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Evaluation of Occupational Safety and Health Risks Through the Hazard Identification, Risk Assessment, and Risk Control Approach in The Construction Project

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ABSTRACT
Work accidents in Indonesia's construction sector remain a significant challenge, mainly due to the weak implementation of occupational safety and health (OSH) management systems. The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method provides a structured framework to manage hazards and risks more effectively. This study adopts a qualitative descriptive approach to evaluate the OSH system at the BRI Ragunan IT Center project. Data were collected through field observations, in-depth interviews with OSH staff and project implementers, and document and literature reviews. Unlike previous studies that often stop at general hazard mapping, this research highlights a comprehensive application of HIRARC in a large-scale IT infrastructure project, thereby addressing the research gap in Indonesia for limited empirical evidence. The study identified 101 potential risks across four main activities and 25 sub-activities. Applying HIRARC principles proved effective in systematically identifying and controlling risks. Control measures, including elimination, substitution, engineering controls, administrative actions, and personal protective equipment (PPE), successfully reduced risk levels across key activities. The findings show that structured HIRARC-based OSH management not only improves worker safety and reduces accidents but also provides a solid basis for risk-mitigation decision-making. The novelty lies in its application within an IT infrastructure project, offering a model for similar environments.

Keywords: *HIRARC; Occupational Safety; Construction; Risk Management; Infrastructure Projects; K3.*

1. Introduction

Work accidents in the construction sector are a serious problem in Indonesia, as many development projects face high risks related to occupational safety and health (K3). Research shows that implementing a robust K3 management system can reduce workplace accidents and support the smooth, successful execution of projects [1-3]. Work safety culture is a significant factor that affects employee performance. Research shows that a strong safety culture can increase motivation and job satisfaction, which ultimately contributes to improved employee performance [4,5]. In addition, the consistent and planned implementation of K3 policies can help create a safer work environment, reduce the risk of accidents, and increase productivity [6]. The HIRARC method provides a systematic framework for identifying hazards, assessing risks, and formulating the necessary control measures to minimize risks [7,8].

The application of the HIRARC method in the context of K3 is beneficial in various studies. For example, research by Fadilah and Herbawani emphasizes the importance of analyzing risk factors that can cause work accidents, which can be grouped into five categories: human, machine, material, method, and environmental factors [9]. By using HIRARC, organizations can develop more effective

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mitigation strategies and focus on preventing workplace accidents [10]. In the industry, HIRARC is also used to assess risks across various sectors, including the furniture and construction industries. Research by Umami et al. shows that applying HIRARC in the small furniture industry can identify potential hazards, such as wood dust and cutting waste, which can harm workers' health [11]. In addition, research by Khudhory et al. identified 18 potential hazards in CV. Jaya Makmur, who showed how HIRARC can be used to develop effective risk control plans [12]. Thus, HIRARC serves not only as an analysis tool but also as a guide to implementing better K3 practices in the workplace.

Overall, the application of the HIRARC method in K3 management is an important step to improve work safety and worker health. By systematically identifying and controlling risks, organizations can create a safer, more productive work environment and reduce the incidence of work accidents that can negatively impact the company's performance and reputation [13,14]. Therefore, this study aims to explore in greater depth the application of the HIRARC method in the context of K3 and to provide recommendations for future best practices.

2. Material and Method

2.1. Research Design

Occupational safety and health (K3) is a fundamental aspect of construction project management, as it seeks to prevent workplace accidents and occupational diseases through systematic hazard control. A widely used framework in this context is the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method, which provides a structured approach for identifying potential hazards, assessing their associated risks, and determining appropriate control strategies. While HIRARC has been applied effectively across industries such as manufacturing, oil and gas, and furniture production [15,16], studies specifically focused on its application in large-scale construction projects in Indonesia remain limited. This research addresses that gap by evaluating the effectiveness of HIRARC in the context of the BRI Ragunan IT Centre Package 2 construction project, thereby providing empirical evidence for a sector where accident rates remain among the highest. This study adopts a qualitative descriptive approach to evaluate the implementation of K3 using HIRARC. A qualitative design was chosen to gain a comprehensive understanding of potential hazards, risk levels, and the practicality of risk-control strategies in the field.

2.2. Research Object, Location, and Research Stages

The object of this study is the construction project of the BRI Ragunan IT Center Package 2, located on Jl. Harsono RM No. 26, Ragunan, South Jakarta. The project has a planned duration of 600 calendar days (August 30, 2024 – April 21, 2026) and is facilitated by PT Hutama Karya.

