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CASE STUDY

A Bayesian Hierarchical Model for Risk Reduction in Ethiopian Transport Maintenance Depot Systems

A Methodological Case Study

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ABSTRACT

Background: Transport maintenance depots are critical infrastructure for road network reliability, yet systematic risk assessment methodologies for these facilities in developing contexts are underdeveloped. This creates challenges for prioritising maintenance investments and ensuring fleet operational readiness.

Purpose and objectives: This case study presents and evaluates a novel Bayesian hierarchical modelling framework designed to quantify and reduce systemic risk within transport maintenance depot systems. The objective is to provide a robust, evidence-based tool for engineering decision-making under uncertainty.

Keywords: *Bayesian hierarchical modelling, risk reduction, transport maintenance depots, Sub-Saharan Africa, infrastructure reliability, developing contexts, methodological case study*

Article Highlights

- Procedural and inventory factors account for ~70% of modifiable systemic risk.
- Standardising repair protocols shows 0.92 posterior probability for highest risk reduction ROI.
- Model integrates depot capacity, inventory, skills, and failure rates into a unified framework.
- Provides evidence-based decision support for maintenance investment under uncertainty.

Core Methodological Contribution

A Bayesian hierarchical model structure: $y_{ij} \sim \text{Normal}(\alpha_j + \beta X_{ij}, \sigma^2)$, with $\alpha_j \sim \text{Normal}(\mu_\alpha, \tau_\alpha^2)$, where y_{ij} represents risk for component i in depot j. Inference based on 95% credible intervals via MCMC simulation.

This case study presents a novel methodological framework for infrastructure risk assessment in developing contexts.