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Development of Aspects of Safety Rating Tools (SRT) Using the Analytical Hierarchy Process (AHP) to Improve Construction Safety Performances

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ABSTRACT : *The construction industry in Indonesia continues to grow in line with the increasing demand for infrastructure followed by a high number of work accidents, indicating the need for a more effective safety system. This study aims to develop a Safety Rating Tools (SRT) based on the Analytic Hierarchy Process (AHP) to improve construction safety performance. The research methodology includes case studies, expert validation, and questionnaire surveys. AHP analysis is used to determine the priority weight of five key aspects in the construction safety management system: leadership and work participation (X1), safety planning (X2), safety support (X3), safety operations (X4), and safety evaluation(X5). The research findings indicate that developing AHP-based SRT can enhance construction safety performance by assigning priority weights to each aspect. X1 have the highest weight (27.014%), followed by X2 (21.491%), X3 (19.095%), X4 (17.960%), and X5 (14.440%). The relationship between SRT aspects and construction safety performance shows a significant influence. The conclusion of this study highlights that the AHP-based SRT development can serve as an effective evaluation tool in improving construction sector safety with a more systematic risk identification process and optimization of safety strategies for accidents in the construction sector can be significantly reduced.*

KEYWORDS - *Safety Rating Tools, Construction Safety Management System, Analytic Hierarchy Process, Work Safety, Construction.*

I. INTRODUCTION

The growth of construction industry in Indonesia followed by high rate of construction accidents, despite existing regulations such as Peraturan Menteri PUPR No. 10 Tahun 2021 on Sistem Manajemen Keselamatan Konstruksi (SMKK) [1]. The construction sector continues to grow, but safety performance remains a major challenge due to lack of effective safety implementation, complexity of construction projects, need for better risk identification and safety strategies, limited monitoring and evaluation, and urgency for enhanced safety rating tools (SRT). The increasing rate of accident is shown at Fig. 1:

Figure 1. Increasing rate of accident in construction (person)

From the picture, the increasing rate of accident happened in construction area is super alarming. It needs urgent solution to be applied immediately.

Previous research on construction safety has extensively explored safety management systems (SMS), risk analysis, and regulatory frameworks [2]. Studies conducted in Hong Kong and Indonesia emphasize the necessity of flexible and comprehensive safety monitoring systems to mitigate workplace accidents [3]. Prior research identifies leadership, safety planning, and systematic evaluation as critical factors in reducing construction-related risks. While regulations such as Permen PUPR No. 10/2021 have been introduced to enhance safety standards in Indonesia, studies reveal significant gaps in implementation, enforcement, and monitoring. Additionally, the application of the Analytic Hierarchy Process (AHP) in safety assessment has been explored, yet few studies have developed a structured Safety Rating Tool (SRT) using AHP specifically tailored to the Indonesian construction sector. This study addresses these gaps by developing and validating an AHP-based SRT, prioritizing key safety aspects, and testing its impact on real-world construction projects to improve safety performance systematically.

The thesis develops a Safety Rating Tool (SRT) based on the Analytical Hierarchy Process (AHP) to improve safety performance in construction. By prioritizing key safety aspects (leadership & participation, safety planning, support, operations, and evaluation), the study aims to create a more reliable and systematic framework for construction safety management.

This thesis contributes to construction safety by developing an AHP-based Safety Rating Tool (SRT) to enhance safety performance in Indonesia. Unlike previous studies, it provides a structured, data-driven model that prioritizes key safety aspects—leadership, planning, support, operations, and evaluation

II. Literature Review

2.1. Costruction

According to Permen PUPR No. 10 of 2021 on Construction Safety Management System (SMKK) guidelines, construction work refers to all or part of activities that include building, operation, maintenance, demolition, and reconstruction of a structure. Based on the Central Product Classification (CPC), construction work utilizing construction techniques is classified into building construction and civil construction.

