Risk Analysis of Occupational Safety and Health Using the HIRARC Method at Building Construction

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ABSTRACT

Occupational health and safety in Indonesia are crucial for improving worker safety and reducing the high incidence of construction-related accidents. In the research conducted on the construction of the Joint Lecture Building at a University in Malang City, a comprehensive analysis will be carried out to manage OHS risks, minimize workplace accidents, and improve work safety. By identifying hazards from each task and determining risks, risk controls for this construction project will be obtained. The work to be studied includes lower structure and upper structure tasks of the project. The research results show that risk control using the HIRARC method identified 52 hazards and risks. The risk analysis for lower structure tasks revealed five extreme risks, ten moderate risks, and four low risks, while the risk analysis for upper structure tasks revealed eight extreme risks and twenty-five moderate risks. The dominant hazard identification factors were machine-related, with seventeen hazard identifications dominated by heavy equipment hitting workers. The second factor was material-related risks, with workers being struck by falling materials and stepping on sharp objects. The third factor was worker-related risks, with seven identified risks dominated by workers falling from heights, followed by work method-related risks with seven identified risks dominated by improper worker positioning causing health issues. The final factor was environmental, with seven identified hazards dominated by landslides. Risk control is divided based on the causes of hazards, namely man, machine, material, method, and environment. Risk control is carried out by identifying based on the five HIRARC control hierarchy levels: elimination, substitution, engineering control, administrative control, and PPE.

Keywords: HIRARC; hazard identification; risk control; occupational safety and health; building construction.

INTRODUCTION

Occupational Health and Safety (OHS) in Indonesia is crucial for improving worker safety and reducing the high incidence of construction-related accidents. In the research conducted on the construction of the Joint Lecture Building in Malang City, a comprehensive analysis will be carried out to manage OHS risks, minimize workplace accidents, and improve work safety. Safety and health in construction sectors are crucial to ensuring that all employees work in a secure and protected environment (Fathullah et al., 2021). It is the duty and responsibility of companies to safeguard their workers, as any injury or loss of human life is unacceptable in any business (Fathullah et al., 2021). Occupational injuries and illnesses affect not only safety and health but also have economic implications due to the high costs associated with work-related injuries (Hinze et al., 2006). It has been observed that construction safety has garnered attention due to the rising workers' compensation insurance premiums, which are a result of the significant increase in medical costs and convalescent care for work-related injuries. In fact, studies across various industries indicate that injury rates and associated costs are higher than average in the construction sector (Dong et al., 2007).

Risk in the workplace can be described as the likelihood of an individual getting injured or facing a negative health outcome due to a hazard. The likelihood of this risk is affected by the type of exposure, the manner of exposure, and the severity of the risk's impact (Fathullah et al., 2021). Effective occupational health and safety management in construction projects is of utmost importance for all organizations and requires the protection of human resources (Soltanzadeh et al.,

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2022). The results of the study by Jilcha & Kitaw (2017) show that innovations in occupational health and safety lead to sustainable development through healthy workers, a safe workplace, a good environment, well-managed workplace accidents, and improved OHS knowledge within the work scope. A successful safety program is built on the commitment and involvement of both management and workers in policy-making and the establishment of an adequate feedback system, which will lead to the continuous improvement of the safety program. (Ihsan et al., 2020).

The method used involves collecting primary data in the form of project documents identifying extreme and fatality-risk hazards, respondent interviews, and field observations to strengthen the data. This research is structured as follows. First, hazard identification with hazard causal factors and the resulting risks based on the aspects of man, machine, material, method, and environment. Second, using the HIRARC method, risk assessment is obtained for the identification of each job in the construction study. Third, a graph of risk assessment for job descriptions and causal factors of hazards is shown. Fourth, this study provides risk control solutions based on hazard causal aspects (Dearman et al., 2016). By taking samples from activities with potential extreme hazards, a risk control analysis will be conducted according to the 5 HIRARC control hierarchy: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) (Ridwan et al., 2022).

Risks were identified in the study by Fauziyah et al. (2021), such as workers being struck by heavy equipment, with risk control including the project providing a flagman to manage traffic, fatigued operators with risk control ensuring operator health and requiring an operational permit, and workers injured by concrete pile cuts with risk control using appropriate PPE. According to Alveriuse et al. (2023) suggests using the hierarchy of control to improve occupational health and safety at the workplace and reduce accidents and injuries, such as administrative control by creating good work SOPs, an emergency response plan, and safety regulations. According to the research by (Ridwan et al., 2022), extreme risk hazards occur due to vehicle movements leading to workers being struck, refueling heavy equipment posing a risk of fuel spills and potential equipment overturns, and scattered materials causing injuries to workers who step on them.

