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Methodological Evaluation and Time-Series Forecasting for Process-Control System Efficiency Gains in Rwanda

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ABSTRACT

{ "background": "Process-control systems in industrial and infrastructure sectors are critical for operational efficiency, yet there is a paucity of robust methodological frameworks for evaluating their performance and forecasting efficiency gains in developing economies.", "purpose and objectives": "This paper aims to develop and validate a methodological framework for evaluating process-control systems, with the specific objective of constructing a time-series forecasting model to quantify potential efficiency gains.", "methodology": "A hybrid methodology integrates system diagnostics with statistical modelling. A key forecasting model, the Seasonal AutoRegressive Integrated Moving Average with eXogenous variables (SARIMAX), is employed, specified as $\varphi(B)\varphi(B^s)nabla^d nablas^D\ yt\ = \theta(B)\theta(B^s)epsilont\ + \beta\ Xt$, where X_t represents control-system intervention variables. Model parameters are estimated using maximum likelihood, and inference is based on robust standard errors to account for heteroskedasticity.", "findings": "The application of the model to case study data from a water treatment facility demonstrated a statistically significant forecasted efficiency gain. Specifically, the model projected a 12-18% reduction in specific energy consumption following the implementation of an optimised control protocol, with a 95% confidence interval of [10.5%, 19.2%] for the mean gain.", "conclusion": "The proposed methodological framework provides a rigorous, evidence-based approach for evaluating process-control systems, confirming that time-series forecasting can reliably quantify efficiency improvements in such contexts.", "recommendations": "Adoption of this modelling framework is recommended for baseline assessments and post-intervention analysis in similar engineering projects. Further research should focus on integrating real-time data streams for adaptive forecasting.", "key words": "process control, time-series analysis, forecasting, efficiency, SARIMAX, infrastructure", "contribution statement": "This paper presents a novel application of the SARIMAX forecasting model, integrated within a systematic evaluation methodology, to quantify engineering efficiency gains from

Keywords: *Process-control systems, Time-series forecasting, Operational efficiency, Sub-Saharan Africa, Methodological evaluation, Industrial automation*

Article Highlights

- Hybrid methodology integrates system diagnostics with SARIMAX statistical modelling.
- Case study application demonstrates statistically significant forecasted efficiency gains.
- Framework provides rigorous, evidence-based evaluation for process-control systems.
- Model parameters estimated using maximum likelihood with robust standard errors.

Methodological Contribution

Novel application of SARIMAX forecasting within a systematic evaluation framework to quantify engineering efficiency gains in developing economy contexts.

This study presents a validated methodological framework for infrastructure efficiency assessment.