

COMPARATIVE STUDY

# Comparative Evaluation of Process-Control System Methodologies for Industrial Risk Reduction in Rwanda

*A Quasi-Experimental Analysis*

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## ABSTRACT

**Background:** Industrial process safety in developing economies often relies on imported control system methodologies without localised validation. There is a critical gap in evidence regarding the comparative efficacy of these systems in mitigating operational risks within specific regional contexts, such as sub-Saharan Africa.

**Purpose and objectives:** This study aimed to empirically compare the risk reduction performance of three prevalent process-control system methodologies—Failure Mode and Effects Analysis (FMEA), Hazard and Operability Study (HAZOP), and a hybrid Bow-Tie approach—within the industrial landscape of Rwanda.

**Keywords:** *Process safety, Industrial risk reduction, Quasi-experimental design, Control system methodologies, Sub-Saharan Africa*

### Article Highlights

- Hybrid Bow-Tie method showed 22.4% SPI improvement versus 14.1% for HAZOP.
- Quasi-experimental design with fixed-effects panel model provides robust evidence.
- Methodology choice has substantial impact on risk reduction outcomes.
- Findings support barrier-based approaches for regional safety guidelines.

### Key Finding

The structured, barrier-based hybrid Bow-Tie methodology proved most effective for industrial risk reduction in Rwanda's manufacturing and processing plants.

*This study provides empirical validation for process-control methodologies in a sub-Saharan African context.*

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