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Research paper

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ABSTRACT

Purpose: Transportation infrastructure construction has an elevated accident risk, with pier and pierhead work being a prime example. The objective of this research is to identify the hazards and risks associated with pier and pierhead work to minimize workplace accidents.

Methods/Design: The study employed a qualitative descriptive method focusing on a case study of the Jakarta LRT Phase 1B project. Data were gathered through a literature review of journals, project-specific JSA (Job Safety Analysis) data, IBRP (Initial Business Risk Profile) data, method statements, and construction OHS (Occupational Health and Safety) regulations. Following the identification of hazards and risks in pier and pierhead work, a quantitative risk assessment was conducted by distributing a likelihood and severity assessment form to project QHSE personnel. Finally, risk control measures were proposed for the assessed risk levels using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method.

Findings: The identification results revealed 89 hazards and 99 risks in pier and pierhead work, including 15 extreme-category hazards, 48 high-category hazards, and 25 medium-category hazards. Based on the assessment, the pier and pierhead casting (concreting) phase carries the most extreme risk, with six identified hazards. The pier and pierhead formwork installation and dismantling phase has the highest number of high risks, with 19 identified hazards. Lastly, the pier and pierhead rebar (steel reinforcement) phase is categorized as having the highest number of medium risks, with 14 hazards found.

Practical implication: Risk control measures were implemented following the hierarchy of control elimination, substitution, engineering controls, administrative controls, and the use of Personal Protective Equipment. This methodology was applied to ensure the effective and efficient prevention of hazards and risks in pier and pierhead work.

INTRODUCTION

As a dense metropolitan city with a 2023 population of 10 million people, Jakarta critically requires an integrated transportation system, as roughly 23% of its workers rely on public transport daily. To address this, the Badan Pusat Statistik Provinsi Dki Jakarta, 2023 is continually upgrading its infrastructure, with the Light Rail Transit (LRT) being a key solution to alleviate traffic congestion and improve mobility. The LRT, an urban-designed light railway, is characterized by its ability to operate individual carriages and service passengers on dedicated tracks (elevated, underground, or at-grade). It is also smaller, has less capacity than traditional rail, and is more environmentally friendly due to its use of electricity(Fardila et al., 2018).

However, LRT construction, particularly the Jakarta LRT Phase 1B (Velodrome–Manggarai) project, faces significant safety challenges. General public safety is threatened by construction work amid dense traffic, which requires careful management to avoid disruption, restricted access, and the risk of falling materials or equipment (Julianto, 2024). Furthermore, worker safety is a major concern, highlighted by previous accidents on similar high-altitude projects, including fatal incidents from falling support pillars and non-fatal falls from height(Aprizaldi & Saputro, 2022).

Currently, the Jakarta LRT Phase 1B project uses the Job Safety Analysis (JSA) and Hazard Identification and Risk Assessment (IBPR) methods for risk control. These methods, however, have limitations: JSA is often seen as too restrictive and focuses more on hazard control than risk probability, while IBPR often lacks in-depth analysis of human and behavioral factors. Given the high-risk nature of elevated construction and past accidents, a more comprehensive approach is needed(Yusup et al., 2024). Therefore, this research aims to utilize the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method, a systematic approach involving identifying hazards, analysing their likelihood and severity, and implementing control measures (elimination, substitution, engineering, administrative, and PPE) on the pier and pierhead work of the Jakarta LRT Phase 1B project. The goal is to reduce the occurrence of similar construction accidents and provide a valuable safety reference for project implementation (Hi Yusuf, 2023).

One of the other methods that can be used for control is the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) Method. HIRARC is a process that begins by defining the type of work activity, then identifying the hazard sources to determine the associated risks. The subsequent step involves assessing and controlling those risks. The goal is to reduce hazard exposure for every type of job (Ressa & Sari, 2023). After hazard identification, an assessment is conducted by analysing the results of the identification. These identified hazards are then calculated using two aspects: likelihood and severity, in a particular job (Permata Sari et al., 2022). Furthermore, control measures against hazards in the work environment are implemented to minimize or eliminate the risk of accidents. These control actions include elimination, substitution, engineering controls, warning systems, administrative controls, and the use of personal protective equipment (PPE). Therefore, HIRARC provides a broader overview of workplace hazards(Patricia et al., 2014).

