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Original Article

Risk Management Analysis of the Clean Water Pipeline Construction Project of PT CATL Karawang Using the HIRARC Method

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Abstract

Construction activities for water pipeline projects in industrial facilities present various occupational and operational hazards that may disrupt project performance if not properly controlled. This study aims to analyze the occupational risks associated with the water pipeline construction project of PT CATL Karawang using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method. The research was conducted through field observation, work breakdown structure analysis, and semi quantitative risk assessment based on likelihood and severity scoring. The results indicated ten (10) dominant hazards across five (5) major activities including trench excavation, pipe lowering, pipe joint installation, backfilling and compaction, pressure testing, and site restoration. Three (3) risks were categorized as high level, namely trench collapse, pipe dropping during lifting, and stuck by heavy equipment, while the remaining risks were classified as medium level. Appropriate risk controls are recommended following the hierarchy of control, emphasizing engineering controls, administrative procedures, and mandatory use of personal protective equipment. The study concludes that the overall risk category of the project is moderate, high and requires consistent monitoring and implementation of control measures to reduce the probability of incident and ensure safe and continuous project execution.

Keywords: HIRARC, Occupational Health, Risk Management, Safety.

1. Introduction

Water pipeline construction in industrial areas plays a critical role in supporting operational continuity and environmental compliance. Karawang, an area that has notably transformed from an agricultural region to a significant industrial city, stands as one of Indonesia's largest industrial zones, making substantial contributions to West Java's Gross Regional Domestic Product through its thriving manufacturing sector (Aruminingsih et al., 2022; Bano & Dyonisius, 2022). The presence of numerous industrial estates, including those for electric vehicle battery cell manufacturing like PT CATL Karawang. In high-capacity battery manufacturing facilities, such as PT CATL Karawang, the installation of a clean water pipeline system is essential for production processes, cooling systems, and sanitation infrastructure. However, construction activities involving excavation, heavy lifting, welding, and pressure testing inherently introduce occupational hazards that may lead to injuries, material damage, delays, and financial losses. Therefore, systematic risk management is necessary to ensure safety performance during the project execution.

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The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) framework has become one of the most widely applied methods for evaluating safety risks in construction projects due to its systematic ability to identify hazards, rank risk levels, and provide structured control measures. A review of previous applications underscores its versatility and specific contributions across diverse project types. Andriani et al. (2022) demonstrated its effectiveness in high-rise steel construction, using HIRARC to quantitatively categorize risk levels and prioritize engineering and administrative controls beyond just personal protective equipment. Similarly, in managing mobile equipment and open-area hazards, Fikri et al. (2022) employed HIRARC to link identified risks directly to causative factors enabling targeted mitigations like signage and tool inspections. The method's adaptability is further highlighted in manufacturing settings, as shown by Prasetyo (2023), where it was critical for pinpointing high-risk production zones and addressing recurrent mechanical and ergonomic hazards. Furthermore, Zahra et al. (2024) applied HIRARC to complex flyover erection, illustrating its role in deconstructing high-risk lifting operations into manageable stages for control. Despite extensive literature on HIRARC, limited studies specifically examine its application in clean water pipeline construction within a high-risk industrial environment such as battery manufacturing. Thus, this research aims to analyze the risks of the water pipeline construction project at PT CATL Karawang using the HIRARC approach to determine priority hazards and appropriate mitigation strategies.

Construction projects that involve underground pipeline installation present various operational and occupational hazards due to excavation activities, heavy lifting operations, welding, and hydraulic pressure testing. Recent studies highlight that the majority of accidents in pipeline construction originate from trench collapse, contact with underground utilities, stuck by incidents involving heavy equipment, and welding related hazards. Safety management therefore requires a systematic risk assessment model to minimize uncertainties during execution (Cahyono et al., 2022).

A hazard is anything that has the potential to cause injury, illness, property damage, environmental harm, or a combination of these negative effects. According to the International Labour Organization (ILO), hazards may originate from physical, chemical, biological, ergonomic, or psychosocial sources. In the construction industry, hazards commonly arise from heavy equipment operations, unstable ground conditions, working at heights, welding activities, material movement, and dynamic work environments.

Hazards in occupational safety are often assessed based on their potential consequences and are commonly associated with two main elements which are likelihood (the probability of an event occurring) and severity (the degree of harm it may cause). These elements form the basis for determining the level of risk that needs to be controlled (Pambudi, 2025). Risk is the possibility of an event occurring that may cause harm, injury, damage, or other negative impacts on people, equipment, the environment, or work processes. According to ISO 31000, risk is defined as “the effect of uncertainty on objectives,” meaning that risk arises whenever uncertainty affects the achievement of objectives.

In construction projects, risks may originate from environmental conditions, worker behavior, equipment use, work methods, or external factors such as weather and soil conditions. Risk in occupational health and safety is generally influenced by two main variables which are likelihood of an event occurring and severity of its consequences. The combination of these two factors determines the risk level, which is used to prioritize appropriate control measures (Rotinsulu et al., 2023).

Risk management is a systematic process of identifying, analyzing, evaluating, and controlling risks to minimize their impacts. ISO 31000 states that the purpose of risk

management is to create value, improve operational effectiveness, ensure safety, and support better decision-making. In the construction sector, risk management is crucial because projects involve hazardous activities such as material handling, excavation, heavy equipment operation, working at heights, and exposure to various physical agents. Without effective risk management, the potential for accidents and material losses increases significantly (Sari et al., 2022).

