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Original Article

Study of Measuring the Application of Construction Safety Management Systems (CSMS) in Indonesia using the Analytic Hierarchy Process

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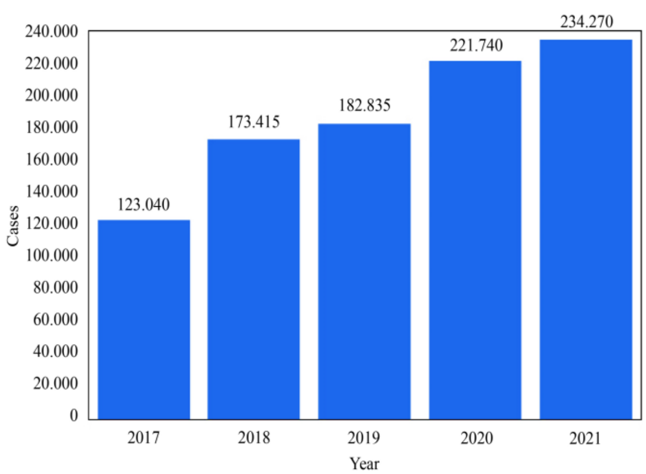
Abstract - *The Indonesian government continues to struggle with how to undertake construction projects safely. The Construction Safety Management System (CSMS) requirements for construction projects are governed by the Indonesian government through the Ministry of Public Works and Housing. Audit surveys are used to gather data for construction projects. Project managers, safety officers, and contractors who were on the job site were interviewed and provided observational data. The purpose of this study is to examine how construction projects can use standards for construction safety management systems. The Analytic Hierarchy Process (AHP) method and Mic software are used in the research methodology. According to the analysis's findings, the implementation of CSMS as a policy for preventing accidents in construction projects in Indonesia is supported by continuous review and corrective action (weight value of 0.225), which is followed by compliance with standard safety procedures at work (weight value of 0.374).*

Keywords - *Construction Safety Management System (CSMS), Construction Project, Indonesia, Analytic Hierarchy Process (AHP).*

1. Introduction

The accident rate in Indonesia grew by 5.65% over the prior year in 2020, per data from the Indonesian Insurance and Social Security (BPJS) Agency [1]. As can be seen in Fig. 1 [1], Indonesia experiences an increase in the number of workplace accidents every year.



Source: Indonesian Insurance and Social Security (BPJS) Agency [1]

Fig. 1 The number of work accidents in Indonesia (2017 – 2021)

Construction has a greater rate of workplace accidents than other industries, according to data from the International Labor Organization (ILO) [2–6]. One of the riskiest industries in the world is the construction sector [7, 8]. Due to lax work safety management system standards implementation, there are frequently accidents in building projects [9]. The implementation of the Construction Safety Management System (CSMS) standards in Indonesian building projects is still subpar, according to data from the monitoring and evaluation conducted by the Indonesian Ministry of Public Works and Public Housing [10].

A technique used to regulate safety operations in order to provide a secure working environment on the construction site is known as construction safety management [11]. Also, prior research reveals that a thorough safety management system is an integral aspect of the safety culture in every business. Nonetheless, a safety management system (SMS) and effective safety practices might differ at each level and organization for a number of reasons. The incidence and occurrence of unwelcome workplace mishaps would undoubtedly decrease with the implementation of a well-organized and flawless safety management system [12]. Decisions taken during the planning and design phases have a significant impact on safety during the construction project.

Four categories of construction safety can be distinguished: planning for safety, employee safety training, first aid and medical procedures, and management safety policies [13]. Although numerous studies have measured the relative efficacy of various techniques.

Starting with the stage of service provider selection and continuing through operation and maintenance, the execution of the CSMS regulation is a program that effectively realizes the prevention of work accidents in building projects.

The Construction Safety Management System (CSMS), which is governed by the Regulation of the Ministry of Public Works and Public Housing Number 10 of 2021, must be implemented in order to ensure workplace safety more effectively. The management flow of businesses and construction parties in construction project activities is described in full in this regulation. The audit system, which is an evaluation and measurement of a project's implementation, cannot be isolated from the implementation of the Construction Safety Management System. In truth, the audit on the use of CSMS in construction projects was not adequately completed in its entirety.

