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Enhancing Construction Safety Evaluation Through a Standardized Rating Tool System

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Abstract

Indonesia has achieved considerable advancements in infrastructure development over the past decade; yet, the incidence of work-related accidents in the construction sector continues to be elevated. Data indicates that the rising trend of infrastructure projects in Indonesia correlates with the annual increase in work-related accidents. This signifies that a construction safety issue persists. Despite the establishment of pertinent rules, the execution of the construction safety management system remains suboptimal. Noncompliance with safety rules is a primary contributor to construction accidents. Consequently, measurement is essential to evaluate the enforcement of construction safety regulations. Regrettably, the execution of safety performance metrics in building projects has been inadequate. It is executed customarily using non-standardized parameters, differing from one project to another. This project seeks to create a rating tool system for assessing construction safety performance and to analyze the relationship model between information systems and safety rating tools in relation to construction safety performance. This study employs both qualitative and quantitative methodologies. The initial phase involved the development of an information system for measuring construction safety performance, utilizing characteristics derived via expert validation. The second stage examined the impact of the system on construction safety performance. The findings indicated that the information system and safety rating tools positively impact construction safety performance. Furthermore, the Safety Rating Tools system standardizes the assessment of construction safety performance, rendering it more straightforward and efficient. The evaluation results aim to enhance compliance to safety standards to prevent building mishaps.

Keywords: Safety Rating Tools; Safety Evaluation; Construction Safety Performance; Safety Management System; Indonesian Construction Projects.

1. Introduction

The construction industry is a crucial catalyst for Indonesia's economy. The government's focus on the construction sector is seen in the 2022 budget allocation for the Ministry of Public Works and Housing (PUPR), amounting to IDR 101 trillion. This budget emphasizes the fulfillment of national strategic initiatives, the development of public

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infrastructure, and the establishment of infrastructure for the future capital city (IKN) [1]. IKN, designated as the forthcoming administrative capital, is one of the National Strategic Projects (PSN) now under construction, comprising governmental buildings and additional infrastructure. High-rise construction projects in IKN employ the design-build (DB) methodology, considering the substantial risks, complexities, and uncertainties associated with the efforts [2, 3]. The design-build procurement method is increasingly employed in numerous national infrastructure projects, especially those linked to the Ministry of PUPR, to expedite infrastructure development in Indonesia.

Over the past decade, Indonesia's construction sector has experienced substantial growth. Nonetheless, its safety performance is still insufficient [4]. The frequency of construction accidents is rising annually, as demonstrated by the recent occurrence at the Attorney General's Office complex, which led to the temporary suspension of MRT Jakarta operations [5]. Construction site accidents represent a significant proportion of worldwide industrial accidents. Data from Japan, South Korea, Singapore, and Hong Kong reveal that, between 1995 and 2005, construction site accidents constituted 20% of all industrial incidents [6-9]. The frequency of accidents in construction projects in Indonesia surpasses that of other industries. The construction industry is prone to workplace accidents, particularly in high-rise building projects, which are complex and require significant work at elevated heights. Such undertakings entail significant hazards, with falls from heights frequently resulting in injuries that may range from minor to catastrophic.

The Indonesian government has instituted regulations and methods to reduce accidents in construction projects. The Minister of Public Works and Housing Regulation No. 10 of 2021 specifies the protocols for the Construction Safety Management System (CSMS) [10]. Despite these limitations, construction safety performance remains insufficient, as evidenced by the persistently high number of accidents thus far [11]. The continuous improvement of safety performance requires an efficient safety management system. Therefore, a measurement tool is necessary to evaluate the implementation of construction safety requirements to achieve the intended safety performance.

The implementation of CSMS standards is closely associated with the audit methodologies employed to assess the safety performance of a construction project. Previous studies have extensively analyzed construction safety audit protocols. However, there is inadequate discussion concerning standardized assessment procedures utilizing measurement devices. The evaluation of CSMS deployment in construction projects has not been comprehensively conducted [12]. The mortality and injury rates in construction over the past decade highlight the imperative of implementing a system that provides real-time data on safety metrics across the industry. Consequently, it is logical to utilize information and communication technology, which directly impacts project safety [13]. Data to improve safety protocols for construction projects may be found in a construction safety management information system [14]. An information system must be designed to facilitate more efficient, organized, accelerated, and secure access to information.

