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Risk Analysis of Occupational Safety and Health in Core Wall Construction Work at a Communication Tower Project

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Abstract.
This study aims to analyze Occupational Health and Safety (OHS) risks in the core wall construction work of the Communication Tower Project, which has reached 70% progress. Over 80% of the work is carried out by vendors and subcontractors, presenting challenges in coordination and standardization of OHS practices. The methods employed include Job Safety Analysis (JSA), Hazard Identification, Risk Assessment, and Determining Control (HIRADC), Analytical Hierarchy Process (AHP), and Cost-Benefit Analysis (CBA). Data were collected through field observations, questionnaires, and interviews with fifteen respondents ranging from field workers to project managers. The results show that the highest-risk activities are climbing formwork and reforming roof, both classified as high-risk. AHP was used to prioritize mitigation actions based on three criteria: severity, likelihood, and cost, with severity identified as the most dominant factor. CBA indicated that despite the relatively high mitigation costs, the proposed controls are effective in significantly reducing risk exposure, especially for activities at height and heavy equipment operation. The integration of these four methods provides a mitigation strategy that is data-driven, cost-efficient, and applicable to large-scale and complex construction projects.

Keywords: Occupational Health and Safety (OSH), Job Safety Analysis (JSA), HIRADC, Analytical Hierarchy Process (AHP), Cost-Benefit Analysis (CBA), Risk Mitigation, Core Wall Construction.

INTRODUCTION

Occupational Safety and Health (K3) is a fundamental aspect of the construction industry, which is known to carry a high risk of occupational accidents and work-related illnesses (Choudhry, 2017; Memon et al., 2020). According to data from the International Labor Organization (ILO), more than 2.3 million deaths occur every year due to work accidents, with the construction sector being one of the main contributors (Hämäläinen et al., 2017; Sousa et al., 2022). One of the high-risk activities in the construction of multi-storey buildings is the construction of a core wall. This structural element serves as the main wall for vertical and lateral load-bearing, as well as acting as the center of rigidity for buildings—particularly in tall structures (Zhao et al., 2019; Huang et al., 2021). However, the execution of core wall work, especially on projects with extreme heights such as the Communication Tower, which reaches 104 meters, presents various potential hazards, including falls from height, being struck by materials, and formwork structure failures (Jang et al., 2020).

The heavy reliance on vendors and subcontractors—accounting for more than 80% of such projects—complicates the supervision and standardization of K3 implementation in the field (Giri et al., 2025). Weak coordination and differing safety cultures among parties contribute to ineffective risk control, violations in the use of personal protective equipment (PPE), and insufficient training for high-risk work (Loosemore & Malouf, 2019; Goh & Ubeynarayana, 2017). Previous studies highlight that fragmented responsibility between contractors and subcontractors often leads to inconsistent safety standards and poor compliance with occupational safety regulations (Manu et al., 2019; Al-Bayati et al., 2020). In addition, inadequate safety training and lack of monitoring in subcontracting systems have been shown to significantly increase accident risks in construction projects (Zou & Sunindijo, 2015; Lingard et al., 2020). This underscores the need for a systematic and integrated risk management approach.

The use of the Job Safety Analysis (JSA) method is important for identifying hazards based on specific work steps, while Hazard Identification, Risk Assessment, and Determining Control (HIRADC) offers a broader risk mapping based on a combination of severity and likelihood of occurrence (OSHA, 2002; OHSAS, 2007). However, both methods alone are insufficient in providing objectively measurable mitigation priorities. Therefore, integration with the Analytical Hierarchy Process (AHP) method is crucial to prioritize risks based on the weighted criteria of severity, likelihood, and cost (Saaty, 1992), and further enriched with the Cost–Benefit Analysis (CBA) approach to ensure cost efficiency in mitigation decision-making (Boardman et al., 2018).

By combining JSA, HIRADC, AHP, and CBA, this study aims to produce a comprehensive, data-driven, and economically viable risk mitigation strategy. This approach is expected to create a more adaptive model for *K3* implementation, especially in large-scale and complex construction projects such as the construction of the Communication Tower *core wall*.

Previous research has highlighted the critical importance of *K3* in the construction industry due to the high risks of accidents and fatalities, particularly in high-rise construction projects. Schuller (1989) examined the structural significance of *core walls* in multi-storey buildings, emphasizing the need for precise engineering and construction practices to maintain building stability, while Bustaman (2022) analyzed accident patterns in *core wall* construction, identifying falls from height, material impacts, and formwork failures as primary hazards. Although these studies provided valuable insights into structural risks and accident types, they did not offer a systematic, economically informed method to prioritize hazard mitigation. Similarly, traditional safety management tools such as JSA and HIRADC have been used to identify hazards and assess risks (OSHA, 2002; OHSAS, 2007), yet they fall short in objectively ranking risks according to severity, likelihood, and cost of mitigation.