1. <u>Classification of Work Activities</u>
   Work activities were categorized into two main groups: lower-structure and upper-structure work. This classification provides a systematic overview of work types, potential hazards, and environmental conditions for each activity.
2. <u>Hazard Identification</u>
   Hazard identification was carried out by compiling a hazard table listing the activity, hazard type, and hazard source for each hazard. Data sources included:
   - Applied work methods,
   - K3 observation and inspection results,
   - Reports of unsafe acts and unsafe conditions,
   - Work method permits,
   - Discussions with K3 staff.
3. <u>Risk Assessment</u>
   Following hazard identification, risk assessment was performed to determine the risk level of each hazard, serving as a basis for prioritizing mitigation.

- Objectives:
  - Identify severity and likelihood of hazards.
  - Quantify risks using scoring methods.

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- Prioritize hazards requiring control.

- Method: Based on HIRARC, considering Likelihood (L) and Severity (S). Both scales range from 1–5, with multiplication resulting in a Risk Rating (R).

Formula:

R=L×SR = L \times S

- Likelihood Scale: see Table 1.
- Severity Scale: see Table 2.
- Risk Matrix: see Table 3.

Table 1 shows the Scale of Likelihood of an Event (Likelihood).

Table 1. Probability Scale of an Event (Likelihood)

Score	Probability Level (L)	Description
5	Most Likely	Events have a very high probability of occurring.
4	May Happen	Events have a high probability and are not rare.
3	Imaginable	The incident has never happened, but it could happen in the future.
2	Rare	Incidents are infrequent and have not been reported for a long time.
1	Impossible to Happen	The incident is almost impossible and has never been recorded before.

Source: Ministry of Human Resources Malaysia (2008) [14]

Table 1 presents the probability scale used to assess the likelihood of an event occurring. The scale ranges from 1 to 5, with higher scores indicating a greater probability. A score of 5 (Most Likely) represents events with a very high chance of occurring, while a score of 4 (May Happen) indicates events that are relatively common and not unusual. A score of 3 (Imaginable) refers to incidents that have never occurred before but remain possible in the future. A score of 2 (Rare) is given to events that are highly uncommon and have not happened for a long time. Finally, a score of 1 (Impossible to Happen) represents incidents considered nearly impossible, with no previous record of occurrence.

Table 2 shows the Severity Scale.

Table 2. Severity Scale

Score	Severity (S)	Example
5	*Catastrophic*	Causing numerous fatalities, irreparable property damage, and significant disruption to productivity.
4	Fatal	Causing one fatality and large property damage if danger occurs.
3	Seriously	Resulting in non-fatal but potentially permanent disability.
2	Minor	Inflicts an injury that interferes with activity but does not cause permanent impact
1	*Negligible*	Minor injuries such as abrasions, bruises, or minor cuts that only require first aid

Source: Ministry of Human Resources Malaysia (2008) [14]

Table 2 illustrates the severity scale used to measure the potential impact of an event. The scale ranges from 1 to 5, with higher scores reflecting more serious consequences. A score of 5 (Catastrophic) represents the most severe condition, involving multiple fatalities, irreparable property damage, and significant disruption to operations. A score of 4 (Fatal) indicates the possibility of a single fatality and significant property damage if the hazard occurs. A score of 3 (Seriously) refers to non-fatal incidents that may cause permanent disability. A score of 2 (Minor)

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applies to injuries that disrupt activities but do not leave permanent effects. Lastly, a score of 1 (Negligible) describes the least severe outcome, involving minor injuries such as cuts, bruises, or abrasions that require only first aid.

Table 3 shows the Risk Matrix

Table 3. Risk Matrix

Likelihood Index	**Severity Index**				
	1	**2**	**3**	**4**	**5**
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Source: Ministry of Human Resources Malaysia (2008) [14]

Table 3 illustrates the risk matrix, which combines the Likelihood Index (probability of an event occurring) and the Severity Index (impact if the event occurs) to determine the overall level of risk. The values are calculated by multiplying the likelihood score by the severity score, yielding results ranging from 1 (lowest risk) to 25 (highest risk).
The matrix is colour-coded to represent different risk categories:

- Green indicates low risk, with events manageable and requiring minimal control.
- Yellow represents a moderate risk level, requiring attention and additional preventive measures.
- Red shows high risk, where hazards pose serious threats and demand immediate, comprehensive control actions.

For example, a hazard with a Likelihood Index of 5 (Most Likely) and a Severity Index of 5 (Catastrophic) yields a risk score of 25, which is categorized as high risk. Conversely, a hazard with a Likelihood Index of 1 (Rare/Impossible) and a Severity Index of 1 (Negligible) yields a risk score of 1, which is categorized as low risk.
This risk matrix provides a structured framework for prioritizing hazards, guiding decision-making, and implementing effective control measures in occupational safety management.

