AFRICAN STRUCTURAL ENGINEERING

CASE STUDY

Bayesian Hierarchical Modelling of Water Treatment Efficiency Gains in Rwanda

A Case Study of System Diagnostics and Optimisation

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ABSTRACT

Background: Water treatment infrastructure in many developing regions faces challenges in performance assessment due to heterogeneous system designs and sparse, inconsistent monitoring data. Conventional engineering models often fail to adequately quantify uncertainty or leverage information across multiple facilities.

Purpose and objectives: This case study aimed to develop and apply a Bayesian hierarchical model to diagnose systemic inefficiencies and quantify potential treatment efficiency gains across a network of water treatment facilities. The objective was to provide a robust, probabilistic framework for infrastructure optimisation.

Keywords: *Bayesian hierarchical modelling, Water treatment efficiency, System diagnostics, Sub-Saharan Africa, Infrastructure optimisation, Developing regions, Performance assessment*

Article Highlights

- Bayesian hierarchical model quantifies efficiency gains across heterogeneous treatment facilities.
- Identifies inlet turbidity management as a critical, system-wide leverage point for improvement.
- Provides a probabilistic framework for infrastructure optimisation under typical data constraints.
- Enables robust performance diagnosis and targeted resource allocation for developing regions.

Methodological Insight

The model formalises plant-level efficiency (α_j) as drawn from a common population distribution, allowing information sharing to improve inference for data-sparse facilities.

This study presents a statistically rigorous framework for infrastructure diagnostics in data-limited contexts.