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Risk Analysis of Occupational Safety and Health (K3) Using the HIRADC Method on Chiller Replacement Works: A Case Study

Toni Yuri Prastowo[1*], Rahmadika Luthfi Manaf Imsarif[2], Dedy Sanjaya[3], Nana Taryana[4]
[1*,2,3]Civil Engineering, [4]Architectural Engineering, Borobudur University
Email: [1*] toniyuri19@gmail.com, [2]rahmadika33@gmail.com, [3]dedisanjayabb@gmail.com, [4]ntaryana72@gmail.com

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ABSTRACT

Occupational safety and health (K3) is an important aspect that must be considered in construction projects to prevent work accidents. This study aims to analyze potential risks and determine control measures using the Hazard Identification Risk Assessment and Determining Control (HIRADC) method on a chiller replacement work at a hotel renovation project in Jakarta, Indonesia. Potential hazards were identified through direct observation, worker interviews, and document review. Risk assessment was carried out by calculating the likelihood and severity scores to determine risk levels. Several control measures were implemented based on the risk hierarchy. A risk comparison before and after implementing controls showed a reduction in risk levels. Structural analysis using ETABS proved that the temporary reinforcement provided structural safety. The estimated cost of Rp. 250,456,350 met K3 budget provisions. This study demonstrates that risk analysis using HIRADC is effective in reducing risks and ensuring K3 aspects in construction works.

1. Introduction

Construction works have various potential hazards due to their complex activities, harsh work environments, and uncertainty factors[1]. Accidents are inevitable if risks are not properly identified and controlled. Thus, occupational safety and health (K3) is imperative to prevent work incidents. The HIRARC method has proven effective in reducing and investigating workplace accidents at power plants, evaluating and classifying risks, and recommending corrective actions for high and extreme risks, while emphasizing the importance of ongoing risk assessments and regular reviews of control measure effectiveness [2].

According to Government Regulation No. 50 of 2012, contractors are responsible for implementing an occupational safety and health management system (SMK3) conforming to OHSAS 18001 to maintain K3 aspects in construction sites[3]. One of the SMK3 components

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is risk management using a structured hazard identification, risk assessment, and risk control (HIRADC) method[4]. HIRADC aids in systematically identifying hazards, evaluating associated risks, and determining adequate control measures[5]. When properly implemented, HIRADC is vital in minimizing risks and securing workers' safety. The HIRARC method successfully identified 18 potential risks in the construction of site offices and building foundations, with risk categories of low (33%), medium (28%), high (17%), and extreme (22%), emphasizing the importance of PPE supervision, safety signage, and regular meetings to enhance workplace safety, particularly for untrained workers [6].

This study aims to analyze K3 risks using the HIRADC method on a chiller replacement project at a hotel renovation in Jakarta, Indonesia. Chiller lifting activities carry high risks due to the equipment's large dimensions and weight. Potential hazards were identified through observations, worker interviews, and documentation reviews. Risk assessments were carried out to determine risk levels before and after control. The cost estimation for K3 facilities was also performed. The results showed that risk levels decreased after controls and the estimated budget complied with regulations. This research demonstrates the effectiveness of HIRADC in controlling risks to achieve K3 objectives in construction works[7].

2. Research Method

2.1. Literature Review

Occupational Safety and Health OHS defines working conditions, work arrangements, and procedures to prevent work-related injuries, diseases, deaths, and promote workers' well-being [8]. OHS aims to protect workers by eliminating or minimizing hazards in the work environment and providing safe machinery and equipment[9]. Workplace hazards stem from occupational processes and behaviors, such as excessive noise, harmful chemicals, work at heights, or unguarded machinery[10]. Accidents often occur due to improper safety protocols, dangerous acts, unsafe equipment, or lack of protective gear [11]. Using Hazard Identification Risk Assessment And Risk Control (HIRARC) can analyze and control potential hazards from work activities, provide risk assessments, and implement risk control measures to achieve effective OHS risk management [12].

Construction work involves various risks despite implementing safety standards and procedures[13]. Risk Control (HIRARC) is an effective risk analysis process adopted in the Risk Management Plan during the construction phase of the project [14]. Hazard identification can reduce and prevent accidents as well as minimize potential hazards [15]. It is associated with complex operations, tough conditions, uncertain factors, and jobsite variations[16]. Contractors are responsible for providing a safe workplace and preventing accidents through an OHS management system conforming to recognized standards like OHSAS 18001 [17]. The implementation of effective OHS management plays a crucial role in minimizing work accidents, meeting 97% of OHS audit criteria with only 6 minor audit findings [18].

Proper risk management is imperative as construction accidents threaten workers' lives and affect project success[19]; The most effective safety program elements in reducing construction safety and health risks are upper management support and commitment, as well as strategic subcontractor selection and management, while the least effective elements are accident recordkeeping and emergency response planning [20].

