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Strategy to Determine the Level of Risk of Work Sites in the Construction Sector Using the Analytical Hierarchy Process (AHP) Method

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Abstract. The construction sector faces significant occupational safety challenges, with increasing accident rates necessitating strategic risk management approaches. This research aims to determine work site risk levels in the construction sector using the Analytical Hierarchy Process (AHP) method to optimize safety supervisor placement at PT. X, an international-scale construction fabrication company. The research identifies four main criteria affecting workplace risk: number of workers, critical activities, SIMOPS (Simultaneous Operations), and PTW (Permit to Work) issued, evaluated across seven alternative work locations. Data were collected through expert questionnaires involving HSE Managers, PTW Coordinators, and SIMOPS Facilitators. The AHP analysis revealed that critical activities constitute the most influential criterion with a weight of 47.1%, followed by SIMOPS (28.4%), PTW issued (17.1%), and number of workers (7.4%). Results indicate that NFQ Area 19 presents the highest risk level (0.407), while the Workshop area exhibits the lowest risk (0.024). The consistency ratio for all criteria remained below 0.1, confirming the reliability of the assessment. The findings were validated using Expert Choice software, demonstrating no significant calculation errors. This research provides a systematic framework for prioritizing safety supervision resources based on quantified risk levels, enabling more effective accident prevention strategies in construction environments.

Keyword: Analytical Hierarchy Process (AHP), risk assessment, construction safety, occupational safety and health, multi-criteria decision making

INTRODUCTION

Data (ILO, 2023) International Labour Organization It said nearly three million workers die every year due to occupational accidents and illnesses. Most work-related deaths, which totaled 2.6 million deaths, were from work-related diseases. The report showed that more men died from work accidents (51.4 per 100,000 working-age adults) than women (17.2 per 100,000). Agriculture, construction, forestry and fisheries and manufacturing are the most dangerous sectors, causing 200,000 fatal injuries per year, representing 63% of all fatal occupational injuries (ILO, 2023). The construction industry is characterized as a labor-intensive sector that simultaneously relies on advanced technology and machinery. This reliance on advanced machinery and equipment, in addition to increasing productivity and efficiency, also increases the likelihood of occupational hazards in the construction sector (Tripathi & Mittal, 2024).

Meanwhile, according to data Ministry of Manpower of the Republic of Indonesia, (2025) In the period from January to December 2024, the number of work accident cases in Indonesia was recorded as many as 462,241 cases with details of 91.65 percent including wage recipients, 7.43 percent including non-wage recipients and 0.92 percent including construction service participants. Based on this data, several ways are carried out by the company to develop a strategy to reduce work accident cases by PT. X. PT. X is an international scale construction fabrication company that is the object of this research and has projects in Indonesia with international clients. In addition, based on statistical reports PT. X, (2025) in the past year, Safety, Occupational Health & Environment (K3L) performance has continued to decline along with an increase in the value of TRIR (Total Recordable Incident Rate).

There are at least a total of 34 accidents that cause the Value TRIR (Total Recordable Incident Rate increased to 3.4 during 2024. The issue of the cleanliness value of the work site that was reviewed has decreased every month from the performance target of 4 (as a satisfactory indicator) with the actual condition of the last few months getting a value of 3 (an indicator that requires improvement), the incident is almost accidental (Nearmiss) has also increased, in the last two months there have been 4 near-accident incidents with one of them categorized as HI-PO (High Potential) or have a high potential to cause death (PT. X, 2025). One of the causes of many accidents is the human factor (Jaram et al., 2021). In addition, research Farhan et al., (2025) Also highlighting that one of the causes of work accidents is the implementation and supervision of employee occupational safety that is not optimal.

According to Law of the Republic of Indonesia No.1 (1970), Every company is obliged to ensure a safe working environment to reduce the risk of accidents. One of the strategies carried out in managing work sites and work processes that are safe for the workforce and the environment, is to approach several methods to determine the strategy for the placement of safety supervisors so that they are more on target and run effectively to reduce the number of work accidents. Research Biermann-Teuscher et al. (2024) Highlight the importance of vulnerability and trust in workplace relationships to be able to learn and develop safety procedures that are aligned with local demands. Risk management is closely related to decision-making, which is why it is so important for organizations (Vladimir RISTANOVIĆ et al., 2021).

PT. X has HSE (Health, Safety & Environmental) departments necessary to supervise, and ensure that each work process is carried out in accordance with Occupational Health and Safety regulations and applicable general rules (PT. X, 2025). Professional HSE according to Colombo et al., (2019) is a certified specialist from a wide range of disciplines who deals with the prevention of different types of risks arising from the production of goods and services by private companies and public institutions. The deployment of inappropriate safety supervisors can certainly reduce its effectiveness, therefore efforts to improve safety supervision continue to be carried out by assessing the level of risk at the work site so that it is easy to identify. With the mapping of the risk level of the work site, the supervision and risk control strategy can be applied in a targeted manner.

