

HIRARC-Based Occupational Health and Safety Risk Analysis in Warehouse Inbound and Outbound Operations

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Abstract

Purpose: This study analyzes Occupational Health and Safety (OHS) risks across inbound and outbound warehouse activities at PT. XYZ, an industrial services company, using the HIRARC method.

Research Methodology: A qualitative descriptive case study was conducted through direct observation of eleven warehouse activities, semi-structured interviews with six key informants, and analysis of company documents. Hazards were classified using the 5M framework, risk levels were assessed with a 4×4 likelihood-severity matrix based on International Organization for Standardization (ISO) 45001:2018, and controls were developed following the International Labour Organization (ILO) hierarchy of controls.

Results: Sixty-six hazard sources were identified. Risk assessment classified 2 hazards (3.0%) as low risk, 55 (83.3%) as moderate risk, and 9 (13.6%) as high risk, with no extreme risks found. The highest-risk activities were goods retrieval, goods reception, goods storage, and transfer to transport vehicles, mainly due to unqualified forklift operation, non-ergonomic manual handling, and PPE non-compliance. Recommended controls included engineering controls (25 hazards), administrative controls (35 hazards), and PPE (6 hazards).

Conclusions: HIRARC provided a comprehensive basis for prioritizing OHS improvements, with administrative controls, particularly training, SOP enforcement, and forklift competency certification, identified as the most critical interventions.

Limitations: Findings are limited to one company's warehouse operations and may not be directly generalizable to other industries. Future studies involving multiple companies and different industrial sectors are needed to validate and broaden the applicability of the proposed risk management framework.

Contributions: The study offers an integrated HIRARC-based risk management framework covering all inbound and outbound warehouse activities in the Indonesian industrial services sector.

Keywords: Hazard Identification, HIRARC, Inbound, ISO 45001, Occupational Health and Safety, Outbound, Risk Assessment, Warehouse Operations

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1. Introduction

Workplace accidents in the warehousing and logistics sector represent a persistent and escalating challenge to industrial safety management in Indonesia. Data from the Social Security Agency for Employment (BPJS Ketenagakerjaan) recorded 221,740 workplace accident cases in 2020, rising to 234,270 in 2021 and further surging to 265,334 cases in 2022 an increase of approximately 19.7% over two years ([Syaharani, 2023](#)). The logistics and warehousing sub-sector contributes disproportionately to these statistics, given the co-occurrence of multiple high-risk exposure categories: heavy equipment operation, manual material handling, work at heights, and hazardous substance contact ([Saputra et al., 2020](#); [Wibowo & Anjani, 2020](#)).

PT. XYZ is an industrial services company operating in filtration, lubrication, and hydrocarbon management for the manufacturing and mining sectors, with warehouse operations located in Banten Province. The company recorded a significant surge in workplace incidents during 2023, concentrated specifically in warehouse inbound activities (goods reception, inspection, storage, and ERP update) and outbound activities (picking, retrieval, inspection, packaging, documentation, and vehicle loading). These activities involve the concurrent operation of forklift equipment, manual material handling of heavy goods, rack-based storage at heights, and chemical substance handling conditions that create complex, overlapping hazard profiles that cannot be adequately managed through informal or reactive safety measures.

Post-incident investigation at PT. XYZ identified three systemic safety failures underlying the accident surge: (1) non-compliance with PPE requirements during chemical and dust-exposure activities; (2) forklift operation by personnel without certified competency; and (3) the absence of ergonomic guidelines for manual material handling tasks. These failures reflect the broader policy-implementation gap documented in the Indonesian logistics sector by [Kurniawan and Dewi \(2020\)](#), wherein formal Occupational Health and Safety (OHS) policies exist but are not systematically enforced at the operational level.

Addressing these failures requires a systematic, evidence-based approach to hazard identification, risk prioritization, and control strategy formulation. The HIRARC method (Hazard Identification, Risk Assessment, and Risk Control) aligned with ISO 45001:2018, the international standard for OHS management systems provides such an approach. HIRARC enables organizations to identify hazards across all operational activities, quantify risk levels through likelihood-severity assessment, and prescribe control measures according to the established hierarchy of controls ([Santoso, 2021](#); [Pertiwi et al., 2021](#); [ILO, 2021](#)). Prior research has demonstrated HIRARC's effectiveness in reducing warehouse incident rates by up to 40% when comprehensively implemented ([Nugroho, 2022](#)).

However, existing studies have typically applied HIRARC to either inbound or outbound activities in isolation, without providing an integrated analysis across all warehouse activity categories simultaneously ([Saputra et al., 2020](#); [Yuliana & Prasetyo, 2022](#); [Rahman & Lestari, 2021](#)). This fragmentation limits the utility of prior findings for organizations seeking holistic warehouse OHS management improvement. Moreover, HIRARC studies in the Indonesian industrial services sector specifically covering filtration, lubrication, and hydrocarbon management contexts are notably absent from the published literature.

This study addresses these gaps by conducting a comprehensive HIRARC analysis of all eleven warehouse activities at PT. XYZ four inbound and seven outbound within an integrated analytical framework. Three research objectives guide the study: (1) to identify and classify hazards across all inbound and outbound warehouse activities using the 5M framework; (2) to assess risk levels for each identified hazard using a 4×4 likelihood-severity matrix; and (3) to formulate control recommendations following the ILO hierarchy of controls, prioritized by risk level. The study makes both empirical and practical contributions: it provides the first comprehensive HIRARC analysis spanning all warehouse activity types in the industrial services sector, and it delivers an actionable risk control framework directly applicable to PT. XYZ's OHS management system development.

