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A Multilevel Regression Model for the Reliability Assessment of Municipal Infrastructure Asset Systems in Kenya

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ABSTRACT

Background: Municipal infrastructure asset systems in Kenya face significant reliability challenges, yet existing assessment methods often fail to account for the hierarchical nature of asset data and varying local conditions.

Purpose and objectives: This paper develops and validates a novel multilevel regression model to quantify the system reliability of municipal infrastructure, specifically water supply networks, by integrating asset condition, operational, and environmental factors.

Keywords: *Municipal infrastructure, Asset management, Reliability assessment, Multilevel modelling, Sub-Saharan Africa*

Article Highlights

- Develops a novel three-level hierarchical model for infrastructure reliability assessment.
- Identifies asset age and soil corrosivity as the most significant predictors of failure.
- Demonstrates superior explanatory power over conventional single-level models.
- Provides a context-sensitive framework for municipal asset management planning.

Methodological Innovation

The core reliability is modelled using a Bayesian Weibull regression, $R(t_{ij}) = \exp(-(\lambda_{ij} t_{ij})^{\beta})$, where $\log(\lambda_{ij}) = \alpha + u_j + v_k + \mathbf{X}_{ij}\mathbf{\beta}$, accounting for assets, subsystems, and municipal systems.

This study presents the first application of Bayesian multilevel Weibull regression to municipal infrastructure in sub-Saharan Africa.