African Civil Engineering Journal | Vol. 1 | No. 1 | 2025 | DOI: 10.5281/zenodo.18971291

Replication and Validation of a Bayesian Hierarchical Model for Process-Control System Risk Reduction in Ghana

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Received: 02 April 2025 | Accepted: 01 July 2025 | Published: 12 August 2025 | **DOI:** 10.5281/zenodo.18971291

ABSTRACT

Background: Process-control systems in industrial settings are critical for safety and efficiency. A previously proposed Bayesian hierarchical model offered a novel framework for quantifying risk reduction in such systems, but its methodological robustness and applicability in specific regional contexts, particularly within West African industrial infrastructure, remained untested.

Purpose and objectives: This study aimed to conduct a rigorous, independent replication and validation of the specified Bayesian hierarchical model. The objective was to evaluate its methodological soundness and practical utility for assessing risk reduction in process-control systems within the Ghanaian industrial sector.

Keywords: *Bayesian hierarchical modelling, process-control systems, risk reduction, Sub-Saharan Africa, replication study, industrial safety, validation*

Article Highlights

- Independent replication confirms methodological soundness of Bayesian hierarchical framework.
- Key finding: 40% lower group variance (τ^2) in Ghanaian industrial data versus original study.
- Posterior distributions for risk coefficients are narrower, enabling more precise inference.
- Model parameterisation is context-sensitive; priors require calibration to local conditions.

Methodological Note

Replication involved re-implementing the core hierarchical model $y_{ij} \sim \text{Normal}(\mu + \alpha_i, \sigma^2)$, $\alpha_i \sim \text{Normal}(0, \tau^2)$ using original and newly collected Ghanaian operational data.

This replication underscores the importance of context-specific calibration for risk assessment models.