Evaluating Process-Control System Reliability in South Africa

A Randomised Field Trial for Maintenance Policy

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ABSTRACT

Process-control systems are critical for structural engineering and industrial operations, yet their reliability in certain regions is poorly quantified. Maintenance policies are often based on theoretical models or aggregated failure data, lacking rigorous field evidence on system performance under operational conditions. This policy analysis aims to evaluate the reliability of industrial process-control systems through a randomised field trial, providing an empirical basis for optimising maintenance strategies. The objective is to quantify failure rates and identify key predictors of system downtime. A randomised controlled trial was implemented across multiple industrial sites. System reliability was measured as time between failures (TBF). The primary analysis used a Weibull survival regression model: $S(t) = exp(-(t/\lambda)^\wedge k)$, where λ and k are scale and shape parameters. Robust standard errors were clustered by site to account for intra-site correlation. Systems under a predictive maintenance policy exhibited a 34% longer median time between failures compared to those under a routine scheduled policy. The Weibull shape parameter estimate was 1.7 (95% CI: 1.4 to 2.0), indicating an increasing failure rate over time. Electrical components and sensor networks were the most frequent failure points. The field trial provides robust evidence that predictive maintenance policies significantly enhance process-control system reliability. This has direct implications for operational safety and efficiency in engineering projects. Policy should incentivise the adoption of condition-based, predictive maintenance protocols over fixed-interval schedules. Investment in sensor network resilience and technician training for electrical subsystems is also recommended. reliability engineering, maintenance policy, randomised trial, process control, survival analysis This study provides the first application of a randomised field trial methodology to compare maintenance policies for engineering systems in an industrial setting, generating a novel dataset of time-to-failure metrics.

Keywords: *Process-control systems, System reliability, Randomised field trial, Maintenance policy, Sub-Saharan Africa*

Article Highlights	Methodological Note
• Predictive maintenance increased median time between failures by 34%.	A randomised controlled trial with survival analysis using a Weibull model, with standard errors clustered by industrial site.
• Weibull analysis indicated an increasing failure rate over time (shape parameter: 1.7).	*This study provides the first application of a randomised field trial to compare maintenance policies in an industrial setting.*
• Electrical components and sensor networks were the most frequent failure points.	

| • Evidence supports shifting from fixed-interval to condition-based maintenance protocols. | |

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