RESEARCH METHODS

Methods

This research was conducted by collecting primary data through interviews and primary data in the form of safety plan documents from the construction project. To facilitate understanding of this research, the researcher has created a research flowchart, which is shown in **Figure 1**. This research is qualitative in nature, involving the collection of secondary data in the form of safety plan documents to identify hazards, risks, and risk assessments on the project. Data analysis is then carried out by classifying hazard identification according to the factors causing project hazards to facilitate the project control determination process. The classification of hazard identification data includes workers, machinery, materials, methods, and the environment (Dearman et al., 2016). Before further data processing, interviews were conducted using the semi-structured interview method to obtain more in-depth results (Mashuri et al., 2022). The interview sampling method was conducted using stratified random sampling by randomly selecting samples and choosing based on the respondent category levels (Tansey, 2007). By combining the snowball sampling method, the researcher increased the number of respondents according to the recommendations of the primary respondents related to the research topic (Leighton et al., 2021).

After obtaining the analysis of hazard factor classification and findings from the interviews, the next step is to determine project controls by sampling activities with potential extreme hazards for risk control analysis according to the 5 HIRARC control hierarchy: elimination, substitution, engineering controls, administrative controls, and PPE (Ridwan et al., 2022). Interviews with respondents were then conducted as a step to validate the data using the member checking method after data analysis, giving respondents the opportunity to verify the accuracy of the analysis and checking data (Miles et al., 2013). Data validation interviews were conducted by holding an FGD (focus group discussion) with respondents at the project site, in accordance with the respondents during primary data collection (Brear, 2019). After receiving feedback from respondents, the next step is to compare the analysis data with the primary data from the FGD to find findings from the research results. The results of this research include risk control using the HIRARC method and the workflow for handling workplace accidents if an accident occurs.

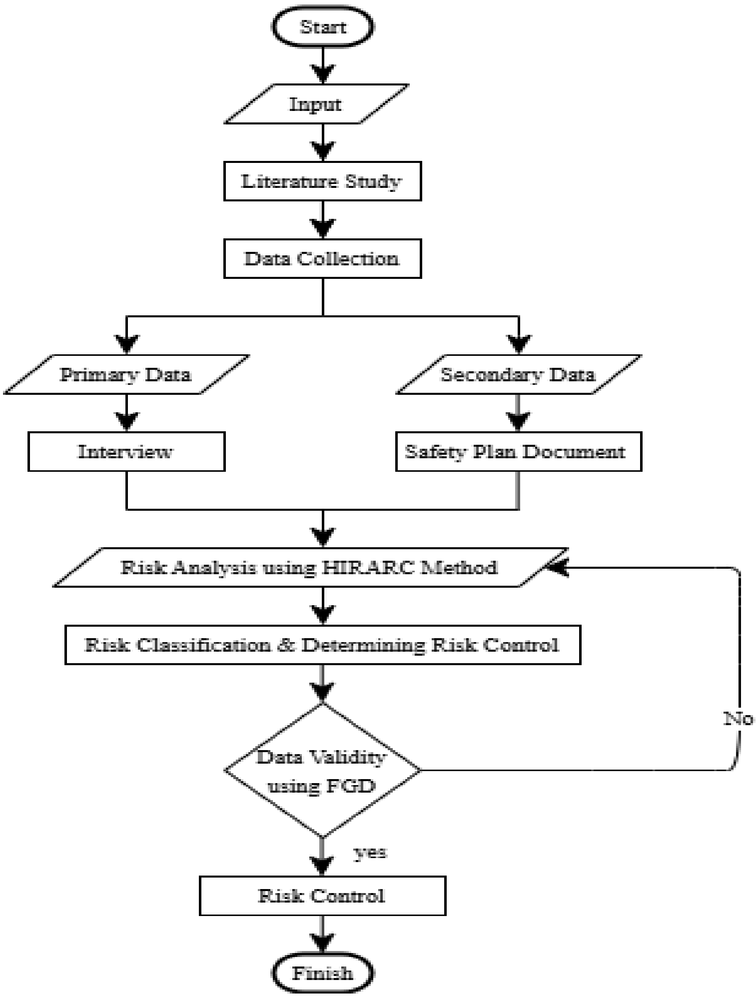

Figure 1. Flow Chart Research Method

Data Analysis

Data analysis in this research was carried out using the descriptive method, which involves identifying project work risk hazards, controlling construction project risks using the HIRARC method, and creating a flowchart for handling workplace accidents. This research is complemented by a literature study of journals related to the research topic.

RESULT AND DISCUSSION

Hazard Identification and Risk Assessments

The results and discussion in this research are part of a process defined in the research methodology. The initial results from the first data analysis include the identification of work activities, hazard identification and causal factors, risks, risk assessment, and risk level outcomes. The assessment based on the risk level matrix was obtained using the rating scales shown in **Table 1** (PUPR, 2019).

Table 1. Matrix Scale of HIRARC Risk Analysis

Rate	Category	Interpretation
1-4	E	Extreme

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5-14	M	Moderate
15-25	L	Low

In the construction project of the Joint Lecture Building in Malang City, the research conducted a risk analysis on the lower structure and upper structure work. A total of 53 hazard and risk identifications were made from the project work activities. Hazard identification was conducted by classifying the determination of hazard causal factors using the 4M1E method, which includes man, machine, material, method, and environment (Dearman et al., 2016). Risk assessment was obtained by determining the likelihood value, which is the frequency of possibility, and multiplying it by the severity value or the level of risk/impact severity (Ihsan et al., 2020). Subsequently, the values were interpreted using the scale provided in **Table 1** to classify the risk levels.

