MAINTENANCE PRIORITIZATION OF ROAD BRIDGE ELEMENTS USING ANALYTIC HIERARCHY PROCESS AND LINEAR AGGREGATION

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1. INTRODUCTION

Nowadays, road bridge asset management, including maintenance, is a popular topic around the world. The importance of bridge maintenance is also growing in Lao PDR, as approximately 70% of bridge were constructed during the era of the Soviet Union. Due to the aging and deterioration, it is necessary to maintain and repair many bridges in Lao PDR, but the Ministry of Public Works and Transport (MPWT) has allocated just 1% of the road budget (approximately 1 million USD) to maintaining bridges, including inspection and surveying. Unfortunately, most of the bridge maintenance budget is spent on emergency maintenance cases. Due to the limited budget, MPWT is developing a bridge management system that will help their organization optimally and efficiently manage the bridge maintenance budget.

This research aims to contribute to rational bridge management in Lao PDR by exploring prioritization methods for bridge maintenance activities. In this research, the analytic hierarchy process (AHP) and linear aggregation method (LAM) are used to calculate the maintenance prioritization at the element level for 20 bridges in Luang Prabang Province, Lao PDR.

2. METHODOLOGY

2.1. Sample

The 20 bridges on National Road number 13 Northern in Luang Prabang province were selected for this study. Due to data limitations, prioritization was based on just four criteria: element importance (B1), element condition (B2), age (B3), and maximum loading on the structure (B4). For B1, four bridge elements are focused on (girder, beam, pier, and footing), and these are separated into three different importance levels (1 to 3) according to degree to which they are affected by traffic loading (Paeglite et al., 2016). B2 was evaluated on five levels of condition rating, which were obtained by inspection (1 to 5). B3 evaluated the age using five different classifications, with older having higher priority, and B4 also used five classifications to evaluate the loading on the overall structure (Paeglitis and Paeglitis, 2010).

2.2. Analysis

AHP and LAM were used to determine the maintenance priority of the bridge elements. AHP is one type of Multi-Criteria Decision Making (MCDM) that can be used to understand and evaluate a complex decision-making problem by using a pairwise comparison matrix, and many researchers propose this method as an easy and useful approach to decision-making. AHP structures the decision-making problem using at least three levels: target or goal at the first level; evaluation criteria at the second; and the decision alternatives at the third. The weight of each criterion can be based on the perception and opinion of the decision-maker using a qualitative pairwise comparison scale (Saaty, 1994). In this research, AHP is used to find local criterion weight in five prioritization scenarios: equal importance, and B1, B2, B3 and B4 each given strong importance over the other criteria. The stepwise equation is given below (Suthanaya, and Artamana, 2017).

Pairwise comparison matrix: $B_{ij} = w_i / w_j$ (1)

Reciprocal number: $B_{ji} = 1/B_{ij}$ (2)

Local weight of criteria i: $W_i = \frac{\left(\prod_{j=1}^{n} B_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} B_{ij}\right)^{1/n}}$ (3)

Where B_{ij} is the pair-wise comparison matrix, w_i and w_j are the relative importance of criteria i and j respectively.

Linear aggregation was used to calculate the priority of the bridge elements using the characteristics of the elements and the weights from the five different weightings scenarios, as shown in Eq. (4) (Yager, 2008). Before beginning linear aggregation, however, the data normalization was performed to rescale the data to a scale of 0 to 1.

Linear aggregation method: $LAM = \sum C_i \times W_i$ (4)

Where C_i is the criteria data (B1, B2, B3, and B4), and W_i is the local weight of all criteria from AHP in five scenarios as equally important and B1, B2, B3 and B4 are strong important weighting than other criteria.

3. RESULTS AND DISCUSSION

3.1. Calculation of weights using Analytic Hierarchy Process

The result of AHP is shown in Figure 1 which represented the local weight of criteria in five different weighting by using a pairwise comparison matrix as equal weight (scenario 1), B1 strong important (scenario 2), B2 strong important (scenario 3), B3 strong important (scenario 4) and B4 strong important (scenario 5). As Figure 1 indicates that in scenario 1 the local weight of the criterion is the same weight as 25%. For scenario 2, scenario 3, scenario 4, and scenario 5, the highest local weight is 62.5% for B1, B2, B3, and B4, respectively. Other local weights of criteria are 12.5%.

