

Methodological Evaluation and Panel-Data Estimation for Process-Control System Reliability in Uganda (2000–2026)

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ABSTRACT

Background: Process-control systems are critical for industrial and infrastructure sectors, yet methodological frameworks for assessing their long-term reliability in resource-constrained settings are underdeveloped. There is a particular lack of longitudinal, data-driven evaluation techniques suitable for the operational environments found in many African nations.

Purpose and objectives: This article presents a methodological framework for evaluating the reliability of industrial process-control systems. Its primary objective is to develop and demonstrate a panel-data estimation model specifically designed to analyse degradation and failure modes over extended operational periods within a Ugandan context.

Keywords: *Process-control systems, Panel-data estimation, System reliability, Sub-Saharan Africa, Resource-constrained settings, Methodological evaluation*

Article Highlights

- Proposes a panel-data model using a GEE framework for longitudinal reliability analysis.
- Methodology specifically designed for data structures and challenges in Sub-Saharan Africa.
- Simulation studies validate the model's performance with systems exceeding a count of 30.
- Framework addresses unobserved heterogeneity between systems through its statistical design.

Core Model Specification

System reliability is modelled as: $\text{logit}(P(Y_{it}=1)) = \beta_0 + \beta_1 X_{1,it} + \dots + \mu_i + \varepsilon_{it}$, with inference based on robust standard errors clustered at the system level.

This article presents a methodological framework; empirical application results are not reported.

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