DEVOTION
Journal of Research and Community Service
Volume 6, Number 8, August 2025
e-ISSN: 2797-6068 and p-ISSN: 2777-0915

Analysis of Occupational Safety Risks in Construction Projects: A Case Research of the Implementation of JSA and Hierarchy of Control

Ade Adilla[1], Pancha Andre R[2], Eriksa Nofta[3], Aryati Indah K[4]
Swadaya Gunung Jati University, Cirebon, Indonesia
Email: adeadilla8@gmail.com, panchaandreromantika@gmail.com,
eriksanoftafadilla@gmail.com, aryatiindah2023@gmail.com

ABSTRACT

Occupational safety and health (K3 - Keselamatan dan Kesehatan Kerja)) is an important element that should not be ignored in the implementation of construction projects. This is due to the high level of risk in the construction industry, which is influenced by a dynamic work environment full of various activities. This research aims to evaluate the potential occupational safety hazards in construction projects using a specific approach. JSA serves as a systematic method for identifying hazards at each work stage, while Hierarchy of Control provides a structured framework for determining risk mitigation priorities based on control effectiveness levels, starting from elimination, substitution, engineering controls, administrative controls, to personal protective equipment (PPE). The research methodology uses a quantitative descriptive approach with the help of questionnaire instruments and field data. Data were analyzed using descriptive analysis, validity and reliability tests, correlation, and regression. The results of the research show that occupational safety risks in projects are relatively high, with several potential main hazards such as falling from height, being hit by materials, and contact with high temperatures. Of the 43 risk variables analyzed, 12 risks (27.91%) were included in the high-risk category and 25 risks (58.14%) were in the moderate-risk category. control is carried out through PPE and engineering control. The implementation of JSA and Hierarchy of Control has proven to be effective in identifying and lowering work risks. The conclusion of this research can be the basis for improving the K3 management system in a more measurable and sustainable direction.

KEYWORDS
Construction Projects, Hierarchy Of Control, JSA, K3, Occupational Safety, Risk Management

INTRODUCTION

The construction industry has a high risk of accidents due to the nature of its dense work, the complexity of the tasks, and the use of heavy equipment, making safety a critical concern (Zhou et al., 2017). The high rate of work accidents in this sector highlights the importance of strengthening the K3 management system through structured safety frameworks (Raimo et al., 2021). One widely used strategy is Job Safety Analysis (JSA), a systematic method to identify and analyze occupational hazards based on the stages of work, which has been proven effective in minimizing human error and operational risks (Teo & Ling, 2017). In addition, the implementation of the Hierarchy of Control (HoC) is also necessary to determine the priority of risk control based on its effectiveness, starting from elimination to administrative controls and PPE (Manuele, 2020). Recent studies also emphasize that integrating JSA and HoC within occupational health and safety management systems improves compliance and reduces accident frequency in construction projects (Alruqi & Hallowell, 2019).

In this research context, JSA functions as a systematic hazard identification tool at each work stage, while HoC provides a structured framework for determining control strategies based on an effectiveness hierarchy: elimination (removing hazards completely), substitution (replacing hazardous materials or methods), engineering controls (isolation through technical systems), administrative controls (work procedures and training), and PPE (personal protective equipment as the last line of defense). The integration of both approaches enables comprehensive risk management, from identification to control implementation (Kure et al., 2022).

According to data from BPJS Ketenagakerjaan (2023), the construction sector recorded 77,295 work accident cases in Indonesia, representing 32.4% of total occupational accidents across all industries. The fatality rate in construction reached 2.1 per 1,000 workers, significantly higher than the national average of 0.8 per 1,000 workers. The *Kementerian Ketenagakerjaan* (Ministry of Manpower) (2024) reported that 68% of construction accidents were preventable through proper implementation of safety management systems, indicating the critical need for systematic approaches like JSA and the Hierarchy of Control in Indonesian construction projects.

In Indonesia, efforts to prevent work accidents remain suboptimal, partly due to traditional views that consider accidents as mere disasters, as well as low awareness of the importance of occupational safety and health aspects in the work environment (Fikri, 2022). The principles of *K3* do not only serve as safety guidelines but also as part of the project's risk management strategy. The implementation of *K3* includes management of the *K3* system, the enforcement of safe work procedures, and the identification and control of potential hazards in the workplace. Thus, implementing *K3* is a key step to minimize work accidents and maintain the operational continuity of projects [H. Pranoto, 2024].