Based on these concerns, a thorough investigation was conducted to evaluate the degree to which each CSMS element was applied in building projects and the results of that investigation are presented in this report. The study's findings provide an excellent measuring instrument for determining how well safety rules are being implemented, particularly on building projects..

2. Literature Review

2.1. Accident

Working on projects is an inherently risk-prone activity, and the risk element increases. Working on projects can cause accidents [14]. An accident in a construction project is an unwanted event that results in losses from human aspects such as fatalities, injuries, etc. Losses from other accidents are caused by economic aspects, such as the loss of compensation for damage due to accidents [15].

2.2. Construction Safety Management System (CSMS)

In Indonesia, the safety management system (SMS) has been regulated by the Indonesian government regulation. Construction work is regulated through the Ministry of Public Works and Public Housing of the Republic of Indonesia Regulation No. 10/PRT/2021.

Improvements to CSMS regulations are underway, along with a new paradigm shift in the concept of occupational safety and health in construction projects, with a focus on protecting human resources (labor) in construction safety, where overall safety is an aspect of the implementation of construction work.

The concept of construction safety based on the CSMS regulation is the fulfillment of four (four) measures consisting of (i) construction engineering safety, including accident protection of materials, construction equipment, and implementation methods in construction projects; (ii) occupational safety and health, including protection from accidents for labor, guests visiting the project, sub-contractor staff, and vendor staff; (iii) public safety, including accident protection for the public or communities around the project area; and (iv) environmental protection, including accident protection of the project environment, land, air, water.

Based on regulations, the Construction Safety Management System (CSMS) is part of the management system for the implementation of work on construction projects to ensure the realization of "construction safety," namely the fulfillment of safety, health, and sustainability standards that ensure the safety of construction engineering, the safety and health of workers' work, public safety, and the environment (Ministry of Public Works and Public Housing Regulation No. 10/PRT/2021).

CSMS regulations have adopted international safety standards, including ISO 45001:2018. CSMS regulations regulate all aspects of work safety, starting with safety planning, safety implementation, safety monitoring and evaluation, and then continuous improvement.

Table 1. Table Element and Sub-Element Regulation CSMS (Ministry of Public Works and Public Housing of the Republic of Indonesia Regulation No.10/PRT/2021)

Main Element	Sub-Element
A. Commitment & Leadership (CL)	A1. Top management commitment
	A2. Leadership and labor involvement
B. Planning (P)	B1. Safety design development and maintenance design
	B2. Construction Safety Plan
	B3. Design for the Safety Plan
	B4. Contract review
C. Implementation (I)	C1. Product purchasing and control
	C2. Compliance with Standard Safety Procedures at work
	C3. Material management and delivery
D. Monitoring and Evaluation (ME)	D1. Safety monitoring and evaluation standards
	D2. Repair report Accident investigation and reporting
	D3. A safety inspection, audit, and evaluation
E. Continous Improvement (CI)	E1. Continuous review and corrective action

CSMC regulations have set construction safety standards throughout the construction project phases, starting with the conceptual project phases, project planning phases, project execution phases, project closing phases, project maintenance and operational phases, and then the project demolition phases.

The construction engineering industry has its own inherent and distinctive features that influence the safety culture in strategic and operational aspects [24]. In the construction project concept development phases, the application of CSCM regulations includes safety review activities on construction projects in project study facilitation activities.

At the detailed engineering design phase, design development is complemented by a safety plan. Furthermore, the safety plan is implemented at the site during the project implementation phase and continuously monitored and evaluated. In the project closing phase, the construction project submission process is also equipped with a safety performance report.

At the maintenance and operational phase of building construction, it is equipped with standard safety procedures for building maintenance and operations. Furthermore, the disassembly process must also adhere to safety standards during the demolition phase.

2.3. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) was developed by Saaty [16,17]. This method is one of the multi-criteria decision-making models that can help the human frame of mind, in which the factors of logic, experience, knowledge, emotions, and feelings are optimized into a systematic process.

Furthermore, AHP is a decision-making method that was developed to determine the priority of several alternatives when several criteria must be considered, as well as to help decision-makers arrange complex problems into a form of an integrated hierarchy or series of levels [18,19].

It has a particular application in group decision-making. It is used around the world in a wide variety of decision situations in fields such as government, business, industry, healthcare, and education. Rather than prescribing a "correct" decision, the AHP helps decision-makers find one that best suits their goals and their understanding of the problem [12,25].

