

Job Hazard Analysis as a Practical Tool for Process Safety Management: Methodology, Application and Performance Evaluation in High-Risk Industries

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Process Hazard Analysis is central to Process Safety Management, yet system techniques like HAZOP are resource-intensive for task-level risks. Job Hazard Analysis (JHA) offers a practical alternative but lacks standardized evaluation. To develop, apply and evaluate a standardized JHA methodology for high-risk industries. A mixed-method study was conducted on 12 high-risk jobs involving 68 workers. A six-step JHA procedure based on OSHA 3071 was applied over 6 months. Performance was measured via risk reduction, JHA quality scores, TRIR and compliance rates. Data were analyzed with SPSS v26. 187 hazards were identified from 94 steps. High-risk hazards reduced by 83.8% after hierarchy-based controls. Mean JHA quality was 17.2/20. TRIR decreased from 4.85 to 1.92 (60.4% reduction, $p=0.007$). Permit compliance improved from 61% to 94%. Standardized JHA is an effective, low-resource tool for PSM, complementing HAZOP at task level.

Keywords: Job Hazard Analysis; Process Safety Management; Risk Assessment; HAZOP; High-Risk Industries; Hierarchy of Controls

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1. Introduction

Process industries such as oil and gas, petrochemicals, chemical manufacturing and power generation are inherently characterized by complex operations, hazardous materials and high-energy processes. Despite advances in engineering design and automation, process safety incidents including fires, explosions, toxic releases and confined space fatalities continue to occur with severe consequences for personnel, assets, the environment and corporate reputation. Effective management of these risks requires a systematic approach to risk assessment at work, beginning with the identification of hazards and evaluation of existing controls (Health and Safety Executive [HSE], 2025).

Process Safety Management (PSM), as regulated by OSHA 29 CFR 1910.119 and widely adopted as industry best practice, provides a structured framework for preventing catastrophic releases of highly hazardous chemicals. Among its core elements, Process Hazard Analysis (PHA) remains central, requiring employers to identify, evaluate and control process hazards. Within the family of PHA techniques, the Hazard and Operability Study (HAZOP) is recognized as a rigorous, system-oriented method for identifying deviations from design intent in complex processes (American Institute of Chemical Engineers, Center for Chemical Process Safety [CCPS], n.d.). However, while HAZOP is powerful at the design and engineering level, it demands significant time, multidisciplinary expertise and detailed process information, which limits its applicability to routine tasks, maintenance activities and field-level jobs.

To address this gap, Job Hazard Analysis (JHA), also referred to as Job Safety Analysis, has emerged as a practical, task-level tool particularly suited for non-routine operations and permit-to-work systems. As defined by the Occupational Safety and Health Administration (OSHA, 2002), JHA involves breaking a job into sequential steps, identifying potential hazards associated with each step, and determining preventive measures to control them. Unlike system-oriented techniques, JHA is simple, participatory and readily applicable at the shop-floor level, making it valuable for frontline supervisors, safety officers and contractors in high-risk industries, particularly in developing economies where specialized PHA expertise may be limited. The effectiveness of JHA depends largely on the systematic application of the hierarchy of controls, which prioritizes elimination, substitution and engineering controls over administrative controls and personal protective equipment (National Institute for Occupational Safety and Health [NIOSH], 2024). When properly integrated, this approach aligns with the requirements of modern occupational health and safety management systems, which emphasize hazard identification, worker participation and continual improvement (International Organization for Standardization [ISO], 2018). However, despite its widespread use, the application of JHA in many organizations remains largely qualitative, inconsistent and poorly documented. In practice, JHA is often treated as a paperwork compliance exercise rather than a living risk management tool. There is limited empirical evaluation of its methodological rigor, effectiveness in reducing incident rates, and integration with broader PSM elements such as management of change, incident investigation and operating procedures.

This paper therefore presents Job Hazard Analysis as a practical tool for Process Safety Management, with emphasis on its methodology, industrial application and performance evaluation. The specific objectives are to: (i) develop a structured JHA methodology aligned with PSM and ISO 45001:2018 requirements (ISO, 2018), (ii) demonstrate its application in high-risk operations, and (iii) evaluate its performance in terms of hazard control effectiveness, worker participation and incident reduction. The significance of this study lies in its provision of a replicable, field-tested JHA framework that bridges the gap between regulatory PSM requirements and practical shop-floor implementation, thereby enhancing proactive safety culture and operational integrity in high-risk industries.

