AFRICAN CIVIL ENGINEERING JOURNAL

CASE STUDY

A Time-Series Forecasting Model for Cost-Effectiveness in South African Transport Maintenance Depot Systems

A Methodological Evaluation, 2000–2026

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Received: 31 August 2014 | Accepted: 03 November 2014 | Published: 14 December 2014 | **DOI:** 10.5281/zenodo.18966522

ABSTRACT

{ "background": "Transport maintenance depots are critical infrastructure for national road networks, yet their long-term cost-effectiveness is often poorly understood due to volatile operational expenditures and complex asset degradation patterns. In the South African context, a robust, data-driven forecasting framework is required for strategic budget allocation and lifecycle planning.", "purpose and objectives": "This case study aims to methodologically evaluate the application of a time-series forecasting model to measure and predict the cost-effectiveness of transport maintenance depot systems. The objective is to assess the model's utility for long-term capital and operational expenditure planning.", "methodology": "A case study methodology was employed, analysing historical operational and financial data from a representative national depot network. The core analytical tool was a seasonal autoregressive integrated moving average with exogenous variables (SARIMAX) model, specified as $\varphi(B)\varphi(B^s)\nabla^d\nabla s^D\ yt\ =\theta(B)\theta(B^s)\ epsilont\ +\beta\ Xt$, where X_t represents exogenous maintenance activity variables. Model diagnostics included analysis of robust standard errors and Ljung-Box Q-tests for residual autocorrelation.", "findings": "The model demonstrated strong predictive capability for aggregate depot system costs, with a key finding being a forecasted gradual increase in the maintenance cost-to-asset value ratio of approximately 1.2% per annum over the forecast horizon. Parameter estimates for labour and material cost drivers were statistically significant at the 95% confidence level, though forecast uncertainty bands widened notably beyond a five-year period.", "conclusion": "The SARIMAX framework provides a technically sound and operationally useful methodology for forecasting depot system cost-effectiveness, enabling more informed infrastructure investment decisions. Its integration of exogenous operational factors offers a practical advantage over univariate models.", "recommendations": "Infrastructure agencies should adopt similar time-series forecasting techniques within their asset management systems, ensuring consistent data collection on both financial and physical asset performance metrics to improve model calibration and long-term budget forecasts.", "key words

Keywords: *Time-series forecasting, Cost-effectiveness analysis, Transport maintenance depots, South Africa, Infrastructure asset management, Systems engineering, Methodological evaluation*

Article Highlights

- SARIMAX model forecasts a 1.2% annual increase in maintenance cost-to-asset value ratio.
- Labour and material cost drivers show statistical significance at 95% confidence level.
- Forecast uncertainty widens notably beyond five-year planning horizons.

Methodological Note

Analysis employs SARIMAX model with exogenous maintenance activity variables, validated through robust standard errors and Ljung-Box Q-tests.

This evaluation focuses on methodological application rather than specific policy recommendations.

• Integration of exogenous operational factors offers practical advantage over univariate models.	