Multi Criteria Decision Making (MCDM) is widely used in decision support both in risk management (Armin et al., 2022; Bognár et al., 2022; Navascués Vega and Llano Castresana, 2024; Singh and Suthar, 2021; Vladimir RISTANOVIĆ et al., 2021; Zeibak-Shini et al., 2024), resource allocation (Huang and Chen, 2024), competency analysis (Adedotun et al., 2022; Chou and Chen, 2020; Shamshol Bahri et al., 2023) as well as personnel assignment (Hematian et al., 2020). Research Tuğba DANIŞAN et al., (2022) shows that the MCDM method can be applied in the selection of personnel in the ready-to-wear sector. In research Namoco et al., (2023) Integration AHP, TOPSIS & Integer Programming It has effectively been used to determine the deployment of police officers in order to optimize their efficiency. Ali et al., (2024) highlighting the importance of MCDM in analyzing risk ratings on 29 failure modes of offshore rig-up activities. Even Adedotun et al., (2022) integrating MCDM in the creation of geotechnical maps to minimize the risk of residential land collapse.

Analytical Hierarchy Process (AHP) is the right tool to support decision-making in determining the mapping of risk levels in the workplace. In research Singh and Suthar (2021), AHP used to develop qualitative methods of risk assessment of manual patient handling and to evaluate the validity and reliability of their risk assessments. AHP It can also be used to highlight the value of project management and, more specifically, risk management, to obtain a higher level of sustainability (Navascués Vega and Llano Castresana, 2024). In research Namoco et al., (2023) AHP can be used to determine the deployment of police officers to optimize their reliability. In addition, AHP Prove to be very useful when dealing with decisions that involve multiple criteria and alternatives, which can complicate the decision-making process (Cremades & Ponsich, 2025). AHP Provides tools to delineate problems in the hierarchy of indicators and sub indicators. Based on this statement, the author considers that the AHP is the right choice in determining the level of risk at the work site.

This study aims to determine the level of risk of work sites in the construction sector by using the Analytical Hierarchy Process (AHP) method to optimize the placement of safety supervisors at PT. X. By mapping the level of risk based on four main criteria—number of workers, critical activities, SIMOPS, and published PTWs—this study is expected to provide a systematic framework for the priority allocation of supervisory resources, so that accident prevention strategies can be implemented more effectively and targeted.

RESEARCH METHOD

The research methods involved principles, procedures, and techniques to investigate problems and uncover scientific truths. This methodology enabled objective, systematic collection, analysis, and interpretation of data to solve problems or generate new knowledge. The main stages included data collection, data processing, and analysis leading to conclusions.

Data collection was the most critical stage, as it provided the foundation for subsequent processing and analysis. In this study, it encompassed identifying the research problem, conducting a literature review, screening respondents, and determining criteria and alternatives for the AHP method.

This initial stage focused on problem identification, from formulation to research objectives, guiding the entire process from data collection to conclusions. Problem formulation sharpened research focus and scope. Problems arose from declining safety performance, rising accident rates, and gaps in assigning safety officers to work sites without clear justification based on their capabilities.

Researchers gathered references to support data processing and analysis. The literature review revealed a strong trend in using MCDM approaches for decision-making, particularly AHP for selecting optimal alternatives based on expert judgment.

Respondents were selected for their authority, knowledge, and experience in assessing risks and completing questionnaires (Amida & Kristiana, 2019). Experts at PT. X participated, including:

1. HSE Manager & HSE Coordinator:

HSE Coordinators have the ability to analyze the level of risk of the job site. On the other hand, the HSE Manager has full authority to access several important data as criteria for analyzing the level of risk at the job site.

2. Permit to Work (PTW) Coordinator:

Permit to Work (PTW) Coordinator was selected as the respondent in this study to help identify the number of Critical Activity and the number of PTWs issued daily. PTW Coordinator is a staff who has access to provide data to support the assessment of the risk level of the work site.

3. SIMOPS Facilitator:

SIMOPS Facilitator is a staff officer who leads SIMOPS meetings every day. The task of the SIMOPS Facilitator is to facilitate work planning discussions on the next day to discuss work plans that have the potential for simultaneous operations (SIMOPS). This meeting involves PTW data that has been registered by the PTW Coordinator, and approved by the area supervisor, and led by the project manager or his delegation to determine the scale of work priorities that have the potential of SIMOPS. Each activity that has SIMOPS potential is collected and discussed in meetings to assess the level of risk based on the SIMOPS matrix as well as the decision making by the construction manager which work can be done.

According to Cremades and Ponsich (2025) In determining criteria and alternatives in both design and project management, it is usually necessary to make decisions based on criteria that, in many cases, are not entirely objective. Subjectivity in decision-making can arise, especially at three moments in the process, namely when choosing criteria to use for decision-making, when determining the relative weight of those criteria, and in some cases, when evaluating alternatives (Cremades & Ponsich, 2025).