Numerous prior studies have contributed to the advancement of research on the assessment of construction safety implementation. Performance measurement constitutes a component of the monitoring and evaluation of CSMS regulations. The safety performance metrics presently employed in the industry lack sufficient sensitivity for application in construction projects. Standardizing safety performance measures is essential for true effectiveness. Previous research has established a safety audit standard to enhance the safety elements of construction [2]. Nonetheless, there is a necessity for a simpler, faster, and efficient method to assess safety performance, enabling real-time monitoring of ratings. This study seeks to establish a measurement system (rating tools) for evaluating the construction safety performance of High-Rise Design-Build projects. This information system will serve as a database and enhance compliance with safety standards.

2. Research Material

2.1. Information System for Assessing Safety Performance

In the current technological era, the advancement of information systems in the construction sector is crucial for improving workplace safety. A fundamental purpose of employing information systems is to efficiently convert data into information or knowledge [15]. Information systems are employed to acquire, organize, collect, assess, and disseminate data with certain objectives in mind [16]. Information systems, especially websites, are essential as they provide convenient access to information available on the internet, accessible at any time and from any location. Websites comprise a series of interlinked pages that contain documents and graphics hosted on a web server [17].

In the construction sector, websites can function as assessment tools that consumers can utilize to appraise construction safety performance. Construction safety performance pertains to the results and work behaviors attained via the implementation of safety management systems to guarantee construction safety. Nugroho et al. [2] elucidates facets pertaining to information systems manifested as websites. The indicators for information systems encompass usability, which pertains to the website's efficacy in delivering user benefits; operational performance, which signifies the website's capability and reliability during use; and design, which refers to the visual elements that facilitate user interactions. Fundamental activities in program development encompass input, process, and output [18], which provide a framework for comprehending and assessing the workflow in the creation of web-based information systems. Various methodologies, such as the Extreme Programming technique, can be employed in website development. This approach comprises four phases: planning, design, coding, and testing. It is one of the most precise methodologies inside agile frameworks that aids in developing software customized to client requirements [19].

2.2. Safety Rating Tools

Measurement in construction safety is essential for attaining more efficient safety management goals. Accurate measurement aids in evaluating, tracking, regulating, and enhancing current safety performance [20]. It facilitates the formulation of explicit goals and objectives for enhanced safety management [21]. Safety Rating Tools are devices utilized to assess the safety performance of a construction project or organization. An audit system serves as an evaluative and measurement instrument for assessing a project's construction safety performance concerning the execution of CSMS rules [22]. This entails completing forms that include audit criteria, which function as indications for safety rating instruments, serving as checkpoints for the implementation of CSMS. Nugroho et al.'s [23] examines the strategy for formulating risk-based construction safety audit process standards and the auditing procedures during the design and construction phases by amalgamating ISO 19011:2018 and the Regulation of the Minister of Public Works and Housing No. 10 of 2021 as criteria for the Construction Safety Management System (CSMS). Based on these criteria and relevant regulations [10], five components can be utilized to assess safety ratings: Leadership and Worker Participation in Construction Safety, Construction Safety Planning, Construction Safety Support, Construction Safety Operations, and Construction Safety Performance Evaluation.

2.3. Construction Safety Performance

Construction safety is a crucial concern in a project. Safety indicators are utilized to assess safety levels in building projects, enabling managers to make educated decisions regarding necessary measures; these activities, prompted by safety indicators, aim to avert future accidents [24]. Assessing safety performance seeks to furnish a comprehensive overview of a project's efficacy and is frequently employed to juxtapose initiatives or corporations against industry benchmarks [25]. Construction safety performance entails attaining safety objectives through the fulfillment of designated indicators. Leading indicators, referred to as proactive or predictive indicators, seek to avert accidents prior to their occurrence, whereas trailing indications, gathered post-accident, serve to assess their consequences [24, 26]. In Indonesia, essential indicators pertaining to construction safety performance are delineated in Regulation of the Minister of Public Works and Housing No. 10 of 2021 [10]. Leading indicators comprise (1) the execution of Leadership and Worker Participation in Construction Safety; (2) the enactment of Construction Safety Policy Elements; (3) Construction Safety Programs; (4) Construction Safety Support; and (5) Inspections and Audits. Lagging indicators include (1) Severity Rate (SR); (2) Occupational Diseases (OD); (3) Environmental Pollution; (4) Security Disturbances; and (5) Incidence of Occupational Diseases.

