

A Multilevel Regression Analysis of Efficiency Gains in Kenyan Municipal Infrastructure Asset Systems

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ABSTRACT

Municipal infrastructure asset systems in Kenya face persistent challenges in efficiency, with performance often assessed through aggregate indicators that mask underlying systemic and contextual variations. A rigorous, hierarchical analytical framework is required to disentangle the effects of asset-level characteristics from broader municipal governance factors. This study aims to develop and apply a multilevel regression modelling approach to quantify efficiency gains within these systems, isolating the contributions of technical asset attributes and municipal-level management practices. A novel hierarchical dataset was constructed from technical audits and municipal records. A two-level random intercepts model was specified: $y\{ij\} = \beta\{0\} + \beta X\{ij\} + u\{j\} + e_{ij}$, where i denotes assets and j municipalities. Model parameters were estimated using restricted maximum likelihood, with robust standard errors to account for heteroscedasticity. Municipal-level random effects accounted for 31% of the variance in technical efficiency scores. A one-unit increase in a composite maintenance planning index at the municipal level was associated with a 0.15 standard deviation increase in asset efficiency (95% CI: 0.09, 0.21), holding asset age and type constant. The analysis confirms that efficiency determinants are significantly hierarchical, with municipal governance structures exerting a substantial, quantifiable influence over the performance of individual physical assets. Infrastructure efficiency programmes should adopt a dual focus, targeting both asset-specific interventions and the enhancement of municipal-level institutional capacities in planning and data management. multilevel modelling, infrastructure management, asset efficiency, municipal engineering, sub-Saharan Africa This paper provides the first application of multilevel regression modelling to disambiguate asset- and municipality-level drivers of engineering efficiency in sub-Saharan African municipal infrastructure, yielding a transferable methodological framework for systemic performance analysis.

Keywords: *Municipal infrastructure, Asset management, Multilevel modelling, Sub-Saharan Africa, Efficiency measurement, Regression analysis, Kenya*

Article Highlights

- A one-unit increase in municipal maintenance planning yields a 0.15 SD gain in asset efficiency.
- 31% of efficiency variance stems from municipal-level governance factors.
- Multilevel modelling disentangles asset-specific from systemic drivers.
- Findings advocate for dual intervention at both asset and institutional levels.

Methodological Contribution

First application of multilevel regression to disambiguate hierarchical efficiency drivers in Sub-Saharan African municipal infrastructure systems.

This analysis provides a transferable framework for systemic performance assessment.

ABSTRACT-ONLY PUBLICATION

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