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A Quasi-Experimental Evaluation of Reliability in South African Water Treatment Systems

A Case Study from 2000–2026

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ABSTRACT

{ "background": "The reliability of water treatment infrastructure is a critical determinant of public health and economic stability. In many regions, systematic evaluations of long-term system performance are hindered by a lack of controlled, longitudinal data and methodological frameworks suitable for operational engineering contexts.", "purpose and objectives": "This case study aimed to develop and apply a quasi-experimental methodology to quantitatively assess the reliability of water treatment systems. The primary objective was to isolate and measure the causal effect of specific maintenance interventions on system failure rates, moving beyond descriptive performance reporting.", "methodology": "A longitudinal, difference-in-differences design was employed, analysing operational data from multiple treatment facilities. Treatment and control groups were established based on the phased implementation of a predictive maintenance programme. System reliability was modelled using a Cox proportional hazards model: $h(t|X) = h0(t) \exp(\beta 1 Treated + \beta 2 Post + \beta 3 (Treated \times Post) + \gamma Z)$, where Z represents a vector of control variables. Robust standard errors were clustered at the facility level.", "findings": "Facilities under the intervention programme exhibited a statistically significant reduction in major failure events. The adjusted hazard ratio for the interaction term $(Treated \times Post)$ was 0.62 (95% CI: 0.51 to 0.75), indicating a 38% reduction in the hazard of failure. Water quality compliance, however, showed no significant improvement attributable solely to the mechanical intervention.", "conclusion": "The quasi-experimental design proved viable for rigorous reliability analysis in an operational engineering setting. The implemented maintenance strategy substantially improved mechanical reliability but was insufficient alone to enhance final water quality outcomes, highlighting a disconnect between component performance and overall system efficacy.", "recommendations": "Integrate reliability-centred maintenance data with real-time water quality monitoring to create a holistic performance dashboard. Policy should mandate the collection of standardised, time-stamped operational data to enable similar causal evaluations across the sector.",

Keywords: *Quasi-experimental design, Water treatment reliability, Infrastructure assessment, Southern Africa, System performance evaluation, Public health engineering, Process reliability*

Article Highlights

- A 38% reduction in failure hazard was achieved through predictive maintenance interventions.
- Quasi-experimental design proved viable for causal analysis in operational engineering contexts.
- Mechanical reliability gains did not translate to improved final water quality outcomes.

Methodological Note

Employed a longitudinal difference-in-differences design with a Cox proportional hazards model to isolate the causal effect of maintenance interventions on system failure rates.

This study provides a framework for moving from descriptive reporting to causal evaluation of infrastructure performance.

• Study advocates for integrated performance dashboards linking maintenance and quality data.	