Based on this background, the research aims to identify hazards, analyse risks, and control risks using the HIRARC method for pier and pier head work in the construction of the Light Rail Transit (LRT) Phase 1B Velodrome-Manggarai. This study is expected to mitigate the causes of similar occupational accidents, benefit the project, and serve as a reference for project implementers during the project execution.

METHODS/DESIGN

Types of Research

This research utilizes a descriptive quantitative method. In line with (Waruwu et al., 2025) In view, quantitative research is a systematic investigation that collects measurable data through mathematical and statistical analysis to conclude aspects such as attitudes, beliefs, and behaviours. In this case, the researcher acts as the main instrument in data collection and analysis(Cahyono et al., 2019). The data analysis is based on primary data (results from observations, interviews, and QHSE worker assessment forms) and secondary data (Job Safety Analysis (JSA) and the execution methods of the LRT project). This data is used to meticulously identify and document the procedures and stages of the pier and pierhead work from initiation to completion.

Location and Time of Research

The location for this study was the Light Rail Transit (LRT) Jakarta Phase 1B Project (Velodrome – Manggarai). This project is divided into two zones: Zone 1 and Zone 2. Zone 1 contains a total of 104 piers and pierheads, while Zone 2 has a total of 83 piers and pierheads. This research focuses specifically on Zone 1, which is indicated by the yellow circle in the Figure1.

Figure 1. Research Location

Research Sample

The sample of this study involves controlling risks using the HIRARC method for the pier and pierhead work on the LRT Jakarta Phase 1B Velodrome-Manggarai project.

Data Collection Technique

Data is an essential factor in this research for analysing, evaluating, and providing recommendations for the ongoing project. The primary data collection method is a Systematic Literature Review (SLR), which involves gathering full scientific articles published within the last 15 years (Ayenti & Susilawati, 2024). This is consistent with the descriptive quantitative method, which relies on mathematical and statistical analysis. Additionally, this study collects primary data through interviews with two QHSE Managers, surveys, field observations, and the

distribution of questionnaires to four QHSE staff members (Manager, Supervisor, Administrative, and Inspector). This is then combined with secondary data such as JSA documents, the project's pier and pierhead work execution methods, and OHS regulations and journals related to HIRARC(Agustin & Rodiah, 2022). All these efforts aim to identify and document the procedures and stages of pier and pierhead work from initiation to completion (Rizki et al., n.d.).

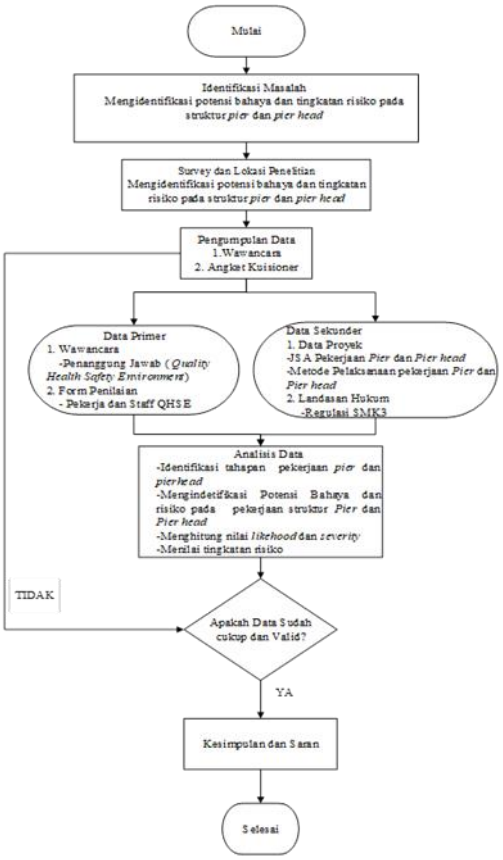

Figure 2. Research Flowchart

Data Analysis Technique

Findings should be an objective description of the results and should be in relation to the objectives of the research. This research utilizes the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method to analyse the pier and pierhead work on the LRT Jakarta Phase 1B Velodrome–Manggarai project, in accordance with the established scope and objectives(Erliana & Aziz, 2020). The approach to the problem begins with studying the literature related to common accidents and errors in this type of work. Subsequently, referring to (Prabowo, 2021) the researcher identifies hazard risks and the possibility of accidents based on the predetermined work steps. The implementation of the research includes the process of collecting risk assessment data covering the values of likelihood and severity through assessment forms given to the LRT project's QHSE staff and workers. The collected data are then used to calculate and determine the risk level for each work stage examined.

