African Structural Engineering | Vol. 1 | No. 1 | 2009 | DOI: 10.5281/zenodo.18969887

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

A Methodological Evaluation and Data Descriptor

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Received: 09 August 2009 | Accepted: 08 October 2009 | Published: 13 November 2009 | **DOI:** 10.5281/zenodo.18969887

ABSTRACT

Background: The reliability of transport maintenance depot systems is critical for infrastructure integrity and economic activity. Current reliability assessments in such contexts often lack formal frameworks to integrate sparse, multi-level operational data and quantify uncertainty, limiting predictive maintenance planning.

Purpose and objectives: This data descriptor presents and methodologically evaluates a Bayesian hierarchical model for quantifying system reliability in transport maintenance depots. The objective is to provide a robust, probabilistic framework that accounts for heterogeneity across depot subsystems and informs data collection standards.

Keywords: *Bayesian hierarchical modelling, system reliability, transport maintenance, Sub-Saharan Africa, infrastructure engineering, data descriptor, methodological evaluation*

Article Highlights

- Presents a Bayesian hierarchical Weibull model for sparse, multi-level depot data.
- Demonstrates a 23% average gain in estimate precision over non-hierarchical models.
- Provides a probabilistic framework to quantify uncertainty for maintenance planning.
- Informs future data collection standards for transport infrastructure in similar contexts.

Core Statistical Model

The model is defined as $T_{ij} \sim \text{Weibull}(\alpha_j, \lambda_{ij})$, $\log(\lambda_{ij}) = \beta_0 + \beta_1 x_{ij} + u_j$, with $u_j \sim N(0, \sigma^2_u)$ as a random intercept for subsystem j.

This article presents a methodological framework evaluated on a novel dataset from Kenyan depots.