Journal of Advances in Science and Technology
Vol. 22, Issue No. 2, April-2025, ISSN 2230-9659

DOI: https://doi.org/10.29070/48tjxfo2

Integrated Risk Assessment Approaches for Workplace Safety: A Study of JSA, FMEA, and Hazard Identification in Industrial Environments

Praduman Sharma [1] * , Vishal Tiwari [2]

1. Research Scholar, Vikrant University, Gwalior, M.P., India
pradumansharma2023@gmail.com ,
2. Assistant Professor, Vikrant University, Gwalior, M.P., India

Abstract: This research examines integrated risk assessment methodologies in industrial settings, emphasising the use of Job Safety Analysis (JSA), Failure Modes and Effects Analysis (FMEA), Hazard and Operability research (HAZOP), and Fault Tree Analysis (FTA). Data were collected using a mixed-methods strategy, including field observations, interviews, and historical safety records from the industrial, chemical, and construction industries. The study delineates prevalent industrial hazards physical, chemical, ergonomic, and psychological and assesses their risks via qualitative and quantitative methodologies. Instruments such as risk matrices, real-time monitoring systems, and safety software (Intelex and Sphera) improved hazard identification and management. Results indicate that high-risk tasks, such as heavy machinery operation and chemical management, need prompt engineering and administrative measures. This research suggests that the integration of structured risk assessment methodologies with contemporary safety technology significantly enhances hazard management and fosters workplace safety.

Keywords: Risk Assessment, JSA, FMEA, Hazard Identification, Workplace Safety

---------------------------- X ----------------------------

INTRODUCTION

Industrial worker safety is of the utmost importance due to the increased risk of dangers caused by complicated procedures and technology. The identification, evaluation, and mitigation of any dangers to infrastructure and personnel depend on thorough risk assessments. [1] The Job Safety Analysis (JSA) and the Failure Modes and Effects Analysis (FMEA) are two of the most popular tools for systematically identifying and ranking potential dangers. While FMEA assesses the frequency, severity, and detectability of system or equipment failures, JSA breaks down specific jobs to identify hazards connected to humans. [2] The combination of these methods provides an all-encompassing strategy for controlling risks at the task and system levels. In order to increase workplace safety and foster a proactive safety culture in industrial environments, this research investigates the potential use of these risk assessment methodologies in conjunction with hazard identification procedures. [3]

REVIEW OF LITERATURE

Salvatore & Pagliaroli (2025) introduced the GEological-geo Technical Index (GETI), a quantitative tool for assessing multi-hazard risks in linear infrastructure. Addressing existing method gaps, GETI accounts for cascading seismic effects like soil liquefaction and landslides through a two-level analysis using conditional probabilities. Italian case studies validate its utility. [15]

Mahmood et al. (2024) Expert input and historical data are used to analyse natural gas pipeline dangers using Fuzzy Bayesian Networks (FBN). External pressures and third-party meddling are major concerns, while age and material cause corrosion. The methodology emphasises localised mitigating techniques for pipeline reliability and safety. [4]

Agrawal et al. (2024) Using Google Earth Engine, Agrawal creates a Flood Hazard Susceptibility map using a multi-layered GIS technique. There are five distinct degrees of flood danger that the tool determines using datasets such as SRTM, NDVI, and JRC Water. Infrastructure design in flood-prone and climate-impacted regions may be facilitated by the model's fast evaluation and decision-making capabilities. [5]

Sahoo et al. (2024) In order to determine what dangers exist in healthcare facilities for patients, staff, and the general public, Sahoo uses HIRA. In order to decrease absenteeism, financial losses, and human mistake, the research highlights the significance of hazard control. Healthcare facilities may enhance their operations and foster a culture of safety via effective risk management. [6]

Wang et al. (2024) To evaluate the risks associated with hydrogen leaks at filling stations, this study integrates 3D geometry models, computational fluid dynamics (CFD) simulations, and incident analysis. Hydrogen tends to pool at the ceiling, according to the research, which demonstrates that ignition point and leak diameter affect dispersion and overpressure. Although heat radiation is not a major concern, excessive pressures may weaken structures and increase the likelihood of accidents. [7]

Rattner et al. (2024) Rattner argues that ecological risk assessment (ERA) models are out of date and proposes replacing them with molecular to ecosystem-level biological indicators. In spite of ongoing legal hurdles, the research recommends combining laboratory and field data for a more complete picture of ecological consequences, including those caused by indirect variables like food poisoning. [8]

