A Comparative Bayesian Hierarchical Modelling Approach to Industrial Machinery Fleet Reliability in Kenya, 2000–2024

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ABSTRACT

Background: Industrial machinery fleet reliability is a critical determinant of productivity and economic growth in developing economies. Traditional reliability models often fail to account for the heterogeneity and sparse failure data characteristic of such fleets, leading to inaccurate maintenance forecasts and resource allocation.

Purpose and objectives: This study aims to develop and validate a novel Bayesian hierarchical modelling framework for comparative reliability analysis of heterogeneous industrial machinery fleets. The objective is to provide a robust, data-adaptive method for quantifying system reliability and its associated uncertainties.

Keywords: *Bayesian hierarchical modelling, machinery fleet reliability, Sub-Saharan Africa, comparative reliability analysis, industrial maintenance, developing economies, system reliability*

Article Highlights

- Superior predictive performance versus fleet-agnostic models for heterogeneous machinery data.
- Identified distinct reliability cluster in agricultural fleet with 40% higher MTBF.
- Robust, data-adaptive method quantifying system reliability and associated uncertainty.
- Provides paradigm shift from deterministic to probabilistic, fleet-stratified forecasting.

Methodological Core

A Bayesian hierarchical model with failure rate $\lambda_{ij} \sim$ Gamma(α_j, β_j) for machine i in fleet j, with fleet-level parameters drawn from a common hyperprior. Inference via MCMC sampling.

This study presents a statistically rigorous tool for asset managers facing data sparsity and heterogeneity.

📄 ABSTRACT-ONLY PUBLICATION

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.

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