

A Bayesian Hierarchical Model for System Reliability in Ghanaian Manufacturing

A Methodological Evaluation

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ABSTRACT

Background: Reliability engineering in manufacturing contexts often relies on classical frequentist methods, which can struggle with complex, multi-level system data and the incorporation of prior operational knowledge. This is particularly relevant in developing industrial economies where system failure data may be sparse or heterogeneous across different plants.

Purpose and objectives: This study presents a methodological evaluation of a Bayesian hierarchical model for quantifying system reliability within the manufacturing sector. The objective is to demonstrate its superiority in handling plant-level variability and providing probabilistic inferences for maintenance decision-making compared to conventional approaches.

Keywords: *Bayesian hierarchical modelling, system reliability, manufacturing systems, Sub-Saharan Africa, reliability engineering, methodological evaluation, industrial maintenance*

Article Highlights

- Bayesian hierarchical model quantifies system reliability with plant-level variability.
- Model reveals substantial heterogeneity in reliability parameters across different facilities.
- Provides probabilistic inferences for maintenance decision-making in sparse data contexts.
- Offers a robust methodological advancement for systems with operational diversity.

Methodological Core

A three-level hierarchical model where component failure rates are drawn from plant-specific Gamma distributions, with parameters from a common hyper-distribution, implemented via Hamiltonian Monte Carlo.

This study evaluates a modelling framework for reliability analysis in contexts with heterogeneous operational data.

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