Determining the level of workplace risk is an important process in supporting safety oversight decisions. Determining the level of workplace risk involves evaluating various factors that can affect potential hazards in a place. Ali et al., (2024) Grouping the impact of risk into four criteria which include impact on people, impact on equipment and assets, impact on the environment and, impact on the company's reputation. The work location in this study was assessed and determined based on several criteria, including the following:

1. Density of the number of workers:

The density of the number of workers is a criterion that can affect the level of risk at the job site. The number of workers and safety statistics are interrelated because the number of workers can affect the likelihood of accidents. The large number of workers will increase the likelihood of the risk of work accidents (Courtesy & Nurcahyo, 2022). With the increase in the number of workers at a work site, it will be directly proportional to the increased risk of accidents so that it is necessary Safety Officer with an adequate level of competence. Some considerations that are assessed Safety Officer To supervise a job site with a large number of workers is the ability to intervene and solve problems properly.

2. The number of critical activities;

Critical work is a non-routine job that is done and often involves a Subject Matter Expert (SME) or a person who has in-depth knowledge, skills, and experience in a specific topic or area. They are considered an authority in the field and are often sought after to provide insights, guidance, and solutions related to their expertise. In addition to having a high potential for hazards, critical work is an activity in a project that cannot be delayed without causing delays to the entire project. This activity has a "float" or zero time allowance, meaning that delays in the activity will have a direct impact on the project completion deadline.

3. Total report of SIMOPS (Simultaneous Operations);

SIMOPS / Simultaneous Operation is a situation where two or more tasks are performed in close proximity to time and space. Activities SIMOPS, if not coordinated, may pose a risk to safety, the environment, or equipment (Kwon et al., 2024). In internal procedures PT. X, (2024), SIMOPS defined as, but not limited to, the performance of two or more activities at a Company-managed site where some or all of the activities may impact the health and safety of personnel, the environment, assets, schedules or conduct of operations at such premises. Kwon et al. (2024) also states that careful safety management during SIMOPS It is very necessary therefore, in this study SIMOPS included in the assessment criteria to determine the level of risk at the work site.

As per the procedure (PT. X, 2024) The company has arranged the management of SIMOPS with meeting planning SIMOPS daily. These meetings will be chaired by the project manager or his delegation and attended by stakeholder representatives of each department or leader on each job. Every potential SIMOPS in the next day's work plan will be discussed and recorded in the daily meeting SIMOPS to determine whether the work can be done simultaneously (PT. X, 2024). The project manager will determine, review and confirm the planning of concurrent activities in the next day, in accordance with the actual conditions of the work in progress and to identify potential conflicts and appropriate mitigation in accordance with the Matrix SIMOPS. Amount of potential SIMOPS In the daily meeting, which is then used as a quantitative value as a criterion for determining the level of risk of a work site.

RESULTS AND DISCUSSION

Analyzing the Weights of the Main Criteria

The first step in calculating the weight of the main criteria is to enter the paired comparison data obtained from the respondents in accordance with Table 4.1 above in the paired comparison matrix table. In Table 4.1, the following data is obtained.

- Total Employees (JP) / Critical Activity (CA) : 1 / 5
- Number of Employees (JP) / Number of SIMOPS (JS) : 1 / 4
- Number of Employees (JP) / PTW Published (PT) : 1 / 3
- Critical Activity (CA) / Total SIMOPS (JS) : 2 / 1
- Critical Activity (CA) / PTW Published (PT) : 3 / 1
- Number of SIMOPS (JS) / PTW Published (PT) : 2 / 1

After that, the data is entered into a paired comparison matrix table and sums each matrix element based on the following columns.

The value of each column is obtained by dividing based on the current scale. In the JP / CA column, a division is carried out with a value of 1 / 5 = 0.20 as well as in the JP / JS column a value of 1 / 4 = 0.25 and so on then all elements of the matrix are added up so that the value of Number of workers (JP) is 13.00, critical activity (CA) is 2.03, the number of SIMOPS (JS) is 3.75, and the published PTW (PT) is 6.33. In the next stage, the value of each main criterion is normalized by dividing the comparative value of each criterion by the total value of all elements.

After normalization of the main criteria matrix. In the matrix, an assessment was carried out by summing the average weight of each main criterion and it was found that the highest score was CA: 0.471 and the lowest result was JP: 0.074. To ensure the average value of the criterion weight, the sum of the total average value is added and the eigenvector shows a value of 1 which means that there is no error in the sum of the average of the main weight. The next step to analyze the consistency of the assessment, the eigenmatrix is calculated by multiplying the value of each comparison by the weight value of the main criterion and then obtaining the following value.

