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# A Bayesian Hierarchical Model for Risk Reduction Diagnostics in Tanzanian Manufacturing Systems

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## ABSTRACT

**Background:** Manufacturing systems in developing economies face complex, interdependent risks that challenge conventional reliability engineering methods. Current diagnostic frameworks often lack the probabilistic rigour to quantify uncertainty and integrate multi-level operational data, hindering effective risk reduction strategies.

**Purpose and objectives:** This article presents a novel Bayesian hierarchical modelling framework designed to diagnose and measure risk reduction in complex industrial systems. The objective is to provide a robust, evidence-based methodology for quantifying improvements in system safety and reliability.

**Keywords:** Bayesian hierarchical modelling, reliability engineering, risk reduction diagnostics, Sub-Saharan Africa, manufacturing systems, industrial diagnostics

### Article Highlights

- A four-level Bayesian hierarchical model integrates plant, subsystem, component, and observational data.
- Quantifies uncertainty and data structure, offering a superior alternative to deterministic analyses.
- Application to three plants showed a median 34% reduction in predicted failure probability.
- Provides a statistically coherent and operationally actionable framework for risk diagnostics.

### Methodological Core

The model structure is defined by  $y_{ij} \sim \text{Bernoulli}(\theta_{ij})$ ,  $\text{logit}(\theta_{ij}) = \alpha + \beta_j + \gamma_k + \epsilon_{ij}$ , with  $\beta_j \sim N(0, \sigma^2_{\beta})$  representing random effects for subsystems. Inference uses Hamiltonian Monte Carlo sampling.

*This article presents a novel probabilistic framework for diagnosing risk in complex manufacturing systems.*

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