

ORIGINAL RESEARCH

Methodological Evaluation and Multilevel Regression Analysis of Risk Reduction in Ghanaian Manufacturing Plant Systems

Kwame Asante¹

¹ Kwame Nkrumah University of Science and Technology (KNUST), Kumasi

Correspondence: kasante@yahoo.com

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ABSTRACT

Manufacturing systems in developing economies face unique operational hazards, yet methodological frameworks for quantifying systemic risk reduction are underdeveloped. Existing studies often lack robust statistical models that account for the hierarchical structure of plant data. This study aims to develop and apply a multilevel modelling methodology to evaluate the efficacy of integrated safety management systems in reducing operational risk within manufacturing plants. A cross-sectional survey collected data on safety climate, engineering controls, and incident rates from 347 workers nested within 23 plants. A three-level random intercepts model was specified: $\log(\text{Incident Rate}_{ijk}) = \beta_0 + \beta_1 X_{ijk} + u_k + v_{jk} + e_{ijk}$, where i, j , and k index workers, departments, and plants, respectively. Parameters were estimated using restricted maximum likelihood with robust standard errors. The multilevel model explained 38% of the variance in incident rates. A one-unit increase in standardised safety climate score at the plant level was associated with a 22% reduction in the incident rate (95% CI: 17% to 27%). Department-level engineering controls showed a weaker, non-significant association. The methodological approach confirms that plant-wide safety climate is a stronger predictor of risk reduction than departmental engineering interventions alone, highlighting the importance of organisational culture. Plant managers should prioritise investments in organisation-wide safety culture programmes. Regulatory bodies should promote multilevel audit frameworks that assess both systemic and localised factors. safety management, hierarchical linear model, industrial engineering, operational risk, developing country This paper provides a novel application of multilevel regression to decompose risk variance in African manufacturing systems, offering a validated methodological tool for plant-level safety evaluation.

Keywords: Manufacturing systems, Risk reduction, Multilevel regression analysis, Sub-Saharan Africa, Occupational safety, Process safety engineering, Industrial hazards

Article Highlights

- Multilevel model explained 38% of variance in manufacturing incident rates.
- Plant-wide safety climate showed significant 22% reduction in risk.
- Department-level engineering controls demonstrated weaker, non-significant association.
- Methodology validates hierarchical analysis for Sub-Saharan industrial systems.

Methodological Contribution

Presents a novel multilevel regression framework for decomposing risk variance in African manufacturing plants, offering a validated tool for plant-level safety evaluation.

This study provides a statistical methodology for evaluating integrated safety management systems 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.



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