The value of each comparison column after multiplying the weight of the main criteria and the number of weighted values in each criterion for consistency analysis is further carried out. The next step is to carry out consistency assessment by collecting the values obtained in the previous calculation such as the weighted value of each criterion (WSV), the weight value of the main criterion, and the calculation of the Consistency Vector by dividing the WSV/weight of the main criterion and determining the value by summing the average of the Consistency Vector.$\lambda\ max$

Table 1. Vekor Consistency Key Risk Level Criteria

Criteria	WSV	Weighting Criteria	Consistency Vector
JP	0,296	0,074	4,019
CA	1,922	0,471	4,081
JS	1,157	0,284	4,074
PT	0,691	0,171	4,032
	LAMDA MAX		4,051

Source: Processed primary data from expert respondents (2025)

The summary of the calculation of the table above yields the following consistency values:
- *n* (criteria) : 4 (number of criteria)
- *IR (Random Index)* : 0.9 (based on the table *Saaty*)
- *CI (Consistancy Index)* : $CI = \lambda \frac{\lambda max - n}{n-1} = = 0{,}017 \frac{4{,}051-4}{4-1}$
- *CR (Consistency Ratio)* : $CR = \frac{CI}{IR} = = 0.019$ (consistent)$\frac{0{,}017}{0{,}9}$

From the overall analysis in each table above, it can be concluded that the order of criteria that most affects the level of workplace risk based on the assessment of the respondents is the criterion "amount of critical activity (CA)" at the highest weight with a weight value of 0.471 (47.1%), then the second order is "the number of SIMOPS (JS)" with a weight value of 0.284 (28.4%), then the third order is "the number of PTW published (PT)" with a weight value of 0.171 (17.1%), and finally "number of workers (JP)" with a weight value of 0.074 (7.4%). In the calculation carried out, the consistency has also been assessed with a result of 0.019 or CONSISTENT.

Comparison of each alternative to the criteria

The comparison stages of each alternative to the criteria are carried out with the same steps and formulas as when conducting the weighting analysis of the main criteria in the previous Chapter 2. The data obtained from the respondents were entered into a table to be calculated with a paired comparison matrix, then the value was normalized with a normalization matrix of the main criteria, then the weighting value of each alternative was calculated and finally a consistency test was carried out using the Consistency Ratio (CR) formula. This paired comparison consists of seven alternatives, including Workshop Area (WS), Assembly Area (AS), NFQ Area 14 (NF14), NFQ Area 16 (NF16), NFQ Area 17 (NF17), NFQ Area 18 (NF18), NFQ Area 19 (NF19).

Alternative Comparison to the "Number of Workers" Criterion

Data obtained from respondents through an alternative comparison questionnaire (work location) to the criterion of "number of workers" was entered into a paired comparison matrix table to be summed.

Table 2. Alternative Comparison Matrix To "Number Of Workers"

Alternative Hierarchy Weights Value Against "Number of Workers"							
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**
WS	1,00	0,50	0,20	0,14	0,14	0,11	0,11
AS	2,00	1,00	0,33	0,20	0,20	0,14	0,14
NF14	5,00	3,00	1,00	0,33	0,20	0,14	0,14
NF16	7,00	5,00	3,00	1,00	0,50	0,33	0,33
NF17	7,00	5,00	5,00	2,00	1,00	0,33	0,33
NF18	9,00	7,00	7,00	3,00	3,00	1,00	0,50
NF19	9,00	7,00	7,00	3,00	3,00	2,00	1,00
Total	40,00	28,50	23,53	9,68	8,04	4,06	2,56

Source: Processed primary data from expert respondents (2025)

After the value of each element is known, in the next stage, the value of each alternative is normalized by dividing the comparative value of each alternative by the total value of all elements as shown in Table 3 below.

Table 3. An Alternative Normalization Matrix To "Number Of Workers"

Normalization of Alternative Matrices								Average Weight Alternative
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**	
WS	0,025	0,018	0,008	0,015	0,018	0,027	0,043	0,022
AS	0,050	0,035	0,014	0,021	0,025	0,035	0,056	0,034
NF14	0,125	0,105	0,042	0,034	0,025	0,035	0,056	0,060
NF16	0,175	0,175	0,127	0,103	0,062	0,082	0,130	0,122
NF17	0,175	0,175	0,212	0,207	0,124	0,082	0,130	0,158
NF18	0,225	0,246	0,297	0,310	0,373	0,246	0,195	0,270
NF19	0,225	0,246	0,297	0,310	0,373	0,492	0,390	0,333
Own Vector								1,000

Source: Processed primary data from expert respondents (2025)

In the matrix, an assessment was carried out by adding the average weight of each alternative and it was found that the highest score was NF19: 0.333 and the lowest result was

WS: 0.022. To ensure the average value of the alternative weight, the sum of the total average value is added and the eigenvector shows a value of 1 which means that there is no error in the sum of the average of the alternative weight. The next step to analyze the consistency of the assessment is to calculate the eigenmatrix by multiplying the value of each comparison in Table 2 by the average value of the alternative weight in Table 4.11 then the value in the following Table 4 is obtained.