2.4. Construction Projects Utilizing Design-Build Contracts

Building projects are initiatives aimed at achieving the tangible results of construction in the shape of enclosed structures that harmonize with their surroundings, while accounting for time, cost, quality, and resources, with the objective of producing outcomes that meet specified functions [27-29]. Every construction project possesses distinct attributes, obstacles, and advantages [30]. Structures are engineered to establish more stable and predictable indoor conditions, facilitating activities that may be impracticable outdoors [31]. Buildings are categorized by height as stipulated in Government Regulation [27]. (1) supertall buildings; (2) skyscrapers; (3) high-rise buildings; (4) medium-rise buildings; and (5) low-rise buildings.

Data from the Electronic Procurement Service of the Government Procurement Policy Agency reveals that design-build contracts for construction projects are prevalent in Indonesia, particularly in the IKN, under the Ministry of Public Works and Housing. The design-build project completion is a contracting method wherein clients hire a singular organization to execute both design and construction tasks under one contract. Projects appropriate for design-build contracts encompass those that are intricate or time-sensitive [32-34]. Studies have shown that, in numerous instances, the design-build (DB) approach is more effective than the design-bid-build (DBB) strategy [35]. Design-build contracts have emerged as a prevalent approach for project execution in both public and private sectors, providing numerous benefits over the traditional design-bid-build system regarding time and cost efficiency [36]. Research in the USA indicated that design-build methods offer a project value advantage of 6% and a project completion time that is 33% more rapid than DBB methods [37].

3. Research Methodology

This study utilizes both qualitative and quantitative methodologies, incorporating a research strategy that encompasses a literature review, questionnaire survey, and interviews. The dependent variable in this study is construction safety performance (Y), comprising the leading indicator (Y1) and the lagging indicator (Y2), whilst the independent factors are the information system (X1) and the safety rating tools (X2). The research process is depicted in a flowchart that delineates the conducted research activities, as represented in Figure 1.

