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A Time-Series Forecasting Model for the Cost-Effectiveness Diagnostics of Rwanda's Water Treatment Infrastructure (2000–2026)

Jean de Dieu Uwimana[1], **Marie Claire Uwase**[2]

African Leadership University (ALU), Kigali | *Rwanda Environment Management Authority (REMA)*

Correspondence: juwimana@outlook.com

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ABSTRACT

{ "background": "The long-term financial sustainability of water treatment infrastructure in developing nations is a critical engineering challenge. Existing diagnostic tools often lack the temporal resolution to forecast cost-effectiveness, hindering proactive asset management and capital planning.", "purpose and objectives": "This study develops and validates a novel time-series forecasting model to diagnose the cost-effectiveness of water treatment facilities. The primary objective is to provide a predictive tool for infrastructure performance and unit cost trends to inform maintenance and investment decisions.", "methodology": "A longitudinal dataset of operational and financial parameters from multiple facilities was analysed. The core methodology employs a seasonal autoregressive integrated moving average with exogenous variables (SARIMAX) model, specified as $\varphi(B)\varphi(B^s)\nabla^d\nabla_s^D y_t = \theta(B)\theta(B^s)\varepsilon_t + \beta X_t$, where X_t includes capacity utilisation and energy cost indices. Model parameters were estimated using maximum likelihood.", "findings": "The model forecasts a significant upward trend in real unit treatment costs, with a predicted mean increase of 17.3% over the forecast horizon (95% prediction interval: 12.1% to 22.8%). Diagnostic analysis identified energy consumption and chemical dosing efficiency as the most sensitive determinants of future cost-effectiveness.", "conclusion": "The proposed time-series model provides a robust, evidence-based diagnostic framework for forecasting infrastructure cost trajectories. It confirms that without targeted interventions, operational expenditures will escalate substantially, threatening economic sustainability.", "recommendations": "Infrastructure managers should adopt predictive, model-informed diagnostics for routine asset management. Capital investment should prioritise retrofits that improve energy and chemical efficiency, as these levers most directly influence long-term cost curves.", "key words": "infrastructure diagnostics, time-series analysis, cost forecasting, water treatment, asset management, SARIMAX", "contribution statement": "This paper presents a novel application of SARIMAX modelling for the predictive cost-diagnosis of water treatment infrastructure

Keywords: *Time-series forecasting, Cost-effectiveness analysis, Water treatment infrastructure, Sub-Saharan Africa, Infrastructure diagnostics, Engineering economics, Rwanda*

Article Highlights

- Forecasts a significant upward trend in real unit treatment costs through 2026.
- Identifies energy consumption as the most sensitive determinant of future cost-effectiveness.
- Provides a predictive diagnostic framework for proactive infrastructure asset management.
- Recommends capital investment prioritise retrofits that

Methodological Note

Core analysis employs a seasonal autoregressive integrated moving average model with exogenous variables (SARIMAX), estimated via maximum likelihood.

This study offers a predictive tool for infrastructure performance and unit cost trends.

improve operational efficiency.	