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A Bayesian Hierarchical Model for the Reliability Assessment of Process-Control Systems in Ethiopia

A Methodological Evaluation

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ABSTRACT

Background: The reliability assessment of process-control systems in industrial settings is critical for operational safety and efficiency. In many developing nations, such assessments are hindered by sparse, heterogeneous data and a lack of methodologies that formally account for operational uncertainty and variability across different sites.

Purpose and objectives: This study presents and evaluates a novel Bayesian hierarchical modelling framework designed to quantify the reliability of such systems within a data-scarce context. The primary objective is to provide a robust methodological tool that integrates multi-source operational data to produce more accurate and interpretable reliability estimates.

Keywords: *Bayesian hierarchical modelling, reliability assessment, process-control systems, Sub-Saharan Africa, industrial safety, developing economies*

Article Highlights

- Bayesian hierarchical model synthesizes sparse, heterogeneous operational data.
- Quantifies reliability with uncertainty for data-scarce industrial contexts.
- Reveals significant inter-plant variability masked by conventional methods.
- Provides plant-specific estimates for targeted maintenance and safety protocols.

Methodological Contribution

A Gamma-LogNormal hierarchical model formalized as $\lambda_{ij} \sim \text{Gamma}(\alpha_i, \beta_i)$, with hyperparameters $\alpha_i, \beta_i \sim \text{LogNormal}(\mu, \sigma^2)$, estimated via MCMC.

This study presents a novel statistical framework for industrial reliability assessment in developing economies.