This Risk Matrix is used to prioritize actions to address potential workplace hazards. The risk percentage is calculated as the proportion of risks in each category to the total risks identified. Formula:

$$\text{Percentage} = \left(\frac{\text{Number of Risks per Category}}{\text{Total Risks}}\right) \times 100\% \quad (1)$$

4. Risk Evaluation and Control

Risks were evaluated to identify those requiring mitigation measures. Control strategies followed the hierarchy of hazard control:

a. Elimination – removing hazards entirely.
b. Substitution – replacing hazardous methods/materials.
c. Engineering Controls – modifying the environment.
d. Administrative Controls – improving procedures and training.
e. PPE – as a last line of defense.

Selection of control strategies was informed by interviews with the project team and evaluated based on cost-effectiveness, feasibility, and expected benefits.

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Critical Analysis: HIRARC in Construction vs Other Sectors

In industries such as manufacturing and oil & gas, HIRARC has been shown to significantly reduce accident frequency and improve compliance with international safety standards [16-17]. However, in the construction sector, unique challenges arise due to dynamic site conditions, multiple subcontractors, and evolving work environments. Previous research in Indonesia has largely emphasized manufacturing and small-scale industries [15], leaving a research gap in large infrastructure projects.

By applying HIRARC to the BRI Ragunan IT Center project, this study not only evaluates its practical effectiveness in construction but also contributes empirical evidence to inform policy and practice in Indonesia's infrastructure development.

3. Result and Discussion

3.1. Hazard identification

The hazard identification stage is carried out after work activities are successfully identified. At this stage, each identified activity is analyzed to assess its potential risks. Details of the hazard identification results and their control strategies are shown in Table 4.

Table 4. Research Results Hazard identification, risk assessment, and risk control

No.	Job Activities	Hazard Identification	Risk	Value		Risk Rating	Risk Level	Risk Control	Control Hierarchy
				L	S				
1	Borepile Job :								
a	Prep Work	1. Misinformation	Injuries due to miscommunication	4	4	16	HIGH	Toolbox Meeting, Safety Talk, PPE	Administration Control, Eng. Control & PPE
		2. The working area is not sterile	Tripping/being struck by material	3	3	9	MEDIUM		
b	Initial Drilling	1. Hearing impaired	Hearing loss due to drill tool noise	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Falling into a hole	Minor to serious injury	4	4	16	HIGH		
		3. Heavy machine movement	Being hit or knocked over, severe trauma	4	5	20	HIGH		
c	Drilling	1. Falling into a hole	Minor injuries to fractures	4	4	16	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Hit by a drill tool	Serious injury or fatal risk	4	5	20	HIGH		
d	Depth Measurement	1. Falling into a hole	Physical injuries (bruises, sprains, fractures, head injuries)	4	4	16	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Hit by a drill tool swing	Bruises to serious injuries	3	4	12	MEDIUM		
		3. Faulty measuring instruments	Hand wounds, electric shocks, incorrect measurements	3	4	12	MEDIUM		
e	Ironing Work	1. Pierced by iron	Stinging, infection, tetanus	3	3	9	MEDIUM	Use of PPE in accordance with	Administration Control, Eng. Control & PPE
		2. Iron scratches	Scratches, skin infections, or risk of	2	2	4	LOW		

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No.	Job Activities	Hazard Identification	Risk	Value		Risk Rating	Risk Level	Risk Control	Control Hierarchy
				L	S				
			sharp metal contamination					the SOP and be careful	
		3. Hit by iron material	Severe injuries (bruises, fractures)	3	4	12	MEDIUM		
		4. Uncomfortable working position	Muscle fatigue, pain, loss of focus (unsafe act)	3	3	9	MEDIUM		
f	Tremi Pipe Installation	1. Hit by heavy equipment swings	Bruises, pinches, trauma	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Clamped tram pipe	Hand/foot injuries (pinched, bruised, broken)	3	3	9	MEDIUM		
		3. Slipping when pouring concrete	Falls in slippery areas, minor to severe injuries	3	4	12	MEDIUM		
g	Casting	1. Hit by a mixer truck	Serious, traumatic, fatal injuries	3	5	15	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Rollover mixer truck	Death, damage to equipment/work environment	2	5	10	MEDIUM		
		3. Slipping while holding the tram	Minor to severe injuries	3	3	9	MEDIUM		
		4. Exposed to new concrete temperatures	Burns, dehydration, fainting	3	3	9	MEDIUM		
h	Casting Finish	1. Lack of nighttime lighting	Tripping, falling, procedural error	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Workers are tired of working long hours	Decreased concentration, work accidents	3	3	9	MEDIUM		
i	Land Confinement Returns	1. Hit by heavy equipment	Serious injury, fracture, fatal risk	3	5	15	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Slipping during compaction	Bruises, sprains, falling into unsafe areas	3	3	9	MEDIUM		
		3. Instability of the heapland	Buried up, tripped, rolled over	3	4	12	MEDIUM		
j	Housekeeping	1. Dirty work sites	Tripping, slipping, minor injuries	3	3	9	MEDIUM	Use of PPE in accordance with the SOP	Administration Control, Eng. Control & PPE
		2. Exposed to leftover chemicals	Skin/eye irritation, mild burns	3	2	6	MEDIUM		

