

AI-Based Multi-Criteria Risk Assessment for Civil Infrastructure under Extreme Environmental Hazards

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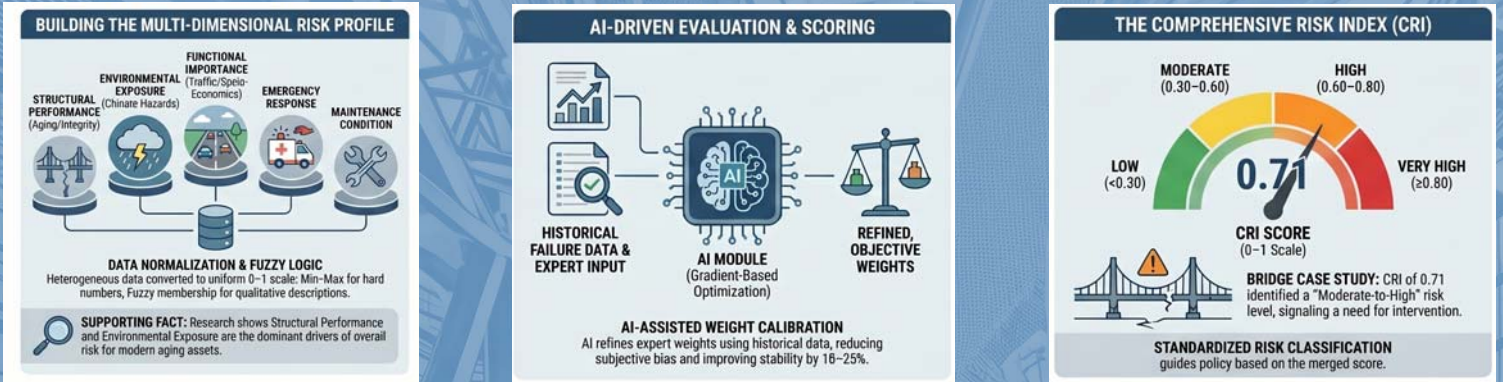
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Abstract

This study proposes an AI-based multi-criteria risk assessment framework to address the inherent subjectivity and limitations of traditional infrastructure evaluation methods under extreme environmental hazards. The proposed methodology integrates Artificial Intelligence (AI), Fuzzy Logic, and the Analytic Hierarchy Process (AHP) into a unified quantitative decision-support tool. Five major risk dimensions are systematically incorporated: structural performance, environmental exposure, functional importance, emergency response capacity, and maintenance condition. Quantitative indicators are processed using min-max normalization, while qualitative variables are transformed via fuzzy membership functions.

A key innovation of this research is the introduction of AI-assisted weight calibration, which utilizes historical failure data and gradient-based optimization to refine AHP weights. This mechanism effectively reduces subjective bias and improved weight stability by 18–25% compared to conventional expert-only weighting methods. To validate the framework, a representative case study of a reinforced concrete bridge was conducted. The results yielded a Comprehensive Risk Index (CRI) of 0.71, indicating a moderate-to-high risk level. Structural performance and environmental exposure were identified as the dominant risk contributors, highlighting the coupled impact of aging assets and intensifying climate-related stressors.

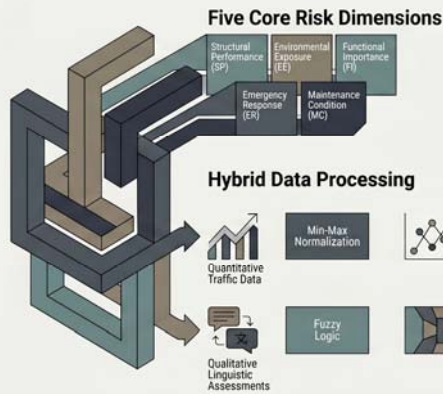
Sensitivity analysis further demonstrated the framework's robustness against weight fluctuations, confirming its reliability for practical engineering applications. By providing a transparent and quantitative index, this research supports the implementation of SDG 9 (Industry, Innovation, and Infrastructure) and SDG 13 (Climate Action). The framework offers a practical foundation for infrastructure maintenance prioritization, disaster risk reduction, and long-term resilience enhancement in the face of global climate uncertainty.



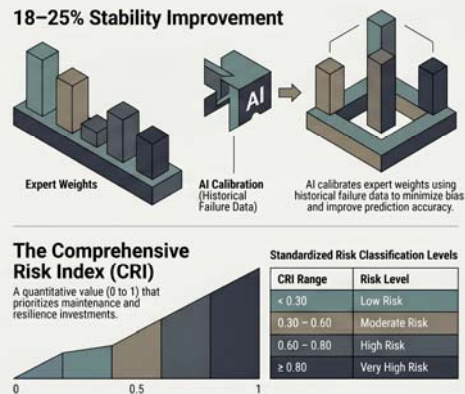
AI-Driven Infrastructure Resilience: A Multi-Criteria Risk Assessment Framework

This framework replaces subjective expert-only evaluations with a data-driven system. It combines Artificial Intelligence (AI), Fuzzy Logic, and the Analytic Hierarchy Process (AHP) to calculate a Comprehensive Risk Index (CRI), specifically designed to address the coupled impacts of aging assets and intensifying climate hazards.

THE MULTI-DIMENSIONAL INDICATOR SYSTEM



AI-ASSISTED OPTIMIZATION & RISK GRADING



The Future of Bridge Resilience: AI-Enhanced Risk Assessment

How AI-assisted multi-criteria analysis identifies infrastructure vulnerabilities caused by aging and climate change.