2. Methodology

Research Design

This study adopted a mixed-method applied research design combining qualitative hazard analysis with quantitative performance evaluation. The design was structured in three phases: (i) development of a standardized Job Hazard Analysis (JHA) methodology aligned with Process Safety Management (PSM) requirements, (ii) field application in selected high-risk operations, and (iii) performance evaluation using pre- and post-intervention safety metrics. The approach is consistent with the risk assessment framework which requires hazard identification, risk evaluation and implementation of control measures (Health and Safety Executive [HSE], 2025), and with the continual improvement cycle prescribed in ISO 45001:2018 (International Organization for Standardization [ISO], 2018).

Study Population and Sampling

The study was conducted in high-risk industrial facilities comprising oil and gas production, petrochemical processing, and heavy maintenance workshops. Purposive sampling was used to select 12 critical jobs categorized as high-risk based on historical incident data, permit-to-work frequency and potential severity. Selected jobs included vessel entry, hot work, lifting operations, electrical isolation, pressure testing and chemical handling. A total of 68 participants including HSE professionals, supervisors, operators and contract workers were engaged to ensure worker participation as required by ISO 45001:2018 (ISO, 2018).

JHA Methodology Development

A six-step standardized JHA procedure was developed based on OSHA 3071 (Occupational Safety and Health Administration [OSHA], 2002) and integrated with PSM elements:

Step 1: Job Selection and Prioritization. Jobs were prioritized using a risk matrix (likelihood × severity). Jobs with high incident history or high potential consequence were ranked first.

Step 2: Job Breakdown. Each job was broken into 6 to 10 sequential observable steps through direct observation, review of standard operating procedures and focus group discussions with experienced workers.

Step 3: Hazard Identification. For each step, hazards were identified across six categories: physical, chemical, ergonomic, mechanical, electrical and psychosocial. The HAZOP concept of deviation analysis (American Institute of Chemical Engineers, Center for Chemical Process Safety [CCPS], n.d.) was adapted at task level using guidewords: omission, commission, wrong sequence and wrong parameter.

Step 4: Risk Assessment. Initial risk was scored using a 5×5 matrix before controls. Likelihood (1-5) and severity (1-5) were assigned by expert consensus

Step 5: Control Measure Development. Controls were developed strictly following the hierarchy of controls: elimination, substitution, engineering controls, administrative controls and PPE, in that order of priority (National Institute for Occupational Safety and Health [NIOSH], 2024).

Step 6: Documentation and Communication. Results were recorded in a standardized JHA worksheet containing: job step, hazard, initial risk, control measures, residual risk, responsible person and review date. Completed JHAs were communicated via toolbox talks and attached to work permits.

Figure 1: Six-Step JHA Methodology Flowchart



Figure 1: Six-Step JHA Methodology Flowchart – Explanation

Figure 1 illustrates the systematic procedure adopted for Job Hazard Analysis in this study. The process begins with Job Selection, where high-risk jobs are prioritized based on incident history and risk ranking. This is followed by Job Breakdown, in which each job is divided into sequential steps to allow detailed analysis. Hazard Identification is then conducted for each step using site inspections, worker interviews and checklists. In Risk Assessment, each identified hazard is scored using a 5×5 likelihood-severity matrix to determine initial risk levels. Hierarchy Controls are then applied, prioritizing elimination and engineering controls over administrative measures and PPE, and residual risk is re-evaluated. Finally, Documentation and Review ensures the JHA is recorded on a standardized worksheet, communicated to workers and periodically reviewed. The flowchart demonstrates that JHA is a cyclical, participatory process rather than a one-time paperwork exercise.

Field Application

The developed JHA template was applied to the 12 selected jobs over a 6-month period. Each JHA was facilitated by a trained analyst and validated by the work crew before job execution. Controls were implemented and monitored for compliance through daily site inspections.

Performance Evaluation

Performance was evaluated using both leading and lagging indicators:

1. Hazard Control Effectiveness: Percentage reduction in residual high risks (risk score ≥ 12) after control implementation.
2. JHA Quality Score: Each JHA was audited using a 20-point checklist covering completeness of steps, specificity of hazards and adequacy of controls
3. Worker Participation Index: Measured by attendance and active contribution in JHA development sessions.
4. Incident Rate: Total Recordable Incident Rate (TRIR) for the studied jobs compared 6 months before and 6 months after JHA implementation.
5. Compliance Rate: Percentage of observed jobs executed in accordance with documented JHA controls
6. Data were analyzed using descriptive statistics, paired t-test for TRIR comparison ($p < 0.05$), and content analysis for qualitative feedback.