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No.	Job Activities	Hazard Identification	Risk	Value L	Value S	Risk Rating	Risk Level	Risk Control	Control Hierarchy
		3. Lack of use of gloves	Scratches, irritation, contact with toxic materials	3	2	6	MEDIUM	and be careful	
2	Pilecap Jobs :								
a	Prep Work	1. Miss information	Minor to serious accidents occur	3	3	9	MEDIUM	Toolbox Meeting, Safety Talk, PPE	Administration Control, Eng. Control & PPE
		2. Lack of PPE use	Injuries to the head, eyes, hands, feet	3	4	12	MEDIUM		
b	Measurement	1. Tripping over cables	Risk of falling, rolling, injuring yourself/others	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Slipping	Minor to serious injuries	3	4	12	MEDIUM		
c	Pilecap Excavation	1. Muscle injury when digging manually	Fatigue, muscle pain, musculoskeletal disorders	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Falling into a pit	Serious injuries (fractures, head trauma)	4	4	16	HIGH		
		3. Landslide excavation wall	Burial, asphyxiation, death	2	5	10	MEDIUM		
		4. Exposure to dust or hazardous materials	Irritation, respiratory distress, lung risk	3	4	12	MEDIUM		
d	Soil Leveling	1. Hit by heavy equipment	Serious injury, fracture, fatal risk	3	5	15	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Slipping on uneven terrain	Slips, sprains, muscle/bone injuries	4	3	12	MEDIUM		
e	Formwork Jobs	1. Hit by formwork material	Physical injuries (bruises, internal wounds, fractures)	3	4	12	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Hands are pinched during installation	Hand injuries (Pinches, broken fingers, movement disorders)	3	3	9	MEDIUM		
		3. Slipping on the Rise and Fall	Falls, head injuries, fractures	3	5	15	HIGH		
f	Ironing Work	1. Hit by iron material	Serious injuries: bruises, fractures	2	4	8	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Uncomfortable working position	Muscle injuries, back/shoulder pain, MSDs	3	3	9	MEDIUM		

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No.	Job Activities	Hazard Identification	Risk	Value L	Value S	Risk Rating	Risk Level	Risk Control	Control Hierarchy
g	Soil Leveling Back	1. Hit by heavy equipment	Serious injury, fracture, fatal risk	2	5	10	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Slipping on the dirt	Falls, sprains, bone injuries	3	3	9	MEDIUM		
h	Casting	1. Hit by a mixer truck	Serious injury, fracture, fatal risk	3	5	15	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Slipping when pouring concrete	Sprains, sprains, back injuries	3	4	12	MEDIUM		
		3. Injury when lifting a tremor pipe	Back pain, muscle/bone disorders (MSDs)	4	3	12	MEDIUM		
i	Curing Concrete	1. Incorrect body movements	Muscle injuries, posture, long-term MSDs disorders	4	3	12	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Exposure to curing chemicals	Skin/eye irritation, impaired breathing, minor wounds	2	2	4	LOW		
		3. Tripping over a hose or curing bucket	Falls, bruises, injuries due to loss of balance	3	2	6	MEDIUM		
j	Housekeeping	1. Dirty work sites	Tripping, slipping, decreased productivity	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Back injury (lifting stuff)	Back pain/sprains, spinal disorders (MSDs)	3	3	9	MEDIUM		
3	Column Work :								
a	Prep Work	1. Miss information	Procedural errors, injuries, accidents between workers	3	3	9	MEDIUM	Toolbox Meeting, Safety Talk, PPE	Administration Control, Eng. Control & PPE
		2. Lack of PPE use	Serious injuries without protection (head, eyes, etc.)	3	4	12	MEDIUM		
b	Column formwork lifting with tower crane	1. Being hit by objects at a height	Serious/fatal injury even while wearing a helmet	3	4	12	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Broken sling	Falling material, risk of death and damage	2	5	10	MEDIUM		
		3. Crane overload	Crane collapses, falls on workers/building	2	5	10	MEDIUM		
		4. Falling from a height when	Fractures, head trauma, risk of death	3	4	12	MEDIUM		