Building construction involves the creation of workspaces with relatively limited locations and conditions, requiring effective management at every stage of progress. Project classification by scale is an essential approach in project management studies, particularly in the construction sector.

Civil construction projects, on the other hand, are characterized by modifying and controlling natural environments for human needs, often covering large and extensive areas. These projects also face diverse geological foundation conditions at different locations and demand advanced construction management to address challenges beyond just progress tracking. This classification helps in determining planning strategies, resource allocation, and effective project management.

Construction projects are categorized into small, medium, and large-scale projects [4]. Small-scale projects involve simple construction work with low investment and short execution time. Medium-scale projects are larger and more complex than small-scale projects, with higher investment values. Large-scale projects cover extensive construction work, high investment, and significant complexity. The key characteristic of large-scale projects is a high investment value, often reaching billions of rupiahs or more.

2.2. Construction Safety Performances

Construction safety encompasses all engineering activities that support construction work in meeting security, safety, health, and sustainability standards, ensuring the safety and health of workers, public safety, property, materials, construction equipment, and the environment (BPSDM, 2019).

The construction industry's activities involve highly complex stages, making it one of the sectors with the most diverse types of work, accompanied by various hazards and a high accident rate [5]. The Construction Safety Management System (SMKK) is a management system for the implementation of construction work to ensure construction safety. SMKK is regulated under the Ministerial Regulation of Public Works and Public Housing (Permen PUPR) No. 10 of 2021 concerning Construction Safety Management System Guidelines.

Rof'ati and Sutanto (2018) state that hazards refer to any condition or action that has the potential to cause damage, injury, or other disruptions. Work accidents are unintended and unexpected incidents that can result in harm to people and property (Permenaker No. 03/MEN/1998). According to Bird and Germain (1990), work accidents fall into three categories: accidents, which cause harm to people or property; incidents, which are undesirable events that have not yet caused harm; and near misses, which are events that nearly result in an incident or accident.

Based on the severity of the consequences, work accidents are classified into three types (Suma'mur, 1981):

1. Minor accidents, which require medical treatment but allow the worker to resume work or rest for less than two days.
2. Moderate accidents, which require medical treatment and more than two days of rest.
3. Severe accidents, which result in amputation or permanent disability.

to prevent work accidents in construction, hazard identification is essential. Ilma and Hebbie Adzim (2020) define hazard identification as the process of recognizing and assessing potential hazards in equipment, workplaces, work processes, procedures, and more. This process helps identify situations or events that may lead to accidents or occupational diseases. Several hazard identification methods commonly used in Indonesia's construction sector include Hazard Identification, Risk Assessment, and Risk Control (HIRARC), Job Safety Analysis (JSA), Hazard and Operability Study (HAZOP), and Failure Mode and Effect Analysis (FMEA)

These instruments play a crucial role in reducing workplace accidents and enhancing construction safety performance in Indonesia. The implementation of these methods aligns with government efforts to improve occupational health and safety (OHS) standards in construction. These instruments serve as the realization of SMKK, as regulated in Permen PUPR No. 10 of 2021.

2.3. Safety Rating Tools (SRT)

According to ISO 31000 and OHSAS 18001, Safety Rating Tools (SRT), also known as construction safety risk analysis, is a method and system used to evaluate hazards, assess risks, and determine necessary control measures to prevent accidents and injuries.

Risk identification is the first critical step in risk analysis. Once risks are identified, they are analyzed to determine the likelihood and impact of their occurrence. Risks are then assessed to determine whether they are acceptable or require mitigation measures.

Dr. Ir. Bambang Supriyadi, a civil engineering expert, emphasizes the importance of safety risk analysis in building construction projects, stating, *"Safety must be the top priority in every construction project. Without proper risk analysis, we risk facing accidents that could harm both workers and the project itself."* Similarly, Prof. Dr. Rina Lestari, a workplace safety specialist, adds, *"Strict safety procedures and adequate training for workers are essential steps to reduce accident risks on construction sites. Risk analysis must be an integral part of project planning."*

Efforts to enhance workplace safety protection require the implementation of the Construction Safety Management System (SMKK), as regulated under Ministerial Regulation of Public Works and Public Housing (Permen PUPR) No. 10 of 2021. The conceptual design of SMKK aims to ensure occupational safety and health throughout the construction project execution while minimizing negative environmental impacts.