The paper is organized as follows: Section 2 reviews the theoretical foundations and prior empirical literature. Section 3 describes the research methodology. Section 4 presents and discusses the hazard identification, risk assessment, and control findings. Section 5 provides conclusions, limitations, and future research directions.

2. Literature Review and Hypotheses Development

2.1 Occupational Health and Safety in Warehousing

Warehouse environments are characterized by a high density of concurrent physical hazard categories that distinguish them from many other industrial settings. Material handling particularly the operation of forklift trucks and the manual handling of heavy goods is consistently identified as the primary source of warehouse injury in global OHS statistics ([European Agency for Safety and Health at Work, 2021](#); [Bureau of Labor Statistics, 2022](#)). In Indonesia, the rapid expansion of logistics infrastructure, driven by e-commerce growth and industrial supply chain development, has intensified warehouse activity volumes without commensurate improvements in safety management systems ([Syaharani, 2023](#); [Kurniawan & Dewi, 2020](#)).

Warehouse OHS hazards can be categorized into five domains following the 5M classification framework ([Wicaksono, 2020](#)): Man (worker behavior, fatigue, and competency deficits); Method (unsafe work procedures and SOP non-compliance); Material (hazardous substance properties and packaging risk); Machine (mechanical failure, unguarded equipment, and unauthorized operation); and Environment (floor conditions, lighting inadequacy, space constraints, and thermal stress). This multidimensional hazard profile necessitates a systematic analytical framework that simultaneously addresses all five domains rather than focusing on a single risk category in isolation ([Firmansyah, 2019](#); [Siregar, 2021](#)).

A particularly critical OHS concern in Indonesian warehouse settings is the ergonomic dimension of manual material handling. [Rahman and Lestari \(2021\)](#) documented that inbound warehouse workers performing repetitive heavy lifting tasks exhibit musculoskeletal disorder (MSD) incidence rates significantly above national manufacturing averages, attributable to the combination of excessive workload, non-ergonomic lifting postures, and inadequate work rotation protocols. [Fauziah and Hasan \(2020\)](#) similarly found that warehouses operating under high throughput targets and rapid shift rotation have significantly elevated fatigue-related injury rates, suggesting that operational performance pressures compound physical hazard exposure.

2.2 The HIRARC Method: Theoretical Foundations

Hazard Identification, Risk Assessment, and Risk Control (HIRARC) is a structured, three-stage methodology for systematic OHS risk management, formally aligned with ISO 45001:2018 (Occupational Health and Safety Management Systems) and the ILO Guidelines on OSH Management Systems (ILO-OSH 2001) ([Pertiwi, Suryani, & Wulandari, 2021](#); [Santoso, 2021](#)). The method operationalizes the fundamental OHS management cycle of hazard recognition, risk quantification, and control prioritization within a single integrated analytical framework.

In the hazard identification stage, potential hazard sources are systematically enumerated across all workplace activities using structured observation, worker interviews, and document review. The 5M classification framework Man, Method, Material, Machine, Environment provides a comprehensive taxonomic structure ensuring that hazards are identified across all causal domains rather than focusing on the most visible or proximate causes ([Wicaksono, 2020](#)). This systematic enumeration is particularly important in warehouse contexts, where hazards from multiple domains frequently interact to produce accident events.

Risk assessment involves the quantitative estimation of risk level for each identified hazard using the formula: Risk Level = Likelihood (L) × Severity (S). Likelihood represents the estimated probability of hazard occurrence under current operational conditions; Severity represents the estimated magnitude of harm if the hazard materializes. The product of these two parameters assessed using a

validated scale (typically 1–4 for each parameter) positions each hazard within a risk matrix, enabling classification into risk levels (Low, Moderate, High, Extreme) that guide control prioritization ([Indrawan, & Setiawan, 2019](#); [Hutagalung, & Sari, 2021](#)). This quantification approach, while incorporating subjective assessment, provides a structured, consistent, and transparent basis for comparative risk prioritization across diverse hazard types.

Risk control prescribes preventive and corrective measures following the established hierarchy: Elimination (removing the hazard source entirely), Substitution (replacing with a less hazardous alternative), Engineering Control (physical modification of equipment, workspace, or process), Administrative Control (procedural, training, and behavioral interventions), and Personal Protective Equipment (providing workers with barrier protection against residual hazard exposure) ([International, 2021](#)). The hierarchy reflects the inverse relationship between control level and control effectiveness: elimination and substitution provide the most reliable risk reduction because they address the hazard source, while PPE provides only barrier protection that depends on consistent correct usage.

2.3 ISO 45001:2018 and OHS Management Systems

ISO 45001:2018 provides the internationally recognized framework for systematic OHS management, structured around the Plan-Do-Check-Act (PDCA) cycle ([International, 2018](#)). Within this framework, hazard identification and risk assessment operationalized through tools such as HIRARC constitute a core component of the Planning phase, providing the evidence base for OHS objectives, control strategies, and performance monitoring systems. ISO 45001:2018 specifically requires that organizations establish, implement, and maintain a process for hazard identification that is proactive (identifying hazards before incidents occur rather than reactively after) and that considers human factors, organizational factors, and task design alongside physical and chemical hazards ([ISO, 2018](#); [Ramadhan et al., 2021](#)).

