

# Methodological Evaluation and Risk Reduction in Ethiopian Manufacturing Plant Systems

*A Multilevel Regression Analysis*

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## ABSTRACT

Manufacturing systems in developing economies face unique operational and infrastructural challenges that elevate systemic risk. Current risk assessment methodologies often lack the hierarchical structure to account for both plant-level and subsystem-level variability, leading to imprecise mitigation strategies. This Data Descriptor presents a novel, hierarchically structured dataset and methodological framework for evaluating systemic risk in industrial plants. The primary objective is to provide a robust empirical foundation for quantifying risk reduction through multilevel modelling. Data were collected via structured audits across multiple manufacturing subsystems (electrical, mechanical, process control). The core analytical method is a three-level random intercepts model, specified as  $y_{ijk} = \beta_0 + \beta_1 x_{ijk} + u_k + v_{jk} + e_{ijk}$ , where  $u_k$  and  $v_{jk}$  are random effects for plant and subsystem, respectively. Inference is based on robust standard errors. The analysis indicates that interventions targeting process control subsystems yield the most significant risk reduction, with a modelled decrease in incident likelihood of approximately 22% (95% CI: 18 to 26) per unit improvement in audit score. Plant-level infrastructural factors accounted for a substantial portion of the residual variance. The multilevel regression approach provides a superior fit for the nested structure of manufacturing system data, enabling more accurate identification of risk factors operating at different scales within a plant. Future risk assessments in similar contexts should adopt a hierarchical data collection and modelling strategy. Investment in process control system resilience is prioritised based on the empirical findings. systemic risk, multilevel modelling, manufacturing resilience, industrial safety, hierarchical data This work provides the first open-access, plant-level dataset structured for multilevel analysis of manufacturing risks in its context and demonstrates a novel application of hierarchical regression for engineering system evaluation.

**Keywords:** Manufacturing systems, Multilevel modelling, Risk assessment, Sub-Saharan Africa, Industrial engineering, Developing economies, Process safety

### Article Highlights

- A three-level random intercepts model quantifies risk across plants, subsystems, and units.
- Process control system improvements show the most significant modelled risk reduction.
- Plant-level infrastructural factors account for substantial residual variance in risk.
- Hierarchical data structure is critical for accurate risk factor identification.

### Core Analytical Method

Three-level random intercepts model:  $y_{ijk} = \beta_0 + \beta_1 x_{ijk} + u_k + v_{jk} + e_{ijk}$ , with inference based on robust standard errors.

*This study provides a novel hierarchical dataset and modelling framework for manufacturing risk in developing economies.*



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