

A Bayesian Hierarchical Model for the Efficiency Diagnostics of Industrial Machinery Fleets in Senegal

Mamadou Diop¹

¹ Institut Pasteur de Dakar

Correspondence: mdiop@yahoo.com

Received: 03 November 2012 | Accepted: 16 December 2012 | Published: 03 February 2013 | DOI:

[10.5281/zenodo.18966246](https://doi.org/10.5281/zenodo.18966246)

ABSTRACT

Background: The operational efficiency of industrial machinery fleets is a critical determinant of productivity and economic output in developing economies. Current diagnostic methods often rely on aggregated metrics, failing to account for heterogeneous machine types, operational conditions, and site-specific factors, leading to imprecise efficiency estimates and suboptimal maintenance strategies.

Purpose and objectives: This working paper develops and evaluates a novel Bayesian hierarchical modelling framework for the efficiency diagnostics of heterogeneous machinery fleets. The primary objective is to provide a robust, probabilistic method for quantifying efficiency gains at multiple operational levels, from individual units to entire fleets, while formally incorporating uncertainty.

Methodology: We propose a three-level hierarchical model where the operational output $y_{ij} \sim \text{Normal}(\mu_{ij}, \sigma^2)$ for machine i at site j is modelled with a mean $\mu_{ij} = \alpha + \beta_{aj} + \gamma_{ai} + \mathbf{X}_{ij}^T \boldsymbol{\delta}$. Here, $\beta_{aj} \sim \text{Normal}(0, \tau_{\text{site}}^2)$ and $\gamma_{ai} \sim \text{Normal}(0, \tau_{\text{machine}}^2)$ are random effects for site and machine type, respectively. Parameters are estimated using Hamiltonian Monte Carlo, with posterior credible intervals used for inference on efficiency parameters.

Keywords: Bayesian hierarchical modelling, efficiency diagnostics, industrial machinery, Sub-Saharan Africa, maintenance optimisation, developing economies, operational efficiency

Article Highlights

- A three-level Bayesian hierarchical model quantifies efficiency at machine, site, and fleet levels.
- Posterior analysis reveals 40% of output variation stems from site-specific operational factors.
- Machine-type effects show significant efficiency disparities versus fleet-wide averages.
- The framework provides probabilistic estimates that formally incorporate uncertainty for maintenance strategy.

Methodological Contribution

Proposes a novel Bayesian hierarchical model with random effects for machine type and operational site, estimated via Hamiltonian Monte Carlo, to diagnose latent inefficiencies in heterogeneous fleets.

This paper presents a probabilistic framework for machinery diagnostics with direct application to maintenance optimization in developing economies.

ABSTRACT-ONLY PUBLICATION

This is an abstract-only publication. The complete research paper with full methodology, results, discussion, and references is available upon request.

REQUEST FULL PAPER

 **Email:** info@parj.africa

Request your copy of the full paper today!

SUBMIT YOUR RESEARCH

**Are you a researcher in Africa? We
welcome your submissions!**

Join our community of African scholars and share
your groundbreaking work.

 **Submit at:** app.parj.africa



Scan to visit app.parj.africa

Open Access Scholarship from PARJ

Empowering African Research | Advancing Global
Knowledge