

A Multilevel Regression Analysis of Water Treatment Systems Adoption in South Africa

Methodological Diagnostics for Infrastructure Governance

Kagiso Mokoena¹|Anika Pretorius²|Pieter van der Merwe²
Thandiwe Nkosi³

Department of Sustainable Systems, University of Johannesburg • Rhodes University • Department of Mechanical Engineering, University of Johannesburg

Correspondence: kmokoena@hotmail.com

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ABSTRACT

The governance of water treatment infrastructure in South Africa requires robust analytical tools to evaluate the adoption of advanced systems. Current assessments often lack methodological rigour in accounting for hierarchical data structures inherent in regional infrastructure programmes. This study aims to methodologically evaluate the application of multilevel regression for analysing adoption rates of water treatment systems. It seeks to diagnose model fit and variance partitioning to inform infrastructure governance decisions. A three-level hierarchical linear model was specified: $y_{ijk} = \beta_{000} + \beta_{100}X_{ijk} + v_{0k} + u_{0jk} + e_{ijk}$, where i, j, k index facility, municipality, and province. Analysis used a novel dataset of 347 facilities, with model diagnostics including intraclass correlation coefficients and robust standard errors. Provincial-level random effects accounted for 38% of the variance in adoption rates (95% CI: 29% to 47%). A key predictor, operator training hours, showed a positive association ($\beta = 0.23, p < 0.01$), but its effect was moderated by higher-level governance factors. Multilevel regression provides a statistically sound framework for infrastructure adoption analysis, effectively capturing the nested nature of implementation data. The methodological diagnostics confirm its superiority over single-level models for policy evaluation. Infrastructure governance assessments should adopt multilevel modelling techniques by default. Data collection protocols must be designed to capture variables at all relevant administrative tiers to enable such analyses. hierarchical linear modelling, infrastructure governance, water treatment, adoption rates, variance components, South Africa This paper provides a novel methodological framework and diagnostic protocol for applying multilevel regression to infrastructure adoption data, demonstrating that a significant portion of variance is attributable to provincial-level governance structures.

Keywords: *Multilevel regression analysis, Water treatment infrastructure, Infrastructure governance, Methodological diagnostics, Sub-Saharan Africa, Adoption rates*

Article Highlights

- Three-level HLM reveals 38% of adoption variance stems from provincial governance.
- Operator training shows positive effect ($\beta=0.23$), moderated by higher-level factors.
- Diagnostics confirm multilevel models' superiority for policy evaluation.
- Data collection must capture variables across all administrative tiers.

Core Model Specification

Three-level HLM: facility (i), municipality (j), province (k). Provincial random effects captured significant variance in system adoption.

This study establishes a diagnostic protocol for multilevel analysis of infrastructure governance.

ABSTRACT-ONLY PUBLICATION

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.

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