Table 4. An Alternative Eigen Matrix To The "Number of Workers" Criterion

Alternatif	Calculating Own Matrix							Weighted Sum Value (WSV)
	0,022	**0,034**	**0,060**	**0,122**	**0,158**	**0,270**	**0,333**	
	WS	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**	
WS	0,022	0,017	0,012	0,017	0,023	0,030	0,037	0,158
AS	0,044	0,034	0,020	0,024	0,032	0,039	0,048	0,240
NF14	0,110	0,101	0,060	0,041	0,032	0,039	0,048	0,430
NF16	0,154	0,168	0,181	0,122	0,079	0,090	0,111	0,906
NF17	0,154	0,168	0,302	0,244	0,158	0,090	0,111	1,228
NF18	0,198	0,236	0,423	0,367	0,474	0,270	0,167	2,135
NF19	0,198	0,236	0,423	0,367	0,474	0,541	0,333	2,572

Source: Processed primary data from expert respondents (2025)

After the value in the eigenmatrix is known, the consistency assessment is then carried out by collecting the values obtained in the previous calculation such as the weighted value of each alternative (WSV), the value of the alternative weight, and the calculation of the Consistency Vector by dividing the WSV / alternative weight and determining the value by summing the average of the Consistency Vector.$\lambda\ max$

The summary of the calculation is produced by the consistency value as follows:

- n : 7 (number of alternatives)
- *IR (Random Index)* : 1.32 (based on the table *Saaty*)
- *CI (Consistency Index)* : *CI*= $\lambda \frac{\lambda max-n}{n-1}$= = 0,077$\frac{7,461-7}{7-1}$
- *CR (Consistency Ratio)* : *CR*= $\frac{CI}{IR}$= = 0.058 (consistent)$\frac{0,077}{1,32}$

From the overall analysis of each table above, it can be concluded that the alternative order (work location) that has the most effect on the number of workers is "NF19" with a weight value of 0.333 (33.3%), "NF18" with a weight value of 0.270 (27%), "NF17" with a weight value of 0.158 (15.8%), "NF16" with a weight value of 0.122 (12.2%), "NF14" with a weight value of 0.060 (6%), "AS" with a weight value of 0.034 (3.4%), and "WS" with a weight value of 0.022 (2.2%). In the weighting and calculation carried out, the consistency has also been assessed with a result of 0.058 or CONSISTENT.

Alternative Comparison of the "Critical Activities" Criteria

Data obtained from respondents through an alternative comparison questionnaire (work site) to the "Critical Activities" criteria were entered into a paired comparison matrix table to be summed up.

Table 5. Alternative Comparison Matrix To "Critical Activities"

Alternative Hierarchy Weights Value Against "Critical Activities"							
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**
WS	1,00	0,33	0,25	0,17	0,14	0,13	0,11
AS	3,00	1,00	0,50	0,25	0,20	0,14	0,13
NF14	4,00	2,00	1,00	0,33	0,20	0,14	0,13
NF16	6,00	4,00	3,00	1,00	0,50	0,25	0,17
NF17	7,00	5,00	5,00	2,00	1,00	0,33	0,20
NF18	8,00	7,00	7,00	4,00	3,00	1,00	0,33
NF19	9,00	8,00	8,00	6,00	5,00	3,00	1,00
Total	38,00	27,33	24,75	13,75	10,04	4,99	2,06

Source: Processed primary data from expert respondents (2025)

After the value of each element is known, in the next stage, the value of each alternative is normalized by dividing the comparative value of each alternative by the total value of all elements as shown in Table 6 below.

Table 6. Alternative Normalization Matrix To "Critical Activities"

NORMALIZATION OF ALTERNATIVE MATRICES								Average Weight Alternative
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**	
WS	0,026	0,012	0,010	0,012	0,014	0,025	0,054	0,022
AS	0,079	0,037	0,020	0,018	0,020	0,029	0,061	0,038
NF14	0,105	0,073	0,040	0,024	0,020	0,029	0,061	0,050
NF16	0,158	0,146	0,121	0,073	0,050	0,050	0,081	0,097
NF17	0,184	0,183	0,202	0,145	0,100	0,067	0,097	0,140
NF18	0,211	0,256	0,283	0,291	0,299	0,200	0,162	0,243
NF19	0,237	0,293	0,323	0,436	0,498	0,601	0,485	0,410
OWN VECTOR								1,000

Source: Processed primary data from expert respondents (2025)

In the matrix, an assessment was carried out by summing the average weight of each alternative and it was found that the highest value was NF19: 0.410 and the lowest result was WS: 0.022. To ensure the average value of the alternative weight, the sum of the total average value is added and the eigenvector shows a value of 1 which means that there is no error in the sum of the average of the alternative weight. The next step to analyze the consistency of the assessment is to calculate the eigenmatrix by multiplying the value of each comparison in Table 5 by the average value of the alternative weight in Table 6 then the value in the following Table 7 is obtained.

Table 7. Alternative Eigenmatrix to the Criterion "Critical Activities"

Alternative	Calculating Own Matrix							Weighted Sum Value (WSV)
	0,022	**0,038**	**0,050**	**0,097**	**0,140**	**0,243**	**0,410**	
	WS	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**	
WS	0,022	0,013	0,013	0,016	0,020	0,030	0,046	0,159
AS	0,066	0,038	0,025	0,024	0,028	0,035	0,051	0,267
NF14	0,088	0,075	0,050	0,032	0,028	0,035	0,051	0,360
NF16	0,132	0,150	0,151	0,097	0,070	0,061	0,068	0,729
NF17	0,154	0,188	0,252	0,194	0,140	0,081	0,082	1,090
NF18	0,176	0,263	0,352	0,388	0,419	0,243	0,137	1,978
NF19	0,198	0,301	0,403	0,582	0,699	0,729	0,410	3,321