The application of *K3* principles is becoming increasingly important as the complexity and scale of construction projects grow. In this sector, a sense of security and comfort while working is a basic need that must be fulfilled by companies as part of their responsibilities to workers. *K3* not only provides protection against the risk of work accidents but also contributes to creating a productive work environment. The implementation of *K3* has been consistently proven to increase workforce motivation and performance, ultimately positively impacting the smooth implementation of projects (K. Permata Sari, 2022).

In addition, by implementing a *K3* management system, the risk of work accidents can be effectively reduced. An effective *K3* system not only protects workers from accidents but also improves project operational efficiency. Research shows that integrating *K3* with a strong organizational culture increases employee job satisfaction, ultimately having a positive impact on project productivity (Suripto, 2019).

However, the existing research gap shows limited studies specifically examining the integrated application of JSA and the Hierarchy of Control in Indonesian construction contexts. Previous studies by Rahman et al. (2023) focused on JSA implementation in manufacturing sectors, while Sari & Wijaya (2022) examined the Hierarchy of Control in mining industries. Nonetheless, a comprehensive analysis combining both methods in construction projects remains underexplored, particularly in developing country contexts where resource constraints and regulatory enforcement challenges differ significantly from those in developed nations.

Based on the identified research gaps and the urgent need to improve construction safety management in Indonesia, this research aims to: (1) evaluate the effectiveness of integrated JSA and Hierarchy of Control implementation in identifying and mitigating occupational safety risks in construction projects, (2) analyze the risk level classification of identified hazards using quantitative risk assessment methods, and (3) develop practical recommendations for improving *K3* management systems in construction projects. The benefits of this research include providing empirical evidence for construction safety practitioners, contributing to the development of context-specific safety management frameworks for the Indonesian construction industry, and offering actionable insights for policymakers to strengthen occupational safety regulations and enforcement mechanisms[A3][A4].

METHOD

This research used both primary and secondary data. In this context, primary data were obtained through interviews, observations, and questionnaire distribution. Secondary data were gathered from literature studies, books, and journals. The research was conducted using a descriptive quantitative method. Data were collected through the distribution of questionnaires to 87 respondents from construction projects. The questionnaire instrument included 43 risk indicators categorized into the planning, implementation, and supervision stages. The assessment scale included the level of frequency and the level of risk impact. The collected data were analyzed quantitatively with the aid of SPSS software. The analysis process included descriptive analysis to determine data trends, as well as validity and reliability tests to ensure the validity of the instrument. The risk assessment parameters and their explanations are listed in Tables 1, 2, and 3.

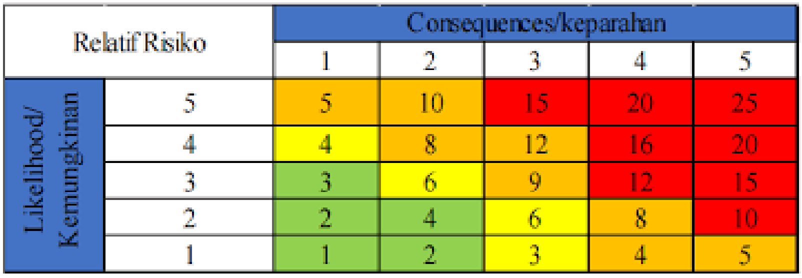
Table 1. Frequency Level Determination

Level Frequency	Category Frequency
1	Almost Never Happens
2	Rare
3	Quite Often
4	Frequent Occurrences
5	Very Frequent

Table 2. Determination of Impact Levels

Level Frequency	Category Frequency
1	No Risk
2	Low Risk
3	Medium Risk
4	High Risk
5	Very High Risk

Table 3. Risk Level Matrix



Relatif Risiko		Consequences/keparahan				
		1	2	3	4	5
Likelihood/ Kemungkinan	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Information:
1 - 4: Classification of small risk levels
5 - 12: Classification of medium risk level
15 - 25: Classification of major risk levels

The risk severity analysis in this research uses a quantitative approach based on a combination of frequency values and the impact of each potential hazard that has been identified. The risk value is calculated by multiplying the average score of the frequency of the event by the resulting impact score (Y = F x D). The results of the calculation are then mapped into a risk level matrix to determine The classification is low, medium, or high.

