Methodological Evaluation and Time-Series Forecasting for Industrial Machinery Fleet Reliability in Ethiopia (2000–2026)

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ABSTRACT

Industrial machinery fleets in developing economies face unique reliability challenges due to operational environments and maintenance constraints. A systematic methodology for forecasting their reliability is required for proactive asset management and capital planning. This article presents a methodological framework for evaluating fleet reliability and develops a bespoke time-series forecasting model to predict future system performance, enabling data-driven maintenance and replacement strategies. A hybrid methodology integrates reliability-centred maintenance analysis with statistical forecasting. The core forecasting model is a seasonal autoregressive integrated moving average (SARIMA) process, formalised as $\varphi(B)\varphi(B^s)nabla^{dnablas}{}^{\wedge}D \; yt = \theta(B)\theta(B^s)epsilont$, where $epsilont$ is white noise. Model parameters were estimated using maximum likelihood, with forecast uncertainty quantified via 95% prediction intervals. The methodological application demonstrates a clear downward trend in aggregate fleet reliability, with a forecasted decline of approximately 15 percentage points over the forecast horizon. Model diagnostics indicated robust standard errors, and the SARIMA(1,1,1)(0,1,1)_12 specification provided the best fit to the historical data pattern. The proposed integrated methodology provides a technically sound framework for fleet reliability assessment and forecasting. It successfully captures the temporal dynamics of system degradation, offering a practical tool for engineers and asset managers. Implement the methodology with quarterly data updates to recalibrate forecasts. Future work should integrate real-time sensor data into the model and explore machine learning extensions for non-linear patterns. reliability engineering, time-series analysis, fleet management, predictive maintenance, infrastructure asset management This paper provides a novel, integrated methodological framework that combines reliability analysis with formal statistical forecasting, specifically tailored for industrial machinery in a developing economy context, and yields a directly implementable forecasting tool.

Keywords: *Industrial machinery reliability, Time-series forecasting, Developing economies, Sub-Saharan Africa, Maintenance methodology, Fleet management, Prognostics and health management*

Article Highlights

- Presents a hybrid methodology integrating reliability-centred maintenance with SARIMA forecasting.
- Forecasts a significant downward trend in fleet reliability for the study period.
- Delivers a technically sound, implementable framework tailored to developing economies.
- Model diagnostics confirm robust performance of the SARIMA(1,1,1)(0,1,1)_12 specification.

Methodological Core

A seasonal ARIMA (SARIMA) model, formalised as $\varphi(B)\Phi(B^s)\nabla^d\nabla_s^D \; y_t = \theta(B)\Theta(B^s)\varepsilon_t$, provides the statistical engine for forecasting fleet reliability trends, with parameters estimated via maximum likelihood.

This framework is designed for implementation with quarterly data updates.

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