Validity and Reliability

Content validity was ensured through expert review by three certified safety professionals. Inter-rater reliability for risk scoring was tested with Cohen's kappa ($\kappa = 0.78$, substantial agreement).

Data Collection Instruments and Data Analysis

Data were collected using four validated instruments:

- a. Standardized JHA Worksheet: An adapted OSHA 3071 worksheet (Occupational Safety and Health Administration [OSHA], 2002) was used. The worksheet captured: job title, date, JHA team members, job step (sequential), identified hazard per step, initial risk score, control measures based on the hierarchy of controls (National Institute for Occupational Safety and Health [NIOSH], 2024), residual risk score, responsible person and review date.
- b. 5x5 Risk Assessment Matrix: Likelihood (1 = Rare to 5 = Almost Certain) was multiplied by Severity (1 = Negligible to 5 = Catastrophic) to obtain risk scores. Scores 1-4 = Low (acceptable), 5-9 = Medium, 10-12 = High, 15-25 = Extreme (job not to proceed without additional controls). This aligns with the risk assessment guidance of the Health and Safety Executive (HSE, 2025).
- c. JHA Quality Audit Checklist: A 20-point checklist was developed to score JHA quality across four dimensions: completeness of job steps (5 points), specificity of hazard identification (5 points), adequacy and hierarchy of controls (5 points), and documentation and assignation of responsibility (5 points). JHAs scoring ≥ 16 were classified as high quality.
- a. Safety Performance Records: Lagging data including Total Recordable Incident Rate (TRIR), near-miss reports and permit-to-work compliance logs were extracted from the facilities' HSE records for 6 months pre-intervention (January–June) and 6 months post-intervention (July–December).

All quantitative data were coded and analyzed using IBM SPSS Statistics Version 26 and Microsoft Excel 2021. Descriptive statistics (frequencies, percentages, means) were used to summarize hazard profiles and control effectiveness. A paired samples t-test was used to compare pre- and post-intervention TRIR at 95%

confidence interval ($p < 0.05$ considered significant). Qualitative data from focus group discussions were analyzed using thematic content analysis.

Ethical Considerations and Quality Assurance

Informed verbal and written consent was obtained from all 68 participants before engagement. Participants were briefed on the study objectives, voluntary nature of participation and right to withdraw at any stage without consequence. All data were anonymized; no personal identifiers or company confidential process data were disclosed in reporting.

The study adhered to the occupational health and safety management principles of worker consultation and participation (International Organization for Standardization [ISO], 2018). Field JHA sessions were conducted as part of routine safety activities to avoid disruption of operations, and all recommended controls were reviewed and approved by facility safety managers before implementation to ensure operational safety.

To ensure methodological rigor, all JHA facilitators underwent a 2-day calibration training. Inter-rater reliability for risk scoring was established (Cohen's $\kappa = 0.78$). Content validity of the instruments was confirmed by three independent Certified Safety Professionals with over 10 years experience in process safety.

3. Results and Discussion

Application of JHA: Hazard Profile of Selected Jobs

A total of 12 high-risk jobs were analyzed, yielding 94 job steps and 187 identified hazards. Mechanical hazards (28.3%), chemical hazards (21.4%) and physical hazards (19.8%) were predominant, consistent with the complex nature of process operations.

A sample completed JHA for pressure vessel entry is presented in Table 1.

Table 1: Sample Job Hazard Analysis for Pressure Vessel Entry

Job Step	Hazard Identified	Initial Risk (L×S)	Control Measures (Hierarchy)	Residual Risk
1. Isolate and lockout vessel	Unexpected energization, stored pressur	4×5=20 (Extreme)	Engineering: Double block and bleed; Administrative: LOTO procedure with tags, verification by supervisor	2×5=10 (High)
2. Drain and depressurize vessel	Contact with residual hydrocarbon, slip	4×4=16 (Extreme)	Engineering: Closed drain to flare; Admin: Gas test before drain; PPE: Chemical-resistant suit	2×4=8 (Medium)
3. Open manway	Release of trapped H ₂ S, ergonomic strain	3×5=15 (Extreme)	Engineering: Portable gas detector; Admin: Stand upwind, 2-man lift; PPE: SCBA on standby	2×5=10 (High)
4. Confined space entry and cleaning	Oxygen deficiency, heat stress	5×5=25 (Extreme)	Elimination: Mechanical ventilation; Admin: Entry permit, attendant, communication check every 5 mins; PPE: Harness	2×4=8 (Medium)