Research Flow Chart

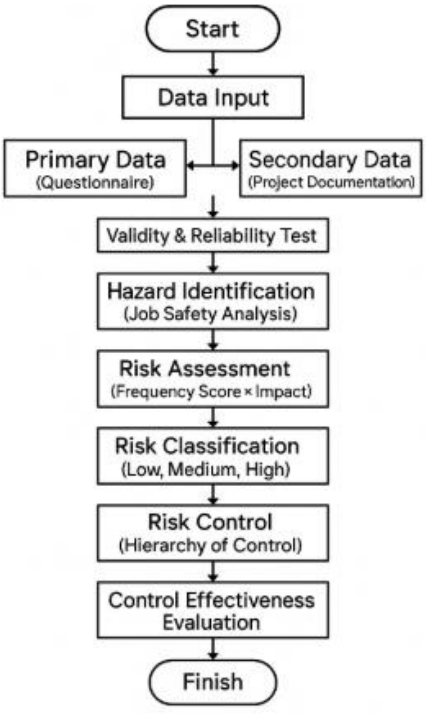


Figure 1. Research Flowchart

RESULT AND DISCUSSION

Hazard Identification

Hazard identification is a systematic process of finding, recognizing, and recording potential sources of hazards that could cause injury, disease, property damage, environmental disturbances, or a combination of all of them in a work activity or work environment.

Table 4. Hazard Identification

No	Hazard Identification	Source
I.	PLANNING	
X1	Lack of personal responsibility and duties	Aryati Indah (2004)
X2	Identification of potential hazards along with appropriate prevention methods	Hidayat (2001)
X3	Inspect equipment and supporting facilities	Hidayat (2001)
X4	Arrange the placement of work infrastructure, equipment, and materials	Hidayat (2001)
X5	Calculate the strength and stability of the work equipment to be used	Hidayat (2001)
X6	Work specifications and work criteria are unclear	Aryati Indah (2004)
X7	Lack of proper placement of core project personnel	Aryati Indah (2004)
II.	IMPLEMENTATION	
X8	Hit by work equipment while doing work.	Annisa Rochmawati (2017)
X9	Falling from a height	Annisa Rochmawati (2017)
X10	Being hit by equipment/materials that fall from a height	Annisa Rochmawati (2017)
X11	Workers exposed to electricity	Gusti, R. N., & Wiguna, P. A. (2021)
X12	Being hit by hard materials or equipment	Beryl Adityanto (2013)
X13	Direct contact with temperature, and noise	Beryl Adityanto (2013)
X14	Workers do not use PPE	Sulhinayatillah (2017)
X15	Improper working equipment condition or lack of maintenance	Bayu Yoni Setyo(2017)
X16	Construction materials that do not meet quality standards	Rizkyana (2020)
X17	Lack of K3 rule signs at the project site.	Nurhuda Destari (2017)
X18	Workers' hands hit by bartenders	Wicaksono (2011)
X19	Worker hit by moving steel parts while lifted by the crane to its position	Wicaksono (2011)
X20	Respiratory disorders due to workers exposed to asbestos dust	Adiyanto (2004)
X21	Respiratory distress due to cement/sand dust	Adiyanto (2004)
X22	Worker injured by ceramic cutting machine	Wicaksono (2011)
X23	Exposed to sparks during welding work	Annisa Rochmawati (2017)
X24	Worker pierced by iron while doing ironing work	Gusti, R. N., & Wiguna, P. A. (2021)
X25	Worker clamped precast tool	Wicaksono (2011)
X26	Workers slip	Wicaksono (2011)
X27	Workers hit *by concrete*	Wicaksono (2011)

X28	Workers' hands hit by hammers	Gusti, R. N., & Wiguna, P. A. (2021)
X29	Workers injured while working with pipes	Wicaksono (2011)
X30	Workers hit by drill	Wicaksono (2011)
X31	Pieces of material particles hitting the eye	Wicaksono (2011)
X32	Working with unfocused and sleepy	
III.	SUPERVISION	
X33	Inspecting the workplace, equipment, K3 equipment Routinely before starting work	Asiyanto (2005)
X34	Conducting supervision in the form of monitoring	Hinze (1997)
X35	Conducting supervision in the form of visits by the board of directors	Hidayat (2001)
X36	Create a K3 report	Hidayat (2001)
X37	Holding K3 meetings	Hidayat (2001)
X38	Inspecting the materials and tools to be used	Asiyanto (2005)
X39	Selecting the workforce	Asiyanto (2005)
X40	Supervise PPE usage	Asiyanto (2005)
X41	Check the safety structure	Asiyanto (2005)
X42	Directly reviewing the implementation of work in the field based on the plan	Khrisna Mochtar (2003)
X43	K3 team carries out periodic safety checks on the workforce	Khrisna Mochtar (2003)

From table 3 above, identify 43 potential occupational hazards in construction projects, grouped into three stages: planning, implementation, and supervision.