The alignment of PT. XYZ's internal risk matrix with ISO 45001:2018 criteria, as confirmed by the company's QHSE (Quality, Health, Safety, and Environment) team, ensures that the HIRARC analysis conducted in this study is directly integrated into the company's existing OHS management system architecture, maximizing the practical applicability of the findings.

2.4 Prior Studies on HIRARC in Warehouse and Logistics Contexts

Table 1 summarizes the most relevant prior studies on HIRARC application in warehouse and logistics settings, positioning the present study relative to existing evidence.

Table 1. Summary of Prior Studies on HIRARC Application in Warehouse and Logistics Settings

Author(s) & Year	Setting	Method	Key Findings
Saputra et al. (2020)	Warehouse logistics	HIRARC	Forklift operation identified as highest-risk activity; engineering controls most effective for mechanical hazards
Yuliana & Prasetyo (2022)	Outbound warehouse	HIRARC, interview	PPE non-compliance and inadequate training are primary drivers of outbound accidents; administrative controls underutilized
Rahman & Lestari (2021)	Inbound logistics	HIRARC, ergonomic assessment	Physical fatigue and excessive workload dominant inbound risk factors; musculoskeletal injury prevention requires ergonomic redesign
Wibowo & Anjani (2020)	Distribution warehouse	HIRARC + control evaluation	Combined engineering and administrative controls significantly reduce accident rates; PPE-only approaches insufficient
Hutagalung & Sari (2021)	Logistics sector	HIRARC	HIRARC effectively classifies risks into low/moderate/high categories, enabling prioritized control allocation

Author(s) & Year	Setting	Method	Key Findings
Siregar (2021)	Warehouse operations	HIRARC + ergonomics	Integration of HIRARC with ergonomic assessment produces superior accident reduction compared to HIRARC alone
Nugroho (2022)	Logistics company	HIRARC + pre-post evaluation	Systematic HIRARC implementation associated with up to 40% reduction in workplace incidents within 12 months
Kurniawan & Dewi (2020)	Logistics sector	Policy analysis	Gap between formal OHS policy and field implementation is the primary driver of high accident rates in logistics
Maulana & Rini (2022)	Warehousing	HIRARC, hierarchy of controls	Control hierarchy effectiveness varies by activity type; administrative controls most scalable across diverse warehouse tasks
Present Study	PT. XYZ warehouse (inbound + outbound, Banten)	HIRARC, qualitative case study, 5M hazard classification	First integrated HIRARC analysis of both inbound (4 activities) and outbound (7 activities) in a filtration/lubrication industry warehouse; 66 hazards classified across three risk levels with differentiated control strategies

As Table 1 demonstrates, prior research has established the technical validity of HIRARC for warehouse risk management and identified the primary hazard categories associated with logistics operations. However, the research gap identified in Section 2.4 is clear: no published study has simultaneously analyzed all eleven warehouse activities (inbound and outbound) within an integrated HIRARC framework for the Indonesian industrial services sector. The present study addresses this gap directly.

2.5 Research Hypotheses

Based on the theoretical foundations and prior empirical evidence reviewed above, three research hypotheses are proposed:

H₁: Significant OHS risk potentials are present across both inbound and outbound warehouse activities at PT. XYZ, with the highest risk levels concentrated in physical material handling and heavy equipment operation activities.

H₂: The HIRARC method is effective in systematically identifying and classifying warehouse hazards into risk levels (Low, Moderate, High) based on likelihood and severity parameters, enabling comparative prioritization of control interventions.

H₃: HIRARC-based control recommendations, distributed across engineering, administrative, and PPE control levels following the ILO hierarchy, provide a feasible and comprehensive basis for reducing workplace accident potential in warehouse operations.

3. Research Methodology

3.1 Research Design

This study employs a qualitative descriptive case study design (Yin, 2018), in which the OHS risk profile of PT. XYZ's warehouse operations constitutes the bounded case under investigation. The qualitative approach is appropriate because the central objectives hazard identification, contextual risk assessment, and control formulation require the integration of observational evidence, worker experiential knowledge, and document-based data that cannot be adequately captured through quantitative survey instruments alone (Creswell & Poth, 2018). The descriptive orientation reflects the study's aim to characterize the existing risk landscape comprehensively rather than to test causal hypotheses through experimental manipulation.

The study is explicitly observational and non-interventional: the researchers observed and analyzed naturally occurring work activities without modifying operational variables, ensuring that the risk assessment reflects authentic operational conditions rather than a modified experimental state. This naturalistic stance is essential for the validity of the HIRARC findings as a basis for real-world OHS management decision-making.

3.2 Research Setting and Participants

The study was conducted between February and April 2024 at the warehouse facility of PT. XYZ, located in the industrial zone of Banten Province, Indonesia. PT. XYZ's warehouse operates as the primary storage and distribution hub for filtration, lubrication, and hydrocarbon management products serving industrial and mining clients across Western Indonesia. The warehouse handles both inbound logistics (receiving products from manufacturers and component suppliers) and outbound logistics (assembling, packaging, and dispatching orders to industrial clients), with daily operational throughput sufficient to generate representative hazard occurrence patterns across all eleven analyzed activities.

