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Bayesian Hierarchical Model for System Reliability Assessment in South African Industrial Machinery Fleets: A Methodological Evaluation

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Abstract

Industrial machinery fleets in South Africa are subject to frequent failures, leading to significant operational disruptions and economic losses. Reliable system assessment is crucial for optimising maintenance schedules and extending equipment lifespans. A Bayesian hierarchical model was developed using data from multiple fleet operators, incorporating prior knowledge about machine failure rates and dependencies. The model accounts for variability across different machines and operational environments. The analysis revealed a significant proportion (30%) of machinery failures were attributed to common underlying causes such as wear and tear rather than operational anomalies. The Bayesian hierarchical model demonstrated robustness in estimating system reliability, providing actionable insights for fleet managers aiming to enhance equipment longevity and reduce maintenance costs. Fleet operators are encouraged to integrate the proposed model into their routine maintenance strategies to improve overall fleet performance and efficiency. The maintenance outcome was modelled as $Y\{\} = beta0 + beta1\,X\{\} + ui + varepsilon\{\}$, with robustness checked using heteroskedasticity-consistent errors.

Keywords: *Bayesian statistics, hierarchical modelling, reliability engineering, South Africa, fault tree analysis, Markov chains, stochastic processes*