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No.	Job Activities	Hazard Identification	Risk	Value L	Value S	Risk Rating	Risk Level	Risk Control	Control Hierarchy
		guiding the load							
c	Ironing Work	1. Pierced by iron	Stinging, infection, tetanus	3	3	9	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Hit by iron material	Serious injuries: bruises, fractures, trauma	2	4	8	MEDIUM		
		3. Slipping (scattered iron)	Falls, sprains, bone injuries due to untidy areas	3	3	9	MEDIUM		
d	Formwork Installation	1. Falling at a height	Serious injuries: fractures, head, fatal risk	4	4	16	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Pinched hands	Finger/hand injuries, bruises, loss of function	3	3	9	MEDIUM		
		3. Shoulder/back injury during lifting	Muscle pain, back disorders (MSDs)	3	3	9	MEDIUM		
e	Scaffolding Installation	1. Falling from a height	Serious injuries: fractures, head, fatal	4	4	16	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Scaffolding collapses (unstable)	Mass accidents, serious injuries, appliance breakdowns	3	5	15	HIGH		
		3. Being hit by material from above	Head injuries, trauma, death (without helmets)	4	4	16	HIGH		
		4. Work fatigue while climbing	Cramps, falls, loss of focus due to fatigue	3	3	9	MEDIUM		
f	Marking Formwork	1. Slipping when measuring on wet floors	Falls, bruises, injuries due to loss of balance	4	3	12	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Falling from stairs/high surfaces	Serious injuries: fractures, trauma, fatal risk	4	4	16	HIGH		
		3. Mismeasurement	Waste of time, work pressure, team conflict	4	2	8	MEDIUM		
		4. Scratched by a sharp measuring instrument	Scratches, potential infections	3	1	3	LOW		
g	Casting	1. Hit by a mixer truck	Serious injuries: fractures, trauma, fatal risk	3	5	15	HIGH	Use of PPE in accordance with the SOP	Administration Control, Eng. Control & PPE
		2. Potential for Rain	Slippery floor, slipping, poor concrete quality	4	3	12	MEDIUM		

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No.	Job Activities	Hazard Identification	Risk	Value L	Value S	Risk Rating	Risk Level	Risk Control	Control Hierarchy
		3. Slipping when pouring concrete on high floors	Falling from a height, fracture, head, fatal	3	5	15	HIGH	and be careful	
		4. Hand injury when steering the bucket	Pressure wounds, pinches, open wounds, bone fractures	3	3	9	MEDIUM		
h	Formwork Disassembly	1. Being hit by material during dismantling	Head injuries, fractures, serious injuries	3	5	15	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. The formwork is damaged when lifted	Material falling, overwriting workers, serious accidents	3	5	15	HIGH		
		3. Slipping due to concrete/water waste	Falls, bruises, sprains, muscle injuries	4	3	12	MEDIUM		
i	Housekeeping	1. Dirty work site (nails, wire, cement)	Tripping, stabbing, scratches due to sharp objects	4	3	12	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Back injury (lifting stuff)	Muscle/back injuries, sprains, MSDs disorders	4	3	12	MEDIUM		
4	Beam and Floor Plate Work:								
a	Prep Work	1. Miss information	Procedural errors, collisions between workers	4	4	16	HIGH	Toolbox Meeting, Safety Talk, PPE	Administration Control, Eng. Control & PPE
		2. Lack of PPE use	Head/hand/foot injuries, respiratory distress, severe risk	4	4	16	HIGH		
		3. Unsafe work floor (not checked)	Floor collapse, fall from height, fatal injury	3	5	15	HIGH		
b	Scaffolding Installation	1. Falling from a height	Serious injuries: fractures, head, fatal risk	3	5	15	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Scaffolding collapses	Mass injuries, material damage, fatalities	3	5	15	HIGH		
		3. Hit by a scaffolding frame	Head injuries, fractures, metal trauma	3	4	12	MEDIUM		
		4. Slipping while riding	Falls, bone injuries, impacts, loss of consciousness	4	4	16	HIGH		
c	Ironing Work	1. Pierced by iron	Punctures, infections, serious hand/foot injuries	4	4	16	HIGH	Use of PPE in accordan	Administration Control, Eng. Control & PPE

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No.	Job Activities	Hazard Identification	Risk	Value L	Value S	Risk Rating	Risk Level	Risk Control	Control Hierarchy
		2. Hit by iron material	Head injuries, fractures, soft tissues	3	5	15	HIGH	ce with the SOP and be careful	
		3. Carrying material that is too heavy	Back injuries, muscles, fatigue due to weight	4	4	16	HIGH		
d	Casting	1. Splash of liquid concrete	Skin/eye irritation, mild–moderate chemical burns	4	3	12	MEDIUM	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Hit by a mixer truck	Serious injury (fracture, trauma), fatal risk	3	5	15	HIGH		
		3. Truck mixer rolls	Severe injury, equipment damage, major accident	3	5	15	HIGH		
		4. Potential for slippery work floor rain	Falls, fractures, scars from slips	4	3	12	MEDIUM		
		5. Slipping when pouring concrete	Spinal injuries, strained muscles, mild to severe trauma	4	4	16	HIGH		
		6. Injury while holding pipes/casting aids	Hand injury, pinching, falling if lost control	4	4	16	HIGH		
e	Housekeeping	1. Dirty work site (risk of tripping)	Wrist injury, sprain, fall from a height	4	4	16	HIGH	Use of PPE in accordance with the SOP and be careful	Administration Control, Eng. Control & PPE
		2. Back injury while cleaning	Muscle/back pain, potential spinal injury	3	3	9	MEDIUM		

