysis includes the assessment of existing protection works, such as bed sills, and their impact in reducing the risk of scour. The design formula recommended by the Federal Highway Administration Hydraulic Engineering Circular No.18 (2001) with many important parameter influenced. The development study obtained an empirical formula based on a set of experimental tests and evaluates the scour depth deterministically using a number of parameters, such as stream flow discharge rate, streambed condition, and shape of river.

2.2. Framework for Assessing River Flow Regime of Bridge Performance

Frameworks are used widely in many disciplines as a means to organize ideas, understand bridge system, and identify cause and failure, and to link and guide decisions about Bridge Management System (BMS) (Fig.2). Data are collected from a number of sources (primarily from periodic bridge inspections) and are transferred to a large database. A sophisticated analysis of the data is performed. This generates
prioritized lists of candidate projects, optimizes bridge replacement and maintenance strategies for various available funding and resource scenarios, predicts the deterioration of bridges over time, allows managers to evaluate different management options, and, in general, provides powerful decision-support tools to help formulate the best program for bridge management. The systems that have already been implemented have been a tremendous benefit to decision-makers.

The purpose of a comprehensive bridge management system is to provide bridge engineers with a tool managing bridge systems under the condition of imbalance between bridge repair and replacement needs and available fiscal resources. The core of system consists of condition rating assessment, bridge traffic safety evaluation, ranking and optimization. Bridge condition ranking is one of the key parameters that used in determining the types of repair necessary for a bridge. The usefulness of BMS depends upon the reliability and accuracy the bridge inspection information. The current bridge inspection practices, however, suffer from three inherent shortcomings [7]:

1. The parameters in bridge inspection is not completely defined or cannot be precisely measured;
2. Personal judgment bias and not subjective are often included but not systematically accounted for in the evaluation process;
3. There is a lack of guidelines establishing the relationship between the extent of deterioration and the assignment of value condition rating.

The purpose of the condition assessment module was to filter the field inspection data of any inconsistencies before entering the BMS. Information available to bridge inspectors as the structural condition is generally imprecise and often can be separate into subjective and objective component [4]. The objective component concerns measurable, countable or quantitative information. The subjective components, on the other hand, include intangible or qualitative information such as judgment and experience of bridge inspector.

3. Result and Discussion

BMS in Indonesia comprises of planning/programming, feasibility study, design, construction, operation and maintenance. In the bridge condition inspection procedure, the first step for bridge rating, the component of bridge will evaluated by parameter evaluation (see Table 1).
| Parameter evaluation | Criteria | Rating |
|-----------------------|----------|--------|
| S (structure)         | Are the defect harmful or otherwise? | 0 1 |
| R (rating)            | What is the level of defect, severe or mild? | 0 1 |
| K (quantity)          | Is the defect extensive (widespread) or localized? | 0 1 |
| F (function)          | Do these elements still function? | 0 1 |
| P (effect)            | Whether the defects seriously affect other elements or traffic flow? | 0 1 |

Bridge Rating: \( Br = S + R + K + F + P \) 0 5

Bridge element consist of two major element of river flow/embankment and under bridge element. In the first major element, the evaluation of the river flow or embankment element is including river flow characteristics, river bank protection and embankment performance. River flow characteristics consist of riverbank, river flow and floodplain condition with a failure types of silt, trash/inhibited water, scouring and river flow. The types of riverbank protection includes krib, gabion and mattresses, concrete retaining wall, rip rap, sheet pile, fender system, retaining wall, and river bed protection. The absence of the riverbank protection is categorized as failure. In under bridge element, the assessment consist of foundation and piers structure condition. Foundation types of bridges are pile, pier foundation, well foundation and drilled shaft foundation. As for the Piers structure, the types are piers, retaining wall and retaining drainage. Both foundation and piers structure determine as fail where movement occurs. Each bridge element (see Table 2) is individually assessed with the same parameter evaluation parameters up to the highest hierarchy element of the bridge as a whole unit.

