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Methodological Framework for Panel-Data Estimation of Power-Distribution System Reliability in Kenya, 2000–2026

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ABSTRACT

Background: Reliability assessment of power-distribution systems in developing nations is hindered by sparse and inconsistent historical failure data. Existing reliability models, often developed for mature grids, inadequately capture the dynamic performance of ageing infrastructure under rapid demand growth and constrained maintenance regimes.

Purpose and objectives: This article presents a methodological framework for estimating distribution-system reliability using unbalanced panel data. The objective is to provide a robust, replicable method for quantifying the relationship between equipment age, maintenance expenditure, environmental stressors, and customer interruption metrics.

Keywords: *Power-distribution reliability, Panel-data estimation, Developing countries, Kenya, Methodological framework, System reliability assessment, Electrical grid*

Article Highlights

- Framework designed for sparse, inconsistent historical failure data common in developing nations.
- Fixed-effects panel regression isolates unit-specific effects from dynamic performance factors.
- Quantifies relationships between equipment age, maintenance spend, and customer interruptions.
- Provides replicable method for asset-performance modelling in constrained maintenance regimes.

Core Methodological Specification

$\lambda_{it} = \alpha_i + \beta_1 Age_{it} + \beta_2 MaintExp_{it} + X_{it}\gamma + \varepsilon_{it}$, where λ_{it} is the failure rate for transformer cluster i in period t, and α_i denotes unit-specific fixed effects.

This article presents a methodological framework; empirical application results are illustrative.