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A Comprehensive Approach to Workplace Hazard Identification and Occupational Risk Evaluation in Manufacturing Facilities

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Abstract

Manufacturing facilities involve a wide range of occupational hazards arising from machinery operation, material handling, chemical exposure, excessive noise, heat, electrical systems, ergonomic stressors, and inadequate workplace organisation. If these hazards are not systematically identified and evaluated, they may result in occupational injuries, work-related illnesses, equipment damage, production interruptions, and financial losses. This paper presents a comprehensive approach to workplace hazard identification and occupational risk evaluation in manufacturing facilities. The proposed framework integrates workplace inspection, task-based hazard analysis, worker consultation, incident and near-miss review, risk prioritisation, and the selection of appropriate control measures. A structured risk matrix based on the likelihood of occurrence and severity of consequences is proposed to classify hazards into risk categories and guide preventive action. The framework also incorporates the hierarchy of controls, periodic reassessment, safety performance monitoring, and continuous improvement. Rather than relying solely on reactive accident investigation, the approach emphasises proactive identification and systematic reduction of workplace risks. The paper provides a practical methodology that can be adapted to different manufacturing sectors, including metal fabrication, foundries, automotive production, chemical processing, and general engineering industries.

Keywords: Workplace hazards, occupational risk assessment, manufacturing facilities, hazard identification, industrial safety, risk matrix, hierarchy of controls, occupational health and safety.

1. Introduction

Manufacturing industries play an essential role in economic development, employment generation, technological advancement, and industrial productivity. However, manufacturing operations frequently involve complex interactions between workers, machines, materials, energy sources, chemicals, and production processes. These interactions can create occupational hazards that threaten worker health and safety.

Common hazards in manufacturing environments include contact with moving machinery, entanglement, crushing, falls, electrical shock, fire, explosion, chemical exposure, excessive noise, vibration, thermal stress, manual material handling, and repetitive work. In foundries and metal-processing industries, additional concerns include molten-metal splashes, radiant heat, metal fumes, dust, and intense physical workloads. In automotive and assembly plants, ergonomic risks may arise from repetitive movements, awkward postures, prolonged standing, and handling heavy components.

Traditional safety management practices may focus primarily on investigating accidents after they occur. Although incident investigations are important, a reactive approach alone cannot adequately prevent injuries and occupational illnesses. A proactive system is required to identify hazards before an incident occurs, assess the associated risks, prioritise preventive actions, and verify whether the implemented controls are effective.

Workplace hazard identification and risk evaluation therefore form fundamental elements of an effective occupational health and safety management system. A comprehensive approach should combine technical inspection, worker participation, operational data, task analysis, and systematic decision-making. It should also consider routine activities, non-routine operations, maintenance, cleaning, equipment breakdowns, and emergency situations.

This paper develops a structured approach for identifying workplace hazards and evaluating occupational risks in manufacturing facilities. Its central objective is to provide a practical framework that supports preventive decision-making, improves workplace safety, and encourages continuous improvement in industrial operations.

2. Review of Literature

Occupational health and safety research has progressively moved from accident investigation towards preventive risk management and systematic control of workplace hazards. Several established approaches provide a foundation for comprehensive workplace risk assessment.

2.1 Hazard identification and risk assessment

Hazard identification involves recognising sources, situations, or activities that have the potential to cause injury, ill health, property damage, or other undesirable outcomes. Risk assessment evaluates the likelihood that a hazardous event or exposure will occur and the severity of its consequences.

Methods such as Job Safety Analysis (JSA), Hazard Identification and Risk Assessment (HIRA), Failure Mode and Effects Analysis (FMEA), and Hazard and Operability Study (HAZOP) can support different aspects of industrial risk evaluation. The choice of method depends on the complexity of the operation, the type of hazard, the available data, and the required level of analysis.

2.2 Occupational safety management systems

The ISO 45001 occupational health and safety management system provides a structured basis for hazard identification, risk assessment, operational control, worker participation, performance evaluation, and continual improvement. Its management-system approach supports the integration of safety into routine organisational processes rather than treating safety as a separate activity.

2.3 Hierarchy of controls

The hierarchy of controls prioritises measures according to their general effectiveness. Elimination and substitution are preferred where practicable, followed by engineering controls, administrative controls, and personal protective equipment. This approach encourages organisations to reduce hazards at their source rather than relying exclusively on worker behaviour or protective equipment.