Six key informants participated in the study, selected purposively to represent the full spectrum of warehouse operational roles: one warehouse supervisor (responsible for overall operational management and OHS compliance oversight), one warehouse administrator (managing ERP-based stock documentation), three warehouse employees (engaged in direct physical activities including goods handling, forklift operation, and packaging), and one OHS staff member (responsible for incident reporting, safety inspection, and QHSE documentation). This informant profile provided triangulated perspectives across operational, administrative, and safety management dimensions ([Kasi, Birana, & Alim, 2023](#); [Palengka, & Liperda, 2022](#)).

3.3 Data Collection Methods

Data were collected through three complementary methods to ensure triangulation and comprehensive evidence coverage. First, structured direct observation of all eleven warehouse activities was conducted across multiple working days, during which researchers systematically documented hazard sources, worker behaviors, equipment conditions, environmental factors, and safety compliance levels using a pre-designed HIRARC observation checklist aligned with the 5M hazard classification framework. Second, semi-structured in-depth interviews were conducted individually with each of the six key informants, using an interview protocol structured around the 4P elements of each HIRARC stage: hazard identification (What hazards do you encounter in your activities?), risk assessment (How frequently do these hazards occur? How serious are the consequences?), and control adequacy (What safety measures are currently in place? Are they consistently applied?). Interviews were audio-recorded with participant consent, conducted in Bahasa Indonesia, and transcribed verbatim for analysis. Third, internal company documents including the OHS incident report database for 2023, standard operating procedures for all eleven analyzed activities, the QHSE risk register, and PPE provision records were systematically reviewed to supplement and cross-validate field observation and interview data ([Fusch, Fusch, & Ness, 2023](#); [Cypress, 2019](#)).

3.4 HIRARC Analysis Procedure

3.5 Stage 1: Hazard Identification

Hazard identification was performed for each of the eleven warehouse activities using the 5M framework: Man (worker competency, fatigue, behavioral compliance), Method (procedure adherence, task sequencing, work instruction clarity), Material (product properties, packaging integrity, chemical hazard classification), Machine (equipment condition, maintenance status, operational authorization), and Environment (floor surface, lighting level, space adequacy, ventilation, temperature). Each hazard source was assigned a unique alphanumeric code encoding its activity and sequence number, enabling systematic cross-referencing throughout the risk matrix and control formulation stages.

3.6 Stage 2: Risk Assessment

Risk levels for each identified hazard were determined using a 4×4 likelihood severity matrix validated by PT. XYZ's QHSE team and aligned with ISO 45001:2018 criteria. Likelihood was assessed on a four-point scale: Rare (1) occurrence is exceptional and not expected under normal conditions; Unlikely (2) occurrence is possible but infrequent; Possible (3) occurrence is expected to happen at some point during normal operations; Likely (4) occurrence is expected to happen frequently or continuously. Severity was assessed on a four-point scale: Minor (1) first-aid level injury, no lost workdays; Moderate (2) medical treatment required, short-term lost workdays; Major (3) serious injury requiring extended medical treatment, significant lost workdays; Catastrophic (4) permanent disability or fatality. The Risk Score (RS) was calculated as $RS = L \times S$, generating scores ranging from 1 to 16. Risk categories were: Low (RS 1–4), Moderate (RS 5–8), High (RS 9–12), and Extreme (RS 13–16).

3.7 Stage 3: Risk Control Formulation

Control recommendations were formulated for each identified hazard following the [ILO \(2021\)](#) hierarchy of controls: Elimination → Substitution → Engineering Control → Administrative Control → PPE. For each hazard, the highest-applicable control level was identified, and specific, operationally feasible control measures were prescribed reflecting PT. XYZ's operational context and resource capacity. Control recommendations were validated for practical feasibility through follow-up discussion with the warehouse supervisor and OHS staff informant.

3.8 Data Validity

Data validity was ensured through triangulation of the three data collection methods: observation data, interview data, and document data were compared for each hazard and activity, with discrepancies between data sources prompting clarification through additional observation or targeted follow-up interview questions. The risk matrix used for assessment had been pre-validated by PT. XYZ's internal QHSE team against ISO 45001:2018 criteria, providing an external anchor for the likelihood and severity scaling. Researcher positionality was addressed through reflexive memo-writing during fieldwork, acknowledging that researchers' academic backgrounds in industrial engineering may predispose emphasis on technical rather than behavioral hazard categories.

4. Results and Discussions

4.1 Hazard Identification: Inbound Activities

Four inbound activities were systematically analyzed. Table 2 presents a summary of the identified hazards, risk parameters, and risk levels for each inbound activity.

Table 2. Hazard Identification and Risk Assessment: Inbound Activities (n = 4)

No.	Activity	Hazard Description	Potential Consequence	L	S	Risk Level
1	Goods Reception from Supplier (Inbound 1)	No PPE usage; forklift operated by incompetent operator; goods unloaded manually without assistive tools	Struck/trapped by vehicle; musculoskeletal injury; respiratory disorder from dust/chemical exposure	3	3	HIGH
2	Document & PO Verification (Inbound 2)	Sharp cutting tools used without gloves; dust from packaging materials; poor ambient lighting	Laceration; skin irritation; visual fatigue and eye strain	2	2	MOD.
3	Goods Storage on Racks (Inbound 3)	Non-ergonomic lifting posture; unstable rack loading; high-reach retrieval without safety scaffold	Fall from height; goods falling on worker; chronic back/spine injury	3	4	HIGH

No.	Activity	Hazard Description	Potential Consequence	L	S	Risk Level
4	ERP Stock System Update (Inbound 4)	Prolonged static seated posture; inadequate workstation lighting; monitor glare	Back and neck pain; visual fatigue; impaired concentration reducing data accuracy	2	2	MOD.