Table 2. Hazard Identification and Risk Assesmesnt

Activity	Hazard Factor	Hazard Identification	Risk	L	S	RA	RL
Lower Sturcture Pile Cap							
Borepile demolition work	Machine	Use of excavator hit by swing bucket	Severe injuries to fatality	4	4	16	E
Casting	Environment	Electrical cables not neatly arranged, short circuit	Electric shock	4	4	16	E
Casting	Environment	Lightning strike	Lightning strike	4	4	16	E
Casting	Man	Casting on the edge of the building causing falls from height	Workers falling from height	4	4	16	E
Casting	Man	Casting on the edge of the building causing falls from height	Scaffolding unable to support load	4	4	16	E
Casting	Environment	No traffic management on site	Collision	4	3	12	M
Casting	Environment	Access roads damaged due to heavy equipment mobility	Traffic congestion	4	3	12	M
Casting	Environment	Access roads damaged due to heavy equipment mobility	Workers hit by equipment mobilization	4	3	12	M
Reinforcement work	Method	Arrival and unloading of steel materials using a mobile crane (material falling on workers)	Severe injuries	3	3	9	M
Reinforcement work	Machine	Operation of bar bender and bar cutter (machine damage, hands pinched/injured)	Body parts injured, scratched, wounded, to cut off	3	3	9	M
Casting	Environment	Access roads damaged due to heavy equipment mobility	Traffic congestion	4	2	8	M

Activity	Hazard Factor	Hazard Identification	Risk	L	S	RA	RL
Casting	Environment	Access roads damaged due to heavy equipment mobility	Tire slipping	4	2	8	M
Reinforcement work	Machine	Access roads damaged due to heavy equipment mobility	Fire and short circuit	3	2	6	M
Brick installation	Method	Lightweight block mobilization manually (material falling, back pain)	Minor injuries, muscle injuries	3	2	6	M
Brick installation	Environment	Work area landslide	Buried, slipped, fell in wet soil	3	2	6	M
Borepile demolition work	Material	Hit by demolition fragments	Moderate injuries	2	2	4	L
Borepile demolition work	Material	Demolition debris collapsed	Moderate injuries	2	2	4	L
Borepile demolition work	Machine	Work tools hitting the body	Moderate injuries	2	2	4	L
Borepile demolition work	Material	Stacked demolition debris collapsing on workers	Moderate injuries	2	2	4	L
Upper Structure							
Excavation process	Man	Worker falls into a hole	Severe injury to fatality due to worker falling	4	4	16	E
Excavation process	Environment	Excavation landslide	Severe injury to fatality	4	4	16	E
Excavation process	Machine	Heavy equipment lacks SIA (Operating Permit)	Heavy equipment damage and can endanger workers	4	4	16	E
Column work	Man	Falling from a height	Severe injury to fatality	4	4	16	E
Beam and floor slab work	Man	Falling from a height	Severe injury to fatality	4	4	16	E
Stair work	Man	Falling from a height	Severe injury to fatality	4	4	16	E
Steel structure work	Man	Worker slips/trips	Severe injury to fatality	4	4	16	E
Pile cap and tie beam work	Material	Worker struck by pile cap	Severe injury to fatality	3	5	15	E
Excavation process	Environment	Noise and vibration exposure to operators and workers	Hearing impairment and potential occurrence of Hand Arm Vibration Syndrome (HAVS)	3	4	12	M
Excavation process	Machine	Emissions from heavy equipment	Pollution from heavy equipment exhaust emissions	3	4	12	M

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Activity	Hazard Factor	Hazard Identification	Risk	L	S	RA	RL
Pile cap and tie beam work	Environment	Excavation landslide	Severe injury to fatality	3	4	12	M
Pile cap and tie beam work	Method	Incorrect working position while moving materials	Health issues	3	4	12	M
Column work	Method	Incorrect working position	Health issues	3	4	12	M
Column work	Material	Cleaning of mixer truck	Pollution from concrete mixer water	3	4	12	M
Beam and floor slab work	Machine	Collapse of scaffolding	Severe injury to fatality	3	4	12	M
Beam and floor slab work	Method	Incorrect working position	Health issues	3	4	12	M
Beam and floor slab work	Material	Cleaning of mixer truck	Pollution from concrete mixer water	3	4	12	M
Stair work	Machine	Collapse of scaffolding	Severe injury to fatality	3	4	12	M
Stair work	Method	Incorrect working position	Health issues	3	4	12	M
Stair work	Material	Cleaning of mixer truck	Pollution from concrete mixer water	3	4	12	M
Steel structure work	Material	Steel collapse/fall	Severe injury to fatality	3	4	12	M
Steel structure work	Method	Incorrect working position	Health issues	3	4	12	M
Excavation process	Material	Struck by material	Severe injury to fatality	3	3	9	M
Pile cap and tie beam work	Machine	Broken work tools	Minor to severe injury	3	3	9	M
Pile cap and tie beam work	Material	Struck by material	Severe injury to fatality	3	3	9	M
Column work	Material	Collapse of column formwork	Severe injury to fatality	3	3	9	M
Column work	Machine	Broken work tools	Minor to severe injury	3	3	9	M
Column work	Material	Struck by material	Severe injury to fatality	3	3	9	M
Beam and floor slab work	Machine	Broken work tools	Minor to severe injury	3	3	9	M
Beam and floor slab work	Material	Struck by material	Severe injury to fatality	3	3	9	M
Stair work	Machine	Broken work tools	Minor to severe injury	3	3	9	M
Stair work	Material	Struck by material	Severe injury to fatality	3	3	9	M
Steel structure work	Machine	Broken work tools	Minor to severe injury	3	3	9	M
Steel structure work	Material	Struck by material	Severe injury to fatality	3	3	9	M