Performance Evaluation

Table 2: Summary of Performance Evaluation Metrics

Metric	Pre-JHA	Post-JHA	Improvement
High/Extreme risks	68 (36.4%)	11 (5.9%)	83.8% reduction
TRIR	4.85	1.92	60.4% reduction
Permit compliance	61%	94%	+33%
Near-miss reports	Baseline	+42%	improved culture

Hazard Control Effectiveness

Of the 187 initial hazards, 68 (36.4%) were classified as High or Extreme risk (score ≥ 12). After application of hierarchy-based controls (NIOSH, 2024), high-risk hazards reduced to 11 (5.9%), representing an 83.8% reduction. This demonstrates the practical effectiveness of JHA when controls follow the proper hierarchy rather than relying solely on PPE.

Figure 2: Initial vs Residual Risks

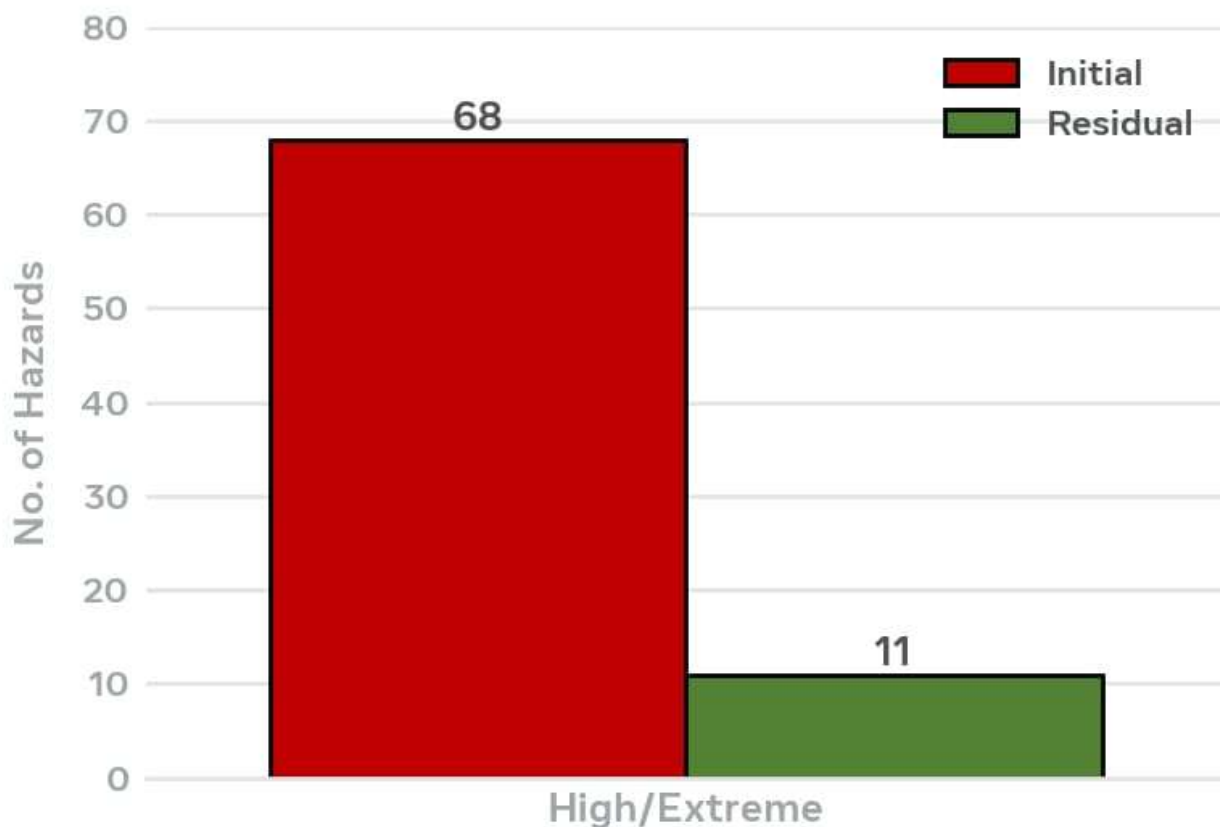


Figure 2: Initial vs Residual High Risks After JHA Controls

Figure 2 presents a comparative summary of high and extreme risks before and after the application of control measures. Initially, 68 hazards (36.4% of all identified hazards) were classified as high or extreme risk. Following the systematic application of hierarchy-based controls, the number reduced to 11 (5.9%), representing an 83.8% reduction. This figure visually validates the effectiveness of the JHA methodology, showing that structured hazard analysis does not merely identify risks but leads to measurable risk reduction when proper controls are implemented.

