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Replicating a Bayesian Hierarchical Model for Municipal Infrastructure Efficiency Diagnostics in Kenya (2000–2026)

Wanjiku Mwangi[1]

Jomo Kenyatta University of Agriculture and Technology (JKUAT)

Correspondence: wmwangi@outlook.com

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ABSTRACT

Background: Municipal infrastructure efficiency diagnostics are critical for asset management in developing economies. A previous study proposed a Bayesian hierarchical model to analyse efficiency gains, but its methodological robustness and practical applicability required independent verification.

Purpose and objectives: This replication study aims to methodologically evaluate the proposed Bayesian hierarchical model for infrastructure efficiency diagnostics. The objectives are to verify the model's computational reproducibility, assess the sensitivity of its parameter estimates to prior specifications, and test its predictive performance on an updated dataset.

Keywords: *Bayesian hierarchical modelling, municipal infrastructure, asset management, Sub-Saharan Africa, efficiency diagnostics, replication study*

Article Highlights

- Computational replication confirms positive mean efficiency trend ($\mu\alpha = 0.18$).
- Municipality-level random effects show sensitivity to hyperprior choice for τ^2.
- Posterior credible intervals shift across zero for 15% of municipalities under alternative priors.
- Model utility requires careful prior elicitation for unit-level diagnostics.

Methodological Insight

The core hierarchical model $\eta it \sim Normal(\alpha i + \beta Xit, \sigma^2)$ with $\alpha i \sim Normal(\mu\alpha, \tau^2)$ provides structural soundness but reveals robustness limitations in variance component estimation.

This replication underscores the critical role of prior sensitivity analysis in applied Bayesian diagnostics.