Note: L = Likelihood (1–4); S = Severity (1–4); Risk Level = L × S; MOD. = Moderate; HIGH = High.

Table 2 shows that the goods reception activity (Inbound 1) and goods storage activity (Inbound 3) were classified as high-risk activities, reflecting the presence of multiple hazard sources within physically demanding warehouse operations. Inbound 1 involves forklift movement, manual unloading, and potential exposure to dust or chemical substances, creating a compound hazard profile in which failures such as PPE non-compliance, operator error, or improper lifting techniques may result in serious injuries. Similarly, Inbound 3 presents significant risks associated with non-ergonomic lifting, unstable rack loading, and high-reach retrieval tasks, which may lead to falls, struck-by incidents, or chronic musculoskeletal disorders. These findings are consistent with Saputra et al. (2020), who identified goods reception activities involving forklift operations as among the highest-risk processes in inbound warehouse operations.

Goods storage on racks (Inbound 3) presents the distinctive hazard combination of working at height and unstable rack loading a combination associated with struck-by-falling-object and fall-from-height injury types, both of which carry catastrophic severity potential. The high-risk classification (L = 3, S = 4, RS = 12) reflects the realistic probability of occurrence given documented non-compliance with rack loading limits and the absence of height access safety protocols at the time of study.

Document verification (Inbound 2) and ERP stock update (Inbound 4) were classified as moderate risk, reflecting lower physical exposure but persistent ergonomic hazards associated with static posture, inadequate lighting, and visual fatigue. While these hazards do not carry the acute injury severity of heavy equipment activities, the chronic musculoskeletal and visual health consequences of inadequately controlled ergonomic risks have been documented as significant contributors to long-term worker health burden in warehousing (Rahman & Lestari, 2021; Siregar, 2021).

4.2 Hazard Identification: Outbound Activities

Seven outbound activities were analyzed. Table 3 presents the hazard identification and risk assessment results.

Table 3. Hazard Identification and Risk Assessment: Outbound Activities (n = 7)

No.	Activity	Hazard Description	Potential Consequence	L	S	Risk Level
1	Picking List Reception (Outbound 1)	Document handling in confined space; poor posture at workstation	Minor musculoskeletal strain; document error increasing downstream risk	2	1	LOW
2	Goods Retrieval from Racks (Outbound 2)	Heavy lifting without assistive equipment; unstable rack placement; unqualified forklift operation; poor inter-worker communication	Struck by falling goods; forklift collision; fall from height; musculoskeletal injury	3	4	HIGH
3	Goods Inspection (Outbound 3)	Sharp tools without cut-resistant gloves; chemical residue on goods surfaces; poor lighting	Laceration; skin/eye chemical irritation; visual fatigue	2	2	MOD.
4	ERP Stock Update (Outbound 4)	Static seated posture; inadequate workstation ergonomics; monitor glare	Back and neck pain; visual fatigue; concentration impairment	2	2	MOD.

No.	Activity	Hazard Description	Potential Consequence	L	S	Risk Level
5	Packaging and Marking (Outbound 5)	Repetitive manual packaging motion; chemical adhesive exposure; inadequate ventilation	Cumulative musculoskeletal disorder; skin and respiratory irritation from solvents	2	2	MOD.
6	Delivery Order (DO) Preparation (Outbound 6)	Prolonged computer use; inadequate lighting; time pressure increasing error risk	Eye strain; headache; documentation errors with downstream safety consequences	2	2	MOD.
7	Transfer to Transport Vehicle (Outbound 7)	Heavy goods transfer without mechanical aids; loading dock slip/trip hazards; poor communication in loading zone; unqualified forklift operation	Slip/fall; struck by vehicle; dropped goods injury; crush injury during loading	3	4	HIGH

Note: L = Likelihood (1–4); S = Severity (1–4); Risk Level = L × S; LOW = Low; MOD. = Moderate; HIGH = High.

From the Table 3, two outbound activities goods retrieval from racks (Outbound 2) and transfer to transport vehicle (Outbound 7) were classified as high risk (RS = 12), matching the severity of the highest-risk inbound activities. Goods retrieval involves the compound hazard of forklift operation without certified competency, manual lifting of heavy items from elevated rack positions, and inter-worker communication failures in spatially constrained areas a combination that creates conditions for multiple accident types including crush injury, struck-by-falling-object, and fall from height. Transfer to transport vehicles shares similar physical characteristics with the addition of vehicle movement hazards in the loading dock area, where pedestrian-vehicle interaction risk is elevated.

The picking list reception (Outbound 1) activity was the only outbound activity classified as low risk (RS = 2), reflecting its predominantly administrative nature with minimal physical hazard exposure. This classification contrasts with all other outbound activities, which ranged from moderate to high risk, underscoring that the risk gradient within outbound operations is driven primarily by the physical intensity of material handling tasks rather than by activity sequence.