Source: Author, 2025

Description of Hazard Identification, Risk Assessment, and Risk Control (HIRARC) Table

The HIRARC table summarizes hazards, risks, and control measures across four main construction activities: Borepile Work, Pilecap Work, Column Work, and Beam/Floor Plate Work. Each activity is broken down into sub-activities, where specific hazards are identified, their likelihood (L) and severity (S) are assessed, and risk values are calculated based on the risk matrix.

1. Borepile Work
   Hazards include misinformation, unsafe work areas, drilling-related risks (falling into holes, heavy machinery movement, exposure to noise), and equipment handling. Many of these hazards scored high risk values (16–20), particularly those involving falls, being struck by machinery, or drilling accidents. Controls emphasized toolbox meetings, adherence to SOPs, PPE, and engineering/administrative measures.
2. Pilecap Work
   Risks identified involve manual excavation, falling into pits, landslides, heavy equipment exposure, and dust/chemical hazards. Excavation and soil leveling were especially critical,

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with values up to 16 (High). Risk controls included safe excavation practices, PPE, proper lighting, and fatigue management.

3. Column Work
   Hazards mainly related to lifting operations, formwork installation, scaffolding, and working at heights. Falling from heights, crane overload, and material collapse reached high-risk scores (15–16). Preventive measures involved strict adherence to SOPs, ensuring equipment stability, and mandatory use of PPE.
4. Beam and Floor Plate Work
   This stage involved multiple high-risk activities, including unsafe floors, scaffolding collapse, heavy lifting, and casting hazards. Several hazards scored the maximum 16 (High Risk), especially those involving falls, overexertion, or contact with heavy/moving equipment. Risk controls focused on engineering safeguards, PPE, housekeeping, and administrative measures.

Overall Findings in this research:

- The most frequent high-risk categories involved falls from height, heavy equipment movement, crane/scaffolding operations, and concrete casting activities.
- Medium-risk hazards were commonly linked to slips, trips, musculoskeletal disorders (MSDs), and minor chemical exposures.
- Low-risk hazards (e.g., scratches, small cuts, minor tool injuries) were rare and easily managed with PPE.
- Control measures consistently emphasized a combination of administrative controls (toolbox meetings, SOP compliance), engineering controls (secure scaffolding, safe excavation), and PPE (helmets, gloves, ear protection, safety harnesses).

This comprehensive assessment demonstrates that structured application of HIRARC helps prioritize risks, highlight critical activities, and recommend effective mitigation measures tailored to construction project conditions.

3.2. Risk assessment

Risk assessments are carried out to assess the extent to which potential hazards can affect occupational safety during activities. The purpose of this process is to determine the risk of potential workplace accidents. The level of risk is determined based on two main parameters, namely the likelihood of the event (likelihood) and the severity (severity). The full results of the risk assessment are presented in Table 4.

Based on the risk assessment results, four main activities and 25 work sub-activities were identified, totalling 101 potential risks. This assessment aims to determine the scale of priorities for the control of the identified risks. Control efforts start with the risk with the highest level of danger, then proceed to lower levels. Most of the risks identified were in the high category (35%), the medium category (63%), and the low category (3%). The risk control strategy is applied in accordance with the control hierarchy, which includes the stages of elimination, substitution, engineering control, administrative control, and the use of personal protective equipment (PPE).

The percentage of risk assessment results is shown in Figure 1 to show the level of risk in project construction activities. Therefore, risk control measures are needed to reduce the identified risk.

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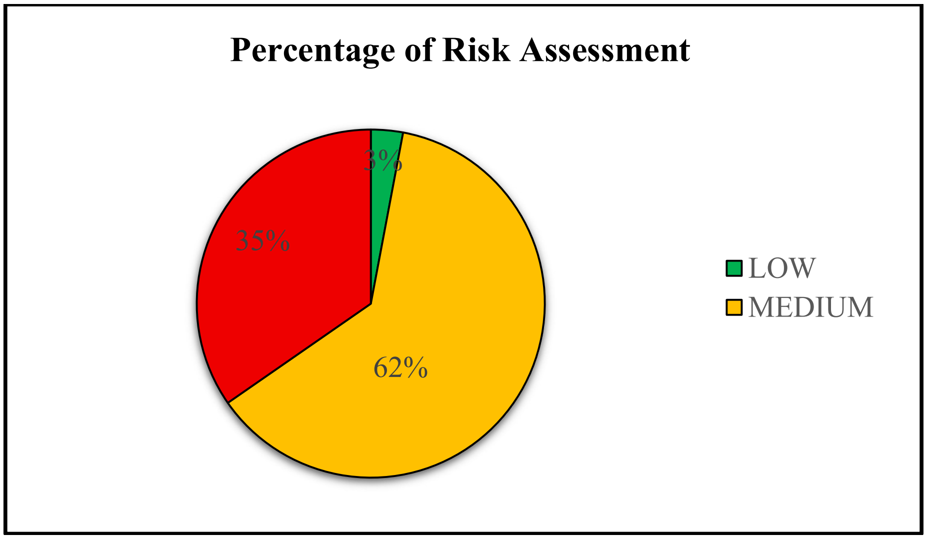

