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RISK-BASED LIFE-CYCLE MANAGEMENT OF DETERIORATING BRIDGES

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PROJECT TITLE
RISK-BASED LIFE-CYCLE MANAGEMENT OF DETERIORATING BRIDGES

FINAL REPORT
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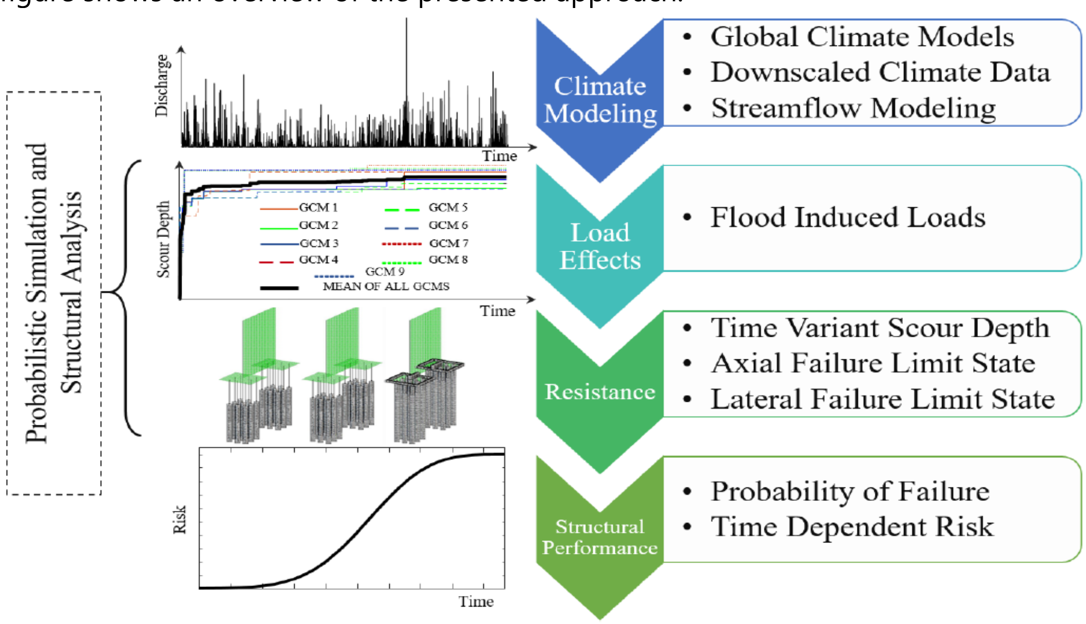
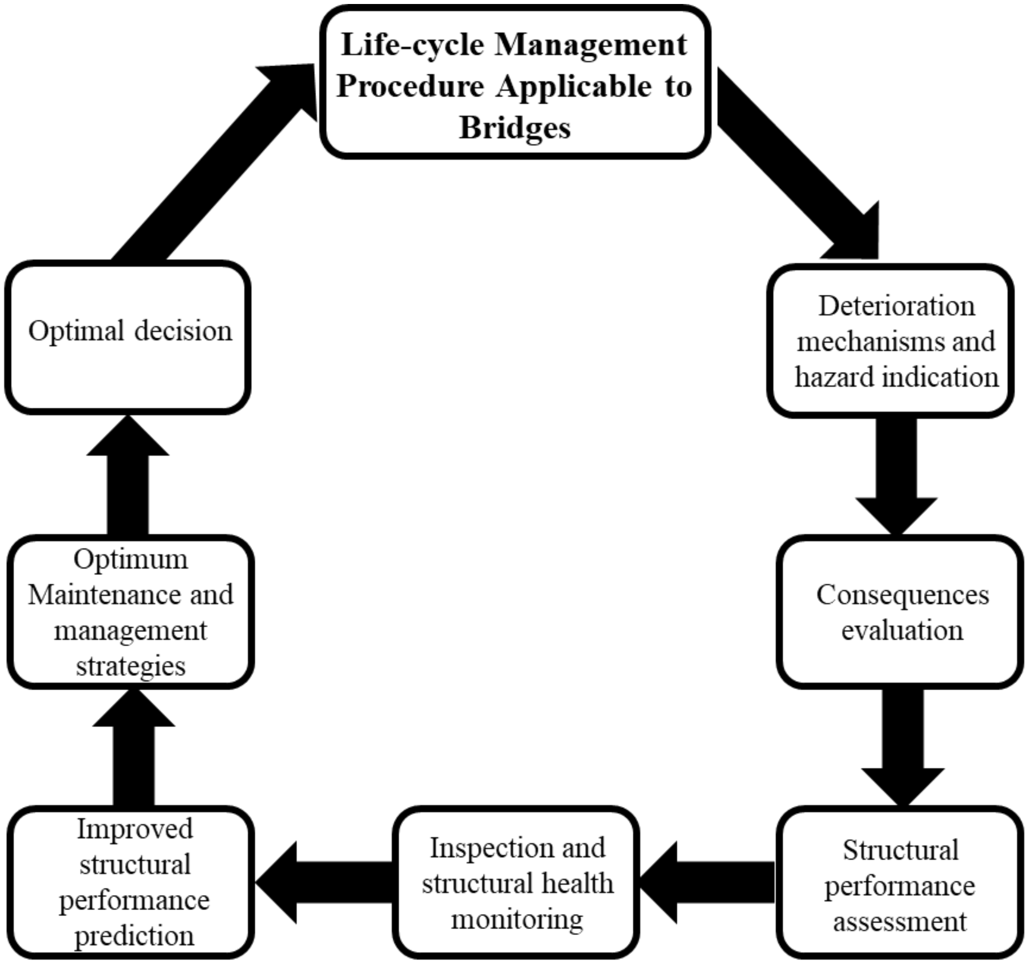
OVERVIEW Bridges are recognized as key components in ground transportation systems. These structures are vulnerable to several deterioration mechanisms which may cause gradual deterioration or sudden failures. These mechanisms can cause a significant drop in the transportation system functionality leading to severe economic and social impacts. Natural hazards (e.g., floods and earthquakes), environmental stressors (e.g., corrosion), and man-made extreme events (e.g., blast explosions and fires) are recognized as the main sources that drive bridge deterioration. Since some of these hazards (e.g., corrosion and floods) may be related to long-term climate behavior, climate change can significantly affect the performance of bridges under these hazards. Quantifying the uncertainties associated with different hazards and deterioration mechanisms should be included in maintenance planning while considering effects of climate change. Furthermore, an optimized maintenance planning to minimize the direct (e.g., structural rehabilitation costs) and indirect costs (e.g., traffic delays and environmental effects) should be performed with climate change in mind.

