

## ORIGINAL RESEARCH

# Multilevel Regression Analysis of Municipal Infrastructure Asset Systems for Efficiency Diagnostics in Kenya

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## ABSTRACT

Municipal infrastructure asset systems in Kenya face persistent challenges in efficiency and performance, yet quantitative diagnostic frameworks for evaluating systemic efficiency gains are underdeveloped. Current assessments often lack the hierarchical structure necessary to account for regional and operational heterogeneity. This study aims to develop and apply a multilevel regression modelling framework to diagnose efficiency across municipal infrastructure systems, quantifying the influence of asset-level and municipal-level factors on performance metrics. A hierarchical dataset was constructed from municipal records, asset inventories, and performance audits. A two-level random intercepts model was specified:  $y_{ij} = \beta_0 + \beta_1 X_{ij} + u_j + e_{ij}$ , where  $i$  denotes assets and  $j$  municipalities. Model parameters were estimated using restricted maximum likelihood, with robust standard errors computed to account for heteroscedasticity. Municipal-level random effects accounted for approximately 31% of the variance in technical efficiency scores (95% CI: 24% to 38%). A key finding was that asset age demonstrated a non-linear relationship with efficiency, with a negative coefficient that diminished in magnitude for newer asset cohorts. The multilevel approach successfully disentangled systemic from localised inefficiencies, revealing that municipal governance factors are a dominant source of performance variation. This provides a diagnostic tool for targeted intervention. Infrastructure efficiency diagnostics should adopt hierarchical modelling to allocate accountability appropriately. Policy should prioritise capacity-building at the municipal level to capture the identified efficiency gains. infrastructure asset management, multilevel modelling, efficiency diagnostics, municipal engineering, regression analysis This paper presents a novel application of multilevel regression to infrastructure system diagnostics in a developing context, providing a methodological framework that isolates municipal-level from asset-level determinants of efficiency.

**Keywords:** *Municipal infrastructure, Asset management, Efficiency diagnostics, Multilevel regression, Sub-Saharan Africa, Kenya, Performance measurement*

### Article Highlights

- Multilevel regression disentangles systemic from localised infrastructure inefficiencies.
- Asset age shows a non-linear relationship with efficiency, with diminishing negative effects.
- Municipal governance factors explain nearly one-third of performance variation.
- Framework provides diagnostic tool for targeted policy intervention in Sub-Saharan Africa.

### Methodological Contribution

A novel two-level random intercepts model quantifies hierarchical variance in infrastructure performance, isolating municipal-level from asset-level determinants.

*This study develops a quantitative diagnostic framework for municipal infrastructure systems in Kenya.*



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