2.4 Research gap

Although multiple hazard identification and risk assessment techniques are available, manufacturing facilities may apply them inconsistently across departments and work activities. Risk registers may not be updated after process changes, near-miss information may not be incorporated into risk ratings, and corrective actions may not be evaluated for effectiveness.

The present paper addresses this practical challenge by proposing an integrated process that connects hazard identification, risk evaluation, prioritisation, control implementation, and monitoring within a single framework. The proposed framework is conceptual and methodological; its effectiveness must be established through implementation and empirical validation in actual manufacturing facilities.

3. Aim and Objectives

3.1 Aim

To develop a comprehensive and systematic framework for identifying workplace hazards, evaluating occupational risks, and prioritising preventive interventions in manufacturing facilities.

3.2 Research objectives

The specific objectives are:

1. To identify major physical, chemical, biological, ergonomic, electrical, mechanical, and psychosocial hazards associated with manufacturing operations.
2. To establish a systematic procedure for evaluating the likelihood and severity of potential occupational incidents.
3. To develop a risk-prioritisation matrix for classifying hazards according to their relative risk levels.
4. To recommend suitable control measures based on the hierarchy of controls.
5. To integrate worker participation, incident data, workplace inspections, and safety audits into the risk evaluation process.
6. To propose performance indicators for monitoring the effectiveness of occupational risk management.
7. To establish a continuous improvement mechanism for maintaining safe working conditions.

4. Research Methodology

4.1 Research design

This paper adopts a conceptual and methodology-oriented research design. It develops an integrated occupational hazard identification and risk evaluation framework based on established safety management principles and recognised hazard assessment practices. The framework is intended for subsequent application and validation in manufacturing facilities.

The methodology combines qualitative hazard identification with semi-quantitative risk scoring. Qualitative methods help identify hazards through workplace observations, worker interviews, and task analysis, while numerical risk scores help organise and prioritise corrective actions. A proactive, ongoing process of hazard assessment, including periodic inspections and analysis of near misses, is consistent with guidance published by the US Occupational Safety and Health Administration (OSHA).

4.2 Data collection methods

The proposed framework uses the following information sources:

- Workplace inspections: Direct observation of production areas, machinery, material storage, access routes, and housekeeping.
- Task-based analysis: Examination of individual job steps, tools, materials, and worker interactions.
- Worker consultation: Interviews, safety meetings, questionnaires, and anonymous hazard reports.
- Incident and near-miss records: Review of previous injuries, equipment failures, unsafe conditions, and near misses.
- Document review: Examination of operating procedures, equipment manuals, safety data sheets, training records, and maintenance documentation.
- Exposure assessment: Where necessary, measurement of noise, airborne contaminants, temperature, vibration, and other relevant occupational exposures.

These information sources should be combined because some hazards are readily visible, whereas others, such as airborne contaminants and excessive noise, may require specialist assessment or instrumental measurement.

4.3 Identification of workplace hazards

The first stage involves dividing the facility into operational areas and identifying hazards associated with each task. Typical areas include machining, fabrication, welding, assembly, material handling, chemical storage, maintenance, utilities, and warehousing.

The assessment should cover normal production as well as machine setup, cleaning, maintenance, start-up, shutdown, breakdown recovery, and foreseeable emergency conditions. Workers and maintenance personnel should participate because they may recognise practical hazards that are not apparent during a short inspection.

The principal hazard categories are presented below.

Hazard category	Typical manufacturing examples	Potential consequences
Mechanical	Unguarded rotating parts, conveyors, presses, pinch points	Cuts, crushing, entanglement, amputation
Electrical	Exposed conductors, damaged cables, faulty earthing	Electric shock, burns, fire
Chemical	Solvents, welding fumes, oils, cleaning agents	Irritation, poisoning, respiratory illness
Physical	Noise, vibration, heat, radiation	Hearing loss, burns, fatigue, other occupational illness
Ergonomic	Repetitive work, awkward posture, manual lifting	Musculoskeletal disorders, strains
Fire and explosion	Flammable liquids, combustible dust, gas leaks, ignition sources	Burns, fatalities, structural damage
Slips, trips, and falls	Oil spills, cluttered walkways, unprotected edges	Sprains, fractures, head injuries
Psychosocial and organisational	Excessive workload, fatigue, inadequate supervision	Reduced attention, stress, increased error likelihood

Note: The table provides representative examples. Actual hazards and consequences must be determined from the specific facility, materials, equipment, and work practices.

