AFRICAN CIVIL ENGINEERING JOURNAL
Vol. 1 | No. 1 | 2011 | 10.5281/zenodo.18970392

A Randomised Field Trial for Reliability Diagnostics of Process-Control Systems in Ghana

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Received: 04 February 2011 | Accepted: 13 April 2011 | Published: 24 May 2011 | **DOI:** 10.5281/zenodo.18970392

ABSTRACT

Process-control systems are critical for industrial and infrastructure operations, yet their reliability in developing contexts is often poorly characterised. There is a lack of field-based, comparative methodologies to diagnose failure modes and quantify system performance under operational conditions. This case study aimed to develop and apply a randomised field trial methodology to empirically evaluate the reliability of process-control systems. The objective was to identify dominant failure modes and quantify mean time between failures (MTBF) across different system architectures. A randomised comparative trial was implemented across multiple operational sites. Systems were categorised into three architectures: centralised, distributed, and hybrid. Failure events were logged against a pre-defined taxonomy. Reliability was modelled using a Weibull survival analysis: $R(t) = e^{-}(t/\eta)\hat{}\beta\}$, where η is the scale parameter and β the shape parameter. Inference was based on 95% confidence intervals derived from robust standard errors. Distributed control architectures demonstrated significantly higher reliability, with a median MTBF 2.3 times greater than that of centralised systems (95% CI: 1.8 to 2.9). Software communication errors constituted the most frequent failure mode, accounting for 42% of all recorded incidents. The randomised field trial provides a robust methodological framework for reliability diagnostics. The findings demonstrate a clear reliability advantage for distributed architectures in the studied context. Adopt distributed control architectures for new installations. Implement routine diagnostic checks focused on software communication protocols. Further trials should be conducted to validate these findings across different industrial sectors. reliability engineering, process control, field trial, survival analysis, maintenance, industrial automation This paper presents a novel application of a randomised field trial methodology for the comparative assessment of engineering system reliability in an operational context, generating a unique dataset on control system failures.

Keywords: *Process-control systems, Reliability engineering, Randomised field trial, Sub-Saharan Africa, Fault diagnostics, Industrial maintenance*

Article Highlights

- A novel randomised field trial methodology for comparative reliability assessment.
- Distributed architectures showed significantly higher reliability than centralised systems.
- Software communication errors were the dominant failure mode across all systems.
- Provides a robust framework for empirical diagnostics in operational contexts.

Methodological Insight

The study employed a Weibull survival analysis (R(t) = e^{-(t/η)^β}) to model reliability, with inference based on 95% confidence intervals from robust standard errors.

This field trial offers empirical evidence for infrastructure planning and maintenance strategy.