RESULTS This study presents a probabilistic framework for risk assessment of bridges under flood and flood induced scour considering climate change. The flood and streamflow prediction are performed using Global Climate Models. The downscaled precipitation and temperature climate data are adopted from the Coupled Model Inter-comparison Project Phase 5 (CMIP5) archive for the location of interest during the time span of 1960 to 2100. Time-dependent scour depth is quantified and its effect on the axial and lateral capacity of the bridge foundation is evaluated. The following figure shows an overview of the presented approach.



The annual point-in-time failure probability of the bridge due to flood-induced loads is used to predict the cumulative failure probability profiles of the bridge. After evaluating the consequences associated with bridge failure, the time variant bridge risk profile is established. This study also presents probabilistic approaches capable of optimizing maintenance activities of deteriorating bridges while considering climate change, direct maintenance costs, and indirect impact arising from maintenance and repair actions. Uncertainties associated with the various stages of the life-cycle management are provided. The presented framework is illustrated through case study considering the South Bound I-35 Bridge over the Red River. The data analysis for the investigated location has shown that precipitation events have become increasingly variable and indications of wetting months shifting further from normal has been observed. For the investigated location, the RCP 2.6 associated with each model predicts the highest scour depth, while the 8.5 RCP values predict the lowest scour depth profiles. The time-variant scour depth significantly depends on the adopted climate scenarios. A variation of 45% in the final scour depth predicted using different climate scenarios has been observed at the studied location. Accordingly, a probabilistic approach considering potential scenarios is necessary to properly quantify the risk of bridge failure due to flood and flood-induced scour hazards.



In addition to the impacts on flood hazard occurrence and scour progression, climate change could also affect the corrosion propagation rate in structural components due to the change in carbon dioxide concentration, temperature, and humidity at a given location. These changes may occur due to carbonation or chloride penetration to steel reinforcement. Specifically, the increase in temperature profiles increases the material diffusivity and consequently increases the corrosion rate in reinforcement.

The infrastructure decision making process is generally affected by the strict budgetary constraints and limited resources available for maintenance and repair operations. Therefore, using optimization techniques could result in achieving appropriate and efficient life-cycle management solutions. These techniques are capable of providing a balance between conflicting life-cycle management criteria (e.g., total maintenance cost and expected service life). Optimization techniques can provide the optimal management activities as the solution of an optimization problem that simultaneously minimizes the life cycle costs and maximizes expected life-cycle management cost. An efficient framework for life cycle management should consist of modules for performance prediction under single or multiple hazards, intervention optimization, reliability and cost-informed decision making.

POTENTIAL BENEFITS The presented approach based on climate models provides a rational prediction of future risk while properly accounting for uncertainties associated with future climate and flood conditions. The proposed risk quantification approach can be integrated into an optimization framework to establish the optimum maintenance solutions which minimize the total life-cycle cost of the bridge under investigation and maximizes its service life.