FINDINGS

Hazard Identification

The hazard identification process for the pier and pier head work involved non-systematic interviews, literature reviews, and the collection of field data related to JSA (Job Safety Analysis), method statements, tools, materials, and HSE (Health, Safety, and Environment) equipment. The interviews were conducted on February 6, 2025, and May 21, 2025, at the location of the management office. The results of the hazard identification (Table 1) for the pier and pier head work were initially obtained by reviewing existing literature, followed by collecting field data such as the Job Safety Analysis and Method Statement documents for the pier and pier head.

Based on the hazard identification results, scaffolding erection poses a primary risk of workers falling from a height due to an unstable structure, potentially causing serious injury or death. During the pier and pierhead reinforcement stage, hazards relate to rebar fabrication on site, where using the bar bending machine risks causing abrasions up to bone fractures. Tools used include the bar cutter and bar bending machine, with reinforcement steel as the main material. Furthermore, formwork installation using a mobile crane carries a high risk; the main danger is steel plates falling onto workers during high-altitude installation. Meanwhile, in the pier and pierhead concrete casting stage, hazards cover the entire process, with the most critical risk being the concrete bucket falling onto workers below. Tools involved in this casting work include the concrete vibrator and concrete bucket.

Risk Level Assessment

Based on the hazard assessment, according to (Damayanti & Nalhadi, 2017)), risk levels are determined via a risk matrix scale utilizing both probability (frequency of occurrence) and severity (impact of the hazard). The assessment identified scaffolding erection as the activity posing the most extreme risk, which includes workers falling during installation, being pinched by the scaffold, falling due to slips, collision with vehicles, trucks falling onto road users, and the concrete bucket falling due to a broken crane sling. Conversely, hazards rated as medium are more numerous, encompassing foot injuries from stepping on rebar/nails, workers falling from a height (during reinforcement and casting), fine iron dust entering the eyes, hands caught by the tying wire cutter, tripping/slipping due to uneven surfaces, being scratched by protruding rebar, electric shock from the concrete vibrator, and exposure to splashing ready-mix (Masjuli et al., 2018).

The bar chart (Figure 3) shows the total number of hazard levels divided into three categories: Extreme, High, and Medium. Based on the data visualization, the High hazard level dominates with the highest frequency, 48 hazards. The second position is held by Medium 26 hazards, while the hazard level recorded the lowest count, 15 hazards.

Table 1. Hazard Identification

I	**Scaffolding Erection**
1	Workers falling during scaffolding erection due to the scaffolding being unstable or collapsing; falling while ascending or descending the scaffold, resulting in slips or trips; and being caught/pinched during the assembly of the scaffold.
II	**Rebar Reinforcement Work**
1	Workers are being caught/pinched by the bar cutter while cutting the reinforcement bars and being caught/pinched by the bar bending machine while bending the reinforcement bars.
2	Workers are struck by rebar fragments during rebar cutting, and foot injuries are caused by stepping on reinforcement bars/wires and nails during the reinforcement work.
3	Workers are being struck by reinforcement materials falling during lifting operations using the tower crane and falling from a height during the installation of reinforcement bars.
4	Workers are being struck by falling material during lifting operations using a mobile crane.
5	Electric shock from a faulty generator
6	Fine iron dust entering workers' eyes; hands being caught/pinched by the wire cutter during the tying of the pier and pierhead reinforcement.
7	Being struck by falling materials/equipment from height due to a broken crane sling during the installation of pier and pierhead reinforcement.
8	Tripping, slipping, and falling due to an uneven working surface.
III	**Rebar Mobilization**
1	Being struck by a passing vehicle, or trucks and their load falling onto road users.
2	The truck gets stuck or becomes unstable while entering the worksite, endangering road users.
IV	**Formwork Dismantling and Installation**
1	Being struck by falling formwork that becomes detached due to a broken crane sling or falling from a height.
2	Being brushed against or struck by the crane during the installation process.
3	Steel plates and other formwork materials falling from the transport vehicle and striking workers.
4	Formwork collapsing due to loose keys, anchors, or tie rods, gaps between panels, or parts that are not properly secured.
5	Finger injuries from nails and being caught/pinched by clamps during formwork connection/assembly.
6	Being caught/pinched between materials or between a material and another surface during formwork shifting/relocation.
V	**Concrete Casting**
1	Being brushed against or struck by the mixer truck.
2	Electric shock from the concrete vibrator, and eyes being struck by splashing concrete while using the vibrator.
3	Workers' eyes and body parts are being exposed to ready-mix concrete and exposure to chemical products.
4	The concrete bucket was falling onto workers below due to a broken crane sling.
5	Structural collapse (formwork, scaffolding, or reinforcement).
VI	**Concrete Curing**
1	Exposure to chemical substances (from curing compounds/materials).
2	Unneatly rolled geotextile sheets are causing workers to trip or slip.
3	Falling from a height while performing concrete curing.