This study aims to develop a comprehensive, data-driven Occupational Safety and Health (OSH) risk mitigation model by integrating JSA, HIRADC, AHP, and CBA for *core wall* construction work, particularly in high-rise communication tower projects. The model is expected to provide a clear and systematic guide for identifying, assessing, and prioritizing workplace risks based on severity, likelihood of occurrence, and the cost-effectiveness of mitigation measures. The practical benefits of this research include improving worker safety and health, minimizing the likelihood of accidents, and supporting project management in making more effective and economically sound OSH decisions. Theoretically, this study contributes to the development of an adaptive and integrated OSH framework for large-scale and complex construction projects, serving as a reference for both industry practice and future research.

MATERIALS AND METHODS

This study aims to analyze Occupational Safety and Health (*K3*) risks in *core wall* work on the Communication Tower project through the integration of the Job Safety Analysis (JSA), Hazard Identification, Risk Assessment, and Determining Control (HIRADC), and Analytical Hierarchy Process (AHP) methods, supported by Cost–Benefit Analysis (CBA) for mitigation cost efficiency. High-risk activities in *core wall* construction, such as working at heights, being struck by materials, and exposure to chemicals, require a systematic approach. JSA is used to identify occupational hazards, HIRADC assesses the risks based on severity and likelihood, AHP determines mitigation priorities objectively, and CBA evaluates their economic viability. Through this integrated framework, it is expected that effective and efficient risk mitigation strategies will be developed to support both project safety and productivity.

This research is a case study on the construction of the Communication Tower *core wall*, focusing on the management of complex *K3* risks. The JSA method is applied to map hazardous work stages such as rebar installation, formwork assembly, concrete casting, and dismantling. HIRADC assesses the level of risk (high, medium, or low), which serves as the basis for developing control measures. AHP is used to prioritize mitigation actions based on the criteria of severity, likelihood, and cost, while the CBA approach evaluates the cost-effectiveness of those controls. The integration of these four methods aims to produce an implementable, efficient, and sustainable *K3* risk management system.

Data were collected through questionnaires, in-depth interviews, and direct observation of 15 respondents from the project team. Primary data included the experiences and perceptions of workers and project managers regarding occupational hazards, while secondary data were obtained from project documents, standard operating procedures (SOPs), and *K3* reports. Research instruments were developed based on JSA, HIRADC, and AHP to identify hazards, assess risks, and establish mitigation priorities. CBA was employed to determine the economic efficiency of proposed risk controls.

Data analysis was conducted through the integration of JSA, HIRADC, AHP, and CBA. Occupational hazards were classified according to the type and stage of activity, followed by semi-quantitative risk assessment using HIRADC. CBA was then applied to compare the benefits of control measures with their implementation costs, while AHP was used to prioritize mitigation strategies by factoring in severity, likelihood, and cost. The final results were validated in collaboration with *K3* experts and project management to ensure the accuracy and feasibility of the proposed mitigation recommendations. This integrated approach ensures that safety strategies are relevant, cost-effective, and ready for on-site implementation.

RESULTS AND DISCUSSION

The research was carried out on the core wall work of the Communication Tower project as high as 104 meters. Risk identification was carried out through observation, interviews, and questionnaires of 15 respondents, consisting of field workers and project managers. Seven main activities were analyzed using JSA and HIRADC methods, namely: reinforcement installation, climbing formwork, concrete casting, formwork dismantling, crane use, roof work (reforming roof), and noise exposure. Risk assessment using the HIRADC approach showed that formwork climbing and roof reforming activities were included in the high risk category. Recommended controls include the use of PPE, high-level job training, guardrail installation, and supervision of work procedures.

Through CBA, mitigation measures such as the installation of lifelines and job training at altitude have proven to be economically feasible even though they require considerable costs. For example, mitigation for climbing formwork reduces the risk from an initial exposure of IDR 63 million to IDR 9.75 million, with a mitigation cost of IDR 110 million, but the economic justification is strong because it reduces extreme risk.

The AHP method is used to determine mitigation priorities. The three main criteria are severity (0.56), likelihood (0.35), and cost (0.09). The AHP results show that the climbing formwork and reforming roof have the highest priority weight (0.376). Validation was carried out through Expert Choice and manual calculations showed high consistency (CR < 0.1).