This identifies dominant risk factors in construction projects, including labor shortages, low productivity, rising material costs, material damage/loss, equipment breakdowns, and schedule delays, and proposes responses to mitigate the negative impacts of these risks through a questionnaire survey and Probability and Impact matrix analysis[21]. It aims to reduce uncertainties and optimize resources by understanding risk factors. The commonly used HIRADC method provides a systematic approach to hazard identification, risk assessment, and risk control determination. Risk identification involves detecting all potential hazards using tools like brainstorming, checklists, interviews, or historical data analysis Risk assessment quantifies the probability and severity of each identified risk[22]. Risk control then determines

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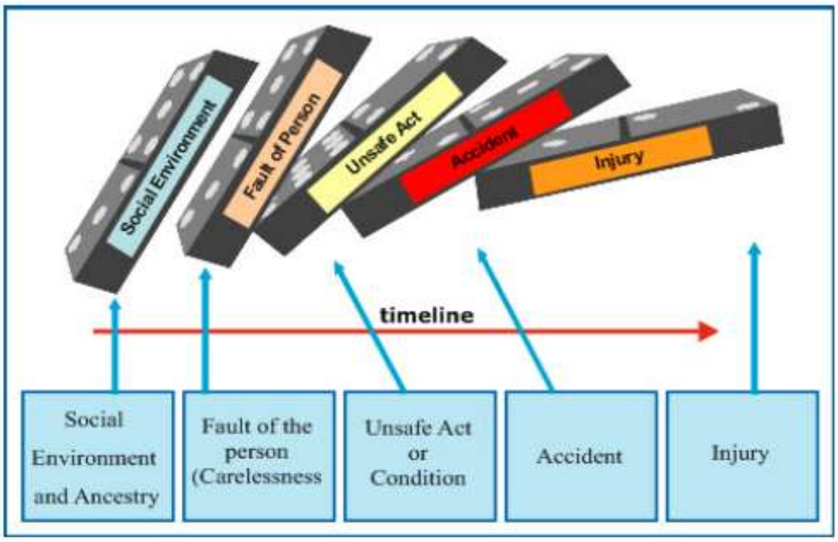
appropriate actions using the risk hierarchy - elimination, substitution, isolation, engineering, administration, or protecting workers with personal protective equipment as the last resort[23]. Periodic reviews keep risks in check, while effective risk management ensures timely responses to achieve risk reduction goals.



Source: safetynet.asia

Figure 1. Heinrich's Domino Theory

Heinrich's Domino Theory of Occupational Health and Safety (OHS) describes the occurrence of workplace accidents as a result of a chain reaction of "dominoes" causing the accident. The principle is similar to a row of dominoes: if one domino falls, the subsequent ones will follow. Accidents are caused by a wide range of factors, including unsafe acts, unsafe methods, the unique nature of the industry, and site conditions [24].

2.2. Methodology

This research employed a qualitative approach using a case study strategy. Data collection was performed through direct site observations, worker interviews, and documentation reviews. Emphasis was given to identifying hazards regarding chiller lifting works, assessing associated risks, and verifying implemented control measures. Interviews involved the project manager, safety officer, and workers to gather substantial input. Documentation reviews covered design drawings, method statements, and safety records.

Potential hazards were listed and risks were assessed based on likelihood and severity scales [25]. Risk levels were calculated and sorted into categories. Control strategies were reviewed against the risk hierarchy. A risk comparison before and after controls determined risk reductions. From the data analysis results, the next chapter creates a matrix using Excel tools for risk calculation and analysis. ETABS modeled the existing structure to assess the structural safety of the temporary reinforcement. The estimated costs of K3 provisions were based on current field prices, with approvals obtained from involved respondents. The method used in this research is Hazard Identification, Risk Assessment, and Risk Control (HIRARC). By using this method, it is expected to reduce the number of accidents, identify the causes of accidents, and establish control measures [26].

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Source: Guidelines for Hazard Identification
Figure 2. Flowchart of HIRARC Process

Process of HIRARC requires 4 simple steps [27]:

a. classify work activities;
b. identify hazard;
c. conduct risk assessment (analyze and estimate risk from each hazard), by calculating or estimating:
    - likelihood of occurrence, and
    - severity of hazard;
d. decide if risk is tolerable and apply control measures (if necessary).

3. Results and Discussions

3.1. Hazard Identification

Twenty-five job activities involving chiller replacement were identified. Potential hazards included workplace conditions, human factors, equipment conditions, work procedures, and environmental factors. A total of 79 hazard sources and 159 potential hazards were determined.