The AHP method is used in this study to determine the priority of the main elements of implementing CSMS regulations. The AHP method helps in grouping elements and sub-elements in structured groups and a hierarchy, then inserts a numerical value instead of the respondent's perception as a relative comparison of Expert Choice.

3. Methodology

3.1. Research Flow Diagram

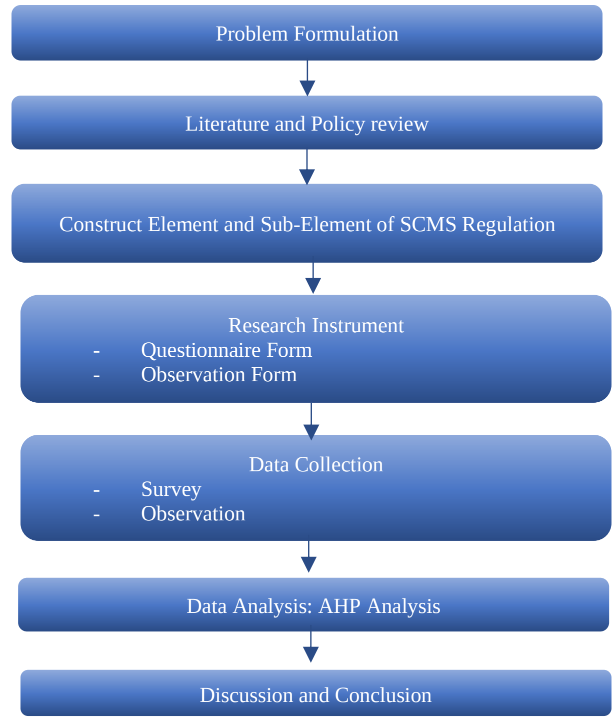


Fig. 2 Research Flow Chart

3.2. Research Instrument

According to Kerlinger (1996), survey research is research conducted on large or small populations, but the data studied are sample data from a population so that relative occurrences, distributions, and relationships between sociological and psychological variables are found.

3.3. Data Collection

This study has two data sources: primary data, information data obtained directly from field observations, and secondary data, complimentary preliminary data, which is generally obtained from library sources.

The Questionnaire Form is a data collection instrument to measure further comparisons of the application of elements and sub-elements of the CSMS Regulation, which significantly affects accident prevention in construction projects.

The measurement scale uses the Random Consistency Index Method. The data collection results from the questionnaire form were further verified through direct observation at the construction project site. A total of 80 (eighty) respondents from five (five) building construction projects that are under construction in Makassar, South Sulawesi Province of Indonesia

Table 2. Table Comparison of Pairwise Comparison

Level of Interest	Definition
1	Both elements have an equally important effect
3	The first main element/sub-element is a little more important than the other main elements/sub
5	The first main element/sub-element is more important than the other main elements/sub
7	The first main element/sub-element is very important more than the other main elements/sub
9	The first main element/sub-element is absolutely more important than the other main elements/sub

Data collection techniques used included closed and open answers. Questionnaires are made so that respondents can provide answers to several alternatives or only one solution. The questionnaire is distributed to all sample respondents, including the project manager, site manager, safety officer, and workers/staff at the site.

3.4. Data Analysis

Data analysis used the Analytic Hierarchy Process (AHP) method with the following basic principles:

3.4.1. Hierarchical arrangement of elements and sub-elements of CSMS Regulation

The first step is that CSMS regulation is first broken down into main elements and sub-elements of CSMS regulation. Furthermore, the hypothetical model was developed by structuring and synthesizing the elements and sub-elements of the CSMS regulation hierarchically.

3.4.2. Comparison of Pairwise Comparison Matrix

After developing the hypothesis of elements and sub-elements of CSMS regulation, pairwise comparisons were then made, namely comparing each element and sub-element obtained. The numerical value is assigned to all comparison scales. Absolute numbers on the scale are the best approximation to pairwise comparisons.