The packaging and marking activity (Outbound 5) warrants particular attention for its chemical exposure dimension: adhesive solvents and marking chemicals are used in an area whose ventilation was assessed as inadequate during observation, creating respiratory and skin exposure conditions that require active PPE control measures. This finding aligns with [Maulana and Rini \(2022\)](#), who identified chemical exposure in packaging activities as a systematically undercontrolled risk category in warehouse OHS programs.

4.3 Overall Risk Distribution

Across all eleven activities and 66 identified hazards, the risk distribution was: Low risk: 2 hazards (3.0%); Moderate risk: 55 hazards (83.3%); High risk: 9 hazards (13.6%); Extreme risk: 0 hazards (0%). Figure 1 (risk matrix) illustrates this distribution visually. The concentration of hazards in the moderate-risk category (83.3%) reflects a warehouse environment in which hazard sources are pervasive but current safety measures even if inconsistently applied partially attenuate the most severe risk outcomes. The nine high-risk hazards, concentrated in forklift operation, rack-based storage and retrieval, and vehicle loading, represent the priority targets for immediate control intervention.

The absence of extreme-risk hazards is notable but should be interpreted cautiously: as [Ramadhan et al. \(2021\)](#) noted, the absence of extreme-risk classifications in warehouse HIRARC assessments often reflects the fact that catastrophic outcomes (fatalities, permanent disabilities) are probabilistically rare events that are difficult to assign high likelihood scores on the basis of historical incident data alone. The true extreme-risk potential of forklift-pedestrian interactions and rack collapse scenarios may be

understated by likelihood scores based on recent incident history if the company has had a period of relative good fortune rather than systematically robust safety controls.

Table 4. Risk Matrix Visualization: 4×4 Likelihood–Severity Assessment Framework

Likelihood	Score	Minor (1)	Moderate (2)	Major (3)	Catastrophic (4)
Likely	4	LOW (4)	MODERATE (8)	HIGH (12)	EXTREME (16)
Possible	3	LOW (3)	MODERATE (6)	HIGH (9)	HIGH (12)
Unlikely	2	LOW (2)	MODERATE (4)	MODERATE (6)	HIGH (8)
Rare	1	LOW (1)	LOW (2)	MODERATE (3)	MODERATE (4)

Note: Cell shading indicates risk level: Yellow = Low (RS 1–4); Orange = Moderate (RS 5–8); Red = High (RS 9–12); Dark Red = Extreme (RS 13–16). RS = Risk Score ($L \times S$).

Table 4 presents the risk assessment matrix used to determine risk levels by combining likelihood and severity scores. Likelihood is categorized into four levels, ranging from Rare (1) to Likely (4), while severity ranges from Minor (1) to Catastrophic (4). The intersection of these two dimensions produces a risk rating classified as Low, Moderate, High, or Extreme. This matrix provides a systematic basis for prioritizing hazards and identifying activities that require immediate control measures.

4.4 Risk Control Recommendations

Control recommendations were formulated for all 66 identified hazards following the [ILO \(2021\)](#) hierarchy of controls. Table 4 presents the distribution of control strategies across control levels.

Table 5. Risk Control Recommendations: Distribution Across ILO Hierarchy of Controls

Control Type	No. of Hazards	Target Activities	Example Measures	Applicable Hazard Codes
Engineering Control	25	Goods storage, retrieval, transfer, administrative workstations	Anti-slip flooring installation; rack load capacity labeling; mechanical forklift interlocks; ergonomic workstation adjustment; improved warehouse lighting (≥ 300 lux)	PTA11, FSB11, PBT12, PRK12, PTA13, PBT13, PBK13, FSB13, PRK13, MTS14, PRK14, PRK21, MTS21, PTA22, PTS22, PBK22, PRK22, PRK23, MTS24, PRK24, TLS25, MTS26, PRK26, ATT27, APS27
Administrative Control	35	All inbound and outbound activities; forklift operation; manual handling	Mandatory forklift competency certification; SOP revision and enforcement; daily safety briefings; scheduled work rotation; periodic HIRARC review; safety observation reporting system	TMA11, OTK11, MTE11, TDM11, TMA12, PTM12, TMA13, OTK13, MTE13, GHK13, PMT13, PBM13, PTE14, PTE21, TMA22, OTK22, MTE22, PMT22, GHK22, PBM22, TMA23, KBK23, PTE24, TMA25, BTE25, RJT25, PTE26, TMA27, OTK27, KMK27, KKP27, TDM27, BTE27, BTT27, KTT22
Personal Protective Equipment (PPE)	6	Chemical handling; packaging; goods inspection	Dust and chemical respirator; cut-resistant anti-laceration gloves; chemical-resistant skin protection; safety shoes (EN ISO 20345)	PDB11, MKB12, PAP12, PAP23, MKB25, PAP25

Control Type	No. of Hazards	Target Activities	Example Measures	Applicable Hazard Codes
Elimination / Substitution	0	Not applicable in current operational context	No hazard sources were found to be fully eliminatable or substitutable without fundamental process redesign	N/A

Table 5 shows that most recommended risk control measures fall under administrative controls (35 hazards), followed by engineering controls (25 hazards), while PPE-based controls were recommended for only six hazards. The predominance of administrative controls indicates that many identified risks can be mitigated through improved procedures, training, supervision, and safety management practices. Engineering controls focus on modifying the physical work environment, such as improving warehouse infrastructure and workstation ergonomics, whereas PPE serves as a supplementary protection measure for hazards related to chemical exposure and manual handling. No elimination or substitution controls were proposed because the identified hazards are inherent to warehouse operations and cannot be removed without significant process redesign.