Questionnaire

There are two forms of questionnaires in this research, namely a questionnaire measuring the frequency of events and a questionnaire assessing the severity of occupational safety risks, in this research there were 87 respondents. The distribution of this questionnaire aims to obtain the value of the frequency mode and the influence of each variable obtained through literature studies.

Test Data Instruments

Validity Test

The validity test aims to ensure that all statements in the questionnaire are effectively able to measure the aspect in question. In this research, the test was carried out using the Pearson correlation method using the help of the SPSS application. The questionnaire is said to be valid if the calculation is > from the table (0.208.). The results of the complete test analysis are presented in Tables 5 and 6.

Table 5. Results of the questionnaire validity test (frequency)

Items	Calculation	Table	Information
x1	0.396	0.208	**VALID**
X.2	0.291	0.208	**VALID**
X.3	0.255	0.208	**VALID**
X.4	0.367	0.208	**VALID**
X.5	0.322	0.208	**VALID**

X.6	0.488	0.208	**VALID**
X.7	0.517	0.208	**VALID**
X.8	0.253	0.208	**VALID**
X.9	0.568	0.208	**VALID**
X.10	0.643	0.208	**VALID**
X11	0.64	0.208	**VALID**
X12	0.663	0.208	**VALID**
X13	0.432	0.208	**VALID**
X14	0.637	0.208	**VALID**
X15	0.641	0.208	**VALID**
x16	0.642	0.208	**VALID**
x17	0.573	0.208	**VALID**
x18	0.71	0.208	**VALID**
x19	0.73	0.208	**VALID**
x20	0.679	0.208	**VALID**
x21	0.59	0.208	**VALID**
x22	0.702	0.208	**VALID**
x23	0.724	0.208	**VALID**
x24	0.705	0.208	**VALID**
x25	0.745	0.208	**VALID**
x26	0.62	0.208	**VALID**
x27	0.742	0.208	**VALID**
x28	0.612	0.208	**VALID**
x29	0.765	0.208	**VALID**
x30	0.748	0.208	**VALID**
x31	0.682	0.208	**VALID**
x32	0.589	0.208	**VALID**
x33	0.248	0.208	**VALID**
x34	0.22	0.208	**VALID**
x35	0.359	0.208	**VALID**
x36	0.275	0.208	**VALID**
x37	0.249	0.208	**VALID**
x38	0.284	0.208	**VALID**
x39	0.311	0.208	**VALID**
x40	0.236	0.208	**VALID**
x41	0.215	0.208	**VALID**
x42	0.235	0.208	**VALID**
x43	**0.231**	**0.208**	**VALID**

(Source: SPSS 2025 Processed Data)

Table 6. Results of the questionnaire validity test (Impact)

Items	Calculation	Table	Information
x1	0,51	0,208	**VALID**
X.2	0,714	0,208	**VALID**
X.3	0,712	0,208	**VALID**
X.4	0,73	0,208	**VALID**
X.5	0,725	0,208	**VALID**

X.6	0,69	0,208	**VALID**
X.7	0,747	0,208	**VALID**
X.8	0,729	0,208	**VALID**
X.9	0,215	0,208	**VALID**
X.10	0,213	0,208	**VALID**
X11	0,253	0,208	**VALID**
X12	0,235	0,208	**VALID**
X13	0,214	0,208	**VALID**
X14	0,382	0,208	**VALID**
X15	0,239	0,208	**VALID**
x16	0,235	0,208	**VALID**
x17	0,225	0,208	**VALID**
x18	0,213	0,208	**VALID**
x19	0,231	0,208	**VALID**
x20	0,226	0,208	**VALID**
x21	0,217	0,208	**VALID**
x22	0,234	0,208	**VALID**
x23	0,254	0,208	**VALID**
x24	0,22	0,208	**VALID**
x25	0,281	0,208	**VALID**
x26	,219	0,208	**VALID**
x27	0,247	0,208	**VALID**
x28	0,401	0,208	**VALID**
x29	0,301	0,208	**VALID**
x30	0,23	0,208	**VALID**
x31	0,247	0,208	**VALID**
x32	0,236	0,208	**VALID**
x33	0,686	0,208	**VALID**
x34	0,77	0,208	**VALID**
x35	0,758	0,208	**VALID**
x36	0,765	0,208	**VALID**
x37	0,817	0,208	**VALID**
x38	0,705	0,208	**VALID**
x39	0,748	0,208	**VALID**
x40	0,799	0,208	**VALID**
x41	0,775	0,208	**VALID**
x42	0,782	0,208	**VALID**
x43	**0,786**	**0,208**	**VALID**