HIRARC (Hazard Identification, Risk Assessment, and Risk Control) has been widely adopted in high-risk construction work because of its ability to identify hazard sources, quantify risks through severity and likelihood scoring, and design structured risk control strategies (Karma et al., 2023). The method has been shown to significantly reduce workplace incidents in mechanical, civil, and industrial installation projects (Lubis et al., 2024; Matullah, 2023). Although HIRARC is widely applied, there remains limited research that addresses risk management in pipeline installations specifically within battery manufacturing industrial sites that involve complex activities and hazardous materials. Therefore, this study intends to fill this research gap by applying HIRARC to the clean water pipeline construction project at PT CATL Karawang.

2. Methods

This study uses the HIRARC framework consisting of three stages: hazard identification, risk assessment, and risk control. The research was conducted in 2025 at PT CATL Karawang through direct observation of construction activities, documentation review (permit to work, work method statement, job safety analysis), and structured interviews with site engineer, site manager, supervisor and safety officer.

Risk levels were calculated using a semi quantitative matrix based on likelihood (L = 1-5) and severity (S = 1-5), where total risk (TR = LxS). The level of risk is categorized into low (1-4), medium (5-11), and high (12-25). Risk controls were determined using the hierarchy of control model elimination, substitution, engineering control, administrative control, and personal protective equipment.

3. Results and Discussion

Based on the secondary data collected throughout the research process, several key work activities were identified as part of the project's operational stages. These activities represent the primary sources of potential hazards and risks, and therefore form the foundation for the subsequent HIRARC analysis conducted in this study. The following work activities were identified and shown in table 1:

Table 1. Project Work Activities List

No	Work Activity
1	Trench excavation
2	Excavating near utilities
3	Pipe lowering
4	Crane operation
5	Welding
6	Confined space
7	Backfilling
8	Pressure testing
9	Site restoration

Source: Secondary data, 2025

Hazard identification found 10 dominant hazards across the following work stages: trench excavation, pipe lowering, joint installation, backfilling and compaction, hydrostatic pressure testing, and site restoration. The identified hazards and their risk classifications are displayed in Table 2.

Table 2. Hazard and Risk Identification

Activity	Hazard	Risk
Trench excavation	Collapse of excavation	Workers buried, severe injury/fatality, material damage
Excavating near utilities	Contact with underground utilities	Electric shock, gas/water leak, utility damage
Pipe lowering	Pipe fall during lifting	Workers struck, serious injury, pipe damage
Crane operation	Crane overload failure	Crane collapse, fatality, equipment/material damage
Welding	Exposure to flame sparks	Burns, fire, respiratory irritation
Confined space	Toxic gas accumulation	Poisoning, unconsciousness, fatality, explosion potential
Backfilling	Struck by heavy equipment	Hit by equipment, serious injury/fatality
	Dust and noise exposure	Respiratory issues, hearing loss
Pressure testing	Pipe burst/overpressure	Injury from high-pressure release, pipe damage
Site restoration	Slip and trip hazards	Falls, sprains, fractures

Source: Researcher's work, 2025

The risk assessment process in this study was carried out to evaluate the level of hazards associated with each identified work activity. This assessment aims to determine the likelihood and severity of potential incidents, allowing for the prioritization of risk control measures. The risk assessment results are listed in table 3.

Table 3. Risk Assessment

Activity	Hazard	L	S	TR	Level
Trench excavation	Collapse of excavation	3	5	15	High
Excavating near utilities	Contact with underground utilities	2	5	10	Medium
Pipe lowering	Pipe fall during lifting	3	4	12	High
Crane operation	Crane overload failure	2	5	10	Medium
Welding	Exposure to flame sparks	3	3	9	Medium
Confined space	Toxic gas accumulation	2	5	10	Medium
Backfilling	Struck by heavy equipment	3	4	12	High
	Dust and noise exposure	2	3	6	Medium
Pressure testing	Pipe burst/overpressure	2	5	10	Medium
Site restoration	Slip and trip hazards	2	3	6	Medium

Source: Researcher's work, 2025

Risk control can be implemented using the hierarchy of controls, including elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). Measures such as installing shoring for excavations, using certified lifting equipment, providing ventilation and gas detection in confined spaces, applying work permit systems (PTW), conducting daily safety briefings, enforcing safe work procedures, and ensuring proper PPE use are essential to reduce risks. With proper and consistent application of these controls, activities with high risk can be reduced to medium or low levels, resulting in a safer working environment.

4. Conclusion

The study's findings reveal a range of hazard potentials inherent in the pipeline construction process, including risks such as trench collapse, contact with underground utilities, pipe falling during lifting, crane overload failure, welding spark exposure, toxic gas accumulation in confined spaces, being struck by heavy equipment, dust and noise exposure, overpressure during testing, and slip-trip hazards. Without proper management, these hazards may result in severe injuries, burns, poisoning, equipment damage, or fatal accidents. The risk assessment indicates that certain activities, such as trench excavation, pipe lowering, and backfilling, are categorized as High risk and demand immediate attention and control measures.

Most other activities are classified as medium risk, still posing considerable danger and requiring consistent monitoring to prevent accidents. This prioritization helps direct resources toward the most hazardous tasks first. Effective risk reduction can be achieved through the hierarchy of controls, encompassing elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). Essential measures include installing shoring for excavations, utilizing certified lifting equipment, providing ventilation and gas detection in confined spaces, implementing a permit-to-work system, conducting daily safety briefings, enforcing safe work procedures, and ensuring proper PPE usage. With consistent and thorough application of these controls, even high-risk activities can be mitigated to medium or low levels, ultimately fostering a safer working environment.

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