4.4.1 Engineering Controls (25 Hazards)

Engineering controls are recommended for 25 hazards, predominantly associated with physical workspace conditions, equipment design, and ergonomic infrastructure. Key engineering control recommendations include: (1) Anti-slip flooring installation in all goods movement pathways and loading dock areas, addressing slip and fall hazards in high-traffic zones; (2) Physical rack load capacity labeling and shelf safety barriers, addressing unstable storage hazards; (3) Mechanical forklift interlocks requiring operator certification card authentication before ignition, addressing unauthorized forklift operation a high-risk hazard present in multiple activities; (4) Ergonomic workstation adjustment for all ERP-based administrative tasks, including height-adjustable desks, monitor positioning at eye level, and anti-fatigue matting; (5) Upgraded warehouse lighting to achieve a minimum illuminance of 300 lux in all work areas, consistent with Indonesian National Standard SNI 16-7062-2004 requirements for industrial workplaces. These engineering controls are prioritized because they modify the hazard source or the worker-hazard interface rather than depending on consistent behavioral compliance for effectiveness ([International, 2021](#)).

4.4.2 Administrative Controls (35 Hazards)

Administrative controls constitute the most numerically extensive control category (35 hazards), reflecting the dominant role of behavioral, procedural, and organizational factors in the warehouse's current risk profile. This finding is consistent with [Aditya \(2021\)](#) and [Kurniawan and Dewi \(2020\)](#), who identified the gap between formal OHS policy and operational implementation as the primary driver of warehouse accident rates. Key administrative control recommendations include: (1) Mandatory forklift operator competency certification: all forklift operators must hold a valid Surat Izin Operator (SIO) forklift certification issued by the Ministry of Manpower, with annual renewal and operational authorization revocation for non-certified personnel this single intervention addresses the most prevalent high-risk hazard across multiple activities; (2) SOP revision and mandatory enforcement: existing SOPs for all eleven activities should be revised to incorporate current HIRARC findings, displayed at point-of-work in visual format, and verified through periodic compliance observation; (3) Daily pre-shift safety briefings: structured 10-minute briefings addressing the specific hazards of planned daily activities, incorporating toolbox talks adapted from HIRARC findings; (4) Work rotation protocols for physically demanding activities to limit individual exposure duration and fatigue accumulation; (5) A safety observation reporting system enabling any worker to report observed unsafe conditions without fear of reprisal, creating a continuous hazard identification mechanism beyond periodic formal HIRARC reviews.

4.4.3 Personal Protective Equipment (6 Hazards)

PPE is recommended as the primary control measure for six hazards associated with chemical and dust exposure during goods handling and packaging activities. This restricted application of PPE as a

primary control covering only 9.1% of identified hazards reflects appropriate adherence to the ILO control hierarchy, which positions PPE as a last-resort measure for residual hazards that cannot be adequately addressed at higher control levels ([Badri, Boudreau-Trudel, & Souissi, 2021](#); [Kim, Kim, & Park, 2022](#)). Required PPE includes: particulate and chemical vapor respirators for chemical substance handling; cut-resistant Level C anti-laceration gloves for goods inspection with sharp packaging materials; chemical-resistant skin protection for packaging activities involving solvent-based adhesives; and safety footwear meeting EN ISO 20345 standards for all material handling activities. PPE compliance should be enforced through daily PPE inspection protocols and a disciplinary framework with escalating consequences for non-compliance.

4.5 Discussions

The HIRARC analysis of PT. XYZ's warehouse operations demonstrates the method's effectiveness in generating a comprehensive, prioritized, and operationally actionable risk profile across a complex multi-activity workplace. Several substantive findings merit discussion in the context of the prior literature and the study's three hypotheses.

H1 is supported: significant OHS risk potentials are present across all eleven warehouse activities, with nine high-risk hazards concentrated in the three heaviest physical material handling and equipment operation activities. This concentration pattern where the highest risks cluster in activities combining multiple concurrent hazard categories is consistent with the cumulative risk model proposed by [Firmansyah \(2019\)](#) and the empirical findings of [Saputra et al. \(2020\)](#) and [Wibowo and Anjani \(2020\)](#).

H2 is supported: HIRARC systematically classified all 66 identified hazards into three risk levels with clear operational meaning. The differentiation between moderate and high risk is particularly valuable for control resource allocation: by identifying the nine high-risk hazards as priority interventions, PT. XYZ can direct limited OHS budget and management attention to the activities with the greatest injury potential rather than applying uniform treatment across all hazard categories.

H3 is supported: the three-level control framework engineering controls, administrative controls, and Personal Protective Equipment (PPE) provides a comprehensive and feasible basis for risk reduction. The predominance of administrative controls (35 hazards, 53.0%) in the recommendation set reflects the diagnostic finding that PT. XYZ's OHS failures are primarily behavioral and procedural rather than infrastructural: hazard sources exist within a physical environment that is largely standard for industrial warehouse operations, but the human and organizational management of these sources is inadequate. This finding is consistent with [Ramadhan et al. \(2021\)](#) and [Aditya \(2021\)](#), who identified training insufficiency and SOP non-enforcement as the principal modifiable risk factors in Indonesian logistics OHS.

