# A Bayesian Hierarchical Modelling Framework for the Reliability Assessment of Industrial Machinery Fleets in Tanzania

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## ABSTRACT

**Background:** The reliability assessment of industrial machinery fleets in developing economies is hindered by sparse, heterogeneous, and censored failure data, which conventional reliability models struggle to analyse effectively. This methodological gap impedes proactive maintenance planning and resource allocation.

**Purpose and objectives:** This article presents a novel Bayesian hierarchical modelling framework designed to quantify the reliability of machinery fleets operating in challenging environments. The objective is to provide a robust methodology for integrating disparate data sources and quantifying uncertainty in reliability parameters.

**Keywords:** *Bayesian hierarchical modelling, Reliability engineering, Industrial machinery fleets, Sub-Saharan Africa, Censored data analysis, Weibull distribution, Developing economies*

### Article Highlights

• A Bayesian hierarchical model integrates sparse, heterogeneous, and censored failure data from machinery fleets.

• The framework formally accounts for both unit-to-unit and fleet-to-fleet variability within a single analysis.

• Methodology provides statistically coherent reliability assessment where conventional models struggle.

• Analysis demonstrates substantial fleet-level heterogeneity in typical Tanzanian operating conditions.

### Methodological Innovation

The core model structures reliability parameters hierarchically: $\log(\lambda_{ij}) = \mu + \alpha_j + \beta x_{ij}$, with fleet-level effects $\alpha_j \sim N(0, \sigma_\alpha^2)$, enabling robust inference from limited data.

*This article presents a novel statistical framework for reliability assessment in data-scarce environments.*

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