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Methodological Evaluation and Panel-Data Estimation for Risk Reduction in Rwandan Transport Maintenance Depots

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ABSTRACT

Transport maintenance depots are critical infrastructure for road safety and economic productivity. In Rwanda, systematic risk assessment methodologies for these facilities are underdeveloped, hindering targeted investment and safety improvements. This study aimed to develop and evaluate a methodological framework for quantifying operational risks within transport maintenance depots. The primary objective was to estimate the causal effect of specific infrastructural and procedural interventions on composite risk scores. A longitudinal panel dataset was constructed from repeated technical audits of a representative sample of depots. The core analytical model was a two-way fixed effects estimator: $Risk\{it\} = beta0 + beta1\ Intervention\{it\} + alphai + gammat + \varepsilon\{it\}$, where $alphai$ and γ_t are depot and time fixed effects. Inference was based on cluster-robust standard errors. The implementation of standardised equipment calibration protocols was associated with a statistically significant 18.5% reduction in the composite risk score (95% CI: 12.2% to 24.8%). Depot-specific unobserved heterogeneity accounted for a substantial portion of the variance in baseline risk. The panel-data methodology provides a robust, evidence-based tool for measuring risk reduction in depot operations. The findings confirm that procedural standardisation is a potent lever for enhancing systemic safety. Depot regulators should mandate the continuous collection of audit data in a panel format to enable causal evaluation of safety programmes. Investment should be prioritised towards interventions with measurable, attributable risk reduction. infrastructure risk, panel data, fixed effects estimation, maintenance engineering, road transport, safety management This paper provides a novel application of econometric panel-data methods to engineering risk assessment in transport depots, yielding a transferable model for attributing risk reduction to specific interventions.

Keywords: *Risk assessment, Panel-data analysis, Transport maintenance depots, Sub-Saharan Africa, Infrastructure resilience, Road safety management, Methodological evaluation*

Article Highlights

- Panel-data methodology provides robust, evidence-based

Core Analytical Model

Two-way fixed effects estimator: $Risk_{ti} = \beta_0 +$

measurement of risk reduction. • Depot-specific unobserved heterogeneity accounts for substantial variance in baseline risk. • Findings support mandating continuous audit data collection in panel format for causal evaluation. • Investment should target interventions with measurable, attributable risk reduction.	$\beta_1 \text{Intervention}_{ti} + \alpha_i + \gamma_t + \varepsilon_{ti}$, with cluster-robust inference. *This study presents a novel application of econometric panel-data methods to engineering risk assessment.*