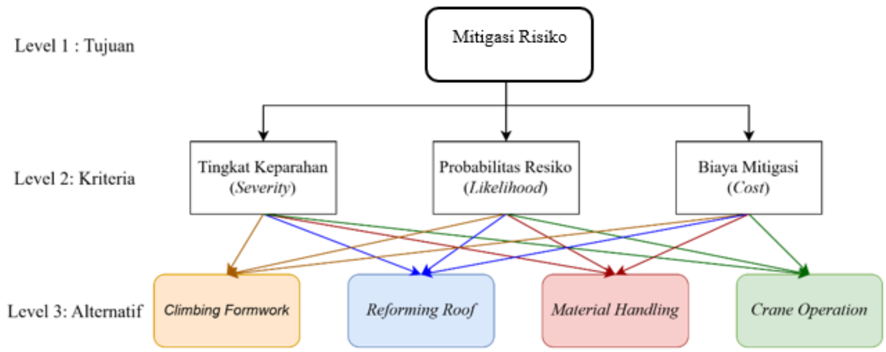

Figure 1. AHP Hierarchy

Based on the reference table above, a comparison table is made for each criterion following an example of a comparison table of the criteria "Severity" with "Cost".

Table 1. Comparison of Severity (S) with Cost (Co)

S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Co

Referring to the table above, a more dominant criterion is chosen by selecting a number so that the comparison of the more dominant criterion values with the reference pairwise comparison can be known. Furthermore, a comparison is made with other criteria, and all comparison values are obtained. The results of the comparison of criteria from Project Manager are as follows:

Table 2. Comparison of Criteria

	Score																	
S	9	8	7	6	~~5~~	4	3	2	1	2	3	4	5	6	7	8	9	Co
S	9	8	7	6	5	4	3	~~2~~	1	2	3	4	5	6	7	8	9	L
L	9	8	7	6	~~5~~	4	3	2	1	2	3	4	5	6	7	8	9	Co

The above results are known to be values of 5, 2, and 5 which state that these values affect how important a value or the weight of the comparison of criteria is with each other. If the value obtained is 1, then it is considered equally important. The results of the questionnaire were then formed in a weight comparison matrix score table with three criteria according to the table above. The goal is to calculate the total amount of the weight of the comparison by entering the inverse value of the score. The existing values and the opposite values of the criteria are obtained as a result of the matrix table as follows:

Table 3. Matrix Comparison of Results Criteria

CRITERIA			
	S	L	C
S	1	2	5
L	1/2	1	5
C	1/5	1/5	1

Based on the results obtained, the priority synthesis calculation is then carried out by dividing each parameter weight by the total number in each column.

Table 4. Comparison of Weights Criteria and Amounts

CRITERIA			
	S	L	C
S	1	2	5
L	0.5	1	5
C	0.2	0.2	1
∑	1.7	3.2	11

Each element in the criterion weight matrix is calculated by dividing the value in each cell by the total number in the corresponding column. As an illustration, for the cells in row K and column K (K/K), the value of 1 is divided by the total of column K, which is 1.7, so that the result is 0.58. This calculation process is carried out consistently for all elements in the matrix. Next, the values on each row are added to obtain the total weight of the criteria parameters of each row. The total value is then divided by the number of elements (n) in the matrix. In this case, the matrix used is 3×3, so the value n = 3. Thus, the weight of the normalized parameters for each criterion is obtained.

Table 5. Comparison of the Weights of the Normalization Criteria

CRITERIA				∑ Weight
	S	**L**	**C**	
S	0,59	0,63	0,45	0,56
L	0,29	0,31	0,45	0,35
C	0,12	0,06	0,09	0,09

The calculation is considered correct if the total weight of the criteria = 1. The above result is known to be 0.56 + 0.35 + 0.09 = 1 so that it can be stated that the result is correct.
If using the calculation of the algebraic matrix, it can be solved as follows:

$$\begin{pmatrix} 0{,}375 & 0{,}375 & 0{,}384 \\ 0{,}125 & 0{,}125 & 0{,}167 \\ 0{,}125 & 0{,}125 & 0{,}065 \\ 0{,}375 & 0{,}375 & 0{,}384 \end{pmatrix} \begin{pmatrix} 0{,}56 \\ 0{,}35 \\ 0{,}09 \end{pmatrix} = \begin{pmatrix} \mathbf{0.37581} \\ \mathbf{0.12878} \\ \mathbf{0.1196} \\ \mathbf{0.37581} \end{pmatrix}$$

Table 6. The priority weight of each alternative

Alternative	Weight	Priority
Climbing Formwork	0.3751	1
Reforming Roof	0.3751	2
Crane Operation	0.12878	3
Material Handling	0.1196	4

The results of the criteria and alternatives scores are compared thoroughly, so that the final calculation results are obtained through *the Expert Choice* application. A summary of the overall results is presented as follows.