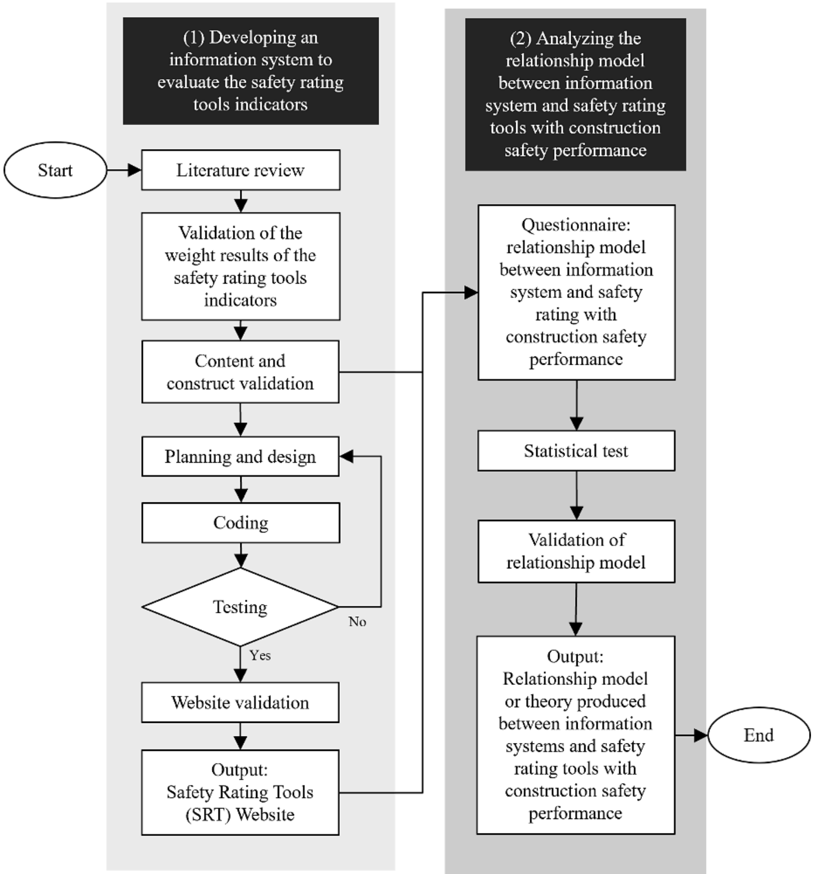

Figure 1. Research Workflow

3.1. The Weighting of Construction Safety Rating Tools Indicators

This study initiates with a literature review of prior research to establish the weights for criteria, sub-criteria, and factors within the indicators of safety rating tools. The weights for five elements were determined using the Analytic Hierarchy Process (AHP) method. The weights for 22 sub-elements were established via a rating scale questionnaire, whereas the weights for 123 factors were computed using the equal weighting method. The weights were validated by experts and utilized as input for the development of the information system. Furthermore, content and construct validation were conducted for information system indicators, safety rating tools, and construction safety performance. The indicators of the safety rating tools are derived from a study of Nugroho et al. [23] and current regulations by the Ministry of Public Work and Housing of the Republic of Indonesia [10]. The validation results served as input for the development of the relationship model. Validation required the involvement of construction safety experts, including safety committee members from the Ministry of Public Work and Housing, and practitioners in the field. Table 1 outlines the profiles of the experts participating in the validation stage.

Table 1. Expert Profile

Expert	Education	Experience	Organization	Notes
E-1	Master	13 years	National Research and Innovation Agency	Practitioner, Researcher
E-2	Doctoral	38 years	Ministry of Public Work and Housing	Committee members
E-3	Master	18 years	Ministry of Public Work and Housing	Head of the Work Unit
E-4	Master	25 years	Construction Organizations	Practitioner
E-5	Doctoral	19 years	Ministry of Public Work and Housing	Head of Sub-Directorate

3.2. The Development of an Information System for Assessing Construction Safety Performance

The information system development commenced with the input derived from the validated weights of the safety rating tools indicators, subsequently progressing through planning and design, coding, and testing phases. The result was a website named Safety Rating Tools (SRT). The SRT website offers information regarding construction safety for buildings under design-build contracts, functions as a guide for assessing construction safety performance in such projects, and serves as a repository for documents that facilitate safety measurement. The safety rating tools are designed to aid committee members in their responsibility of monitoring and evaluating construction projects that present substantial safety risks, as stipulated in the Minister of Public Work and Housing Decree No. 1593/KPTS/M/2023 [38].

The initial phase of system development comprised planning and design activities. The system architecture was modeled with the Unified Modeling Language (UML), utilizing a Use Case Diagram, as illustrated in Figure 2. This document outlines the interaction processes between users and the developed system. Users are granted access at several levels: public (other users), service providers (contractors), and committee members. Individuals seeking to assess safety performance in their roles as committee members or contractors must log in. Users lacking a username and password are restricted to accessing only general information regarding the safety rating tools available on the home menu and are unable to engage in measurement processes. Administrators possess the ability to log in and have comprehensive access to user and system settings. A flowchart was utilized in database modeling to illustrate the algorithm, which represents the process of measuring safety performance. This flowchart depicts the sequential process beginning with login, followed by data input, submission of supporting documents, and culminating in the calculation of construction safety performance scores. Figure 3 illustrates the algorithm utilized for assessing safety performance on Service Provider accounts (a) and Committee Member accounts (b).

The coding phase involved the implementation of the system's planning and design into software. The web-based information system was developed utilizing the CodeIgniter Framework and PHP as the programming language. PostgreSQL served as the database management system, and the Java Spring Boot Framework was utilized for backend management. CodeIgniter was selected for its maintenance and development efficiency, facilitated by the Model–View–Controller (MVC) programming paradigm. The models were implemented as user interfaces utilizing PHP through a structured programming approach. The database design was executed through SQL queries in PostgreSQL to establish the required tables for the information system. The SRT system organizes data, encompassing safety rating tools and construction safety performance, within relational tables in the database. The integration of Spring Boot with PostgreSQL facilitates efficient management of data transactions and user requests in backend operations.