Chandrasekar et al. (2024) In a manner that is similar to that of Rattner, Chandrasekar emphasises the need of modernising wildlife ERA methodologies by decreasing dependence on conventional whole-animal observations. In order to address indirect ecological consequences and improve the accuracy of risk assessments in environmental protection, the research advocates for the use of innovative assessment methodologies and ecosystem models. [9]

Kwon et al. (2024) unveil the HIRAS system for spotting hazards in industrial maintenance environments when many tasks are running in parallel. In scheduled operations, the model detected hazards with a 97.5% success rate and in unexpected ones; it was 89.3% accurate, using 40 job safety analyses (JSA) from the South Korean steel sector. Worker knowledge and job safety equipment should be integrated to enhance hazard management in the workplace, according to the research. [10]

Ismail et al. (2023) The East Suwawa Gold Mine's mechanical, physical, and chemical dangers are the subject of this study's Hazard Identification and Risk Assessment (HIRA) evaluation. The investigation, which was based on quantitative data from 100 responders, uncovered 12 major risks, 2 category 1 hazards, 7 priority 3 dangers, and 2 extremely high-risk hazards. These results show how critical it is to implement safety measures right once to reduce major risks in the workplace. [11]

STATEMENT OF THE PROBLEM

In industrial environments, workplace safety usually takes top priority since many hazards constantly compromise workers' health and welfare. Incidents, injuries, or deaths still happen in many different sectors even with major progress in laws, knowledge, safety precautions, and protections. Usually, insufficient hazard identification, poor risk assessment methods, and inadequate management strategies to lower discovered dangers are the fundamental reasons of these continuous problems. Moreover, many businesses have either totally neglected or poorly implemented safety management strategies, which results in inadequate mitigation of potential risks. Usually, the fast evolution of industrial processes and technical innovations generates new, unexpected hazards that conventional safety precautions could find challenging to regulate. Globalisation and industry expansion make it difficult to apply consistent safety rules and regulatory compliance in many different fields. As such, many companies struggle to match their safety standards with national and international safety rules. This paper aims to investigate these challenges by means of an analysis of the effectiveness of present safety management strategies, review of current risk assessment methods, and investigation of the impact of legislative frameworks on enhancing occupational safety. By identifying the key factors contributing to safety concerns, the research will propose strategies to improve hazard identification, risk management practices, and safety culture within industrial environments, ultimately contributing to a safer and more efficient workplace.

OBJECTIVES

- To examine various types of industrial hazards and their potential risks to worker safety.
- To evaluate different risk assessment methods used in identifying and managing workplace hazards effectively.
- To assess the effectiveness of Industrial Safety Management Systems in preventing and mitigating workplace risks.

RESEARCH METHODOLOGY

This study explores the evolution of risk assessment in industries, highlighting key influences like legislation and technology. It examines various industrial hazards and evaluates the effectiveness of modern safety tools and methods. The research also outlines current safety regulations aimed at improving workplace safety.

Data Collection

Primary data: Obtaining real-time insights into workplace safety and risk exposure was accomplished by the collection of primary data through the use of site visits, direct observations, and semi-structured interviews with workers and safety officials, and structured questionnaires.

Secondary data: Secondary data consisted of historical safety records, incident reports, regulatory papers, and academic literature. These types of data provided contextual background and highlighted long-term safety patterns.

Sample Size

Data on more than 47 identified risks were gathered throughout the six-month research, which focused on three industrial sectors: manufacturing, construction, and chemicals. Field observations, audits, reports, and interviews and surveys with more than 200 trained employees were the sources of input. A thorough assessment of occupational risks and the efficacy of the JSA, FMEA, HAZOP, and FTA techniques were supported by this varied sample.

Tools and Technologies

Key tools and technologies used include Sphera, Intelex, and various sensors such as gas, noise, temperature, pressure, and vibration, along with smart helmets. These enable real-time monitoring and enhance industrial safety management.

Integrated Risk Assessment Approaches in Industrial Safety

The researchers in this study used the frameworks of JSA, HAZOP, FMEA, and FTA to identify every possible danger in a manufacturing setting. HAZOP looked at process irregularities to find equipment-related dangers, whereas JSA analysed everyday activities to reduce human risk. Both FMEA and FTA helped identify the causes of important occurrences, while FMEA ranked failure modes by probability and severity. A risk matrix was used to rank and treat dangers efficiently, combining quantitative data with qualitative expert opinions. All industrial processes might benefit from proactive, data-driven risk management thanks to this unified strategy.