3.2. Risk Assesment

Table 1. Risk Category in Chiller Replacement Work Before Control

No	Job Activities	Average Risk Value	Category Risk
Preparatory Work and Construction of Temporary Facilities			
1	Warehouse and Site Office Creation	8	Medium Risk
2	Mobilization and Demobilization of Heavy Equipment	20	High risk
3	Work Tools	6	Medium Risk
4	Placement of wooden blocks for temporary chiller stands	9	Medium Risk
5	Placement of iron plates for crane mounts	9	Medium Risk
Demolition Work			
1	Demolition gardens and fountains	9	Medium Risk
2	Demolition of security post	9	Medium Risk
3	Pruning tree branches and twigs	12	Medium Risk
4	demolition pole flag	12	Medium Risk
5	demolition of rooftop parapet walls	12	Medium Risk

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No	Job Activities	Average Risk Value	Category Risk
6	Demolition installation & existing chiller	16	High risk
Temporary Structural Strengthening Work			
1	Marking areas	6	Medium Risk
2	Installation plate iron	8	Medium Risk
3	Reinforcement Frame Structure	12	Medium Risk
Chiller Replacement Work			
1	Half Lane Closure	15	Very High Risk
2	Crane arm settings	20	Very High Risk
3	Operation crane arm to the rooftop	25	Very High Risk
4	Installation slings and belts to the existing chiller machine	20	High risk
5	Reduction of existing chiller	20	Very High Risk
6	Placement of existing chiller directly onto the truck	20	Very High Risk
7	Installation of iron pipes for temporary chiller stands on the rooftop	20	Very High Risk
8	Installation slings and belts to the new chiller machine	20	High risk
9	Lifting the new chiller to the prepared iron pipe holder	16	High risk
10	Reposition the chiller machine to the chiller foundation	16	High risk
11	Installation chiller pipe installation	16	High risk

Source: Risk Category Project (2024).

Risk assessments on each potential hazard using likelihood and severity scales produced 167 identified risks. Risk levels were categorized as very high (24%), high (28%), medium (48%), and none as low. The average risks fell under the medium category.

3.3. Risk Control

Table 2. Risk Category in Chiller Replacement Work After Control

No	Job Activities	Average Risk Value	Risk Category
Preparatory Work and Construction of Temporary Facilities			
1	Warehouse and Site Office Creation	2	Low Risk
2	Mobilization and Demobilization of Heavy Equipment	4	Low Risk
3	Preparation of Work Tools	4	Low Risk
4	Placement of wooden blocks for temporary chiller stands	4	Low Risk
5	Placement of iron plates for crane mounts	4	Low Risk
Demolition Work			
1	Demolition of gardens and fountains	4	Low Risk
2	Demolition of security post	4	Low Risk
3	Pruning tree branches and twigs	6	Medium Risk
4	dismantling of the flagpole	6	Medium Risk
5	demolition of rooftop parapet walls	4	Low Risk

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No	Job Activities	Average Risk Value	Risk Category
6	Dismantling of existing installations & chillers	2	Low Risk
Temporary Structural Strengthening Work			
1	Marking areas	2	Low Risk
2	Installation of iron plates	2	Low Risk
3	Preparation of Structural Strengthening Framework	4	Low Risk
Chiller Replacement Work			
1	Half Lane Closure	2	Low Risk
2	Crane arm settings	4	Low Risk
3	Operation of crane arm to rooftop	4	Low Risk
4	Installation of slings and belts to existing chiller machines	6	Medium Risk
5	Reduction of existing chiller	6	Medium Risk
6	Placement of existing chiller directly onto the truck	4	Low Risk
7	Installation of iron pipes for temporary chiller stands on the rooftop	4	Low Risk
8	Installation of slings and belts to the new chiller machine	6	Medium Risk
9	Lifting the new chiller to the prepared iron pipe holder	6	Medium Risk
10	Reposition the chiller machine to the chiller foundation	6	Medium Risk
11	Installation of chiller pipe installation	4	Low Risk

Source: Risk Category Project (2024).

Established control measures emphasized elimination, substitution, isolation, engineering, administration, and personal protective equipment based on risk priority. Controls included work briefings, permit systems, fall protection gears, lifting slings inspection, signage, lighting provisions, and machinery certifications.

3.4. Risk Comparison

Post-control risk assessment showed reductions with no very high-risk and high-risk activities remaining. Medium risks decreased to 28% and low risks increased to 72%. The average risks shifted to the low category. Risk controls effectively reduced potential hazards.

3.5. Structural Analysis

The existing structure analysis using ETABS proved the temporary steel column reinforcement was able to safely bearing additional chiller lifting loads without failures or code violations. Structural safety was achieved.

3.6. Cost Estimation

The estimated total K3 budget of IDR 250,456,350 includes things such as documentation, training, personal protective equipment, first aid kit, signage, and insurance. At 1.7% of the project cost, it complied with the 1-2.5% budget provision.

4. Conclusion and Suggestion

4.1. Conclusion

The research demonstrated that risk analysis using the HIRADC method helped minimize construction accident potentials. Hazard identification allowed 79 risks to be recognized and properly managed. Post-control assessments proved risk reductions through implemented

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controls. Structural analysis verified reinforcement adequacy, while cost estimation aligned with regulations. The results highlight the effectiveness of HIRADC in securing K3 aspects and achieving the zero-accident goal. Future works may explore integrated risk-cost analysis and the actual post-project risk performance.

4.2. Suggestion

The suggestions provided include analyzing additional solutions necessary to enhance research outcomes, such as exploring the integration of new technology in risk management or evaluating the long-term impact of safety interventions on project outcomes.

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