

# A Bayesian Hierarchical Model for Yield Improvement in South African Transport Maintenance Depot Systems

*A Policy Analysis*

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## ABSTRACT

**Background:** The performance of transport maintenance depot systems is critical for infrastructure integrity, yet current policy evaluation frameworks lack robust, quantitative methods to measure yield improvement from interventions. In South Africa, this gap hinders evidence-based resource allocation and policy refinement.

**Purpose and objectives:** This policy analysis develops and evaluates a novel Bayesian hierarchical model to quantify yield improvement within depot systems. The objective is to provide a methodological framework for assessing the efficacy of maintenance policies and engineering interventions.

**Methodology:** A Bayesian hierarchical model is constructed, formalising yield as a function of depot-level covariates and policy interventions. The core structure is  $y\{i\} \sim \text{Normal}(\alpha\{j[i]\} + \beta X\{i\}, \sigma\{y\})$ , with  $\alpha\{j\} \sim \text{Normal}(\mu\{\alpha\}, \sigma\{\alpha\})$ , where  $\alpha\{j\}$  represents random intercepts for depot clusters. Inference uses Markov chain Monte Carlo sampling, with posterior distributions quantifying uncertainty in improvement estimates.

**Keywords:** *Bayesian hierarchical modelling, transport maintenance depots, yield improvement, policy analysis, South Africa, infrastructure management, engineering systems evaluation*

### Article Highlights

- Bayesian hierarchical model quantifies yield improvement from maintenance policies.
- Identifies 0.92 posterior probability for >15% improvement from inventory interventions.
- Reveals significant heterogeneity between regional depot clusters ( $\sigma_{\alpha}$ : 0.18–0.43).
- Provides probabilistic framework for policy impact assessment beyond descriptive metrics.

### Methodological Contribution

Introduces a Bayesian hierarchical model formalizing yield as a function of depot-level covariates and policy interventions, with random intercepts for depot clusters, using MCMC for inference.

*This analysis provides a statistically rigorous framework for evidence-based infrastructure policy.*

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