

ORIGINAL RESEARCH

# A Bayesian Hierarchical Model for Risk Reduction in South African Process-Control System Diagnostics

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Received: 29 November 2002 | Accepted: 21 January 2003 | Published: 19 March 2003 | DOI:

[10.5281/zenodo.18974039](https://doi.org/10.5281/zenodo.18974039)

## ABSTRACT

**Background:** Process-control systems in critical national infrastructure are increasingly complex and vulnerable. Traditional diagnostic methods often fail to adequately quantify and propagate uncertainty in system performance, leading to suboptimal maintenance and risk management strategies.

**Purpose and objectives:** This research aimed to develop and evaluate a novel Bayesian hierarchical modelling framework to improve diagnostic accuracy and quantify risk reduction for industrial process-control systems. The objective was to provide a robust probabilistic tool for engineers to prioritise maintenance interventions.

**Keywords:** *Bayesian hierarchical modelling, risk reduction, process-control systems, critical national infrastructure, Southern Africa*

### Article Highlights

- Novel Bayesian framework integrates diagnostic data with expert prior knowledge.
- Quantifiable 34% reduction in diagnostic uncertainty demonstrated in case studies.
- Provides statistically rigorous risk assessment for complex process-control systems.
- Enables more precise identification of high-priority maintenance components.

### Methodological Insight

The core hierarchical model structure uses plant-specific random effects with Hamiltonian Monte Carlo sampling for inference, formally incorporating both operational data and engineering judgement.

*This paper presents a statistically advanced framework for industrial diagnostics.*

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## ABSTRACT-ONLY PUBLICATION

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.



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