The data analysis results, as shown in **Table 2**, indicate the use of the HIRARC method with varied risk outcomes ranging from low, medium, to extreme risks. There are 10 work activities, namely beam and floor slab work, bore pile demolition work, brick installation, casting, column work, excavation process, pile cap and tie beam work, reinforcement work, stair work, and steel structure work. In these activities, several hazards and risks were identified. In the bore pile demolition work, a hazard was identified with the machine hazard factor, specifically the use of an excavator hit by a swing bucket. This activity has a risk of severe injuries to fatality with an extreme level. Work accidents involving excavators have resulted in several worker fatalities (Tian et al., 2023).

In the lower structure work, casting has a variety of hazard identifications including worker, machine, material, and environmental factors. Electrical cables that are not neatly arranged can cause short circuits, with the risk of electric shock being classified as extreme risk. The next hazard is related to workers, specifically the risk of falling from the edge of the building during casting, which is also classified as extreme risk. Another risk is the scaffolding not being strong enough to support loads, which can lead to collapse. According to a study by Zermane et al. (2022), the risk of workers falling from heights requires extra attention when working at heights. Another factor is the machine factor with the identified hazard of access roads being damaged due to heavy equipment mobility. This has the risk of traffic congestion on heavy equipment mobilization routes and tires getting stuck in sunken roads. Both of these hazards are classified as moderate risk. Furthermore, there is the environmental factor, with the lack of traffic management on the site leading to collisions between heavy equipment, which is also classified as moderate risk.

Reinforcement work has three hazard identifications: the operation of bar bender and bar cutter with machine hazard factors, with the risk of body injuries up to cuts and fires due to short circuits. The identification of reinforcement work falls under moderate risk factors. This risk is discussed in the study. Another hazard related to work methods is the risk of damaged roads due to the mobilization of heavy equipment carrying materials for reinforcement work. The next identification is brick installation with the work method risk factor of improper lifting of bricks, which poses a risk of muscle injury, and the environmental factor of slipping on wet soil when working in landslide-prone areas. These risks are classified as moderate.

In excavation work, there are four hazard identifications. The first is from the human factor, with the hazard of workers falling into a hole and the risk of severe injury to fatality due to workers slipping. The second factor is machinery, specifically heavy equipment without an Operating Permit, with the risk of equipment damage and potential danger to workers. The third factor is the environment, where excavations experience landslides, posing a risk of severe injury to fatality. These three hazards have an extreme risk level, requiring extra attention during implementation to avoid these risks. The final factor is material, with the hazard of scattered cement residues from heavy equipment, which can cause soil pollution and is assessed with a moderate risk level. This is reflected in a study by Akboğa Kale (2021), which states that excavation work has hazard identifications with a mortality risk rate of 58% from workplace accidents and 32.2% severe injuries.

In column work, there are five hazard identifications caused by man, machine, material, and work methods. For the human factor, the hazard identified is workers falling from heights, with the risk of severe injury to fatality. The risk level for this hazard is extreme. For the machine factor, the hazard identified is equipment failure, which poses a risk of minor to severe injuries to workers. For the material factor, the hazards include scaffolding collapse and falling materials, which can cause severe injury to fatality to workers. Additionally, the material factor includes the hazard of standing water from concrete that can cause environmental pollution. The final factor is the work method, with the hazard of incorrect worker positioning leading to health issues. The risk assessment for the machine, material, and work method factors is moderate.

In beam and floor slab work, there are six hazard identifications from the factors of man, machine, material, and work methods. The hazard with an extreme risk level is identified under the man factor, with the risk of workers falling from heights, which can cause severe injury to fatality. For the material factor, the hazards include environmental pollution from scattered cement and falling materials that pose a risk of severe injury to fatality to workers. For the machine factor, the hazard identified is equipment failure, posing a risk of minor to severe injuries to workers. The final factor