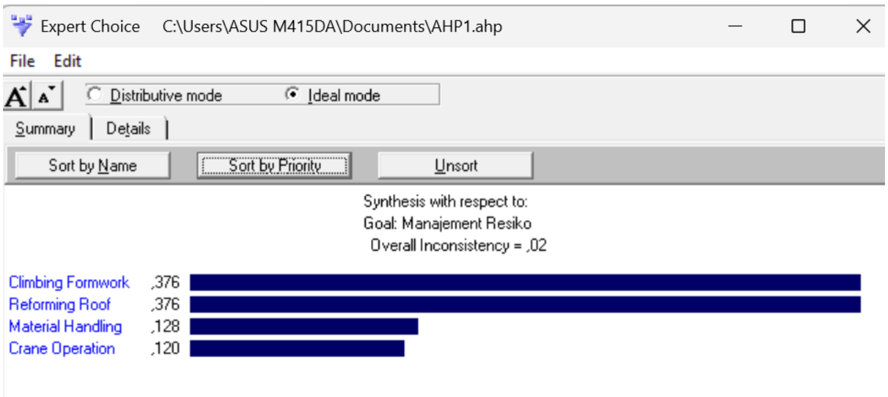

Figure 2. Expert Choice *Overall Results*

The results of the analysis resulted in a comparison that showed the order of alternative priorities based on their respective weights. This comparison is the basis for making the most effective risk management strategy decisions.

Table 7. Comparison of Manual and *Expert Choice results*

Alternative	Hasil EC	Hasil Manual	Correction	Priorities
Climbing Formwork	0.376	0.376	0.00	1
Reforming Roof	0.376	0.376	0.05	2
Material Handling	0.128	0.129	0.00	3
Crane Operation	0.120	0.120	0.00	4

The results of the calculation using Expert Choice show that there is a very small difference, which is 0.05%, so it can be concluded that the results have a high level of consistency. Based on the overall analysis of AHP, the risk management alternatives that have the highest priority are Climbing Formwork and Reforming Roof with a priority weight of 0.376. Furthermore, Material Handling ranks second with a weight of 0.128, followed by Crane Operation with a priority weight of 0.120.

CONCLUSION

Based on the results of the risk analysis for *core wall* work in the Communication Tower Project, it can be concluded that this activity carries a high level of Occupational Safety and Health (*K3*) risk. Several critical activities—such as formwork climbing, roof re-forming, lifting materials using cranes, and concrete casting—present serious potential hazards, including the risk of falling from heights, being struck by materials, ergonomic strain, and exposure to hazardous chemicals. Risk identification and analysis were carried out through an integrated approach that combined Job Safety Analysis (JSA), Hazard Identification, Risk Assessment and Determining Control (HIRADC), Analytical Hierarchy Process (AHP), and Cost–Benefit Analysis

(CBA). The HIRADC method successfully classified most of these risks as medium to high. Through the implementation of control strategies—such as installing guardrails, using full-body harnesses, providing work-at-height training, and regulating heavy equipment operation areas—the overall risk level was significantly reduced.

Risk mitigation priorities were determined using the AHP method, which considered three main criteria: severity, likelihood, and mitigation cost. The analysis results indicated that severity was the most dominant factor influencing mitigation decisions. Formwork climbing and roof re-forming activities ranked highest in priority, as they collectively posed the greatest combined risk. Evaluation through the CBA approach showed that although investments in risk mitigation were substantial in nominal terms, they yielded significant benefits in reducing the potential for fatal accidents and project delays. From an efficiency standpoint and in line with the principle of caution against extreme risks, these control measures were deemed feasible to implement.

The integration of JSA, HIRADC, AHP, and CBA methods establishes a systematic, data-driven framework for *K3* risk management. This approach enables more objective decision-making while supporting the efficient allocation of resources to high-risk work areas. The findings of this study are expected to serve as a practical guideline for project management in enhancing workplace safety, maintaining productivity, and ensuring the sustainability of large-scale and complex construction projects.

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