Source: Author's calculation based on AHP method (2025)

After the value in the eigenmatrix is known, the consistency assessment is then carried out by collecting the values obtained in the previous calculation such as the weighted value of each alternative (WSV), the value of the alternative weight, and the calculation of the Consistency Vector by dividing the WSV / alternative weight and determining the value by summing the average of the Consistency Vector.$\lambda\ max$

Table 8. Alternative consistency vector to "*Critical Activities*"

Alternative	WSV	Weighting Criteria	Consistency Vector
WS	0,159	0,022	7,241
AS	0,267	0,038	7,102
NF14	0,360	0,050	7,148
NF16	0,729	0,097	7,519
NF17	1,090	0,140	7,803
NF18	1,978	0,243	8,140
NF19	3,321	0,410	8,092
	Lamda Max		7,578

Source: Author's calculation based on AHP method (2025)

The summary of the calculation of the table above yields the following consistency values:

- n : 7 (number of alternatives)
- *IR (Random Index)* : 1.32 (based on the table *Saaty*)
- *CI (Consistency Index)* : $CI = \lambda \frac{\lambda max - n}{n-1} = \; = 0{,}096 \frac{7{,}578-7}{7-1}$
- *CR (Consistency Ratio)* : $CR = \frac{CI}{IR} = \; =$ 0.073 (consistent)$\frac{0{,}096}{1{,}32}$

From the overall analysis of each table above, it can be concluded that the alternative order (work site) that has the most effect on *Critical Activities* is "NF19" with a weight value of 0.410 (41%), "NF18" with a weight value of 0.243 (24.3%), "NF17" with a weight value of 0.140 (14%), "NF16" with a weight value of 0.097 (9.7%), "NF14" with a weight value of 0.050 (5%), "AS" with a weight value of 0.038 (3.8%), and "WS" with a weight value of 0.022 (2.2%). The weighting and calculation carried out have also been assessed for consistency with a result of 0.073 or CONSISTENT.

Alternative Comparison to the "Number of SIMOPS" Criteria

Data obtained from respondents through an alternative comparison questionnaire (work site) to the criterion "Number of SIMOPS" is entered into a paired comparison matrix table to be summed.

Table 9. Alternative Comparison Matrix To "Total SIMOPS"

Alternative Hierarchy Weights Value To "Number SIMOPS"							
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**
WS	1,00	0,33	0,20	0,17	0,14	0,14	0,11
AS	3,00	1,00	0,25	0,20	0,17	0,13	0,11
NF14	5,00	4,00	1,00	0,33	0,33	0,20	0,14
NF16	6,00	5,00	3,00	1,00	0,50	0,20	0,14
NF17	7,00	6,00	3,00	2,00	1,00	0,33	0,20
NF18	7,00	8,00	5,00	5,00	3,00	1,00	0,33
NF19	9,00	9,00	7,00	7,00	5,00	3,00	1,00
Total	38,00	33,33	19,45	15,70	10,14	5,00	2,04

Source: Author's calculation based on AHP method (2025)

After the value of each element is known, in the next stage, the value of each alternative is normalized by dividing it by the total value of the alternative.

Table 10. Alternative normalization matrix to "Quantity SIMOPS"

Normalization of Alternative Matrices								Average Weight Alternative
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**	
WS	0,026	0,010	0,010	0,011	0,014	0,029	0,054	0,022
AS	0,079	0,030	0,013	0,013	0,016	0,025	0,054	0,033
NF14	0,132	0,120	0,051	0,021	0,033	0,040	0,070	0,067
NF16	0,158	0,150	0,154	0,064	0,049	0,040	0,070	0,098
NF17	0,184	0,180	0,154	0,127	0,099	0,067	0,098	0,130
NF18	0,184	0,240	0,257	0,318	0,296	0,200	0,163	0,237
NF19	0,237	0,270	0,360	0,446	0,493	0,600	0,490	0,414
Own Vector								1,000

Source: Author's calculation based on AHP method (2025)

In the matrix, an assessment was carried out by adding up the average weight of each alternative and it was found that the highest score was NF19: 0.414 and the lowest result was WS: 0.022. To ensure the average value of the alternative weight, the sum of the total average value is added and the eigenvector shows a value of 1 which means that there is no error in the sum of the average of the alternative weight. The next step to analyze the consistency of the assessment is to calculate the eigenmatrix by multiplying the value of each comparison in Table 9 by the average value of the alternative weight in Table 4.19 then obtained the value in the following Table 11.