Table 2. The element hierarchy and bridge failure related with river flow regime assessment

![Diagram of the element hierarchy and bridge failure related with river flow regime assessment](image-url)
Table 3. Value of bridge condition rating

| Score | Element / Bridge Condition                        |
|-------|--------------------------------------------------|
| 0     | good condition and without damage                |
| 1     | minor damaged, only require routine maintenance  |
| 2     | damage that requires monitoring or periodic maintenance |
| 3     | damage that requires immediate action            |
| 4     | in critical condition                            |
| 5     | not functioning or collapse                      |

At the end of the procedure, the bridge will be categorized based on the bridge performance. The condition of bridge is rating from 0 to 5. It is based on the approach of level of failure of bridge, so when the element of bridge in good condition and without damage, it rates with 0 (zero). The highest rate of 5 is when the bridge is not functioning or the bridge is collapse (Table 3). The framework for assessing river flow regime of bridge performance can be used to monitor and analyze the river condition that affected the bridge (Figure 3). The bridge condition rating provides information on prevention programs in the future. (Figure 4).

4. Conclusion
In the first major element, the evaluation of the river flow or embankment element is including river flow characteristics, river bank protection and embankment performance. River flow characteristics consist of riverbank, river flow and floodplain condition with a failure types of silt, trash/inhibited water, scouring and river flow.

The types of riverbank protection includes krib, gabion and mattresses, concrete retaining wall, rip rap, sheet pile, fender system, retaining wall, and river bed protection. The absence of the riverbank protection is categorized as failure.

In under bridge element, the assessment consist of foundation and piers structure condition. Foundation types of bridges are pile, pier foundation, well foundation and drilled shaft foundation. As for the Piers structure, the types are piers, retaining wall and retaining drainage. Both foundation and piers structure determine as fail where movement occurs. The bridge condition rating is important to provide prevention programs in the future.

Acknowledgements
The authors are grateful to Directorate General of Higher Education, Ministry of Research and Technology, Indonesia for the funding support.

References
[1] Thomas, A.H., Dustin, E., L., Robert, L.B., Jeffrey, S.C., (2007). *Hydraulic Survey and Scour Assessment of Bridge 534, Tanana River at Big Delta, Alaska*. Virginia: Scientific Investigation Report 2006-5282, USGS
[2] Taylor J. D., Richard J. H., Ryan L. F., (2017). *Bridge Scour Countermeasure Assessments at Select Bridges in the United States*. United States: Scientific Investigation Report 2017–1048, USGS
[3] Agus H.W., Suripin, Suhrayanto, (2017). River Performance Assessment Model. *Procedia Engineering*, 171 (2017) 1505 – 1513. DOI: 10.1016/j.proeng.2017.01.482/(Elsevier) CC BY-NC-ND.
[4] Peggy, A.J., (2006), *Assessing Stream Channel Stability at Bridge in Physiographic Regions*. Publication of FHWA-HRT-05-072
[5] K.c. Sinha, M.D. Bowman, Y. Jiang, S. Murthy, M. Saito, (1990). Emerging Methodologies For Bridges Management Systems. *Proceedings of the NATO Advanced Research Workshop on Bridge Evaluation, Repair and Rehabilitation*, 23. DOI: 10.1007/978-94-009-2153-5
[6] Alipour A., Shafei B., 2012. Performance Assesment of Highway Briges under Earthquake and Scour Effects.15 WCEE, Lisboa.
[7] Tee, A.B., Bowman, M.D. and Sinha, K.c. (1989), "A System for Bridge Structural Condition Assessment," Report No. FHWA/NJHRP-89-9, Joint Highway Research Project, School of Civil Engineering, Purdue University, West Lafayette, Indiana.
[8] Tafarojnoruz. A., Gaudio R., Calomino. F. 2012. Evaluation of Flow-Altering Countermeasures against bridge pier scour. *Journal of Hydraulic Engineering*. Vol 138 (3). 297-305
[9] Federal Highway Administration-US Department of Transportation. [https://www.fhwa.dot.gov/policy/2006cpr/](https://www.fhwa.dot.gov/policy/2006cpr/)
[10] Bridge Management System, Bina Marga, 2018. Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia.