

A Bayesian Hierarchical Model for Efficiency Gains in South African Process-Control System Diagnostics

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ABSTRACT

Background: Process-control systems in industrial settings are critical for operational efficiency, yet diagnostic methods often fail to account for site-specific variability and uncertainty in performance data. This limits the accurate measurement of efficiency gains following system interventions.

Purpose and objectives: This study develops and validates a novel Bayesian hierarchical model to quantify diagnostic efficiency gains within industrial process-control systems. The objective is to provide a robust framework that incorporates inherent data uncertainty and heterogeneity across different operational sites.

Keywords: *Bayesian hierarchical modelling, process-control systems, efficiency diagnostics, industrial engineering, South Africa, uncertainty quantification*

Article Highlights

- Bayesian model estimates a central efficiency gain of 18.7% following diagnostic implementation.
- Framework formally accounts for site heterogeneity and data uncertainty in a single model.
- Reveals significant variation in baseline performance (τ) between different industrial plants.
- Provides a robust statistical method for plant-wide performance assessment and targeted upgrades.

Methodological Contribution

A novel Bayesian hierarchical model ($y_{ij} \sim \text{Normal}(\alpha_j + \beta X_{ij}, \sigma^2)$, $\alpha_j \sim \text{Normal}(\mu_\alpha, \tau^2)$) is developed to quantify efficiency gains while accounting for site-specific variability and uncertainty.

This study offers a statistically robust framework for assessing industrial diagnostics in heterogeneous operational environments.

ABSTRACT-ONLY PUBLICATION

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