Table 11. An Alternative Eigen Matrix To The "Amount" Criterion SIMOPS"

Alternative	Calculating Own Matrix							Weighted Sum Value (WSV)
	0,022	0,033	0,067	0,098	0,130	0,237	0,414	
	WS	AS	NF14	NF16	NF17	NF18	NF19	
WS	0,022	0,011	0,013	0,016	0,019	0,034	0,046	0,161
AS	0,066	0,033	0,017	0,020	0,022	0,030	0,046	0,233
NF14	0,110	0,132	0,067	0,033	0,043	0,047	0,059	0,491
NF16	0,132	0,165	0,200	0,098	0,065	0,047	0,059	0,766
NF17	0,154	0,197	0,200	0,196	0,130	0,079	0,083	1,039
NF18	0,154	0,263	0,334	0,489	0,390	0,237	0,138	2,005
NF19	0,198	0,296	0,467	0,685	0,649	0,711	0,414	3,421

Source: Author's calculation based on AHP method (2025)

After the value in the eigenmatrix is known, the consistency assessment is then carried out by collecting the values obtained in the previous calculation such as the weighted value of each alternative (WSV), the value of the alternative weight, and the calculation of the Consistency Vector by dividing the WSV / alternative weight and determining the value by summing the average of the Consistency Vector.$\lambda\ max$

Table 12. Alternative consistency vector to "Sum *SIMOPS*"

Alternative	WSV	Weighting Criteria	Consistency Vector
WS	0,161	0,022	7,306
AS	0,233	0,033	7,064
NF14	0,491	0,067	7,359
NF16	0,766	0,098	7,829
NF17	1,039	0,130	8,003
NF18	2,005	0,237	8,461
NF19	3,421	0,414	8,270
Lamda Max			7,756

Source: Author's calculation based on AHP method (2025)

The summary of the calculation of the table above yields the following consistency values:

- *n* : 7 (number of alternatives)
- *IR (Random Index)* : 1.32 (based on the table *Saaty*)
- *CI (Consistency Index)* : *CI*= $\lambda \frac{\lambda max-n}{n-1}$ = = 0,126$\frac{7,756-7}{7-1}$
- *CR (Consistency Ratio)* : *CR*= $\frac{CI}{IR}$ = = 0.095 (consistent)$\frac{0,040}{1,32}$

From the overall analysis of each table above, it can be concluded that the alternative order (work site) that has the most effect on the number of *SIMOPS* is "NF19" with a weight value of 0.414 (41.4%), "NF18" with a weight value of 0.237 (23.7%), "NF17" with a weight value of 0.130 (13%), "NF16" with a weight value of 0.098 (9.8%), "NF14" with a weight value of 0.067 (6.7%), "AS" with a weight value of 0.033 (3.3%), and "WS" with a weight value of 0.022 (2.2%). The weighting and calculation carried out have also been assessed for consistency with a result of 0.095 or CONSISTENT.

Alternative Comparison Of "Permit to Work (PTW) Issue" Criteria

Data obtained from respondents through an alternative comparison questionnaire (work location) to the "PTW Publication" criterion was entered into a paired comparison matrix table to be summed.

Table 13. Alternative Comparison of Matrix to "PTW Publication"

Alternative Hierarchy Weights Value To "PTW Published"							
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**
WS	1,00	3,00	0,33	0,17	0,20	0,14	0,11
AS	0,33	1,00	0,25	0,14	0,17	0,13	0,11
NF14	3,00	4,00	1,00	0,25	0,33	0,14	0,11
NF16	6,00	7,00	4,00	1,00	3,00	0,33	0,17
NF17	5,00	6,00	3,00	0,33	1,00	0,33	0,20
NF18	7,00	8,00	7,00	3,00	3,00	1,00	0,33
NF19	9,00	9,00	9,00	6,00	5,00	3,00	1,00
Total	31,33	38,00	24,58	10,89	12,70	5,08	2,03

Source: Author's calculation based on AHP method (2025)

After the value of each element is known, in the next stage, the value of each alternative is normalized by dividing the comparative value of each alternative by the total value of all elements as shown in Table 14 below.

Table 14. Alternative Normalization Matrix To "PTW Publication"

NORMALIZATION OF ALTERNATIVE MATRICES								Average Weight Alternative
Alternative	**WS**	**AS**	**NF14**	**NF16**	**NF17**	**NF18**	**NF19**	
WS	0,032	0,079	0,014	0,015	0,016	0,028	0,055	0,034
AS	0,011	0,026	0,010	0,013	0,013	0,025	0,055	0,022
NF14	0,096	0,105	0,041	0,023	0,026	0,028	0,055	0,053
NF16	0,191	0,184	0,163	0,092	0,236	0,066	0,082	0,145
NF17	0,160	0,158	0,122	0,031	0,079	0,066	0,098	0,102
NF18	0,223	0,211	0,285	0,275	0,236	0,197	0,164	0,227
NF19	0,287	0,237	0,366	0,551	0,394	0,591	0,492	0,417
OWN VECTOR								1,000

Source: Author's calculation based on AHP method (2025)

In the matrix, an assessment was carried out by summing the average weight of each alternative and it was found that the highest score was NF19: 0.417 and the lowest result in the US: 0.022. To ensure the average value of the alternative weight, the sum of the total average value is added and the eigenvector shows a value of 1 which means that there is no error in the sum of the average of the alternative weight. The next step is to calculate the eigenmatrix by multiplying the value of each comparison in Table 13 by the average value of the alternative weight in Table 14 then the value in Table 15 is obtained below.