Table 1 Summary of Sites and Data Collection Activities

Site ID	Facility Type	Observations Conducted	Interviews Conducted	Employee Surveys Completed
S1	Manufacturing Plant	5	4	25
S2	Construction Site	4	3	20
S3	Warehouse Facility	3	2	15
Total		**12**	**9**	**60**

Table 2 Profile of Survey Participants

Role	Number of Respondents	Percentage (%)
Production Workers	20	33.3%
Maintenance Technicians	12	20.0%
Supervisors/Foremen	15	25.0%
Safety Officers	8	13.3%
Managers	5	8.4%
Total	**60**	**100%**

RESULTS

The results of industrial risk assessments using FTA, JSA, HAZOP, and FMEA, identifying frequent hazards like physical injuries, chemical exposures, ergonomic strain, and psychological stress. High-risk tasks such as equipment use and chemical handling required urgent controls. A mix of qualitative and quantitative methods, including risk matrices, helped prioritize risks. Engineering controls proved effective, while administrative measures and training varied. Technologies like Intelex and Sphera supported real-time hazard monitoring and response.

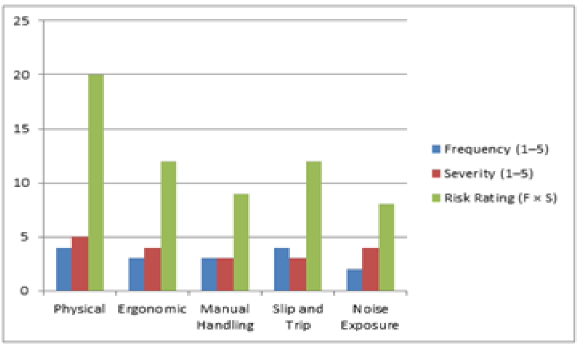

Figure 1: Job Safety Analysis (JSA)

The figure presents five hazard types assessed by frequency and severity on a 1–5 scale. Physical hazards scored the highest risk rating (20), indicating critical concern. Ergonomic and slip/trip hazards followed with moderate ratings. Manual handling and noise exposure showed lower risks but still required attention for safety management.

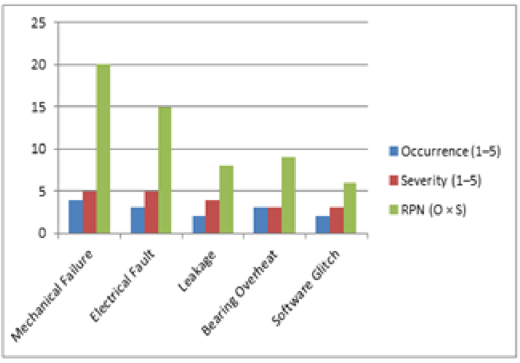

Figure 2: Failure Modes and Effects Analysis (FMEA)

The figure lists five risks assessed by occurrence and degree of importance. The largest risk (RPN 20) is mechanical failure; second is electrical malfunction (RPN 15). While software faults offer the lowest danger, leaky and bearing overheat represent intermediate risk levels. These ratings direct maintenance and preventative action priorities.

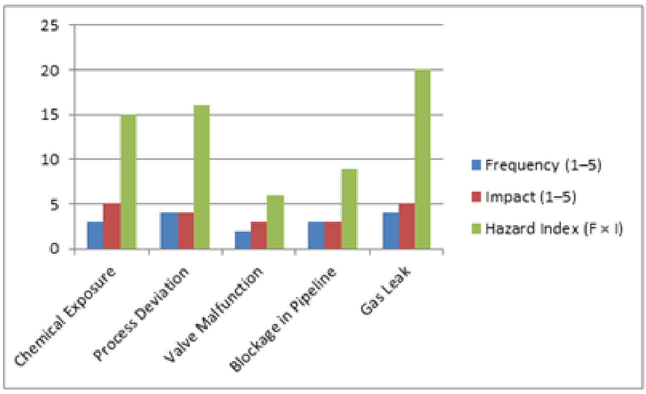

Figure 3: HAZOP (Hazard and Operability Study)

The figure shows different kinds of hazards together with a hazard evaluation. Frequency time's impact produces the danger index. For instance, chemical exposure has a danger rating of 15 by frequency of 3 and impact of 5. With a hazard level of 20, gas leaks provide the most serious threat.

