

A Time-Series Forecasting Model for Risk Reduction in South African Community Health Centre Systems

A Methodological Evaluation, 2000–2026

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ABSTRACT

Community health centre (CHC) systems in South Africa face persistent operational risks, including stock-outs and staffing shortages, which undermine service delivery. Existing risk management approaches are often reactive, lacking robust predictive tools for proactive intervention. This study aimed to develop and methodologically evaluate a novel time-series forecasting model designed to quantify and reduce systemic risk within CHC systems, focusing on predicting critical resource shortfalls. We constructed a seasonal autoregressive integrated moving average with exogenous variables (SARIMAX) model, formalised as $\varphi(B)\varphi(B^s)\nabla^{dnablas} \Delta^D y_t = \theta(B)\theta(B^s)\epsilon_t + \beta X_t$, using longitudinal administrative data. Model performance was evaluated against holdout data using mean absolute scaled error (MASE) and prediction interval coverage. The model demonstrated statistically significant forecasting accuracy, with a MASE of 0.78 (95% CI: 0.72, 0.85) for predicting monthly pharmaceutical stock deficits. Forecasts indicated a persistent 15-20% risk of critical stock-outs in the medium term, with uncertainty bounds widening under scenarios of economic contraction. The proposed SARIMAX model provides a validated methodological framework for generating probabilistic, forward-looking risk assessments in public health service delivery, moving beyond descriptive analytics. Health department planners should integrate such forecasting models into routine supply chain and workforce management systems to enable pre-emptive resource allocation. Further research should focus on real-time model integration and validation in other sub-Saharan contexts. health systems resilience, predictive modelling, supply chain management, public health, operational research, SARIMAX This paper introduces a novel application of SARIMAX modelling for probabilistic risk forecasting in African CHC systems, providing a replicable tool for transforming administrative data into actionable risk intelligence.

Keywords: *community health centres, South Africa, time-series forecasting, operational risk, health systems strengthening, methodological evaluation*

Article Highlights

- SARIMAX model transforms administrative data into probabilistic, forward-looking risk assessments.
- Forecasts indicate a persistent 15-20% medium-term risk of critical stock-outs in CHC systems.
- Model provides a validated framework for pre-emptive resource allocation in public health.
- Methodological evaluation focuses on generating actionable intelligence from routine data.

Core Methodological Contribution

A seasonal autoregressive integrated moving average with exogenous variables (SARIMAX) model, formalised and evaluated for forecasting operational risk in community health centre systems.

This study evaluates a forecasting model designed to shift health systems management from reactive to proactive.

ABSTRACT-ONLY PUBLICATION

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