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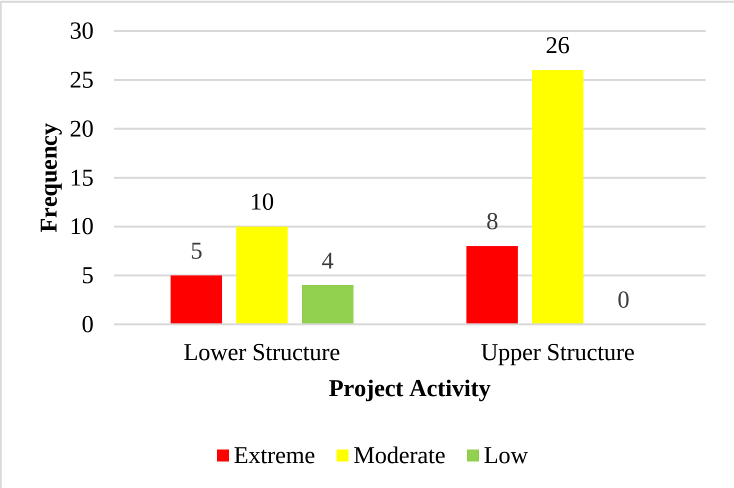
is the work method, with the hazard of incorrect worker positioning leading to health issues. The risk assessment with a moderate risk level applies to the machine, material, and work method factors. This statement is supported by research conducted by Kim et al. (2023), which indicates that column, beam, and floor slab work predominantly involves workplace accidents such as falling materials and falls from heights.

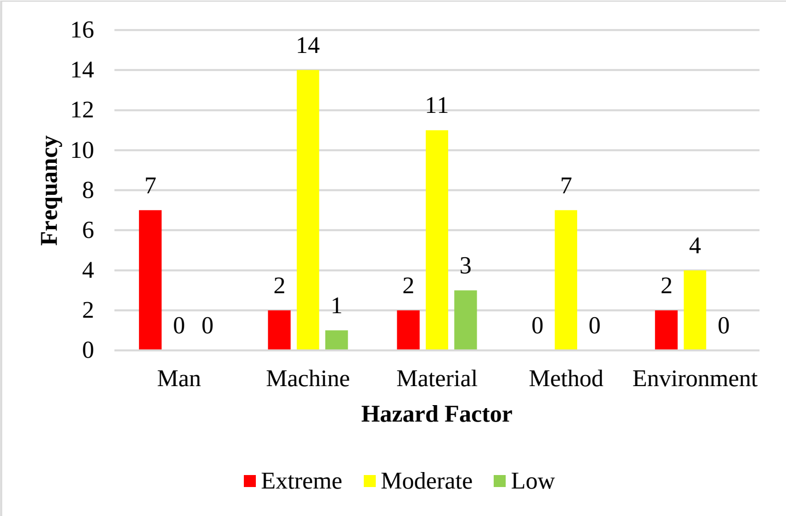
In pile cap and tie beam work, there are five hazard identifications caused by machines, materials, work methods, and the environment. In the machine aspect, there is the hazard of equipment failure, which can cause minor to severe injuries to workers. For the material factor, there is the hazard of workers being struck by pile caps, which has the risk of severe injury to fatality, making this hazard fall into the extreme category. Another material factor hazard is workers being struck by falling materials, with the risk of severe injury to fatality, and the risk level is moderate. In the work method factor, the hazard of incorrect worker positioning leads to health issues, with the risk level being moderate. Lastly, the environmental factor hazard of excavation landslides poses the risk of severe injury to fatality, making this hazard fall into the moderate risk level. This statement is supported by the research of Fauziyah et al. (2021), which states that the risk of workers being struck by pile caps is a dominant hazard.

In stair work, there are five hazard identifications from man, machine, material, and method factors. The man factor is the cause with an extreme risk level. The hazard is workers falling from heights, posing the risk of severe injury to fatality. For the machine factor, the hazard identified is the collapse of formwork, with the risk of severe injury to fatality to workers. The material factor includes two hazard identifications: workers being struck by falling materials with the risk of moderate injury to fatality and standing water from concrete posing a pollution risk. The final hazard factor is the work method, with the hazard of incorrect positioning while working, leading to health issues for workers. The machine, material, and method factors have hazards with a moderate risk level. This statement is supported by the research of Ryu et al. (2021), which mentions that falling from heights is a dominant risk in construction work.

In steel structure work, there are 5 hazard identifications caused by man, machine, material, and work methods. The worker factor is the risk of workers falling from heights, with the risk of severe injury to fatality, making this an extreme risk hazard. The machine factor is equipment failure, which can pose a risk of minor to severe injuries to workers. The material factor hazard includes steel collapse and falling materials, with the risk of severe injury to fatality. The final factor is the work method, with the hazard of workers incorrectly positioning themselves while working, leading to health issues. Hazards in the machine, material, and work method factors in steel structure work have a moderate risk level.



(a) Hazard Risk Level Chart for Construction Activity



(b) Hazard Risk Level Chart for Hazard Factor

Figure 2. Hazard Risk Level Chart (a) Construction Activity (b) Hazard Factor

Figure 2 (a) shows the graph depicting the correlation between the frequency of project hazard risks from three classification levels and project activity work. It can be concluded that lower structure work has a variety of risk level values, with details including five extreme risks, ten moderate risks, and four low risks. By calculating the median value from this data, it is concluded that lower structure work has a median value of 9.89, with the interpretation in Table 1 indicating a moderate risk level. Meanwhile, in upper structure work, there are hazard identifications with eight moderate risk levels and twenty-five extreme risks. By calculating the median value of the risk levels in upper structure work, a median value of 10.75 is obtained, with the interpretation indicating a moderate risk level.