(Source: SPSS 2025 Processed Data)

Reliability Test

The reliability test to measure the consistency of the questionnaire instrument and the method used was *Cronbach's Alpha*, with a result of 0.924 in the frequency aspect and 0.863 in impact. Both were well above the minimum limit of 0.60, close to 1. It can be seen in tables 6, 7, and 8.

Table 7. Cronbach's Alpha Frequency Value

Reliability Statistics	
Cronbach's Alpha	*N of Items*
0.924	43

(Source: SPSS 2025 Processed Data)

Table 8. Cronbach's Alpha Impact Value

Reliability Statistics	
Cronbach's Alpha	*N of Items*
0.863	43

(Source: SPSS 2025 Processed Data)

Table 9. Reliability Test Values

Cronbach's Alpha	Interpretation
≥ 0.90	Highly reliable
0,80 – 0,89	High reliability
0,70 – 0,79	Quite reliable
0,60 – 0,69	Medium reliable
< 0.60	Unreliable

Risk Assessment

Determination of Risk Level and Classification

The determination of risk classification is carried out based on the results of the identification of grouped hazards into three stages of activities: planning, implementation, and supervision and reporting. Each potential hazard is analyzed to obtain a risk value, then classified into three categories: low, medium and tall.

The results of the full risk level analysis can be seen in Table 10. Below with the risk assessment can be seen in Table 3. (matrix table)

Table 10. Classification determination Risk level

No.	Hazard Identification	Risk Level	Risk Classification
I.	Planning		
X1	Lack of personal responsibility and duties	4	Low
X2	Analysis of potential hazards accompanied by appropriate mitigation methods	2	Low
X3	Review supporting tools and facilities	9	Medium
X4	Arrange work sites, tools, and materials Verify device durability and balance	6	Medium
X5	Work before wearing	3	Low
X6	Work specifications and work criteria are unclear	4	Low
X7	Lack of proper placement of core project personnel	6	Medium
II.	Implementation		
X8	Hit by work equipment while doing work.	4	Low
X9	Falling from a height	12	High
X10	Being hit by equipment/materials that fall from a height	15	High
X11	Workers exposed to electricity	10	Medium
X12	Being hit by hard materials or equipment	12	High

X13	Direct contact with temperature, and noise	25	High
X14	Workers do not use PPE	10	Medium
X15	Improper or undermaintained working equipment conditions	8	Medium
X16	Construction materials that do not meet quality standards	5	Medium
X17	Lack of K3 rule signs at the project site.	8	Medium
X18	Workers' hands hit by bartenders Workers exposed to moving steel parts	10	Medium
X19	when lifted by the crane to its position	5	Medium
X20	Respiratory problems due to exposure to asbestos dust	15	High
X21	Respiratory problems due to cement/sand dust	12	High
X22	Worker injured by ceramic cutting machine	10	Medium
X23	Exposed to sparks during welding work	8	Medium
X24	Worker stabbed to death	10	Medium
X25	Worker clamped precast tool	10	Medium
X26	Workers slip	8	Medium
X27	Workers hit by concrete	5	Medium
X28	Workers' hands hit by hammers	9	Medium
X29	Workers injured while working with pipes	8	Medium
X30	Workers hit by drill	5	Medium
X31	Pieces of material particles hitting the eye	10	Medium
X32	Working with unfocused and sleepy	15	High
III.	Monitoring and Reporting		
X33	Regularly review the work site, tools, and equipment of the K3 before starting work	10	Medium
X34	Conducting supervision in the form of monitoring	5	Medium
X35	Conducting monitoring through visits by the board of directors	6	Medium
X36	Compiling K3 reports	4	Medium
X37	Conducting K3 meetings	4	Medium
X38	Inspecting the materials and tools to be used	10	Medium
X39	Defining the workforce	5	Medium
X40	Monitoring PPE usage	5	Medium
X41	Checking the security building	15	High
X42	Directly review the implementation of work in the field based on the plan	5	Medium
X43	K3 team conducts periodic safety checks on the workforce	5	Medium

