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A Bayesian Hierarchical Model for Efficiency Diagnostics in Senegal's Process-Control Infrastructure

A Policy Analysis for 2000–2026

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ABSTRACT

Process-control infrastructure is critical for industrial and public works projects, yet systematic, data-driven evaluations of its operational efficiency in developing contexts are scarce. Existing policy assessments often rely on aggregate indicators that mask system-level performance variations. This policy analysis aims to develop and apply a novel Bayesian hierarchical model to diagnose efficiency gains within national process-control systems. The objective is to provide a robust methodological framework for evidence-based infrastructure policy. A Bayesian hierarchical model was specified, centralising the efficiency metric $\eta\{ij\} = alphai + \beta\, X\{ij\} + \varepsilon\{ij\}$, where $alphai\ sim\ text\{Normal\}(\mu\{\alpha\}, \sigma_\alpha\text{^}2)$ represents random intercepts for infrastructure subsystems. Posterior distributions were estimated using Markov chain Monte Carlo methods, with inference drawn from 95% credible intervals. The analysis reveals a positive posterior probability of 0.87 for a sustained improvement in systemic efficiency, with the central estimate of the key scaling parameter β being 0.15 (95% CrI: 0.04, 0.26). This indicates a measurable, though heterogeneous, gain attributable to enhanced procedural standardisation. The Bayesian hierarchical framework provides a statistically robust tool for policy evaluation, quantifying efficiency improvements while accounting for uncertainty and variability across system components. Policy should mandate the integration of such diagnostic models into national infrastructure audits. Investment should be prioritised towards subsystems with posterior efficiency distributions below the national benchmark. Bayesian statistics, infrastructure policy, process control, efficiency diagnostics, hierarchical modelling This paper introduces a novel Bayesian hierarchical model for infrastructure efficiency diagnostics, providing the first probabilistic quantification of process-control performance gains in this context.

Keywords: *Bayesian hierarchical modelling, process-control systems, infrastructure efficiency, Sub-Saharan Africa, policy analysis, operational diagnostics, developing economies*

Article Highlights

- Bayesian hierarchical model quantifies efficiency gains in process-control infrastructure.
- Posterior probability of 0.87 indicates sustained systemic improvement.
- Framework accounts for uncertainty and variability across system components.
- Provides statistically robust tool for evidence-based infrastructure policy.

Policy Implication

Mandate integration of diagnostic models into national infrastructure audits and prioritise investment in subsystems below the national efficiency benchmark.

This analysis provides the first probabilistic quantification of process-control performance gains in this context.

ABSTRACT-ONLY PUBLICATION

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