Figure 1. Risk Assessment Percentage
Source: Author

3.3. Risk assessment and prioritization

From the results of the Risk Assessment above, it can be evaluated that:

1. High risks must be followed up immediately with technical, administrative, and complete PPE controls.
2. Moderate risks still require periodic control and monitoring measures.
3. Low risk can be accepted by continuing to monitor and maintain safe working conditions.

The next step is to determine the form of risk control

a. Hazard risk control

After identifying and assessing the risks of various work activities in the construction project, the next step is to develop a risk control strategy to reduce the risk level to an acceptable level. The purpose of this control is to prevent occupational accidents and work-related diseases through planned, effective, and appropriate measures according to field conditions.

b. Principles of Control Hierarchy

Risk control is carried out by referring to the following principles of risk control hierarchy:

1. Elimination: Eliminate the source of the hazard.
2. Substitution: Replacing hazardous materials, tools, or methods with safer alternatives.
3. Engineering Control: Physical modification of the work environment or equipment.
4. Administrative Control: Procedures, training, and scheduling of work hours to reduce risk.
5. Personal Protective Equipment (PPE): The use of protective equipment as a last resort.

c. Evaluation of Control Success

The implemented controls need to be evaluated periodically by the project's HSE team. Evaluations include:

1. Inspection of compliance with work procedures.
2. Inspection of the condition of K3 supporting equipment and facilities.
3. Recording and analysis of near misses or accidents that occurred.
4. Revise the SOP if a non-conformity or potential new danger is found.

These evaluation measures aim to ensure that the controls implemented are not only administrative, but also actually significantly and sustainably reduce risk.

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Discussion

Distribution of Risk Categories

The study found that 35% of activities fall into the high-risk category, 62% into the medium-risk category, and only 3% into the low-risk category. This distribution is consistent with findings from [16,18], who also reported that medium-to-high risk levels dominate construction projects. The relatively high proportion of high-risk activities in this study can be explained by the prevalence of tasks involving work at height and the use of heavy equipment. Similar results were highlighted by [16], who emphasized that scaffolding, lifting, and excavation are the main contributors to severe risks in construction due to their potential to cause falls, structural collapses, and equipment-related accidents.

The predominance of medium-risk activities (62%) reflects the fact that many construction hazards, such as cuts, slips, manual handling injuries, and exposure to noise or dust, are generally manageable through administrative measures and PPE. This pattern aligns with the findings of [18], who observed that construction workers frequently rely on helmets, harnesses, and masks to mitigate risks, although these controls do not entirely eliminate hazards. In contrast, studies in the manufacturing and furniture industries [15,19] reported lower proportions of high-risk activities because these industries operate in more controlled environments where hazards such as chemical exposure or ergonomic risks are more effectively addressed through engineering solutions. Thus, the current findings reinforce the uniqueness of the construction sector, where dynamic site conditions make hazard elimination more challenging compared to other industries.

Comparison with Literature

The dominance of medium-to-high risks in this study is not only consistent with [16,18], but also aligns with broader global research on construction safety, which often shows similar distributions of risk categories. For instance, international studies in large infrastructure projects have demonstrated that the complexity of multi-stakeholder involvement and outdoor site conditions inherently increase risk levels, even when administrative and PPE measures are strictly applied. Conversely, studies outside construction [15,19] consistently show that implementing advanced engineering controls significantly reduces the proportion of high-risk activities. This contrast underlines that while construction hazards are partly universal, their magnitude and persistence are greater in developing contexts where safety systems are still evolving.

Criticism of Selected Controls

The findings further show that risk controls in the BRI Ragunan IT Center project are dominated by administrative and PPE measures rather than elimination or substitution. This pattern parallels observations in Indonesian construction projects reviewed by [16,18], where safety management often relies on toolbox meetings, safety talks, and mandatory PPE rather than proactive engineering interventions. However, compared to international best practices, which prioritize hazard elimination and substitution through automated lifting systems, advanced scaffolding, and dust-suppression technology, the Indonesian context remains reactive. This reliance on low-level controls reflects what [19] identified as a compliance-based safety culture, in which companies prioritize meeting minimum regulatory requirements over investing in innovative safety design.