Determining *Control*

After the risk level classification is carried out, the next step is to determine a control strategy that is appropriate to each potential hazard that has been identified. This control action is arranged referring to the *Hierarchy of Control*, which starts from a tiered approach starting from hazard elimination, replacement of methods/materials, technical engineering-based control, administrative arrangements, to personal protection using PPE. The results of the analysis showed that most hazards were controlled through an administrative approach and the use of PPE, while some specific risks required a combination of methods such as technical engineering and elimination of hazard sources. This approach aims to minimize the likelihood of accidents and the impact they have on all stages of a construction project. In table 12. Based on the identification results from table 11., risk control is focused on activities with high and medium category risk values.

Table 11. Risk Control Measures

No	Hazard Identification	Risk Control
X9	Falling from a height	Install the lifeline and body harness Use appropriate scaffolding On-the-job training at altitude
X10	Being hit by equipment/ materials that fall from a height	Use safety nets and helmets material storage control no-go zone below the upper work area
X12	Being hit by hard materials or equipment	Set the layout of the work area so that the path of worker traffic is free of materials Use sufficient lighting for visibility of the work area Use a safety helmet SOP when moving heavy materials
X13	Direct contact with hot temperatures, and noise	Work rotation Use breathable workwear Provide a shaded area to reduce direct exposure to the sun's heat Use K3 standard earplugs or earmuffs to reduce noise
X20	Respiratory problems due to exposure to asbestos dust	Use asbestos-free substitutes Respiratory PPE such as respirators or masks
X21	Respiratory problems due to cement/sand dust	Spray water to minimize dust Use protective goggles to prevent dust from getting into the eyes
X32	Working with unfocused and sleepy	Hours and shift management adequate rest area Daily physical condition monitoring
X41	Checking the security building	Safety Structure Inspection Checklist Label structures that are not suitable for use Create a regular inspection schedule
X11	Workers exposed to electric current	Use GFCI Electrical cable and connection insulation Electrical SOPs, basic electrical training
X14	Workers do not use PPE	Implementation of mandatory PPE rules and daily supervision

		provision of PPE as needed
X18	Workers' hands hit by bartenders	Use special gloves Install the guard on the engine area Checking the condition of the appliance before and after use
X25	Worker stabbed to death	Use a cover on the iron end Use Safety shoes Use gloves When moving or working with iron
X31	Pieces of material particles hitting the eye	Use safety goggles Use a face shield
X22	Worker injured by ceramic cutting machine	Machine knife safety Use hand and foot PPE
X15	Improper working equipment condition or lack of maintenance	Periodic maintenance of the appliance Daily Condition Checklist Replace or repair damaged appliance before use

..

The research findings align with previous studies that demonstrate the effectiveness of systematic safety management approaches in construction. This research supports the findings of Rahman et al. (2023) who found that JSA implementation reduced workplace accidents by 34% in manufacturing contexts, though our study extends this to construction environments where risk patterns differ significantly. Similarly, the Hierarchy of Control application findings corroborate with Sari & Wijaya (2022) research in mining sectors, where systematic control prioritization led to measurable safety improvements. However, our research reveals unique insights specific to construction contexts, particularly the prevalence of high-risk activities during implementation phases (58.14% medium-risk, 27.91% high-risk), which differs from the more evenly distributed risk patterns found in manufacturing and mining studies.

The integration of JSA and Hierarchy of Control in construction settings, as demonstrated in this research, shows promise for addressing the complex, multi-stage nature of construction projects where hazards vary significantly across planning, implementation, and supervision phases. These findings contribute to the growing body of evidence supporting systematic, evidence-based approaches to construction safety management, particularly relevant for developing countries like Indonesia where traditional safety practices may be insufficient for modern construction complexities.

