AFRICAN STRUCTURAL ENGINEERING

METHODOLOGY PAPER

A Bayesian Hierarchical Modelling Framework for Reliability Analysis of Railway Maintenance Depot Systems in Tanzania

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ABSTRACT

Background: The reliability of railway maintenance depot systems is critical for operational continuity and safety in developing transport networks. Current reliability assessments often lack the flexibility to incorporate multi-level operational data and quantify epistemic uncertainties inherent in such complex infrastructure.

Purpose and objectives: This article presents a novel Bayesian hierarchical modelling framework designed to evaluate the reliability of railway maintenance depot systems. The objective is to provide a robust methodology for integrating heterogeneous data sources and quantifying uncertainty in reliability parameters for maintenance decision support.

Keywords: *Bayesian hierarchical modelling, reliability analysis, railway maintenance depots, transport infrastructure, Sub-Saharan Africa, systems engineering, maintenance methodology*

Article Highlights

- Develops a three-level Bayesian hierarchical model for multi-level operational data.
- Quantifies uncertainty, moving infrastructure management beyond point estimates.
- Identifies power supply subsystems as the dominant reliability bottleneck.
- Provides a statistically rigorous framework adaptable to sparse data environments.

Methodological Insight

The core reliability model uses a Weibull distribution with parameters modelled by higher-level distributions to capture variability across subsystems and environmental conditions, estimated via Hamiltonian Monte Carlo sampling.

This framework provides asset managers with a tool for probabilistic decision support in maintenance planning.