Several key SMKK aspects influence overall construction performance, as outlined in Permen PUPR No. 10 of 2021:

1. Leadership and Worker Participation in Construction Safety
2. Construction Safety Planning
3. Construction Safety Support
4. Construction Safety Operations
5. Construction Safety Evaluation

These five aspects serve as preventive measures against construction accidents, known as leading indicators within the SMKK framework. To support SRT implementation under Permen PUPR No. 10 of 2021, several key safety management instruments are utilized in Indonesia, including:

1. Work Traffic Management Plan *(Rencana Manajemen Lalu Lintas Pekerjaan ((RMLLP))*
2. Environmental Management and Monitoring Plan *(Rencana Kerja Pengelolaan dan Pemantauan Lingkungan Hidup (RKPPL))*
3. Construction Safety Plan *(Rencana Keselamatan Konstruksi (RKK))*
4. Conceptual Design of Construction Safety Management (for planning and evaluation)
5. Construction Quality Program (for supervision and management)
6. Construction Work Quality Plan *(Rencana Mutu Pekerjaan Konstruksi (RMPK))*

Globally, countries such as the United States, Australia, and the United Kingdom also implement high safety standards in the construction sector:

1. Occupational Safety and Health Administration (OSHA) – United States: Provides strict workplace safety regulations, including the use of Safety Rating Tools.
2. Safe Work Australia: Develops occupational safety and health guidelines incorporating risk assessment tools.
3. Health and Safety Executive (HSE) – United Kingdom: Regulates workplace safety and provides guidance on risk assessment in construction.

The key differences between SRT in Indonesia and other countries lie in approach and methodology. In developed nations, integrated safety management systems and behavior-based approaches are more common. In contrast, Indonesia primarily relies on checklists and risk matrices.

Additionally, workplace safety awareness in developed countries is generally higher, with stricter regulation enforcement. In Indonesia, despite the existence of regulations, challenges in enforcement and worker awareness remain key obstacles. SRT models in other countries tend to be more comprehensive and integrated, allowing for deeper risk evaluations and more effective mitigation measures. While Indonesia has made progress, further improvements are needed through enhanced training and awareness programs. Weighting the aspects of the Construction Safety Management System (SMKK) is crucial, particularly based on case study findings from previous research, for several reasons:

1. Identifying Dominant Factors Affecting Construction Safety
2. Evaluating the Effectiveness of SMKK Implementation
3. Analyzing Barriers and Supporting Factors in SMKK Implementation
4. Applying SMKK to High-Risk Construction Projects

Based on recent studies, aspect weighting in SMKK is essential to:

1. Identify and prioritize key safety factors affecting construction projects.
2. Evaluate the effectiveness of SMKK implementation in a focused and objective manner.
3. Analyze obstacles and supporting elements in SMKK execution.
4. Adapt SMKK application to specific project risk levels.

By incorporating aspect weighting, SMKK implementation becomes more effective, efficient, and tailored to the unique safety requirements of each construction project.

2.4. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured decision-making method designed to assist individuals or groups in making complex decisions by comparing multiple alternatives based on various criteria (Thomas L. Saaty, 1970). The AHP method aims to break down complex problems into smaller, structured elements in a hierarchical format, making analysis and decision-making more manageable. AHP has some advantages which are AHP transforms broad and unstructured problems into a flexible and easily understandable model, AHP solves complex research problems through systematic and deductive integration, AHP can be applied to independent system elements without requiring a linear relationship, AHP represents natural human thinking, which tends to group system elements into different levels containing similar elements, AHP provides a measurement scale and method for determining priorities, AHP considers logical consistency in assessments used to establish priorities. AHP evaluates the relative priority of factors within a system, enabling decision-makers to choose the best alternative based on their goals, and AHP helps refine problem definitions and enhances assessment and understanding through an iterative process.

