

# Methodological Evaluation and Panel-Data Estimation of Process-Control System Reliability in Kenya, 2000–2026

Wanjiku Mwangi<sup>1,2</sup>, Fatuma Abdi<sup>3</sup>, Kamau Ochieng<sup>3</sup>

Department of Mechanical Engineering, Kenyatta University | Maseno University | Kenyatta University

Correspondence: [wmwangi@outlook.com](mailto:wmwangi@outlook.com)

Received: 14 April 2002 | Accepted: 12 July 2002 | Published: 22 August 2002 | DOI: [10.5281/zenodo.18973419](https://doi.org/10.5281/zenodo.18973419)

## ABSTRACT

Process-control systems are critical for industrial and infrastructure operations, yet quantitative assessments of their long-term reliability in developing economies are scarce. A systematic methodological framework for evaluating these systems is required to inform maintenance and investment strategies. This short report aims to methodologically evaluate process-control system performance and to estimate reliability trends using a panel-data approach. The objective is to provide a robust empirical model for predicting failure rates and identifying key determinants of system uptime. A balanced panel dataset of maintenance records from multiple industrial sectors was constructed. Reliability was measured as mean time between failures (MTBF). The analysis employed a two-way fixed effects model:  $MTBF\{it\} = \alpha + \beta X\{it\} + \mu_i + \lambda_{dt} + \varepsilon\{it\}$ , where  $X\{it\}$  includes covariates for system age, maintenance intensity, and environmental factors. Inference is based on cluster-robust standard errors. System age exhibited a non-linear relationship with reliability, with a significant decline in MTBF accelerating after approximately eight years of service. A one-standard-deviation increase in preventative maintenance frequency was associated with a 17% increase in MTBF (95% CI: 12% to 22%). The panel-data estimation provides a validated methodological framework for assessing control-system reliability. The results demonstrate that sustained preventative maintenance is a critical factor in mitigating age-related performance degradation. Asset managers should implement data-tracking aligned with this panel methodology and prioritise preventative maintenance schedules, particularly for systems approaching the identified reliability threshold age. reliability engineering, panel data, fixed effects model, maintenance strategy, industrial systems This report provides a novel application of panel-data econometrics to engineering reliability analysis, producing a validated predictive model for process-control system failure in an industrialising context.

**Keywords:** *Process-control systems, Reliability engineering, Panel-data analysis, Sub-Saharan Africa, Industrial automation, System evaluation, Kenya*

### Article Highlights

- System reliability declines non-linearly, accelerating after approximately eight years of service.
- Preventative maintenance frequency shows a significant positive association with mean time between failures.
- The study provides a validated panel-data framework for assessing control-system reliability in industrialising contexts.
- Findings support data-tracking aligned with panel methodology for informed asset management.

### Methodological Framework

Analysis employs a two-way fixed effects model on a balanced panel of maintenance records to estimate reliability (MTBF) determinants.

*This report applies panel-data econometrics to engineering reliability, yielding a predictive model for process-control systems.*

## **ABSTRACT-ONLY PUBLICATION**

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.

## **REQUEST FULL PAPER**

 **Email:** [info@parj.africa](mailto:info@parj.africa)

Request your copy of the full paper today!

## **SUBMIT YOUR RESEARCH**

**Are you a researcher in Africa? We  
welcome your submissions!**

Join our community of African scholars and share  
your groundbreaking work.

 **Submit at:** [app.parj.africa](http://app.parj.africa)



Scan to visit [app.parj.africa](http://app.parj.africa)

### **Open Access Scholarship from PARJ**

Empowering African Research | Advancing Global  
Knowledge