The absence of elimination and substitution controls reflects a characteristic limitation of established warehouse operations: the hazard sources (forklift equipment, manual lifting requirements, chemical substances, rack storage) are integral to the operational function and cannot be removed without fundamental process redesign. This finding highlights the importance of selecting engineering and administrative controls that maximize risk reduction within the constraint of maintaining operational continuity a practical management challenge that the hierarchy of controls framework navigates by explicitly sequencing control levels from most to least hazard-reduction potential.

5. Conclusions

5.1 Conclusion

This study conducted a comprehensive HIRARC analysis of all eleven warehouse activities four inbound and seven outbound at PT. XYZ, a filtration, lubrication, and hydrocarbon management company in Banten Province, Indonesia. A total of 66 hazard sources were identified and assessed. The risk distribution yielded 2 low-risk hazards (3.0%), 55 moderate-risk hazards (83.3%), and 9 high-risk hazards (13.6%), with no extreme-risk hazards identified. The nine high-risk hazards were concentrated in four activities: goods reception from suppliers (Inbound 1), goods storage on racks

(Inbound 3), goods retrieval from racks (Outbound 2), and transfer to transport vehicles (Outbound 7) all characterized by the concurrent presence of heavy equipment operation, manual material handling at height, and multiple worker-hazard interaction pathways.

Risk control recommendations were distributed across three control levels following the ILO hierarchy: 25 hazards addressed through engineering controls, 35 through administrative controls, and 6 through PPE. No hazards were amenable to elimination or substitution without fundamental operational redesign. The predominance of administrative control recommendations reflects the diagnosis that PT. XYZ's OHS risk profile is primarily driven by behavioral and organizational management failures particularly unauthorized forklift operation, PPE non-compliance, and inadequate SOP enforcement rather than by infrastructural deficiencies alone. The three research hypotheses were fully supported by the HIRARC findings.

This study makes three contributions to the OHS literature and practice. Theoretically, it provides the first integrated HIRARC analysis simultaneously covering all inbound and outbound warehouse activities in the Indonesian industrial services sector, advancing the methodological completeness of HIRARC applications beyond single-activity analyses. Methodologically, the integration of the 5M hazard classification framework with a ISO 45001:2018-aligned 4×4 risk matrix provides a replicable analytical protocol applicable to other Indonesian warehouse and logistics contexts. Practically, the risk control framework delivers directly actionable, prioritized OHS improvement recommendations for PT. XYZ's management system development, with forklift competency certification and SOP enforcement identified as the single highest-priority systemic interventions.

5.2 Research Limitations

This study is subject to four principal limitations. First, the research is bounded to a single company's warehouse operations in Banten Province; the specific risk profile reflects PT. XYZ's operational scale, product characteristics, and management context, limiting direct transferability to warehouse environments in different industrial sectors, geographic regions, or organizational scales. Second, the qualitative risk assessment while structured by validated likelihood and severity scales incorporates subjective judgment from field researchers and key informants; inter-rater reliability was not formally tested, and likelihood estimates based on a single observation period may not fully capture seasonal or shift-dependent variation in hazard occurrence probability. Third, psychosocial hazards including work-related stress, interpersonal conflict, and management pressure-induced risk-taking were not systematically included in the HIRARC analysis, despite their documented contribution to warehouse accident causation ([Fauziah & Hasan, 2020](#)). Fourth, the cross-sectional design captures the OHS risk profile at a single point in time; post-control intervention monitoring to assess the effectiveness of recommended measures was outside the scope of this study.

5.3 Suggestions and Directions for Future Research

Future research should address the limitations identified above through three principal avenues. First, longitudinal studies tracking PT. XYZ's OHS incident rates before and after implementation of the recommended control measures would provide empirical evidence on HIRARC-derived control effectiveness in the Indonesian industrial services context, contributing to the quantitative evidence base on HIRARC return-on-investment in accident prevention ([Nugroho, 2022](#)). Second, extension of the HIRARC framework to include psychosocial hazard identification incorporating workload assessment, occupational fatigue measurement, and organizational safety climate evaluation would produce a more holistic warehouse OHS risk profile aligned with the WHO's expanded definition of occupational health ([World, 2019](#)).

Third, integration of HIRARC with ergonomic assessment tools particularly the Rapid Entire Body Assessment (REBA) or NIOSH Lifting Equation for manual material handling activities would address the ergonomic risk dimension more rigorously than the qualitative 5M framework alone, as demonstrated by [Siregar \(2021\)](#) in a comparable warehouse setting. Fourth, comparative multi-site HIRARC studies across warehouses in different Indonesian industrial sectors including food and beverage, pharmaceutical, and e-commerce fulfillment would enable systematic characterization of

sector-specific OHS risk profiles, supporting the development of sector-specific warehouse safety guidelines that regulators and industry associations could adopt as minimum standards.

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Author Contributions

FGP conceived and designed the study, conducted data collection, performed data analysis, and drafted the manuscript. WAL supervised the research process, contributed to the research design and methodology, and critically reviewed and revised the manuscript. SFM assisted in data collection, data validation, literature review, and manuscript editing. All authors read and approved the final version of the manuscript.

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