Keywords: Maintenance Prioritization, Bridge Elements, Pair-Wise Comparison, Linear Aggregation
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3.2. Prioritization by Linear Aggregation Method

The results of LAM are illustrated in Figure 2 for the four bridge elements under the five scenarios for all 20 bridges. As LAM results ranged between 0 and 1, higher values indicated a higher priority, and lower values indicated a lower priority.

Figure 2 shows that the girder in bridge number 1 has the first ranking for bridge element maintenance prioritization in scenario 1, scenario 2, scenario 4, and scenario 5. However, for scenario 3 this bridge element ranked 2nd and the pier and the footing were the first rankings for bridge elements priority. For bridge number 2 to bridge number 20, all 5 scenarios' results had the same bridge element priority starting from the highest to lowest ranking as the girder, beam and pier, and footing respectively.

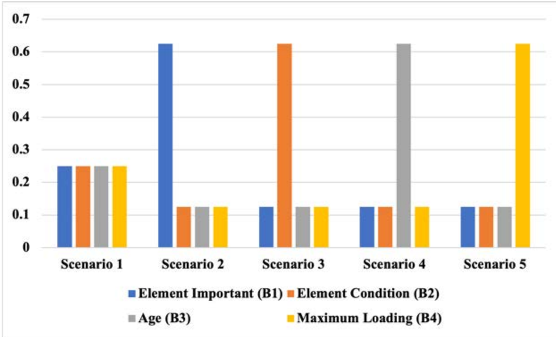

Figure 1. Pairwise comparison results

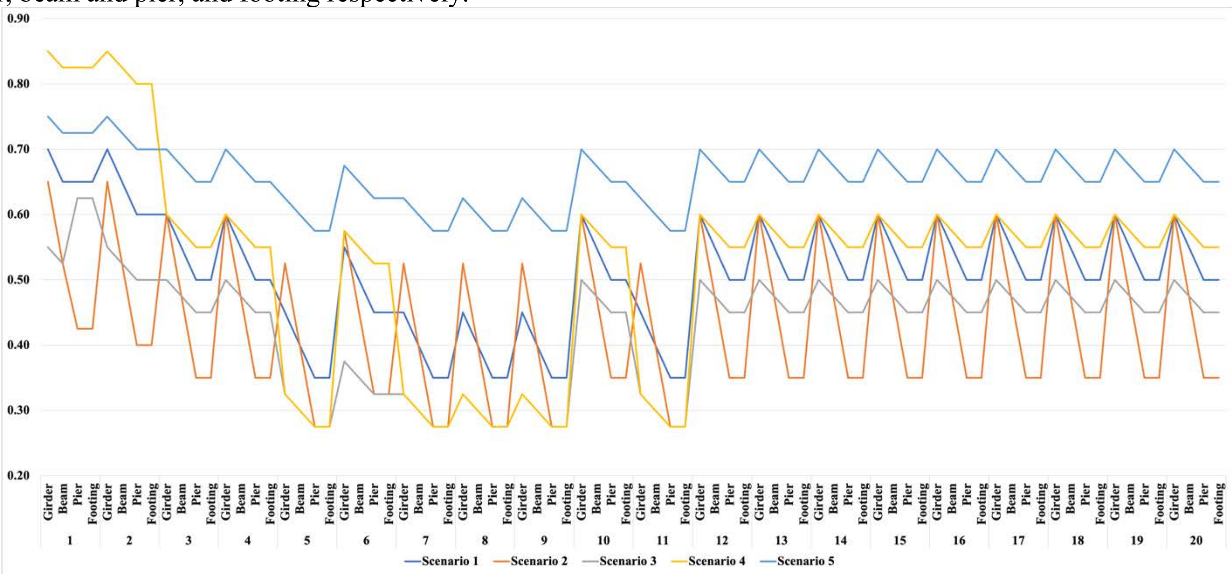

Figure 2. Bridge elements prioritization results

As LAM results on bridge number 1, scenario 3 is a very different output from other scenarios shown on the pier, and the footing is the first ranking of the bridge element maintenance prioritization. That case means the element condition (B2) is the most critical criterion in bridge number 1 because of all 5 scenarios were analyzed with the same value of bridge elements except only important weighting.

4. CONCLUSION

This research was carried out to develop a method for bridge element maintenance prioritization based on the data currently available for the road bridge elements. Two different types of MCDM technique - Analytic Hierarchy Process and Linear Aggregation Method - were combined and applied to calculate the bridge element's maintenance prioritization. The result of this study found bridge element's condition was more important than other criteria in scenario 3. This research will help determine the optimal order for maintaining bridge elements and will support the rational bridge management in Lao PDR.

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