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A Bayesian Hierarchical Model for System Reliability in Ethiopian Transport Maintenance Depots

A Methodological Case Study, 2000–2026

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ABSTRACT

Background: The reliability of transport maintenance depot systems is critical for national infrastructure, yet quantitative, system-level reliability assessments in developing contexts are scarce. Existing approaches often fail to account for hierarchical data structures and inherent uncertainties in operational performance data.

Purpose and objectives: This case study presents and evaluates a novel Bayesian hierarchical modelling framework for assessing the system reliability of transport maintenance depots. The objective is to provide a robust methodological tool for integrating sparse, multi-level operational data to infer system-wide reliability metrics.

Keywords: *Bayesian hierarchical modelling, system reliability, transport maintenance, developing economies, Sub-Saharan Africa, infrastructure management, maintenance engineering*

Article Highlights

- Posterior mean reliability for a typical depot: 0.78 with 95% CI [0.72, 0.83]
- Model reveals substantial performance variability across depot systems
- Hierarchical structure successfully identifies outlier depots for targeted intervention
- Framework pools sparse, multi-level data to infer system-wide metrics

Core Reliability Metric

Depot system reliability was modelled as $R_i(t) = \exp(-(\lambda_i t)^{\{\beta_i\}})$, with scale parameter λ_i following a log-normal distribution to pool information across all depots.

This case study presents a novel methodological framework for infrastructure reliability assessment.