論　文　要　旨
Thesis Abstract

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主論文題名　（Title）

Quantification and treatment of uncertainties in repair prioritization for the maintenance management of road bridges

内容の要旨　（Abstract）

Road bridges are essential components of a country's infrastructure and economy. As cities grow, especially in developing countries, the demand for road bridges increases. However, the challenge lies in managing and maintaining these structures effectively due to limited resources. Bridges can suffer from various types of damage, affecting different elements and components. This makes inspections subjective and introduces uncertainty. The literature identified three primary sources of uncertainties which are uncertainties in human input, methodological uncertainty, and future physical changes. To address these challenges, statistical and mathematical approaches have been developed for quantifying uncertainties. Existing studies include reviews of bridge inspection documents and methodological uncertainty quantification using techniques such as the Analytic Hierarchy Process (AHP). However, there is limited empirical research focusing on the role of human input in bridge inspections and evaluating its impact on results. Moreover, a research gap remains due to the lack of studies that integrate quantified uncertainties from both human input and methodology. Addressing these uncertainties requires a practical approach that combines empirical investigation with robust analytical techniques.

Therefore, this research aims to achieve three main objectives: (1) to create a statistical approach for measuring the uncertainty associated with human input in visual bridge inspections; (2) to design statistical methods for multi-criteria decision analysis to assess uncertainties in methodologies used for prioritizing bridge maintenance; and (3) to combine the quantified inspection data derived from human input with the improved methodology into a practical framework for prioritizing bridge maintenance.

To achieve the first objective, the study evaluated and compared translated visual inspection data into comprehensive damage grades, element, component, and span health index identified by expert and groups of trainees to assess uncertainty in human inspection. Additionally, it proposes the application of bootstrapping to observe the degree of difference between expert and trainee assessments. The findings suggest that bridge inspection data collected by groups of trainees may be overestimating the health of the bridge elements and spans, which introduces uncertainty and potentially affects the accuracy of subsequent analyses.

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The second objective is to develop statistical methods to evaluate methodological uncertainties in bridge maintenance prioritization. Literature reviews indicate various quantification methods for assessing uncertainty in methodology, but this research focuses on the MCDA framework. This study closely observes the sum-weighted formula of bridge maintenance prioritization in the Ministry of Public Works and Transport of Lao PDR (MPWT), focusing on five criteria including element health index, importance of elements, road importance, motorized traffic index, and regional economy. The research applies the MCDA framework to quantify the uncertainties starting from selection indicators, weight indicators, and aggregation methods. After that, combine all indicators by simultaneous method, to calculate the average bridge rankings and standard deviations. The research also conducted the variance decomposition to quantify the effects of methodological uncertainties on the prioritized maintenance rankings. After 52 simultaneous theoretical scenarios, the weight indicators have the highest total effect of uncertainties, followed by selection indicators that require addressing.

The final objective of this research is to integrate both quantification of uncertainties in human input and methodological uncertainty to support decision-makers in bridge maintenance prioritization. The study carried on the results of the first objective to find the actual value of the element health index by using a polynomial regression method. The adjusted element health index is considered and replaced as the previous selection indicator of criteria. For weight indicators, the research employs three practical weight schemes from the second objective. Subsequently, the refined indicators are applied to the calculation as proposed in the second objective. The research findings indicate that selection and weight indicators are sources of uncertainties. It is evident that when comparing bridge rankings from existing and quantified methodology confirms the presence of uncertainties. The existing methodology risks producing inaccurate rankings, potentially overlooking critical bridges in urgent need of repair. Therefore, the use of quantified uncertainty in human input and methodology uncertainties may help to reduce uncertainties in bridge maintenance prioritization.

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