III. Research Methodology

This research process is structured step by step using a flowchart method to systematically address the research objectives and answer each research question in a measurable manner, ensuring that the goals are achieved effectively and efficiently**.** The methodology for each RQ is shown in Fig. 2:

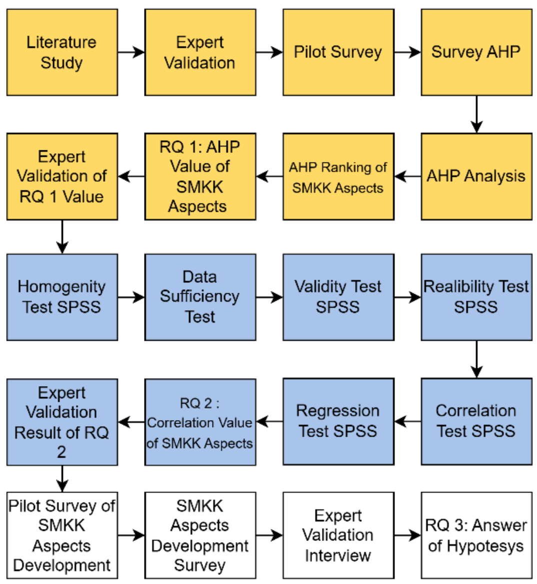

Figure 2. Methodology for each RQ

This study employs a quantitative research methodology using the Analytic Hierarchy Process (AHP) to develop and validate a Safety Rating Tool (SRT) for construction safety evaluation. The research follows a case study approach, supported by expert validation and survey methods to assess and prioritize key safety aspects. Data collection includes expert interviews to refine the SRT framework, questionnaires distributed to 92 construction professionals, and case studies analyzing real-world construction projects. The AHP method is applied to structure safety aspects into a hierarchical model, conduct pairwise comparisons, and determine priority weights while ensuring logical consistency through Consistency Ratio (CR) calculations. Additionally, statistical validation using SPSS is conducted to assess data reliability. The developed AHP-based SRT model is then implemented and tested on selected construction projects to evaluate its effectiveness in improving safety compliance and reducing accident risks.

IV. Result and Discussion

4.1. Aspects of SRT SMKK

Based on the literature review (Rosmariani, 2025; R. Arifuddin, 2024; and Mariana F., 2023) and expert validation**,** 5 (five) independent variables and 21 indicators have been identified as influencing the dependent variable of construction safety performance. The identified variables are in Table 1:

Tab;e 1. X & Y Variables

Code	Indicator
X1	Leadership and Worker Participation in Construction Safety
X.1.1	Management ensures its commitment to external and internal safety issues
X.1.2	Establishes an organizational structure for SMKK management
X.1.3	Defines construction safety commitments and workforce preparation

Code	Indicator
X.1.4	Conducts supervision, training, accountability, resource allocation, and support
X2	Construction Safety Planning
X.2.1	Implements Hazard Identification, Risk Assessment, Control, and Opportunities (IBPRP)
X.2.2	Establishes technical, managerial, and workforce action plans incorporated into facilities and programs
X.2.3	Ensures compliance with construction safety standards and regulations
X.2.4	Controls, designs, and reviews contracts
X3	Construction Safety Support
X.3.1	Determines resources such as technology, equipment, materials, and costs
X.3.2	Sets minimum competency standards for the workforce
X.3.3	Ensures commitment to the executing organization
X.3.4	Establishes communication management with all stakeholders
X.3.5	Determines documented information
X4	Construction Safety Operations
X.4.1	Plans the implementation of the Construction Safety Plan
X.4.2	Conducts control of construction safety operations
X.4.3	Establishes emergency preparation and response measures
X.4.4	Determines construction accident investigations
X5	Performance Evaluation of SMKK Implementation
X.5.1	Conducts monitoring or inspections
X.5.2	Conducts audits
X.5.3	Conducts evaluations
X.5.4	Establishes management reviews
Y1	Construction Safety Performance