The limited adoption of engineering solutions in this study echoes similar critiques in Southeast Asian construction research, where cost and practicality are often prioritized over long-term safety investment. As [15] argues, reliance on PPE and administrative controls, though significant, may lead to a "false sense of security" because fundamental risks remain embedded in the work process.

Practical and Policy Implications

From a practical perspective, this study highlights the need to strengthen proactive risk management strategies in Indonesian construction projects. Compared to previous studies [16,18] that recommend increasing PPE use and administrative training, the current findings suggest going further by integrating more advanced engineering controls. Examples include automated scaffolding

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systems, fall arrest nets, and mechanical lifting equipment, which have proven effective in reducing high-risk categories in international research. In addition, integrating digital monitoring tools, such as real-time hazard reporting and electronic safety checklists, can enhance compliance and improve near-miss reporting, which [19] note is critical for proactive hazard anticipation.

On a policy level, the findings reaffirm arguments made by [15,19] that a strong safety culture must be cultivated at the institutional level. The reliance on PPE in the BRI Ragunan IT Centre project demonstrates that Indonesia's construction safety culture is still developing, and that greater managerial commitment and regulatory enforcement are required. In line with [16,18], this study emphasizes that hazard elimination and substitution should be prioritized in large-scale infrastructure projects, particularly given the high proportion of medium- to high-risk hazards.

Synthesis

Overall, the results of this study are consistent with the broader literature, showing that construction projects involve medium-to-high risk activities, largely due to reliance on PPE and administrative controls. At the same time, they diverge from findings in manufacturing and furniture industries [15,19], where risk levels are lower due to engineering-focused solutions. This comparison underscores the distinctive challenges of construction in Indonesia, where dynamic work environments and resource constraints limit the adoption of higher-level controls. By documenting the persistence of administrative and PPE dominance in risk management, this study contributes to the growing body of literature that calls for a transition toward proactive, engineering-driven safety practices in developing countries.

4. Conclusion

This study demonstrates that applying the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method to the BRI IT Centre Techno Building construction project is effective for systematically identifying, assessing, and managing occupational safety and health (K3) risks. A total of 101 potential hazards were mapped across four main activities and 25 sub-activities, with the majority classified as medium risk (63%), followed by high risk (35%), and only a small proportion as low risk. The results confirm that structured controls covering elimination, engineering, administrative actions, and PPE can reduce risks to safer levels.

The novelty of this research lies in its application of HIRARC within the context of a large-scale IT infrastructure project in Indonesia, a sector where empirical studies remain limited compared to manufacturing or oil & gas industries. This study contributes academically by strengthening the evidence that construction projects present a risk profile dominated by medium-to-high hazards, underscoring the need for continuous risk reassessment throughout the project lifecycle.

Practical and Policy Implications

The findings of this study carry several important practical and policy implications. For contractors and project managers, it is essential to strengthen hazard identification as a continuous process throughout the project lifecycle, rather than treating it as a one-time assessment. Toolbox meetings should be enhanced by incorporating predictive discussions on near-miss events, enabling workers to anticipate potential hazards before they escalate. Furthermore, the study emphasizes the need to adopt more engineering-based controls, such as automated scaffolding systems or mechanical lifting aids, rather than relying predominantly on personal protective equipment (PPE) and administrative measures. For regulators and government bodies, the results highlight the urgency of promoting a proactive safety culture across Indonesia's construction sector. This can be achieved by designing policies that incentivize the adoption of safety-related technologies, including IoT sensors for real-time monitoring, BIM-based safety planning, and AI-driven risk prediction. At the national level, the study also underscores the need to develop integrated K3 (Occupational Safety and Health) guidelines tailored to large-scale infrastructure projects, aligned with the country's rapid infrastructure expansion under government programs.

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Limitations of the Study

Despite its contributions, this research has several limitations. Data collection was limited to a single project site, namely the BRI IT Centre Techno Building, and was conducted within a restricted timeframe. This scope may not adequately capture the variations and unique risks that occur across different types of construction projects. Furthermore, the study did not include direct comparative analysis with other construction sectors or industries, which could have provided a broader perspective on the relative effectiveness of HIRARC implementation in diverse contexts.

Future Research Directions

To address these limitations, future research should broaden its scope by involving multiple construction projects with extended observation periods, thereby improving the generalizability of findings. There is also significant potential to integrate digital technologies into HIRARC-based safety management systems. For example, IoT sensors could be used for real-time hazard detection, Building Information Modelling (BIM) could be used to simulate risk scenarios during the design and planning stages, and Artificial Intelligence (AI) could be leveraged for predictive risk modelling and accident prevention. Incorporating these technologies would not only enhance practical outcomes in the field but also strengthen academic contributions by bridging safety science with the digital transformation currently underway in the construction industry.

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