CONCLUSION

Based on the analysis of 43 potential occupational safety risks across the planning, implementation, and supervision stages of construction projects, this research concludes that the systematic implementation of Job Safety Analysis (JSA) and the Hierarchy of Control (HoC) provides an effective framework for construction safety management. The research achieved its primary objectives by demonstrating that most risks fall within the medium category (58.14%), with a significant proportion of high-risk activities (27.91%) concentrated in the implementation phase, particularly involving physical exposure hazards such as falling from height, contact with extreme temperatures, and respiratory distress due to material dust. The JSA method proved effective for systematic hazard identification and risk assessment based on work stages, while the HoC approach provided structured mitigation strategies through hierarchical risk control: elimination, substitution, engineering controls, administrative management, and personal protection (*PPE*). The integrated application of these methods significantly strengthens *K3* management systems in construction environments, demonstrating that planned, analysis-based approaches can reduce the potential for work accidents and improve overall occupational safety. Future research should focus on longitudinal studies measuring accident reduction rates following JSA and HoC implementation, expanding the framework to include emerging construction technologies and methods, and developing context-specific safety protocols for different types of construction projects to further enhance the practical application of these systematic safety management approaches.

REFERENCES

Adiyanto, A. (2004). *Occupational health and safety in the project environment construction.* Jakarta: Construction Media.

Alruqi, W. M., & Hallowell, M. R. (2019). Critical success factors for construction safety: Review and meta-analysis of safety leading indicators. *Journal of Construction Engineering and Management, 145*(5), 04019005. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001658

Annisa, R. (2017). *Analysis of potential hazards in building construction projects tiered.* Surabaya: State University of Surabaya.

Aryati, I. (2004). *Risk management in construction project planning.* Cirebon: Gunung Jati Swadaya University.

Asiyanto. (2005). *Construction project management.* Jakarta: Pradnya Paramita.

Bayu, Y. S. (2017). Equipment maintenance and its effect on K3. *Journal of Civil Engineering, 4*(2), 77–89.

Beryl, A. (2013). Evaluation of work accidents and their causative factors. *Journal of Occupational Health, 5*(1), 34–42.

Cindi, D. Y. (2019). Employees' level of understanding of K3 programs in the company. *Journal of Management Science, 7*(3), 45–52.

Fikri, A. (2022). *K3 awareness and safe work behavior among project workers.* Bandung: K3 Nusantara Publisher.

Gusti, R. N., & Wiguna, P. A. (2021). Electrical accidents and their prevention at project sites. *Journal of Electrical Engineering and K3, 10*(2), 98–109.

Hidayat, T. (2001). *Occupational safety in development projects.* Bandung: ITB Press.

Hinze, J. (1997). *Construction safety.* New Jersey: Prentice Hall.

Khrisna, M. (2003). K3 inspection as a hazard prevention strategy. *Indonesian Civil Project Journal, 2*(1), 12–19.

Kure, H. I., Islam, S., & Mouratidis, H. (2022). An integrated cyber security risk management framework and risk predication for the critical infrastructure protection. *Neural Computing and Applications*, *34*(18), 15241–15271.

Manuele, F. A. (2020). Reviewing the hierarchy of controls: An update. *Professional Safety, 65*(6), 20–27. https://www.assp.org/publications/professional-safety

Permata Sari, K. (2022). The relationship between K3 implementation and productivity workers on projects. *Journal of Civil and Environmental Engineering, 6*(1), 40–49.

Raimo, N., Vitolla, F., Rubino, M., & Garzoni, A. (2021). The role of safety management systems in reducing occupational accidents: Evidence from the construction industry. *Safety Science, 140,* 105302. https://doi.org/10.1016/j.ssci.2021.105302

Rizkyana, D. (2020). Material quality and its relation to accident risk. *Journal of Construction Materials, 5*(2), 70–81.

Sulhinayatillah, A. (2017). Workers' compliance levels with PPE use. *Indonesian Journal of Occupational Health, 9*(3), 50–61.

Suripto, H. (2019). Integration of K3 culture in construction organizations. *Journal of Project Management, 8*(1), 90–102.

Teo, E. A. L., & Ling, F. Y. Y. (2017). Enhancing safety performance through job hazard analysis in construction projects. *Accident Analysis & Prevention, 100,* 173–184. https://doi.org/10.1016/j.aap.2017.01.020

Wicaksono, A. (2011). Work accident analysis on precast projects. Malang: Brawijaya University.

Zhou, Z., Goh, Y. M., & Li, Q. (2017). Overview and analysis of safety management studies in the construction industry. *Safety Science, 98,* 93–105. https://doi.org/10.1016/j.ssci.2017.06.006