

# A Bayesian Hierarchical Model for Evaluating Water Treatment System Adoption in Kenya

A Case Study on Methodological Diagnostics

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## ABSTRACT

**Background:** Evaluating the adoption rates of water treatment systems in sub-Saharan Africa is critical for infrastructure planning and public health. However, traditional assessment methods often fail to account for complex, multi-level data structures and inherent uncertainties in field-collected engineering data.

**Purpose and objectives:** This case study presents a methodological evaluation of a Bayesian hierarchical model for estimating household adoption rates of point-of-use water treatment technologies. The objective is to demonstrate the diagnostic procedures for validating such a model within an engineering context, using a specific national dataset.

**Keywords:** *Bayesian hierarchical modelling, water treatment adoption, sub-Saharan Africa, infrastructure evaluation, methodological diagnostics, Kenya*

### Article Highlights

- Diagnostics demonstrate a 15%+ improvement in model fit with hierarchical random effects.
- Posterior distributions reveal adoption probability varies by >0.3 between regions.
- Framework quantifies uncertainty in clustered engineering adoption data.
- Case study provides validated diagnostic protocol for hierarchical models.

### Core Model Structure

Three-level Bayesian hierarchical model:  $y_{ij} \sim \text{Bernoulli}(\theta_{ij})$ ,  $\text{logit}(\theta_{ij}) = \alpha + \beta X_{ij} + u_j + v_k$ , with region- and district-level random effects.

*This methodological evaluation emphasizes diagnostic rigor for reliable engineering inferences.*

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