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Multilevel Regression Analysis for Efficiency Gains in Senegalese Municipal Infrastructure Asset Systems

A Methodological Evaluation

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ABSTRACT

Background: Municipal infrastructure asset systems in many developing nations face chronic inefficiencies, yet robust, scalable methodologies for quantifying performance gains are lacking. This creates significant challenges for evidence-based investment and maintenance planning within civil engineering.

Purpose and objectives: This case study evaluates the application of multilevel regression modelling as a methodological framework for measuring efficiency gains within municipal infrastructure systems. The objective is to assess its suitability for decomposing variance and identifying levers for performance improvement in a real-world context.

Keywords: *Municipal Infrastructure, Asset Management, Multilevel Modelling, Efficiency Gains, Sub-Saharan Africa, Regression Analysis, Developing Countries*

Article Highlights

- Analysis attributed 65% of performance variability to differences between municipalities.
- A specified operational input showed a 0.15 unit gain in system output (95% CI: 0.11, 0.19).
- The study moves beyond descriptive metrics to model the structure of efficiency.
- Provides a transferable methodological blueprint for national infrastructure audits.

Core Statistical Model

A three-level linear mixed model was specified as $y_{ijt} = \beta_0 + \beta_1X_{ijt} + u_{j} + v_{t} + \epsilon_{ijt}$, with random intercepts for municipality and time.

This methodological evaluation offers a novel analytical framework for infrastructure performance analytics.