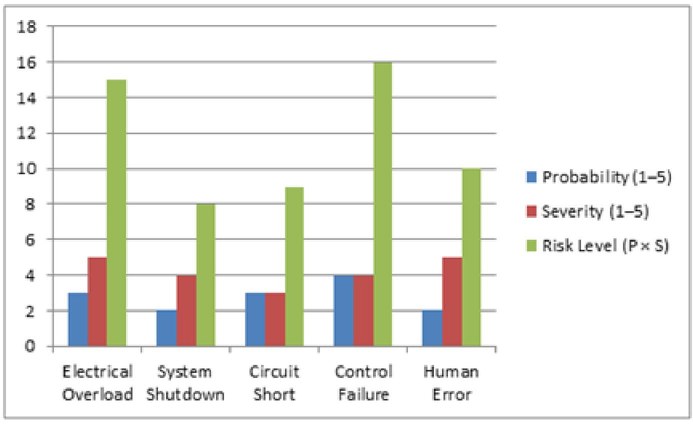

Figure 4: Fault Tree Analysis (FTA)

The figure lists several dangers according to their likelihood and degree; risk is computed by multiplying these elements. Control failure, for example, has a danger level of 16 but electrical overload only has a risk level of 15. These tests help to prioritise safety measures and lower probable risks.

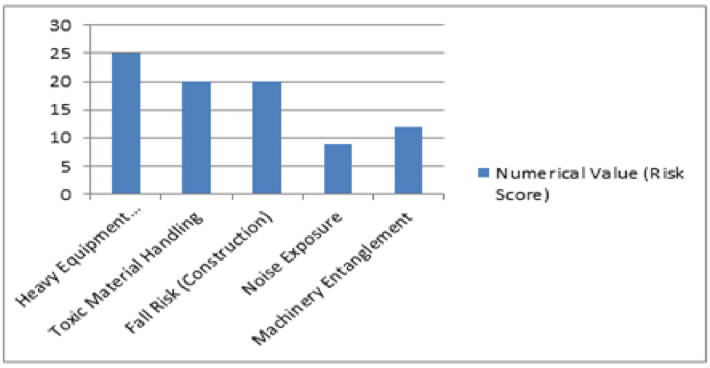

Figure 5: Qualitative Risk Assessment

The figure ranks risks according to risk, likelihood, and degree of seriousness. For instance, noise exposure has a moderate risk score of 9; heavy machinery operating has a highest risk score of 25. This evaluation helps to rank different workplace risks' safety precautions.

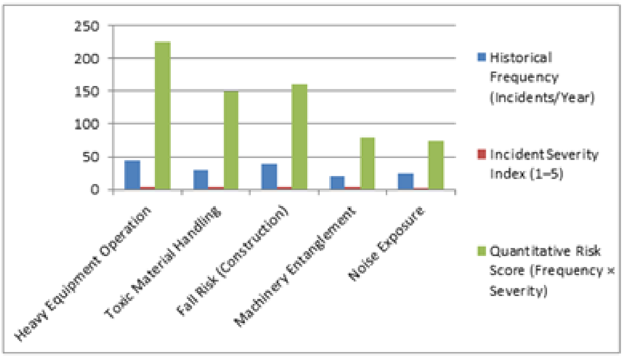

Figure 6: Quantitative Risk Assessment

The graphic depicts the hierarchy of workplace hazards based on quantitative risk ratings, derived from the product of event frequency and severity. The operation of heavy equipment has the greatest danger, with a score of 225, signifying both frequent and serious occurrences. Conversely, noise exposure has a much lower risk score of 75, indicating it presents a somewhat less threat. This comparison aids in prioritising safety improvements according to the aggregate effect of the frequency and severity of each danger.

Quantitative data analysis and qualitative risk matrices enabled risk assessment and targeted remedies. Engineering controls like ventilation and safety interlocks were more effective than administrative measures, which were inconsistent. Safety management systems like Intelex and Sphera, which enable real-time threat monitoring and response, emphasise the need of merging old and new methods to improve workplace safety.

DISCUSSION

The finding and rating industrial hazards in varied situations, HAZOP, FTA, JSA, and FMEA are the best integrated risk assessment techniques. Entangled machinery slips, and ergonomic issues were the most prevalent physical dangers, although chemical exposures and equipment failures were high-risk.

The Workplace safety has been significantly enhanced across several industries by the use of structured risk assessment techniques like JSA, FMEA, and HAZOP. If we want to know how human, technological, and organisational elements interact to cause accidents, we need to do a systematic hazard analysis [12]. The layered method improves remedial and preventative measures by merging analysis at the task level with evaluation of failures across the system [13]. In addition, it has been highlighted that proactive risk management and a significant decrease in incident rates are the results of such integration in the presence of a robust safety culture and channels for constant feedback [14].

CONCLUSION

The research emphasises how well integrated approaches, such as FMEA, HAZOP, FTA, and JSA, manage industrial hazards. The most frequent risks were operational and physical; particularly while handling equipment and being around chemicals. Real-time monitoring and control were made possible by tools like as Sphera and Intelex. All things considered, tech integration and methodical evaluation are essential for safer enterprises.