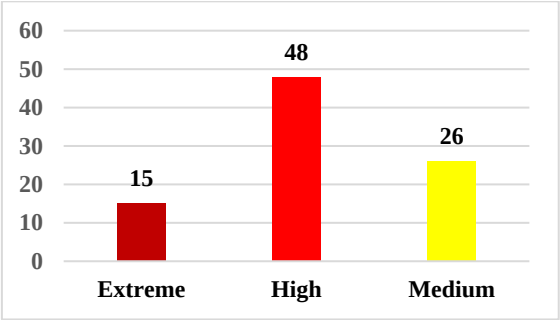

Figure 3. Bar Chart of Total Hazard Levels

Risk Control

Risk controls for the pier and pier head work are implemented hierarchically for each risk level. Extreme risk controls are multi-layered: technically, physical guards like railings are installed (Yuliarty & Suseno Bakti, 2025) and routine inspection of equipment suitability is performed. Administratively, specific work permits, safe work procedures, and the installation of warning and prohibition signs are enforced. One example of a warning sign used in the LRT Jakarta 1B project is shown in Figure 4.

Figure 4. Warning Sign

Risk control for pier and pier head work is implemented hierarchically, beginning with foundational administrative controls like Toolbox Meetings, ensuring SIO/SILO certification, and providing MSDS. Controls for Extreme Risks are layered, including technical measures such as installing railings and conducting routine equipment inspections, alongside administrative measures like special work permits and warning signs. High Risks focus primarily on preventing "struck-by" incidents through barricades, inspected lifting gear, and strict work permits for specific tasks (like installation or casting). Finally, Medium Risks are managed by emphasizing awareness and housekeeping; controls include immediately stopping unsafe work, providing Safety Inductions, running 5R/5S tidiness programs, and enforcing the use of basic PPE like gloves and safety shoes (Rohmah et al., 2023).

PRACTICAL IMPLICATION

The practical HIRARC method for occupational risk control on the LRT project is focused on shifting resources to targeted hierarchical interventions: Extreme Risks (like falling during scaffolding or crane operations) mandate immediate investment in Engineering Controls (such as permanent railings) and strict administrative measures like zero-tolerance SIO/SILO checks and specialized Work Permits for high-risk activities (casting/dismantling). High Risks must be

addressed through technical measures like barricades and inspected lifting gear, while Medium Risks demand better housekeeping 5R or 5S and task-specific safety inductions to manage frequent hazards like slips, trips, and minor injuries; ultimately, the study provides a validated risk register and a framework for all future pier and pier head construction projects to accelerate proactive safety planning.

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DISCLOSURE STATEMENT

Hereby certify and guarantee that there are no known actual or potential conflicts of interest, including financial, professional, or personal relationships, that could have appeared to influence the content, data analysis, or conclusions presented in this manuscript.

The research was conducted and reported objectively, and the author(s) received no funding or benefits from any commercial party, political organization, or other interest group that would compromise the integrity or impartiality of the findings regarding risk control measures on the Jakarta LRT Phase 1B project.

NOTES ON CONTRIBUTOR

Abyan Rakha Rafiamno is a student of Civil Engineering, at the Faculty of Vocational Studies, Yogyakarta State University. Her academic pursuits are centered on the practical and applied domains of civil engineering, with a strong commitment to contributing meaningfully through research initiatives and scholarly project.

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