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Randomised Field Trial for Reliability Diagnostics of Municipal Infrastructure Asset Systems in Rwanda

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ABSTRACT

Municipal infrastructure asset systems in many developing nations face significant reliability challenges, yet diagnostic methodologies often rely on non-randomised, convenience-based sampling, which can introduce substantial bias into system performance estimates. This study aimed to evaluate the methodological efficacy of a randomised field trial for generating unbiased reliability diagnostics of municipal water distribution networks, with the objective of establishing a robust framework for infrastructure system assessment. A stratified randomised sampling design was implemented across a network of municipal water systems. System reliability was modelled using a proportional hazards framework, $h(t|X) = h0(t)\, exp(beta1\, X1 + beta2\, X_2)$, where covariates included pipe material and soil corrosivity. Inference was based on robust standard errors to account for cluster-level heterogeneity. The randomised trial design reduced spatial sampling bias by an estimated 40% compared to prior non-randomised audits. A key technical finding was that asbestos cement pipes exhibited a hazard ratio of 2.3 (95% CI: 1.7 to 3.1) for failure relative to ductile iron, controlling for soil conditions. The randomised field trial provides a methodologically superior approach for diagnosing infrastructure reliability, yielding less biased and more generalisable estimates of system performance crucial for asset management planning. Municipal engineers and asset managers should adopt randomised sampling strategies for baseline condition assessments. Future research should integrate this diagnostic method with predictive maintenance algorithms. infrastructure reliability, asset management, randomised trial, proportional hazards model, water distribution networks This paper provides the first application of a formally randomised field trial methodology for municipal infrastructure diagnostics in a sub-Saharan context, demonstrating its utility in reducing spatial sampling bias.

Keywords: *Randomised controlled trial, Infrastructure asset management, System reliability, Sub-Saharan Africa, Municipal engineering, Field diagnostics, Maintenance strategies*

Article Highlights

- First application of a formally randomised field trial for infrastructure diagnostics in sub-Saharan Africa.
- Randomised sampling reduced spatial bias by ~40% versus

Methodological Insight

A stratified randomised sampling design and proportional hazards model were deployed to generate unbiased reliability estimates for municipal water networks.

non-randomised methods. • Asbestos cement pipes showed a 2.3x higher failure hazard versus ductile iron. • Proposes a robust framework using proportional hazards modelling for asset reliability.	*This study establishes a methodologically superior framework for infrastructure asset diagnostics.*