FUTURE SCOPE

The combined use of JSA, FMEA, HAZOP, and FTA has shown useful in boosting worker safety across many industrial situations. Future studies, may concentrate on automating risk grading and hazard detection by using cutting-edge technology like artificial intelligence, machine learning, and predictive analytics. Proactive risk management can be further enhanced by extending the use of real-time monitoring tools, such as smart wearables and IoT-enabled sensors. Future studies could explore industry-specific adaptations of integrated assessment models, ensuring they are scalable and customizable for diverse operational contexts. Continuous feedback loops and interaction with cloud-based safety technologies may also enable enhanced incident monitoring, analysis, and preventative actions.

References

1. Kim, E.-A., & Kang, S.-K. (2021). Historical review of the list of occupational diseases recommended by the International Labour Organization (ILO). Annals of Occupational and Environmental Medicine, 25(1), 14.

2. Li, J., & Wang, X. (2018). Occupational health risk assessment and intervention strategies for workers in the chemical industry. Journal of Occupational Health and Safety, 16(3), 253–268.

3. Yari, S., Akbari, H., Gholami Fesharaki, M., Khosravizadeh, O., Ghasemi, M., Barsam, Y., et al. (2018). Developing a model for hospital inherent safety assessment: Conceptualization and validation. International Journal of Risk & Safety in Medicine, 29(3–4), 163–174.

4. Mahmood, Y., Chen, J., Yodo, N., & Huang, Y. (2024). Optimizing natural gas pipeline risk assessment using hybrid fuzzy Bayesian networks and expert elicitation for effective decision-making strategies.

Journal of Natural Gas Science and Engineering, 125, Article 205283. https://doi.org/10.1016/j.jgsce.2024.205283

5. Agrawal, R., Singh, S. K., Kanga, S., Sajan, B., Meraj, G., & Kumar, P. (2024). Advancing flood risk assessment through integrated hazard mapping: A Google Earth Engine-based approach for comprehensive scientific analysis and decision support. Journal of Climate Change, 10(1), 47–60. https://doi.org/10.3233/jcc240007
6. Sahoo, B., Sahoo, M. C., & Pillai, J. S. (2024). Making our hospitals a safe workplace: Hazard identification and risk assessment at a tertiary-level public hospital in Eastern India. Cureus, 16(4), e59110. https://doi.org/10.7759/cureus.59110
7. Wang, F., et al. (2024). Deterministic risk assessment of hydrogen leak from a fuel cell truck in a real-scale hydrogen refueling station. International Journal of Hydrogen Energy, 50, 1103–1118. https://doi.org/10.1016/j.ijhydene.2023.09.114
8. Rattner, B. A., et al. (2024). Wildlife ecological risk assessment in the 21st century: Promising technologies to assess toxicological effects. Integrated Environmental Assessment and Management, 20(3), 725–748. https://doi.org/10.1002/ieam.4806
9. Chandrasekar, V., Jayanthi, A., Arindam, P., Syed, K. D., & Aparajita, M. (2024). Integrated approaches for immunotoxicity risk assessment: Challenges and future directions. Discover Toxicology. https://doi.org/10.1007/s44339-024-00010-w
10. Kwon, S. J., Choi, S. W., & Lee, E. B. (2024). Hazard identification and risk assessment during simultaneous operations in industrial plant maintenance based on job safety analysis. Sustainability, 16(21), Article 19277. https://doi.org/10.3390/su16219277
11. Ismail, S. I. C., Irwan, I., & Lalu, N. A. S. (2023). Analysis of potential hazards for work accidents using the HIRA (Hazard Identification and Risk Assessment) method on gold mine workers in East Suwawa District. Gorontalo Journal of Health Science and Community, 7(1), 99–107. https://doi.org/10.35971/gojhes.v7i1.16187
12. Leveson, N. G. (2021). Engineering a safer world: Systems thinking applied to safety. MIT Press.
13. Kletz, T. (2019). What went wrong? Case histories of process plant disasters and how they could have been avoided (5th Ed.). Elsevier.
14. Hale, A., Borys, D., & Else, D. (2020). Management of safety rules and procedures: A review of the literature. Safety Science, 48(8), 990–1001.
15. N. Salvatore and A. Pagliaroli, “A Novel Quantitative Approach for Multi-Hazard Risk Assessment of Linear Infrastructure: A Geological-Geotechnical Index,” vol. 2, no. 2, pp. 1–16, 2025, doi: 10.70465/ber.v2i2.24.