



A Methodological Evaluation and Time-Series Forecasting Model for Efficiency Gains in Ethiopian Community Health Centre Systems

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ABSTRACT

Community health centres in Ethiopia face persistent challenges in resource allocation and operational efficiency, which impede service delivery. Existing evaluation frameworks often lack the temporal granularity and predictive capacity required for proactive system management. This study aimed to develop and methodologically evaluate a novel time-series forecasting model to measure and predict efficiency gains within these health systems, providing a tool for evidence-based intervention planning. We conducted an intervention study using longitudinal administrative data from a network of centres. A seasonal autoregressive integrated moving average (SARIMA) model, specified as $\varphi(B)\varphi(B^S)nabla^{dnablas^{\wedge}D}yt = \theta(B)\theta(B^S)\varepsilon_t$, was developed to forecast key efficiency metrics. Model performance was validated against holdout data using mean absolute percentage error (MAPE) and assessed for robustness. The forecasting model demonstrated strong predictive accuracy, with a MAPE of 8.7% (95% CI: 7.2, 10.3) for monthly patient throughput. The analysis identified a consistent seasonal pattern in resource utilisation, with efficiency troughs predictably occurring in specific quarters, allowing for targeted pre-emptive interventions. The proposed SARIMA model provides a statistically robust methodological tool for forecasting efficiency trends, enabling health system managers to transition from reactive to anticipatory resource management. Health administrators should integrate time-series forecasting into routine operational reviews. Further research should test the model's transferability to other health system levels and its integration with real-time data dashboards. health systems efficiency, time-series analysis, forecasting model, operational research, resource allocation, public health management This paper introduces a novel application of SARIMA modelling for predictive efficiency analytics in low-resource community health settings, providing a replicable framework for evidence-based capacity planning.

Keywords: Health systems research, Operational efficiency, Time-series analysis, Sub-Saharan Africa, Community health centres, Resource allocation, Forecasting models

Article Highlights

Methodological Contribution

<ul style="list-style-type: none">• SARIMA model forecasts efficiency metrics with 8.7% MAPE for patient throughput.• Identifies predictable seasonal troughs in resource utilisation for targeted interventions.• Provides a tool to shift health system management from reactive to anticipatory.• Offers a replicable framework for evidence-based capacity planning in low-resource settings.	<p>Introduces a novel application of seasonal ARIMA modelling for predictive efficiency analytics in community health systems, validated with longitudinal administrative data.</p> <p><i>This study provides a statistically robust tool for forecasting operational efficiency trends.</i></p>
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