Meanwhile, the graph shown in **Figure 2 (b)** illustrates the correlation between risk frequency and hazard factors. It can be concluded that the worker factor is the only factor with one risk level, which includes seven extreme risks. Thus, it can be concluded that the worker factor has a median value of 18.5 at the extreme risk level. According to research by Fauziyah et al. (2021), the highest order of hazard identification and risk is the worker factor, with the description of the risk of workers falling from heights. This is evidenced in Figure 2 (b), where workers have the highest extreme risk level dominated by the hazard of workers falling from heights.

The machine factor has varying risk levels, with two extreme risks, fourteen moderate risks, and one low risk. By calculating the median, a value of 9.2 is obtained at the moderate risk level. According to research by Osei-Asibey et al. (2021), machines and equipment play a significant role in workplace accident risks due to inadequate tools and workers' lack of understanding of the equipment. The material factor has two extreme risks, eleven moderate risks, and three low risks. By calculating the median, a value of 8.5 is obtained at the moderate risk level. Based on research by Osei-Asibey et al. (2021), material is a contributing factor to workplace accidents due to low-quality materials and materials contaminated with chemicals.

The work method factor has seven moderate risks, with a median value of 8.3, which is at the moderate risk level. According to research by Nyabioge et al. (2021), work methods are a factor in hazards due to poor safety management conditions. The environmental factor has hazard identifications with two extreme risks and four moderate risks. The conclusion is that the environmental factor has a median value of 11.7, which falls under the moderate risk level. According to research by Osei-Asibey et al. (2021), the environmental factor plays a significant role

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in workplace accidents, and project cleanliness is a critical aspect to consider. Research by Yao et al. (2022) shows that the environmental factor contributes to the causes of construction accidents.

Determining Risk Control

After conducting hazard and risk identification analysis, the next step is to implement risk controls for each hazard factor. Policies are carried out according to the hierarchy of risk controls: elimination (E) by removing the hazard source so that the hazard becomes nonexistent, substitution (S) by replacing tools, materials, and methods with safer alternatives, engineering controls (EC) by modifying the design, administrative controls (AC) by creating procedures and providing training for workers, and PPE (P) to protect individuals from hazards (Ridwan et al., 2022). This research classifies hazard controls by hazard factors: man, machine, material, method, and environment (Dearman et al., 2016).

Table 3. Risk Control Based on Hierarchy Control

Hazard Factor	Risk Control		
Man	AC	Training and Education	Providing regular training on workplace safety, the use of personal protective equipment (PPE), and emergency procedures.
	AC	Supervision and Compliance	Conducting strict supervision to ensure workers comply with all safety procedures.
	AC	Job Rotation	Implementing job rotation and adequate rest to prevent fatigue and improve worker concentration.
	AC	Installation of Safety Signs	Providing signs to always comply with regulations at the project site.
	AC	Worker Health Control	Ensuring workers are in good health before starting work.
	P	Personal Protective Equipment	Ensuring all workers use PPE according to the PPE Matrix.
Machine	EC	Proper Use	Ensuring machines and equipment are used according to manufacturer instructions and for the correct purpose.
	EC	Machine Safety	Installing safety devices on machines to prevent accidents, such as machine guards and emergency stop systems. Providing spill kits on all large vehicles/heavy equipment to prevent oil spills.
	EC	Heavy Equipment Operation	Setting a maximum speed limit of 20 km/h.
	AC	Routine Maintenance	Conducting regular inspections and maintenance on all machines and equipment to ensure they are in good condition, safe to use, and pass the preiodic motor vehicles test.
	AC	Operator Training	Ensuring workers are trained and have an operator license for operating heavy machinery and equipment.
Material	EC	Lifting Technique	Using proper techniques and equipment to lift and transport materials, such as forklifts and cranes.
	AC	Safe Storage	Storing materials safely and neatly to prevent falls or being struck.
	AC	Hazardous Material Handling	Implementing special procedures for handling hazardous chemicals, including using appropriate PPE and proper storage.

Hazard Factor	**Risk Control**		
Method	AC	Inventory and Control	Conducting regular inventory and material control to prevent shortages or excess stock that could pose risks.
	EC	Safe Road Access	Installing lights on access roads, creating special lanes for heavy equipment and large vehicles, and making semi-permanent safety railings as barriers for work access roads.
	EC	Lifting Technique	Using proper techniques and equipment to lift and transport materials and using correct manual lifting techniques.
	AC	Standard Operating Procedures	Developing and implementing SOPs for all work activities, ensuring all workers understand and follow the procedures. Implementing a rule not to lift loads more than 25% of one's body weight.
	AC	Risk Assessment	Conducting risk assessments for every new work method or changes to existing work methods.
	AC	Regular Work Schedule	Creating regular and realistic work schedules to avoid rushing work that could cause accidents.
	AC	Safety Signs	Installing safety cones or road area barriers and using light sticks during traffic control.
Environment	EC	Dust and Pollution Control	Using good ventilation systems and dust control methods to maintain air quality at the workplace. Conducting regular road spraying.
	EC	Noise Inspection	Using a Sound Level Meter
	AC	Cleanliness and Tidiness	Maintaining cleanliness and tidiness at the work site to reduce the risk of slips, trips, and falls.
	AC	Weather Monitoring	Considering weather conditions in project planning and execution. For example, stopping work at heights during strong winds or heavy rain.
	AC	Signs and Warnings	Installing warning signs and safety signs in hazardous or high-risk areas.
	AC	Emergency Response Plan	Developing and training on emergency response plans for various situations, such as fires, chemical spills, and evacuations.