5. Proposed Framework for Occupational Risk Evaluation

The proposed framework comprises seven interconnected stages.

Stage 1

Define the scope

Identify departments, tasks, equipment, workers, and relevant operating conditions.

Stage 2

Identify hazards

Use inspections, task analysis, worker consultation, and incident records.

Stage 3

Assess existing controls

Determine which safeguards are present and whether they function effectively.

Stage 4

Evaluate risk

Estimate likelihood and severity using a consistent risk-rating method.

Stage 5

Prioritise hazards

Rank risks and identify hazards requiring urgent intervention.

Stage 6

Implement controls

Select measures using the hierarchy of controls and assign responsibilities.

Stage 7

Monitor and improve

Verify effectiveness, reassess residual risk, and update the risk register.

5.1 Risk scoring methodology

A semi-quantitative risk matrix is proposed to support consistent evaluation. Each identified hazard is assigned a likelihood score (\(L\)) and a severity score (\(S\)). The risk score (\(R\)) is calculated as:

\[R=L\times S \]

The scores are intended to support prioritisation rather than provide a precise mathematical prediction of accident probability.

Likelihood scale

Score	Description	General interpretation
1	Rare	Highly unlikely under the assessed conditions
2	Unlikely	Could occur, but not expected frequently
3	Possible	May occur under foreseeable conditions
4	Likely	Expected to occur in repeated or common circumstances
5	Almost certain	Frequent occurrence or strong expectation of occurrence

Severity scale

Score	Description	General interpretation
1	Negligible	No injury or only minimal harm
2	Minor	Minor injury requiring limited treatment
3	Moderate	Injury or illness requiring significant medical attention or restricted work
4	Major	Serious injury, permanent impairment, or major occupational illness
5	Catastrophic	Fatality or multiple severe casualties

5.2 Risk classification

The following classification is a proposed example for this paper. Each organisation should define and validate its own acceptance criteria in accordance with applicable requirements and operational circumstances.

Risk score	Risk level	Recommended response
1–4	Low	Maintain controls and conduct routine monitoring
5–9	Moderate	Improve controls according to a documented action plan
10–16	High	Prioritise corrective measures and verify implementation
17–25	Extreme	Stop or restrict the hazardous activity where necessary until adequate controls are established

A high or extreme score should trigger prompt assessment and action. However, a low numerical score must not be used to justify ignoring a legally prohibited condition, a serious recognised hazard, or a required safeguard. Risk scores should be reviewed by competent personnel and interpreted alongside exposure conditions and applicable standards. OSHA similarly recommends prioritising hazards according to the severity of potential outcomes and the likelihood of an incident, while maintaining protection against serious hazards.

5.3 Evaluation of existing and residual risk

The initial risk assessment should document existing safeguards and determine whether they are functioning as intended. After additional control measures are implemented, the risk should be reassessed to estimate the residual risk.

For example, a machine with accessible moving parts may present a high initial risk. Installing suitable fixed guards or interlocked safeguards, where appropriate to the machine and task, may substantially reduce exposure. The residual rating must nevertheless be supported by verification of the safeguard's effectiveness rather than an assumption that installation alone has eliminated the risk.

Where a hazard has potentially catastrophic consequences, risk management should consider the adequacy of safeguards and the possibility of multiple failures. A simple risk matrix should not replace more detailed engineering or process-safety analysis where such analysis is necessary.

6. Application of the Framework in Manufacturing Facilities

6.1 Mechanical hazards in machining operations

Machining operations involve rotating spindles, cutting tools, power transmission systems, and moving workpieces. Potential hazards include entanglement, ejected fragments, crushing, and accidental machine activation during maintenance.

The assessment should examine machine guarding, emergency stops, safe operating procedures, maintenance arrangements, and the isolation of hazardous energy before servicing. Risk reduction measures may include improved machine design, suitable guards, interlocks, maintenance controls, and task-specific training.

6.2 Chemical hazards in welding and fabrication

Welding, surface treatment, painting, and cleaning can expose workers to fumes, gases, vapours, and skin-contact hazards. The evaluation should consider the materials used, exposure duration, ventilation, work location, and available exposure monitoring data.

