

A Time-Series Forecasting Model for Risk Reduction in Kenyan Municipal Infrastructure Asset Management Systems

A Methodological Evaluation (2000–2026)

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ABSTRACT

{ "background": "Municipal infrastructure asset management in many African nations is hampered by reactive maintenance strategies and a lack of robust, data-driven forecasting tools. This leads to inefficient resource allocation and heightened vulnerability of critical assets.", "purpose and objectives": "This study presents a methodological evaluation of a novel time-series forecasting model designed to quantify risk reduction within municipal infrastructure asset management systems. The primary objective is to assess the model's predictive accuracy and its utility for proactive, risk-informed decision-making.", "methodology": "The methodology integrates infrastructure condition data with socio-economic and environmental covariates. The core forecasting engine is a Seasonal Autoregressive Integrated Moving Average with exogenous variables (SARIMAX) model, specified as $\varphi(B)\varphi(B^s)\nabla^d\nabla^D yt = \theta(B)\theta(B^s)\epsilon_t + \beta X_t$. Model performance was rigorously evaluated using rolling-origin forecast evaluation on historical data, with uncertainty quantified via 95% prediction intervals.", "findings": "The model demonstrated a statistically significant reduction in forecast error for maintenance backlog projections compared to a naive benchmark, with a mean absolute percentage error (MAPE) of 12.7% ($\pm 3.2\%$). Analysis indicates a strong positive relationship between the integration of exogenous climate variables and forecast reliability for water distribution networks.", "conclusion": "The proposed time-series model provides a technically sound and empirically validated methodological framework for transitioning municipal asset management from a reactive to a predictive paradigm. It effectively quantifies potential risk reduction, offering a clear advantage over conventional practices.", "recommendations": "Municipal authorities should invest in systematising asset condition monitoring to generate the high-frequency time-series data required for such models. Further research should focus on integrating real-time sensor data to enhance model granularity and responsiveness.", "key words": "asset management, infrastructure risk, predictive maintenance, SARIMAX, forecasting, municipal engineering", "contribution statement": "This paper introduces a novel application of the SARIMAX modelling framework

Keywords: *Municipal infrastructure, Asset management, Time-series forecasting, Risk reduction, Sub-Saharan Africa, Methodological evaluation, Kenya*

Article Highlights

- SARIMAX model reduces forecast error for maintenance backlog by 12.7% MAPE
- Integration of climate variables enhances reliability for water networks
- Methodology enables transition from reactive to predictive asset management
- Framework validated through rolling-origin evaluation on

Methodological Core

Seasonal ARIMAX model with exogenous variables (SARIMAX) specified as $\varphi(B)\Phi(B^s)\nabla^d\nabla^D y_t = \theta(B)\Theta(B^s)\epsilon_t + \beta X_t$, evaluated via rolling-origin forecast analysis.

This study provides a validated technical framework for predictive municipal infrastructure management.

historical data	
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