The risk controls obtained are shown in **Table 3** from the analysis results using the HIRARC method. The first hazard factor is the worker factor (man), which involves implementing six policies according to the hierarchy of risk controls. Five of these are administrative controls, namely: conducting safety training and education, strict supervision of workers, creating job rotation schedules, installing safety signs, and controlling workers' health. The sixth control is the use of PPE, ensuring workers use the appropriate personal protective equipment for each task. According to research by Ridwan et al. (2022), administrative control through safety training can mitigate the risks caused by workers. The second hazard factor is machinery, which involves three engineering control policies: using machines and tools according to their proper purpose, installing machine safety devices, and setting minimum speeds for heavy equipment. Two administrative controls are also implemented: routine maintenance and operator training.

For the material hazard factor, one engineering control is implemented: using proper techniques and equipment for transporting materials. Additionally, three administrative controls are applied: providing storage for materials, implementing special procedures for handling hazardous materials, and conducting material inventory and control. For the work method hazard factor, two engineering controls are implemented: installing lights and warning signs and determining techniques for lifting tools and materials. Administrative controls include creating safe work method SOPs, conducting

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risk assessments for new tasks, creating effective work schedules, and providing signs to prevent risks. For the environmental hazard factor, risk control efforts involve two engineering controls: using ventilation systems and sound level meters to control noise. Administrative controls include maintaining cleanliness, weather monitoring, providing safety signs, and creating emergency response plans.

CONCLUSION

Identification of hazards for lower and upper structure construction in this study was conducted using the HIRARC method and classified based on hazard sources using the 4M1E method, which includes man, machine, material, method, and environment (Dearman et al., 2016). Risk assessment was performed using a scale on the HIRARC matrix (PUPR, 2019). The results indicate that lower structure work has five extreme risks with a predominance of worker hazard factors and the risk of workers falling from heights, ten moderate risks with a predominance of hazard factors from damaged access roads due to heavy equipment, which risks severe injuries to workers from being hit during heavy equipment mobilization, and four low risks with a predominance of material hazard factors from being struck by concrete material, which risks moderate injuries to workers. Upper structure work has eight extreme risks with a predominance of worker hazards from falling from heights, with risks ranging from severe injuries to fatalities, twenty-five moderate risks with a predominance of material hazards, including workers falling material with risks of severe injuries to fatalities and scattered concrete material with environmental pollution risks. Each hazard factor is managed using the risk control hierarchy: elimination, substitution, engineering control, administrative control, and PPE (Ridwan et al., 2022). The study results show that for the worker factor, risk control includes administrative controls such as routine safety training, supervision to ensure the use of PPE, proper work rotation to avoid fatigue, providing safety signage, monitoring worker health, and PPE usage. For the machine factor, risk control involves engineering controls such as ensuring the correct use of tools, installing safety equipment on heavy machinery, and setting low maximum speeds on heavy equipment. Administrative controls for the machine factor include routine maintenance of machinery/equipment and training for operators. For the material factor, engineering controls include using correct techniques for lifting loads and mobilizing materials. Administrative controls involve creating SOPs for work, assessing risks for new tasks, setting regular schedules, and providing safety signage. For environmental aspects, engineering controls include pollution control and noise level checks using a sound level meter, while administrative controls involve maintaining cleanliness to avoid hazardous material contact, weather monitoring, providing safety signage, and developing emergency response plans.

REFERENCES

Akboğa Kale, Ö. (2021). Characteristic analysis and prevention strategy of trench collapse accidents in the U.S., 1995-2020. Revista de La Construcción, 20(3), 617–628. https://doi.org/10.7764/RDLC.20.3.617

Brear, M. (2019). Process and Outcomes of a Recursive, Dialogic Member Checking Approach: A Project Ethnography. Qualitative Health Research, 29(7), 944–957. https://doi.org/10.1177/1049732318812448

Dearman, John, Smith, R., & Jones, L. (2016). Factors Causing Accidents in the Workplace. Journal of Safety Research 47 (2): 123-135.