4.2. AHP Result

Based on the results of AHP analysis, the findings include the AHP weights for the five independent variables (X), as presented in the Table 2:

Table 2. Ranking of SRT SMKK Aspects

Aspect of SMKK	AHP Value (%)	Ranking
Leadership and work participation	27,014	1
Construction Safety Plan	21,491	2
Construction Safety Support	19,095	3
Construction Safety Operation	17,960	4
Construction Safety Evaluation	14,440	5

From the AHP analysis result, the findings show that leadership and work participation account for 27.014%, safety planning 21.491%, safety support 19.095%, safety operations 17.960%, and safety evaluation 14.440%. The most significant factor influencing construction safety performance is leadership and work participation, while the least influential factor is safety evaluation.

Projects with high SRT compliance have lower accident rates and better adherence to safety standards **(**Permen PUPR No. 10 of 2021, ISO 45001**).** SRT helps identify projects with weak safety systems, allowing for quick corrective actions to be implemented.

4.3. Correlation Between Variable X and Y

Based on the correlation data processing result in SPSS, the correlation values are obtained as presented in the Table 3:

Table 3. SPSS Correlation Value

Variable		Value	Correlation
X1	X2	0,375	significant
	X3	0,150	Less significant
	X4	-0,414	Significant
	X5	-0,588	Significant
	Y	0,221	Significant
X2	X3	0,592	Significant
	X4	-0,065	Less significant
	X5	-0,372	Significant
	Y	0,624	Significant
X3	X4	0,205	Significant
	X5	-0,116	Less significant
	Y	0,770	Significant
X4	X5	0,366	Significant
	Y	0,386	Significant
X5	Y	0,085	Less significant

From the table the information shows that:

1. The correlation between leadership and worker participation (X1) and safety planning (X2) is significant (0.375), its correlation with safety support (X3) is less significant (0.150), with safety operations (X4) is significant (-0.414), with safety evaluation (X5) is significant (-0.588), and with construction performance (Y) is significant (0.221).
2. The correlation between safety planning (X2) and safety support (X3) is significant (0.592), its correlation with safety operations (X4) is less significant (-0.065), with safety evaluation (X5) is significant (-0.372), and with construction performance (Y) is significant (0.624).
3. The correlation between safety support (X3) and safety operations (X4) is significant (0.205), its correlation with safety evaluation (X5) is less significant (-0.116), and with construction performance (Y) is significant (0.770).
4. The correlation between safety operations (X4) and safety evaluation (X5) is significant (0.366), and its correlation with construction performance (Y) is significant (0.386).
5. The correlation between safety evaluation (X5) and construction performance (Y) is less significant (0.085).

From the table, the information also shows that X1, X2, X3, and X4 significantly influence construction safety performance, while X5 has less significant impact on construction safety performance.

From the regression analysis, obtained using SPSS, the modeling of the relationship between the independent variables (X) representing SRT SMKK aspects and the dependent variable (Y) representing construction performances is formulated as follow:

$$Y = 0{,}258 + 0{,}193X_1 + 0{,}193X_2 + 0{,}204X_3 + 0{,}205X_4 + 0{,}186X_5$$

Explanation:

- Intercept (0.258): Indicates that without leadership and worker participation, safety planning, safety support, safety operations, and safety evaluation, construction safety performance has a low baseline value.
- Coefficient X1 (0.193): Leadership and worker participation in construction safety have a significant and positive contribution.
- Coefficient X2 (0.193): Safety planning has a significant and positive contribution.
- Coefficient X3 (0.204): Safety support has a significant and positive contribution.
- Coefficient X4 (0.205): Safety operations have a significant and positive contribution, making it the most influential variable in improving safety performance. This emphasizes the importance of more efficient safety operations in construction.
- Coefficient X5 (0.186): Safety evaluation has a significant and positive contribution.

