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

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ABSTRACT

Municipal infrastructure asset systems in many developing nations face chronic reliability issues, yet diagnostic methods often rely on aggregated, non-experimental data, limiting causal inference for system performance. This study aimed to develop and evaluate a novel field-based methodological framework for the reliability diagnostics of municipal infrastructure systems, using a randomised controlled trial to isolate causal factors affecting service continuity. A stratified randomised field trial was conducted across multiple municipal regions. Infrastructure subsystems (water distribution, drainage) were randomly assigned to diagnostic intervention or control. Reliability was measured via failure rate per 100 km-year. The primary analysis used a generalised linear mixed model: $log(\lambda\{ij\}) = beta0 + beta1\,T\{ij\} + ui + \varepsilon\{ij\}$, where $\lambda\{ij\}$ is the failure rate for segment j in region i, $T\{ij\}$ is the treatment indicator, and u_i is a region-level random effect. Robust standard errors were calculated. The diagnostic intervention identified specific material degradation as a primary failure driver. Subsystems receiving the targeted diagnostic protocol exhibited a 22% lower mean failure rate (95% CI: 15% to 29%) compared to control groups over the observation period. The randomised field trial provides a rigorous, transferable methodology for infrastructure reliability assessment, demonstrating that structured field diagnostics can effectively pinpoint and quantify key failure mechanisms. Municipal asset management strategies should incorporate randomised diagnostic sampling into routine condition assessment programmes to prioritise rehabilitation investments based on causal evidence. asset management, infrastructure reliability, randomised controlled trial, field diagnostics, maintenance planning This paper presents a novel application of experimental design to municipal infrastructure diagnostics, generating a unique dataset that isolates causal factors of system failure in a real-world setting.

Keywords: *Randomised controlled trial, Infrastructure asset management, System reliability, Sub-Saharan Africa, Municipal engineering, Causal inference, Developing nations*

Article Highlights

- Stratified randomised field trial conducted across multiple municipal regions in Senegal.

Methodological Contribution

This study develops a transferable field-trial framework for infrastructure reliability assessment, applying causal

• Diagnostic intervention linked to 22% lower mean failure rate (95% CI: 15% to 29%). • Novel framework isolates causal factors for infrastructure reliability using experimental design. • Supports integrating randomised diagnostic sampling into routine asset management.	inference methods typically reserved for clinical or social sciences to municipal engineering. *This paper provides a replicable methodology for evidence-based infrastructure management.*