Dong, X., Ringen, K., Men, Y., & Fujimoto, A. (2007). Medical Costs and Sources of Payment for Work-Related Injuries Among Hispanic Construction Workers. Journal of Occupational & Environmental Medicine, 49(12), 1367–1375. https://doi.org/10.1097/JOM.0b013e31815796a8

Fathullah, M., Yusoff, N. R. N., Darmawan, V. E. B., Yong, C. P., Eng, C. G., Er, S. P., Ying, T. M., & Hui, W. Q. (2021). Hazard and safety evaluation in construction sites in Malaysia: A case study. 020183. https://doi.org/10.1063/5.0045234

Fauziyah, S., Susanti, R., & Nurjihad, F. (2021). Risk assessment for occupational health and safety of Soekarno-Hatta international airport accessibility project through HIRARC method. IOP

Conference Series: Earth and Environmental Science, 700(1), 012048. https://doi.org/10.1088/1755-1315/700/1/012048

Hinze, J., Devenport, J. N., & Giang, G. (2006). Analysis of Construction Worker Injuries That Do Not Result in Lost Time. Journal of Construction Engineering and Management, 132(3), 321–326. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:3(321)

Ihsan, T., Hamidi, S. A., & Putri, F. A. (2020). Penilaian Risiko dengan Metode HIRADC Pada Pekerjaan Konstruksi Gedung Kebudayaan Sumatera Barat. Jurnal Civronlit Unbari, 5(2), 67. https://doi.org/10.33087/civronlit.v5i2.67

Jilcha, K., & Kitaw, D. (2017). Industrial occupational safety and health innovation for sustainable development. Engineering Science and Technology, an International Journal, 20(1), 372–380. https://doi.org/10.1016/j.jestch.2016.10.011

Kim, K.-N., Kim, T.-H., & Lee, M.-J. (2023). Analysis of Building Construction Jobsite Accident Scenarios Based on Big Data Association Analysis. Buildings, 13(8), 2120. https://doi.org/10.3390/buildings13082120

Leighton, K., Kardong-Edgren, S., Schneidereith, T., & Foisy-Doll, C. (2021). Using Social Media and Snowball Sampling as an Alternative Recruitment Strategy for Research. Clinical Simulation in Nursing, 55, 37–42. https://doi.org/10.1016/j.ecns.2021.03.006

Mashuri, S., Sarib, M., Alhabsyi, F., Syam, H., & Ruslin, R. (2022). Semi-structured Interview: A Methodological Reflection on the Development of a Qualitative Research Instrument in Educational Studies.

Miles, M., Huberman, M., & Saldaña, J. (2013). Qualitative Data Analysis: A Methods Sourcebook. In Zeitschrift fur Personalforschung (Vol. 28).

Nyabioge, B., Ogoro, E., & Okeri, E. (2021). Construction Health and Safety Management and its Influence on Project Success in Nairobi County. International Journal of Soft Computing and Software Engineering [JSCSE], Volume-8, 17–19.

Osei-Asibey, D., Ayarkwa, J., Acheampong, A., Adinyira, E., & Amoah, P. (2021). An Examination of Causes of Accidents and Hazards in the Ghanaian Construction Industry. Open Journal of Safety Science and Technology, 11(02), 66–88. https://doi.org/10.4236/ojsst.2021.112006

PUPR. (2019). Ministerial Regulation Number 21/PRT/M/2019 Guidelines for Construction Safety Management Systems.

Ridwan, A., Nuroni, A., Adelia, A., & Sonda, A. (2022). Analysis of occupational health and safety at a maritime warehouse using Hazard Identification, Risk Assessment and Risk Control (HIRARC). Journal Industrial Servicess, 8(2), 187–192. https://doi.org/10.36055/jiss.v8i2.17293

Ryu, H., Ha, S., Son, K., & Son, S. (2021). Development of a quantification model for human accidents on construction sites in South Korea. Journal of Asian Architecture and Building Engineering, 20(6), 760–767. https://doi.org/10.1080/13467581.2020.1816472

Soltanzadeh, A., Mahdinia, M., Omidi Oskouei, A., Jafarinia, E., Zarei, E., & Sadeghi-Yarandi, M. (2022). Analyzing Health, Safety, and Environmental Risks of Construction Projects Using the Fuzzy Analytic Hierarchy Process: A Field Study Based on a Project Management Body of Knowledge. Sustainability, 14(24), 16555. https://doi.org/10.3390/su142416555

Tian, Z., Yu, Y., Xu, F., & Zhang, Z. (2023). Dynamic Hazardous Proximity Zone Design for Excavator Based on 3D Mechanical Arm Pose Estimation via Computer Vision. Journal of Construction Engineering and Management, 149(7), 4023048. https://doi.org/10.1061/JCEMD4.COENG-13071

Yao, G., Sun, W. T., & Yang, Y. (2022). Analysis and Identification of Building Construction Accident Risk in China basing Exclusively Database. IOP Conference Series: Earth and Environmental Science, 1101(7), 072009. https://doi.org/10.1088/1755-1315/1101/7/072009

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Zermane, A., Mohd Tohir, M. Z., Baharudin, M. R., & Mohamed Yusoff, H. (2022). Risk assessment of fatal accidents due to work at heights activities using fault tree analysis: Case study in Malaysia. Safety Science, 151, 105724. https://doi.org/10.1016/j.ssci.2022.105724