

A Bayesian Hierarchical Model for the Reliability Assessment of Industrial Process-Control Systems in South Africa

A Policy Analysis for Maintenance and Governance

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ABSTRACT

Background: Industrial process-control systems are critical infrastructure for South Africa's manufacturing and resource sectors, yet their reliability is often compromised by ageing assets, inconsistent maintenance regimes, and a lack of robust, data-driven assessment frameworks. Current policy and governance structures lack a formal probabilistic methodology to quantify system failure risks and inform maintenance investment.

Purpose and objectives: This policy analysis article develops and demonstrates a novel Bayesian hierarchical model to assess the reliability of such systems. Its objective is to provide a methodological foundation for evidence-based maintenance policy and governance, enabling the prioritisation of interventions and resource allocation.

Keywords: *Bayesian hierarchical modelling, reliability assessment, process-control systems, industrial maintenance policy, Southern African development*

Article Highlights

- Bayesian hierarchical model quantifies subsystem reliability heterogeneity with MTBF varying over 300%
- Identifies high-impact maintenance targets for optimal resource allocation under budget constraints
- Provides statistically rigorous framework for moving beyond calendar-based maintenance schedules
- Enables evidence-based policy through posterior predictive checks of system availability

Methodological Innovation

The model employs Gamma-distributed failure rates with hyperpriors that pool information across heterogeneous subsystems, improving inference for data-sparse systems.

This analysis provides a quantitative foundation for maintenance policy reform in industrial infrastructure.

ABSTRACT-ONLY PUBLICATION

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