AFRICAN STRUCTURAL ENGINEERING

ORIGINAL RESEARCH

A Bayesian Hierarchical Model for the Reliability Assessment of Municipal Infrastructure Asset Systems in Rwanda

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ABSTRACT

Background: The reliability assessment of municipal infrastructure asset systems in developing nations is often hampered by sparse, heterogeneous, and uncertain data. Conventional reliability models struggle to integrate multi-source information and quantify epistemic uncertainty, limiting their utility for asset management decision-making.

Purpose and objectives: This study develops and applies a novel Bayesian hierarchical model to evaluate the system reliability of municipal infrastructure assets, specifically water distribution networks and road segments. The objective is to provide a robust probabilistic framework that accounts for data limitations and supports infrastructure investment prioritisation.

Keywords: *Bayesian hierarchical modelling, infrastructure asset management, reliability assessment, Sub-Saharan Africa, municipal engineering, data scarcity, developing nations*

Article Highlights

- Quantifies system reliability with sparse, heterogeneous municipal data
- Reveals 30% of failure rate variability stems from regional disparities
- Provides a probabilistic framework to guide infrastructure investment
- Integrates condition audits with expert judgment to model uncertainty

Methodological Insight

A Gamma-distributed hierarchical model structures failure rates (λ_ij) with group-level parameters informed by community-wide hyperpriors, estimated via MCMC simulation.

This study advances probabilistic reliability assessment for infrastructure in data-scarce contexts.