

A Comparative Methodological Evaluation of Manufacturing Plant Systems in Rwanda

A Bayesian Hierarchical Model for Risk Reduction

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ABSTRACT

Background: Manufacturing systems in developing economies face unique operational risks, yet methodological frameworks for their comparative evaluation are often inadequate. Existing risk assessment models frequently lack the capacity to integrate multi-level data and quantify uncertainty in a principled manner.

Purpose and objectives: This study aims to develop and apply a novel Bayesian hierarchical model for the comparative methodological evaluation of manufacturing plant systems, with the objective of quantifying risk reduction and identifying dominant failure pathways.

Keywords: *Bayesian hierarchical modelling, manufacturing systems, risk reduction, Sub-Saharan Africa, comparative methodology, operational risk*

Article Highlights

- Bayesian hierarchical model pools data across plants for robust comparative analysis.
- Identifies systemic electrical faults as primary contributor to operational downtime.
- Quantifies uncertainty with 95% credible intervals for risk parameter estimates.
- Demonstrates 24.7% mean risk reduction from predictive maintenance protocols.

Methodological Innovation

The core model, $Y_{ij} \sim \text{Normal}(\alpha_j + \beta X_{ij}, \sigma^2)$, $\alpha_j \sim \text{Normal}(\mu_\alpha, \tau^2)$, enables plant-specific risk estimation while sharing strength across the manufacturing cohort.

This study presents a novel analytical framework for manufacturing risk assessment in developing economies.

ABSTRACT-ONLY PUBLICATION

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