Expert validation confirms that this Safety Rating Tool (SRT) model is not only statistically relevant but also practically applicable. Experts agree that developing SRT using the AHP method enhances construction safety performance. This model demonstrates that SRT SMKK development has a real impact on improving construction safety performance.

The AHP analysis considers the overall ranking of SMKK aspects based on data from 92 respondents, while the regression analysis evaluates the individual weights of SRT SMKK aspects per respondent's response. Both analyses produce the same ranking of importance.

From the correlation test results in RQ1, a significant relationship is found among the variables: leadership and worker participation (X1), safety planning (X2), safety support (X3), safety operations (X4), safety evaluation (X5), and construction performance (Y), which is visually represented in Fig. 2 and Fig. 3:

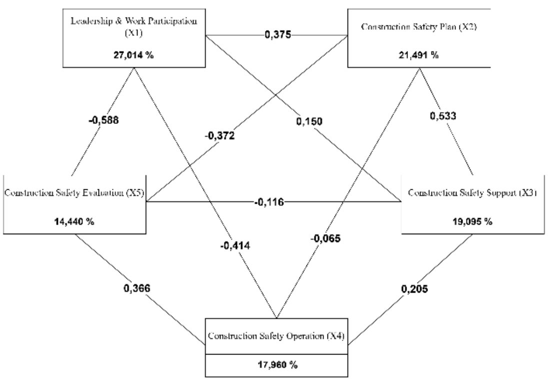

Fig 2. Correlation between X Variables

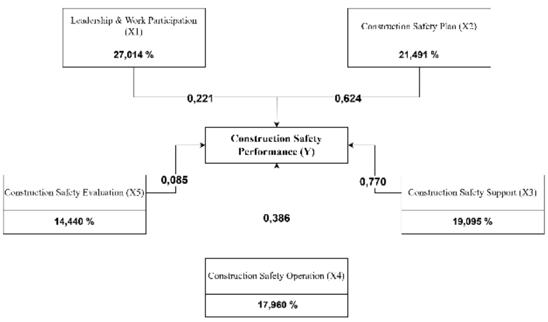

Fig 3. Correlation Between X & Y Variables

4.4. Implementation of the SRT Model in Projects

From the questionnaire on the application of AHP-based SRT SMKK weighting, the following project assessments were obtained at table 4:

Table 4. AHP-based SMKK Weighting Projects

	Kemenko IKN (%)	**Stadion Surajaya Lamongan (%)**	**RS UPT Vertikal Surabaya (%)**
Leadership and work participation	27,014	24,3126	25,6633
Construction Safety Plan	21,491	21,491	19,3419
Construction Safety Support	16,8036	16,0398	16,8036
Construction Safety Operation	17,96	17,96	15,266
Construction Safety Evaluation	14,44	13,718	12,996
Total Value	97,7086	93,5214	90,0708

- Kemenko IKN Project with a score of 97.709%
- Surajaya Lamongan Stadium Project with a score of 93.522%
- UPT Vertical Hospital Surabaya Project with a score of 90.071%

These results indicate that the development of SRT SMKK categorizes all three projects (Kemenko IKN Project, Lamongan Stadium Project, and UPT Vertical Hospital Surabaya Project) under the "very satisfactory" safety performance category (ranging between 85-100%).

Based on these results, construction professionals provided the following recommendations for improvement:

1. The project assessment scale needs to be expanded for greater accuracy.
2. Project performance evaluation forms should be filled out by inspectors for regular site inspections.
3. Sub-indicators and descriptions in the performance evaluation form should be adjusted based on specific tasks being inspected to enhance effectiveness.

