

# A Randomised Field Trial for Risk-Based Diagnostics of Municipal Infrastructure Asset Systems in Kenya

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## ABSTRACT

{ "background": "Municipal infrastructure asset management in many African contexts relies on reactive, condition-based approaches, leading to inefficient resource allocation and heightened failure risks. A paradigm shift towards proactive, risk-informed diagnostics is required but lacks robust field validation in these settings.", "purpose and objectives": "This study aimed to evaluate the efficacy of a novel risk-based diagnostic framework for municipal infrastructure systems through a randomised field trial. The primary objective was to quantify the reduction in unplanned maintenance events and associated cost variances achieved by the intervention.", "methodology": "A cluster-randomised controlled trial was conducted across 42 municipal asset systems. Intervention clusters received the risk-based diagnostic protocol, which prioritised assets using a Bayesian risk score  $Ri = P(Fi) \times C(Fi | \theta)$ , where  $P(Fi)$  is the probability of failure and  $C(\cdot)$  is the consequence function parameterised by  $\theta$ . Control clusters continued with standard practice. Primary outcomes were analysed using generalised linear mixed models with robust standard errors.", "findings": "Systems under the risk-based protocol experienced a 34% reduction (95% CI: 22% to 46%) in major unplanned maintenance events per annum compared to control systems. The intervention also significantly reduced the variance in annual maintenance expenditure by 41%, indicating improved budgetary predictability.", "conclusion": "The risk-based diagnostic framework demonstrably enhances the resilience and financial predictability of municipal infrastructure management. It represents a viable, evidence-based alternative to conventional condition-led approaches.", "recommendations": "Municipal engineers and asset managers should adopt probabilistic risk models as the foundation for diagnostic programmes. Policy should mandate risk-based prioritisation in infrastructure investment planning to optimise limited public funds.", "key words": "asset management, risk-based diagnostics, randomised controlled trial, infrastructure resilience, municipal engineering, sub-Saharan Africa", "contribution statement": "This paper provides the first experimental evidence from a randomised field trial on the effectiveness of a Bayesian risk-scoring model for municipal

**Keywords:** *Municipal infrastructure, Asset management, Sub-Saharan Africa, Risk-based diagnostics, Randomised field trial, Condition assessment, Kenya*

### Article Highlights

- Cluster-randomised trial across 42 municipal asset systems in Kenya.
- 34% reduction in major unplanned maintenance events with risk-based protocol.
- 41% reduction in variance of annual maintenance expenditure.
- Bayesian risk score prioritises assets using probability and consequence of failure.

### Methodological Note

The intervention employed a Bayesian risk score,  $Ri = P(Fi) \times C(Fi | \theta)$ , to prioritise assets, contrasting with standard condition-based practice in control clusters.

*This trial provides experimental evidence for proactive infrastructure management in Sub-Saharan Africa.*



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