Generating Historical Condition Ratings for the Reliable Prediction of Bridge Deteriorations

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Summary

Bridge Management Systems (BMSs) have been developed since the early 1990s as a decision support system (DSS) for effective Maintenance, Repair and Rehabilitation (MR&R) activities in a large bridge network. Historical condition ratings obtained from biennial bridge inspections are major resources for predicting future bridge deteriorations via BMSs. However, available historical condition ratings are very limited in all bridge agencies. This constitutes the major barrier for obtaining reliable future structural performances. To alleviate this problem, the Backward Prediction Model (BPM) technique for generating the missing historical condition ratings has been developed, and its reliability has been verified using existing condition ratings available from the Maryland Department of Transportation, USA. The function of the BPM is to establish the correlations between the known condition ratings and non-bridge factors including climate, traffic volumes and population growth. Such correlations can then be used to obtain the bridge condition ratings of the missing years. Based on these generated datasets, the current bridge deterioration model can predict future bridge conditions. The existing 4 National Bridge Inventory (NBI) and 9 BPM-generated historical condition ratings were used as input data to compare the prediction accuracy using deterministic bridge deterioration models. The comparison results showed that prediction error decreased as more historical data became available. This suggested that the BPM can be used to generate additional historical condition ratings, which are essential for bridge deterioration models to achieve more accurate prediction results. However, there are still significant limitations identified in the current bridge deterioration models. Hence, further research is necessary to improve the prediction accuracy of bridge deterioration models.

Keywords: Maintenance, Repair and Rehabilitation (MR&R); Bridge Management Systems (BMSs); Bridge condition ratings; Backward Prediction Model (BPM); Non-bridge factors; Bridge deterioration model.

1. Introduction

This paper presents a research study conducted in an attempt to improve long-term predictions of the BMSs. Firstly, a set of missing historical bridge condition ratings was generated using the neural network based Backward Prediction Model (BPM). Deterministic deterioration models were then employed based on complete historical condition ratings obtained from the results of BPM. The future bridge condition ratings predicted by these models were then compared with the existing bridge data to determine the level of prediction accuracy.

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2. Backward Prediction Model (BPM)

The BPM predicts the selected or entire periods of historical bridge condition rating to overcome the lack of existing BMS condition ratings. The function of the developed BPM is to establish the correlation between the known condition ratings and non-bridge factors including climate, traffic volume and population growth. Such correlation can then be used to obtain the bridge condition ratings of the missing years.

3. Comparison of BPM results with National Bridge Inventory

To carry out the backward comparison, 5 sets of existing NBI data were used in this study as BPM training inputs and outputs (from 1996 in 2-year increment to 2004) to generate historical condition ratings for the periods of 1968 to 1994 in 2-year increments. All the prediction errors derived from the BPM using 6 refined non-bridge factors are less than those obtained from using the original 21 non-bridge factors. This prediction accuracy improvement could be attributable to the elimination of irrelevant factors, which cause the noise level that existed in the original set of factors. The BPM with refined non-bridge factors was therefore used in the subsequent research stage.

4. Current bridge deterioration models

The current bridge deterioration models can be categorised as deterministic, stochastic and artificial intelligence. This paper focuses on the first two types of the model as they are prevalent in many BMSs currently in use worldwide. Among the deterministic models, regression analysis is a method widely used in many bridge management systems. As for stochastic technique, Markovian model is considered as the most common of this category. However, the Markovian model is not suitable for the NBI. Thus, only regression analyses were used in the current study to predict future bridge conditions based on generated historical data from the BPM methodology.

5. Comparison of deterioration models

Comparisons of prediction error were carried out by using 4 existing NBI records and 9 BPM-based generated condition ratings, for both linear and non-linear regression techniques. In case of linear regression, the average error of 33.3% from the prediction using 4 NBI records decreases to 7.0% when using 9 generated condition ratings. Similarly for the case of non-linear regression, the prediction error decreases from 25.6% to 9.0% when the number of input datasets increases. This finding indicated that, in deterministic models, the historical data generated by the BPM technique could contribute to the improvement of prediction accuracy.

6. Discussion and Conclusion

Using BPM to generate more historical condition data could contribute to improved prediction of future bridge conditions because prediction error became smaller as more input data obtained. These finding, however, should be interpreted in light of the following main limitations of the deterministic deterioration models employed in this paper: (1) their prediction is based only on an average condition of a bridge structure with no regard to the variability of condition rating distribution in each year; and (2) they disregard the interaction between the different bridge structure elements. Further research is required to address such limitations and should aim to develop a more robust deterioration model that fully exploits the benefits of BPM-generated historical condition records.