Interviews with stakeholders involved in the three construction projects revealed the following key findings:

1. Leadership and Worker Participation (AHP Weight: 27.014%, Priority 1)
    - Project leadership plays a crucial role in ensuring smooth project execution and worker participation in safety measures.
    - Management involvement in safety-related decision-making directly impacts accident prevention.
    - Communication between management and workers is essential to enhance safety awareness through training and safety briefings.
2. Safety Planning (AHP Weight: 21.491%, Priority 2)
    - High-quality safety planning, including risk identification, significantly influences on-site safety performance.
    - A clear Construction Safety Plan (RKK) is a key factor in reducing workplace accidents.
    - Periodic revisions to safety plans are necessary to improve effectiveness and adapt to project dynamics.
3. Resource Support (AHP Weight: 19.095%, Priority 3)
    - The availability of resources such as budgets and safety equipment are critical to the successful implementation of SMKK.
    - Proper training for workers enhances their ability to follow safety procedures.
    - Management support in providing healthcare facilities and first aid stations is crucial for rapid response to workplace accidents.
4. Safety Operations (AHP Weight: 17.960%, Priority 4)
    - Regular safety inspections increase worker compliance with safety procedures.
    - An effective incident reporting system allows for faster and more accurate preventive actions.
    - Risk communication during work activities plays a crucial role in reducing accident potential, particularly through safety inductions and other safety measures.
5. Performance Evaluation (AHP Weight: 14.440%, Priority 5)
    - Periodic evaluations of SMKK performance help identify areas that need improvement for better workplace safety.
    - Worker feedback contributes significantly to improve safety management systems in construction projects.
    - Measuring the success of safety programs has a significant impact on shaping future safety policies and procedures.

These findings confirm that leadership, planning, and resource support play a major role in the successful implementation of Safety Rating Tools (SRT). Additionally, safety operations and performance evaluation are key factors in enhancing the safety culture in the construction sector.

V. CONCLUSION

This study aims to develop Safety Rating Tools (SRT) in the construction industry using the Analytic Hierarchy Process (AHP) to improve occupational safety performance in construction projects.

The results of the AHP analyses indicate that leadership and worker participation have the highest weight in influencing safety performance in construction projects, with a score of 27.014%. This finding highlights the crucial role of leadership in construction companies, both at the management and project supervisor levels, in ensuring worker compliance with safety standards. Other factors with significant weights include:

- Safety planning (21.491%), reflecting the importance of risk mitigation strategies from the early stages of the project. Without proper planning, construction projects become more vulnerable to workplace accidents.
- Safety support (19.095%), involving the provision of appropriate personal protective equipment (PPE), occupational health facilities, and clear regulations on safety procedures.
- Safety operations (17.960%), covering the implementation of on-site safety standards, including routine inspections and adherence to safe work procedures.
- Safety evaluation (14.440%), which measures the effectiveness of the safety system and enables continuous improvement.

Overall, these results confirm that leadership and worker participation are key factors in improving construction safety, followed by proper planning, sufficient support, and ongoing evaluation to ensure the effectiveness of safety systems.

This study also successfully identifies the relationship between SRT aspects and improvements in construction safety performance. The model developed in this research demonstrates that each SRT aspect contributes differently to the effectiveness of safety implementation in construction projects.

Through expert validation, SRT is recognized as an evaluation tool that helps identify weaknesses in construction safety systems. The AHP-based model allows decision-makers to prioritize safety aspects that require improvement, enabling more effective resource allocation.

The findings also show that management support, in the form of safety training, proper PPE provision, and policies supporting workplace safety, plays a crucial role in the successful implementation of the SRT model. Therefore, construction companies should continuously invest in worker training and capacity building to enhance their understanding of workplace safety and its proper application in the field.

Based on these findings, it can be concluded that the development of AHP-based Safety Rating Tools (SRT) is an effective approach to improving construction safety performance in Indonesia. The key factors influencing SRT implementation effectiveness are leadership and worker participation, followed by safety planning, support, operations, and evaluation. The model developed in this study allows construction projects to systematically identify safety risks, prioritize actions, and improve compliance with workplace safety regulations.

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