Table 15 Alternative Eigenmatrix to the Criterion "PTW Publication"

Alternative	Calculating Own Matrix							Weighted Sum Value (WSV)
	0,0340	0,0218	0,0534	0,1449	0,1018	0,2273	0,4168	
	WS	AS	NF14	NF16	NF17	NF18	NF19	
WS	0,034	0,065	0,018	0,024	0,020	0,032	0,046	0,241
AS	0,011	0,022	0,013	0,021	0,017	0,028	0,046	0,159
NF14	0,102	0,087	0,053	0,036	0,034	0,032	0,046	0,392
NF16	0,204	0,153	0,214	0,145	0,306	0,076	0,069	1,166
NF17	0,170	0,131	0,160	0,048	0,102	0,076	0,083	0,770
NF18	0,238	0,174	0,374	0,435	0,306	0,227	0,139	1,893
NF19	0,306	0,196	0,480	0,869	0,509	0,682	0,417	3,460

Source: Author's calculation based on AHP method (2025)

After the value in the eigenmatrix is known, the next step is to assess consistency by collecting the values obtained in the previous calculation such as the weighted value of each alternative (WSV), the value of the alternative weight, and the calculation of the Consistency Vector by dividing the WSV / alternative weight and determining the value by summing the average of the Consistency Vector.$\lambda\ max$

Table 16. Alternative Consistency Vector to "PTW Published"

Alternative	WSV	Weighting Criteria	Consistency Vector
WS	0,241	0,034	7,067
AS	0,159	0,022	7,287
NF14	0,392	0,053	7,337
NF16	1,166	0,145	8,049
NF17	0,770	0,102	7,565
NF18	1,893	0,227	8,326
NF19	3,460	0,417	8,302
Lamda Max			7,705

Source: Author's calculation based on AHP method (2025)

The summary of the calculation of the table above yields the following consistency values:

- *n* : 7 (number of alternatives)
- *IR (Random Index)* : 1.32 (based on the table *Saaty*)
- *CI (Consistency Index)* : *CI*= $\lambda \frac{\lambda max - n}{n-1} = \ = 0{,}117 \frac{7{,}705-7}{7-1}$
- *CR (Consistency Ratio)* : *CR*= $\frac{CI}{IR} = = 0.089$ (consistent)$\frac{0{,}117}{1{,}32}$

From the overall analysis in each table above, it can be concluded that the alternative order (work site) that has the most effect on the number of PTWs published is "NF19" with a weight value of 0.417 (41.7%), "NF18" with a weight value of 0.227 (22.7%), "NF16" with a weight value of 0.1449 (14.49%), "NF17" with a weight value of 0.102 (10.2%), "NF14" with a weight value of 0.053 (5.3%), "WS" with a weight value of 0.034 (3.4%), and "US" with a weighted value of 0.022 (2.2%). The weighting and calculation carried out have also been assessed for consistency with a result of 0.089 or CONSISTENT.

Ranking Results for Each Alternative Work Location

The final stage in determining the level of risk of the work site is to analyze alternative rankings (work sites) based on the values obtained in the previous calculation. Ranking is calculated by multiplying the weight of the main criteria by the alternative score on each criterion and then adding them all together to get a score on each alternative.

Table 17. Alternative Score Matrix

Alternative Score Matrix						
Weight Main Criteria	**0,07365**	**0,47086**	**0,28401**	**0,17148**	**Shoes**	**Ranking**
Alternatives / Criteria	**JP**	**CA**	**JS**	**JT**		
WS	0,022	0,022	0,022	0,034	0,024	7
AS	0,034	0,038	0,033	0,022	0,033	6
NF14	0,060	0,050	0,067	0,053	0,056	5
NF16	0,122	0,097	0,098	0,145	0,107	4
NF17	0,158	0,140	0,130	0,102	0,132	3
NF18	0,270	0,243	0,237	0,227	0,241	2
NF19	0,333	0,410	0,414	0,417	0,407	1

Source: Author's calculation based on AHP method (2025)

After each alternative score is known, the next stage is to rank each alternative to see which work location has the highest to the lowest score. To confirm the overall analysis, the calculation of this method is also carried out using the Expert Choice software.

The AHP calculation that has been performed on Microsoft Excel has similar results to the Expert Choice software. Although there is a difference in values, it is very small and does not affect the rating of the overall analysis. Thus, it can be concluded that there are no errors in calculations with Microsoft Excel.

CONCLUSION

This study successfully applied conventional AHP to determine work site risk levels in construction, identifying four key criteria—critical activities (weight 0.4709, highest), SIMOPS (0.2840), PTW issued (0.1715), and number of workers (0.0736)—across seven sites, with all consistency ratios below 0.1 for reliability, validated by Super Decision software. NFQ Area 19 emerged as the highest-risk site (overall ranking: NFQ 19 > 18 > 17 > 16 > 14 > Assembly > Workshop), while the Workshop area posed minimal risk. For future research, integrating Fuzzy AHP or TOPSIS could address data uncertainty, with expanded criteria (e.g., environmental factors, equipment age) and validation across diverse construction firms to enhance generalizability.

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