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A Bayesian Hierarchical Model for Cost-Effectiveness in South African Industrial Machinery Fleet Systems

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ABSTRACT

Background: The management of industrial machinery fleets represents a significant capital and operational expenditure for heavy industries. Current cost-effectiveness evaluations often rely on deterministic models that fail to adequately account for operational variability and uncertainty inherent in complex, multi-site systems.

Purpose and objectives: This short report presents a novel Bayesian hierarchical modelling framework designed to quantify the cost-effectiveness of industrial machinery fleets. The objective is to provide a robust probabilistic method for integrating heterogeneous operational data to inform maintenance and replacement decisions.

Keywords: *Bayesian hierarchical modelling, cost-effectiveness analysis, industrial machinery fleets, Sub-Saharan Africa, maintenance optimisation, heavy industry, capital expenditure*

Article Highlights

- Bayesian framework quantifies uncertainty in lifecycle cost analyses for heavy machinery.
- Posterior probability >0.85 favors predictive over reactive maintenance strategies.
- Model integrates heterogeneous operational data from multi-site fleet systems.
- Hierarchical structure separates fleet-level from machine-level effects.

Methodological Note

The model specification $\alpha_i \sim \text{Normal}(\mu_{\alpha}, \tau^2)$ explicitly estimates variance between fleets, revealing management practice impacts.

This report presents a probabilistic alternative to deterministic cost-effectiveness models.