3.4.3. Eigenvalue and Eigenvektor

After the respondent has entered his perception of the importance of the elements and sub-elements of the regulation CSMS, the priority weight calculation is carried out using matrix and vector operations. The formula for calculating the eigenvalue and the eigenvector is

$$A.w = \lambda.w$$

w = eigenvector
λ = eigenvalue
A = matriks bujursangkar

3.4.4. Consistency Index/CI

The calculation of the consistency index value can be done with the formula:

$$CI = \left(\frac{\lambda_{max} - n}{n-1}\right)$$

CI = consistency index
λmax =eigenvalue maximum
n = matrix order

3.4.5. Random Index

The random index represents the average consistency of a comparison matrix measuring 1 to 10 obtained from an experiment at the Oak Ridge National Laboratory by the Wharton School.

Table 3. Tabel Random Consistency Index (RI)

N	1	2	3	4	5	6	7	8	9	10
R	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.41

3.4.6. Consistency Ratio

To calculate the value of the consistency ratio by using the calculation formula:

$$CR = \sqrt{\frac{CI}{RI}}$$

CR = Consistency Ratio
RI = Random Consistency Index

Measurements of consistency aim to ensure the consistency of the responses given by the respondents. If CR < 0.1, the pairwise comparison value in the given element and sub-elements matrix are consistent. If CR > 0.1, then the pairwise comparison value in the given element and subelement matrix is inconsistent. So if it is not consistent, then filling in the values in the paired matrix on the elements and sub-elements must be repeated.

4. Results and Discussion

4.1. Hierarchy of Problems

Hierarchical arrangement After the problem is defined, the next step is to break down the whole issue into its elements. The elements and sub-elements in this study are the criteria and sub-criteria used by companies in selecting the regulations of CSMS, as referred to in [20].

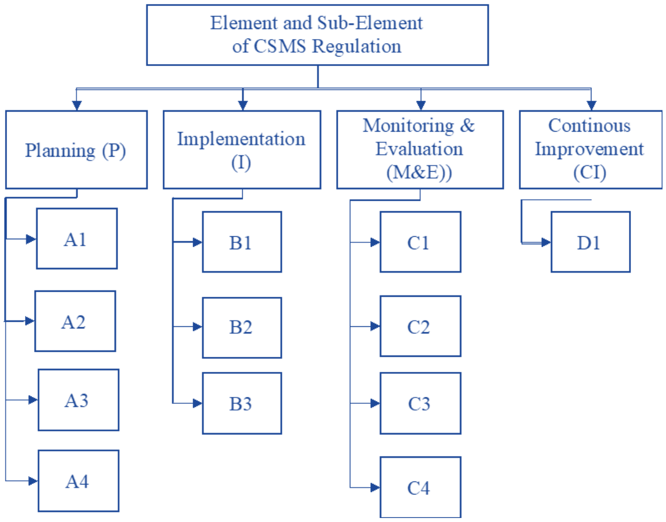


Fig. 2 Hierarchy chart of Elements and Sub-Elements of CSMS Regulation

4.2. Pairwise Comparison Matrix

Describe each element's relative contribution of influence to each of the criteria goals at the level above it.

Table 4. Table Pairwise Comparison Matrix between the main element

Main Elements	CL	P	I	M & E	CI
CL	1				
P		1			
I			1		
M & I				1	
CI					1

4.3. Normalization Matrix

The respondents' assessments obtained were then normalized using a matrix and geometry (geometric mean). The normalization calculation is done by dividing the value by the total number of column values. The results are shown in the following Table 5.

The total row in the normalized results is then divided by the number of criteria to get the weight of the requirements. The following results show the value of the criteria's weight.

Table 5. Table Pairwise Comparison Matrix between the main element of CSMS Regulation

ME	CL	P	I	M & E	CI
CL	0.3	0.1	0.3	0.1	0.2
P	0.1	0.1	0.083	0.083	0.131
I	0.3	0.3	0.417	0.417	0.395
M & E	0.1	0.1	0.083	0.083	0.079
CI	0.2	0.2	0.417	0.417	0.395

Table 6. Table Main Element Weight

Main Element	Weight
Commitment & Leadership (CL)	0.310
Planning (P)	0.099
Implementation (I)	0.301
Monitoring & Evaluation (ME)	0.086
Continuous Improvement (CI)	0.204

Table 7. Table Variable Global Weight Value

No	Sub-element of CSMS	Global Weight
A1	Top management commitment	0.156
A2	Leadership and labor involvement	0.132
B1	Safety design development and maintenance design	0.055
B2	Construction safety plan	0.013
B3	Design for safety control	0.028
B4	Contract review	0.017
C1	Product purchasing and control	0.05
C2	Compliance with Standard Safety procedures at work	0.374**
C3	Material management and delivery	0.082
D1	Safety monitoring and evaluation standards	0.034
D2	Repair report	0.014
D3	Accident investigation and reporting	0.027
D4	Safety inspection, audit and evaluation	0.081
E1	Continuous review and corrective action	0.225**

The results of the analysis show that the commitment and leadership element (CL) has the highest weight (0.310), followed by the implementation element (weight value 0.301) and continuous improvement (weight value 0.204).

