AFRICAN CIVIL ENGINEERING JOURNAL
Vol. 1 | No. 1 | 2023 | 10.5281/zenodo.18969521

A Comparative Bayesian Hierarchical Model for Municipal Infrastructure Risk Reduction in Ethiopia: 2000–2026

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Received: 05 April 2023 | Accepted: 13 May 2023 | Published: 06 July 2023 | **DOI:** 10.5281/zenodo.18969521

ABSTRACT

Background: Municipal infrastructure systems in developing nations face significant challenges from ageing assets, population growth, and climate stressors. Traditional risk assessment methods often lack the flexibility to integrate sparse, multi-source data and quantify uncertainty for long-term planning.

Purpose and objectives: This study aims to develop and evaluate a novel comparative Bayesian hierarchical model for quantifying risk reduction across diverse municipal infrastructure asset systems. The objective is to provide a robust, probabilistic framework for prioritising interventions and forecasting future risk trajectories.

Keywords: *Bayesian hierarchical modelling, municipal infrastructure, risk reduction, Sub-Saharan Africa, comparative study, asset management, climate resilience*

Article Highlights

- Bayesian hierarchical model enables comparative risk analysis across diverse infrastructure assets.
- Framework synthesizes sparse, heterogeneous data for robust probabilistic forecasting.
- Projected divergence in risk profiles informs strategic intervention prioritization.
- Method provides statistically rigorous uncertainty quantification for long-term planning.

Methodological Innovation

A Bayesian hierarchical model with partial pooling across assets and temporal components, using Hamiltonian Monte Carlo for inference on risk trajectories.

This study offers a transferable probabilistic framework for infrastructure risk management in data-scarce contexts.