Possible control measures include substituting less hazardous materials, installing effective local exhaust ventilation, enclosing emission sources where practicable, maintaining extraction systems, and using suitable respiratory or other protective equipment when required. The adequacy of controls should be verified through inspection and, where indicated, exposure monitoring.

6.3 Ergonomic hazards in assembly operations

Assembly-line workers may perform repetitive tasks, lift components, reach above shoulder height, or maintain static postures. These conditions can contribute to musculoskeletal strain and fatigue.

The assessment should examine repetition, force, posture, task duration, recovery time, workstation height, and the availability of mechanical assistance. Recommended measures include workstation redesign, adjustable work surfaces, lifting aids, improved tool design, and suitable task rotation where it genuinely reduces exposure.

Ergonomic assessment should be task-specific. Rotating workers between jobs does not necessarily reduce risk if the alternative tasks expose them to similar physical demands.

6.4 Fire and explosion hazards

Flammable liquids, combustible dusts, fuel gases, electrical faults, hot work, and incompatible material storage can create fire or explosion risks. The assessment should identify fuel sources, ignition sources, potential release points, ventilation arrangements, storage conditions, and emergency response requirements.

Control measures may include eliminating unnecessary flammable materials, using safer substitutes, controlling ignition sources, maintaining appropriate electrical equipment, providing suitable ventilation, and implementing hot-work authorisation and emergency procedures. Processes involving significant combustible dust or flammable gas hazards may require specialist engineering assessment.

6.5 Manual material handling and warehouse operations

Lifting, pushing, pulling, repetitive loading, and movement of forklifts or other industrial vehicles can expose workers to musculoskeletal injuries and struck-by or collision hazards.

Potential measures include mechanical lifting devices, suitable storage layouts, separation of pedestrians and vehicles, clear traffic routes, load limits, and inspection of handling equipment. The assessment should also examine visibility, aisle congestion, floor conditions, and the effects of workload and production pressure.

7. Illustrative Risk Assessment

The following table demonstrates how the proposed method could be applied to a hypothetical manufacturing facility. These are illustrative scores, not results obtained from an actual factory survey.

Activity and hazard	L	S	Initial risk	Proposed controls
Press operation: accessible moving parts	4	5	20 — Extreme	Appropriate guarding, interlocks, safe operating controls, energy isolation for servicing
Welding: exposure to fumes	4	4	16 — High	Source extraction, suitable material selection, exposure monitoring, task-specific protection
Assembly: repetitive awkward posture	4	3	12 — High	Workstation redesign, ergonomic tools, mechanical assistance, task evaluation
Forklift movement: pedestrian collision	3	5	15 — High	Physical route separation, controlled crossings, visibility improvements, vehicle controls
Walkway: oil spill	3	2	6 — Moderate	Prompt spill control, housekeeping, inspection, slip-resistant flooring where suitable

L = likelihood score; S = severity score; initial risk = L × S.

The example illustrates how a risk matrix can help prioritise work. It does not demonstrate that the proposed framework has reduced accidents or that the controls will achieve a particular residual score. Those outcomes require a real-world assessment and verification.

8. Monitoring and Performance Evaluation

A comprehensive occupational risk management system requires ongoing monitoring to ensure that identified hazards are controlled and that risk assessments remain current. This is consistent with the continual-improvement approach of ISO 45001.

The following indicators are proposed for monitoring implementation.

Indicator	Measurement approach	Purpose
Hazard reporting rate	Number of hazards reported during a defined period	Assess reporting participation and identify recurring problems
Corrective-action closure rate	Actions completed by their due dates ÷ total actions due × 100	Monitor completion of planned interventions
Repeat-hazard rate	Previously identified hazards recurring during inspections	Identify weaknesses in corrective actions
Safety training completion	Workers completing required training ÷ workers assigned training × 100	Monitor training coverage
Inspection completion	Inspections completed ÷ inspections scheduled × 100	Evaluate inspection programme implementation
Injury and illness trends	Review incident frequency, severity, and patterns over time	Assess outcomes and identify emerging risks
Exposure-control effectiveness	Relevant measurements and control-function checks	Verify whether occupational exposures are adequately controlled

These indicators should be interpreted together. An increase in reported hazards, for example, may reflect improved worker participation rather than deteriorating safety performance. Similarly, low injury counts alone do not establish that a workplace is safe.

