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A Bayesian Hierarchical Model for Power-Distribution System Reliability

A Policy Analysis for Ghana, 2000–2026

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ABSTRACT

Background: Ghana's power-distribution network has faced persistent reliability challenges, with frequent outages impacting economic development. Existing policy evaluations often rely on aggregate failure rates, lacking the granularity to identify specific equipment vulnerabilities and regional disparities that inform targeted infrastructure investment.

Purpose and objectives: This policy analysis aims to develop and apply a novel Bayesian hierarchical model to quantify the reliability of distribution system components. The objective is to provide evidence-based insights for prioritising maintenance and capital renewal within the national grid.

Keywords: *Bayesian hierarchical modelling, power-distribution reliability, sub-Saharan Africa, infrastructure policy, engineering systems analysis, electrical grid resilience*

Article Highlights

- Distribution transformers account for 42% of system unreliability in Ghana's grid.
- Northern regions show 0.92 posterior probability of failure rates exceeding national median.
- Model enables geographically and technically differentiated investment strategies.
- Bayesian hierarchical Weibull survival model treats failure times as right-censored data.

Policy Imperative

Findings underscore the necessity of moving beyond aggregate metrics to component-level, probabilistic reliability modelling for effective grid planning and investment prioritisation.

This analysis provides a granular, evidence-based framework for targeting infrastructure renewal.