4.4. Calculating Global Weight

After each criterion and sub-criteria are found, synthesis is carried out to obtain the overall alternative weight of the existing standards. Previously, the weight or priority (local priority) had to be searched for the global value (global priority) first. To get the global priority, multiply the local priority by the above priority level.

4.5. Consistency Index Value of Each Criterion

This consistency measurement is intended to show the inconsistency of the responses given by the respondents. If CR is less than or equal to 0.1, then the pairwise comparison value in the given criteria matrix is consistent. If CR > 0.1, then the pairwise comparison value in the given criteria matrix is inconsistent.

Table 8. Table Value of the Consistency Ratio (CR) Criteria

Element	CR	Description
Commitment & Leadership	0.030	Consistent
Planning (P)	0.01	Consistent
Implementation	0.02	Consistent
Monitoring & Evaluation (M&E)	0.02	Consistent
Continuous Improvement (CI)	0.02	Consistent

The data above shows that all the main variables (level 1) have a CR of 0.1, so the value of pairwise comparisons in the given criteria matrix is consistent.

4.6. Consistency Index Value of Each Criterion

After determining the value of the global weight and the consistency value of the variable ratio, a parameter model for measuring the performance of CSMS is made can be described in the Table 9.

The results of the sub-element comparison analysis show that the sub-elements (i) Compliance with Standard Safety Procedures at Work and Continuous Review and Corrective Action are very important policies to implement to prevent accidents in construction projects. These results indicate that the implementation of construction safety policies in accident prevention focuses more on safety construction programs at the site, such as ensuring that all work that takes place is in accordance with safety standards. It is necessary to further regulate the technical standards of construction work as a labor guide in carrying out work in the field, for example, safety standards in excavation work, structural work safety standards, etc.

Table 9. Table Parameters for measuring the CSMS

No	Sub Element	Implementation Achievement Level
		Maximum Achievement Criteria
1	Top management commitment	11.00%
2	Leadership and labor involvement	13.5%
3	Safety design development and maintenance design	5.5%
4	Construction safety plan	1.3%
5	Design for safety control	2.8%
6	Contract review	1.7%
7	Product purchasing and control	0.5%
8	Compliance with Standard Safety procedures at work	37.4%
9	Material management and delivery	8.2%
10	Safety monitoring and evaluation standards	3.4%
11	Repair report	1.4%
12	Accident investigation and reporting	2.7%
13	Safety inspection, audit and evaluation	8.1%
14	Continuous review and corrective action	22.5%

5. Conclusion

The results of the identification of elements and sub-elements of CSMS regulations on construction projects through a literature and policy study obtained five main elements, including (i) safety commitment and leadership elements; (ii) safety planning elements; (iii) safety implementation elements; (iv) monitoring and evaluation elements; and (v) continuous improvement safety elements. Each main element consists of sub-elements involved in a safety commitment and leadership element, i.e. top management commitment and Leadership and labor involvement. Sub-element of the planning element, i.e., safety design, development, and maintenance design; construction safety plan; design for safety control; contract review. Sub-element of the instrument element, i.e., product purchasing and control, compliance with standard safety procedures at work, material management, and delivery. Sub-element of the planning element, i.e., safety design, development, and maintenance design; construction safety plan; design for safety control; contract review. Sub-element of the instrument element, i.e., product purchasing and control, compliance with standard safety procedures at work, material management, and delivery. Sub-element of the monitoring and evaluation element, i.e., safety monitoring and evaluation standards, repair reports, accident investigation and reporting, safety inspection, audit, and evaluation and sub-element of the continuous improvement element, i.e., continuous review and corrective action.

Furthermore, the analysis results show that compliance with standard safety procedures at work has the highest weight (0.374), followed by continuous review and corrective action (weight value 0.225), which contribute to implementing CSMS as a policy for preventing accidents in construction projects.

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