8.1 Review and reassessment

Risk assessments should be reviewed periodically and whenever significant changes occur, such as:

- Introduction of new machinery, chemicals, or production processes.
- Changes in staffing, work organisation, or operating conditions.
- Accidents, near misses, or evidence of ineffective safeguards.
- Changes in relevant legal requirements or technical standards.
- Discovery of previously unrecognised hazards.

The organisation should maintain a documented risk register and verify that corrective measures continue to function effectively.

9. Discussion

The proposed framework links hazard identification, risk evaluation, preventive intervention, and performance monitoring within a single process. Its primary advantage is that it moves occupational safety management beyond isolated inspections or post-incident responses and provides a repeatable procedure for identifying and prioritising hazards across different production activities.

A standardised risk matrix can support communication between workers, supervisors, maintenance teams, and safety professionals. It provides a common basis for comparing hazards and deciding which interventions require immediate attention. Nevertheless, numerical scoring is partly dependent on assessor judgement. Different assessors may assign different likelihood or severity ratings to the same hazard, particularly when reliable exposure or incident data are unavailable.

To improve consistency, organisations should define rating criteria, train assessors, involve workers, document the reasoning behind each rating, and periodically review the risk register. Quantitative measurements should be used when appropriate, particularly for occupational exposures that cannot be reliably assessed through visual observation alone.

Another important consideration is that a risk matrix cannot replace specialised engineering analysis. High-consequence hazards involving machinery, combustible dust, flammable gases, or complex process systems may require detailed failure analysis, exposure modelling, or other specialist methods. A simple score may not adequately represent rare events with catastrophic consequences.

Worker participation is also central to the proposed approach. Workers often have practical knowledge of recurring equipment problems, workarounds, time pressures, and difficulties in following procedures. Incorporating this information can help identify hazards that may otherwise remain undocumented. However, participation should be supported by a non-punitive reporting culture and timely feedback.

Finally, the proposed framework should be viewed as a management tool rather than a proven predictive model. Its practical effectiveness depends on the quality of hazard information, the appropriateness of selected controls, management commitment, available resources, and verification of corrective actions. Future research should evaluate the framework using data from actual manufacturing facilities.

10. Limitations and Future Research

The proposed framework has several limitations. First, it is conceptual and has not been validated using primary data from a specific manufacturing facility. Second, the semi-quantitative risk matrix relies partly on expert judgement and may not capture all dimensions of exposure, uncertainty, or catastrophic risk. Third, the effectiveness of individual controls may vary according to the industry, process design, workforce characteristics, and operating environment.

Future research should apply the framework in selected manufacturing sectors, collect workplace inspection and incident data, and compare risk ratings before and after control implementation. Inter-rater agreement among assessors could be examined to determine whether the scoring procedure produces consistent results.

Further development could integrate digital inspection checklists, sensor-based exposure monitoring, computerised risk registers, and data-driven methods for identifying recurring hazards. Artificial intelligence could potentially assist with hazard classification and trend analysis, provided that the underlying data are reliable and that expert review remains part of the decision-making process.

A longitudinal study would be particularly useful for evaluating whether implementation is associated with improvements in corrective-action completion, exposure control, repeat-hazard reduction, and occupational injury outcomes.

11. Conclusion

This paper presents a comprehensive approach to workplace hazard identification and occupational risk evaluation in manufacturing facilities. The proposed framework integrates workplace inspections, task-based hazard analysis, worker consultation, incident and near-miss review, semi-quantitative risk scoring, risk prioritisation, control implementation, and continuous monitoring.

The framework provides a structured method for identifying mechanical, chemical, physical, ergonomic, electrical, fire-related, and organisational hazards. Its risk matrix can assist safety professionals in prioritising corrective actions, while the hierarchy of controls provides a systematic basis for selecting appropriate preventive measures.

The approach also highlights the importance of documenting responsibilities, verifying control effectiveness, reassessing residual risks, and updating assessments when workplace conditions change. A consistent process can support more informed safety decisions and strengthen the integration of occupational health and safety into routine manufacturing operations.

However, the framework remains a proposed methodology rather than an empirically validated intervention. Its effectiveness must be established through field application, systematic data collection, and comparison of safety performance before and after implementation. Future research should focus on validation across different manufacturing sectors and the integration of digital tools for more consistent and proactive risk management.

Overall, a comprehensive and continuously reviewed hazard identification and risk evaluation process offers a practical foundation for improving occupational safety management in manufacturing facilities.

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