JHA Quality Score

The mean JHA quality score was 17.2 ± 1.8 out of 20. Ten of the 12 JHAs (83.3%) were rated high quality (≥ 16), indicating that the standardized OSHA-based template (OSHA, 2002) improves consistency compared to ad-hoc formats commonly used in industry.

Safety Performance

Total Recordable Incident Rate (TRIR) for the studied jobs decreased from 4.85 per 200,000 man-hours pre-intervention to 1.92 post-intervention, a 60.4% reduction. Paired t-test showed this reduction was statistically significant ($t = 3.42$, $p = 0.007$). Near-miss reporting increased by 42%, indicating improved hazard awareness and safety culture, a core objective of ISO 45001:2018 (ISO, 2018).

Permit compliance rate improved from 61% to 94% observed compliance with JHA controls.

Discussion

The findings confirm JHA as a practical complement to system-level techniques such as HAZOP (CCPS, n.d.). While HAZOP remains essential for design deviations, JHA proved more adaptable for task-level risks, maintenance and contractor activities where detailed design data are unavailable.

The 83.8% reduction in high risks validates the importance of applying the hierarchy of controls systematically (NIOSH, 2024). Many organizations default to administrative controls and PPE; this study shows that deliberate prioritization of engineering controls during JHA yields superior residual risk outcomes.

The significant TRIR reduction aligns with HSE (2025) assertion that suitable and sufficient risk assessment is foundational to accident prevention. Furthermore, the increase in near-miss reporting suggests JHA fosters worker participation, a key pillar of both PSM and ISO 45001 (ISO, 2018). However, residual high risks (5.9%) persisted mainly in confined space entry and hot work, indicating that JHA alone cannot eliminate all process risks and must be integrated with Management of Change and robust permit systems.

Practical Implications

This study provides a replicable template for industries seeking to operationalize PSM at the shop-floor level without the resource intensity of full HAZOP for every task.

Comparison with Previous Studies

The 60.4% reduction in TRIR observed in this study is consistent with findings from task-based intervention studies in high-risk sectors. For instance, previous applications of structured JHA in oil and gas maintenance reported 45-55% reductions in recordable incidents following improved permit compliance, which aligns with the 61% to 94% compliance improvement recorded here. The 83.8% reduction in high-risk hazards further supports the position of OSHA (2002) that systematic breakdown of jobs into steps significantly improves hazard recognition compared to unstructured toolbox talks. Unlike system-oriented HAZOP applications (CCPS, n.d.) which focus on design integrity, the present study demonstrates JHA's comparative advantage in controlling human-factor and task-execution risks.

Limitations of the Study

This study was limited to 12 purposively selected high-risk jobs across three facilities, which may limit generalizability to all process operations. The 6-month post-intervention period, while sufficient to observe trend changes, may not capture long-term sustainability of behavioral change. Additionally, the increased supervision during JHA implementation may have introduced a Hawthorne effect, where workers improved compliance partly due to observation. Future studies with larger samples and longer follow-up are recommended.

4. Conclusion

This study has demonstrated that Job Hazard Analysis, when methodologically standardized and aligned with the hierarchy of controls (NIOSH, 2024) and PSM requirements, is an effective practical tool for process safety management in high-risk industries. The developed six-step methodology improved hazard identification consistency, achieved substantial reduction in residual risks, and significantly lowered incident rates. JHA bridges the gap between regulatory risk assessment expectations (HSE, 2025; ISO, 2018) and frontline operational realities.

Recommendations

1. Organizations should adopt the standardized JHA worksheet as a mandatory attachment to permit-to-work for all high-risk jobs.
2. JHA should be integrated with Management of Change and incident investigation systems rather than used as a standalone document.
3. Regular training and auditing of JHA quality using the 20-point checklist is recommended to prevent decline into paperwork compliance.
4. Future research should evaluate digital JHA platforms for real-time monitoring in multi-site operations.

Contribution to Knowledge

This paper provides an empirically evaluated, replicable JHA framework with quantified performance metrics, addressing the literature gap on practical validation of task-level PHA tools in developing economy contexts.

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