MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 24-531 (project 676) | August 2024

Optimal Selection of Upgrade and Maintenance Interventions to Minimize Life-Cycle Cost

the ISSUE

The maintenance and upgrade of infrastructure and buildings are critical for ensuring their performance and safety. However, inadequate planning and budget allocation often result in delayed maintenance, leading to performance problems and costly interventions.

the RESEARCH

This study presents two novel models. The first focuses on bridges and uses machine learning techniques to predict the condition of concrete bridge elements based on the National Bridge Inventory (NBI) and National Bridge Elements (NBE) databases. The model uses binary linear programming to identify the optimal selection of maintenance interventions and their timing to maximize bridge performance. The model's primary contributions are the development of a novel system that integrates machine learning techniques and linear programming, predicting bridge element conditions based on NBE's health index metric, and generating long-term maintenance plans to maximize the performance of bridges within available budgets. The second model focuses on buildings and proposes a computationally efficient model for identifying optimal upgrade and maintenance interventions to minimize the equivalent annual operation and maintenance cost (EAOMC) while complying with specified annual budgets and building operational performance. The model integrates reactive, preventive, and predictive maintenance strategies based on component types and incorporates a simulation-based approach to evaluate buildings' energy and water consumption. The model's primary contribution is the integration of maintenance and upgrade interventions to maximize economic benefits and reduce operational and maintenance costs.

MOUNTAIN-PLAINS CONSORTIUM REGION 8

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South Dakota State University
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Project Title

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the FINDINGS

Results show the developed models can assist decision-makers, such as highway agency staff and building owners, in allocating limited financial resources for maintenance more efficiently and cost-effectively. The proposed approach can lead to significant economic and environmental benefits by reducing the life-cycle cost of bridges and buildings while ensuring their performance, safety, and sustainability.

the IMPACT

The research has significant implications in terms of cost and performance. By integrating machine learning and binary linear programming, the models can predict the condition of concrete bridge elements and select optimal maintenance actions to maximize performance within budget constraints. For buildings, the model identifies upgrade and maintenance plans that minimize the EAOMC while adhering to specified budgets and performance criteria. These innovations can lead to substantial cost savings; for example, optimal maintenance and upgrade interventions for buildings can save operational costs by up to 50% over a 20-year study period.

For more information on this project, download the Main report at https://www.ugpti.org/resources/reports/details.php?id=1195

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.