AFRICAN CIVIL ENGINEERING JOURNAL

ORIGINAL RESEARCH

# A Bayesian Hierarchical Model for Evaluating Power-Distribution Equipment Adoption in South Africa, 2000–2026

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Received: 10 February 2004 | Accepted: 05 May 2004 | Published: 03 June 2004 | **DOI:** 10.5281/zenodo.18973244

## ABSTRACT

**Background:** The reliability of electrical infrastructure is critical for economic development. In South Africa, ageing power-distribution equipment and inconsistent adoption of modern systems pose significant challenges to grid stability and expansion. Existing evaluation methods often lack the capacity to integrate sparse, heterogeneous data and quantify uncertainty in adoption forecasts.

**Purpose and objectives:** This study aimed to develop and apply a novel Bayesian hierarchical model to evaluate the adoption rates of key power-distribution equipment, specifically transformers and ring main units, across the national network. The objective was to provide probabilistic forecasts of adoption to inform infrastructure investment and policy.

**Keywords:** *Bayesian hierarchical modelling, power-distribution networks, equipment adoption, Southern African Power Pool, reliability engineering, infrastructure assessment*

### Article Highlights

- Bayesian model quantifies high uncertainty in regional adoption forecasts
- Substantial heterogeneity found across provinces and municipalities
- Slow equipment transition threatens national grid modernisation
- Probabilistic forecasts enable targeted infrastructure investment

### Core Methodology

Bayesian hierarchical model with binomial likelihood and logistic regression, using MCMC sampling to estimate posterior distributions of adoption rates.

*This study provides probabilistic forecasts to inform infrastructure policy.*