The website was subsequently tested for operational errors. The employed testing method was blackbox testing, which assesses the functionality of various form inputs. The testing was performed from the user's perspective to verify that the website aligns with the specified requirements and is devoid of functional errors, excluding considerations of code or technical implementation. Upon completion of the website, it was subjected to validation by experts via interviews and questionnaires to collect feedback regarding its performance. The validation included members of the safety committee from the Ministry of Public Works and Housing, as well as construction safety practitioners, with the data presented in Table 1.

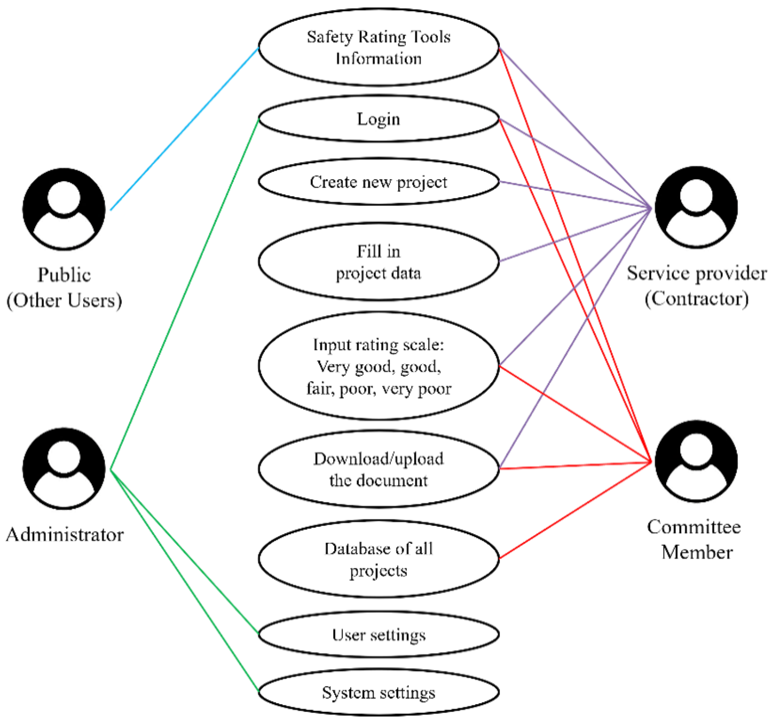

Figure 2. Use Case Diagram of the Safety Rating Tools

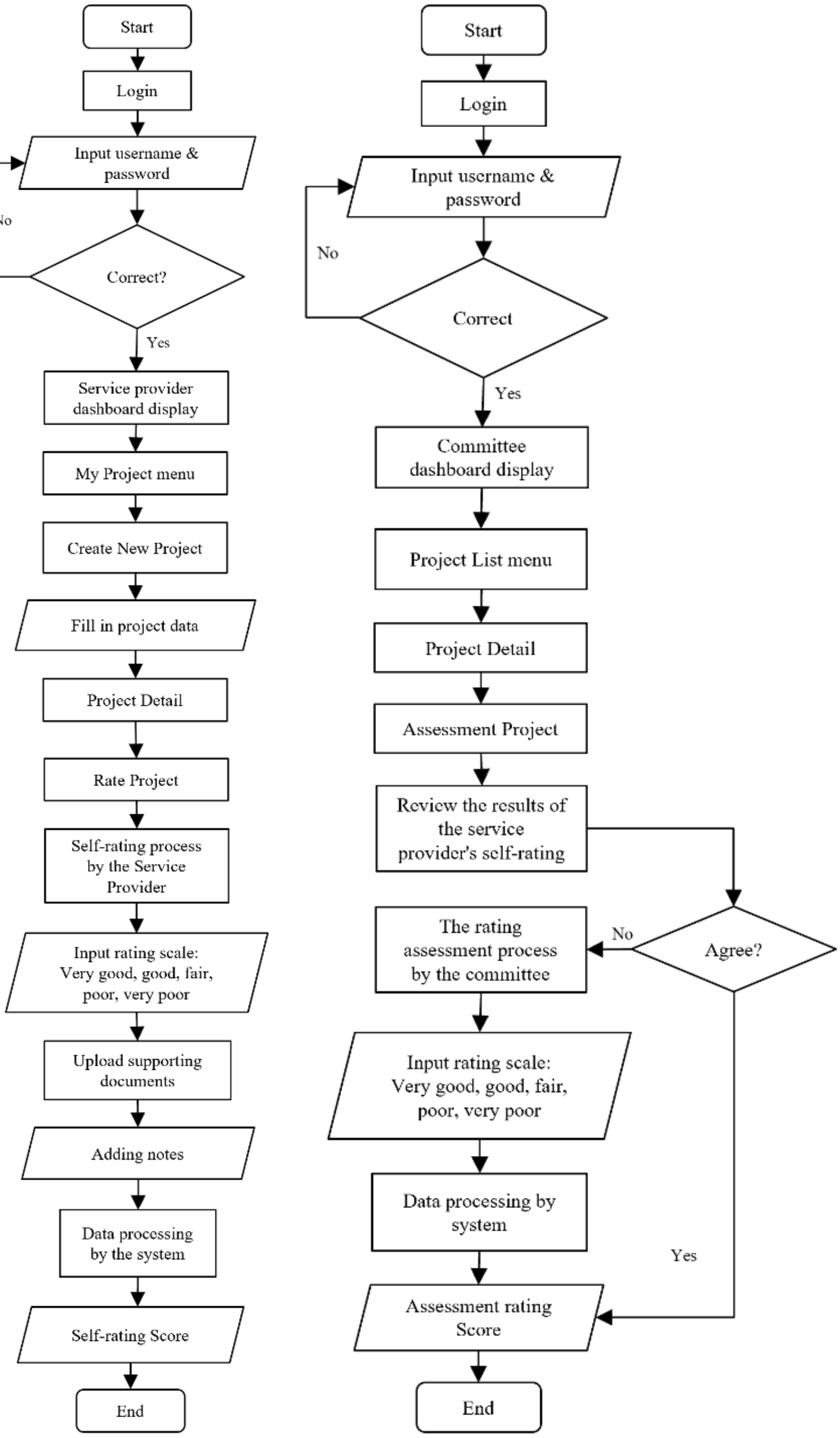

Figure 3. The Algorithm for Assessing Safety Performance: (a) Self-Rating; (b) Assessment Rating

3.3. Model of the Relationship Between Information Systems, Safety Rating Tools, and Construction Safety Performance

The objective of the relationship model questionnaire was to collect data on the connection between construction safety performance and information systems, as well as safety rating tools. The study involved 30 respondents, comprising committee members or practitioners who possessed at least a bachelor's degree and a minimum of 5 years of experience in design-build construction for building projects. A five-point Likert scale was employed to assess respondents' perceptions, with a score of 5 signifying a substantial impact of an indicator on construction safety performance, and a score of 1 indicating no significant impact. The statistical tests provided by SPSS software were utilized to analyze the data collected from the respondents. The conducted statistical tests comprise a homogeneity test, data sufficiency test, validity test, reliability test, correlation analysis, and regression analysis. This process yields a relationship model or theory linking information systems and safety rating tools to construction safety performance.

4. Results and Discussion

This section presents the research findings. The discourse is segmented into two sections: developing an information system for safety rating tools and analyzing the relationship model between the information system and safety rating tools in relation to construction safety performance.

4.1. Developing an Information System for Safety Rating Tools

The validated weights of the safety rating tool indicators served as inputs for the development of the web-based information system. The validation results reveal the following weights for the elements: Leaders and Workers Participation in Construction Safety at 16%, Construction Safety Planning at 31%, Construction Safety Support at 14%, Construction Safety Operations at 20%, and Construction Safety Performance Evaluation at 19%. Table 2 presents the scores for each element, sub-element, and factor. The weights for each factor were derived by multiplying the factor weight, sub-element weight, and element weight. The weight for F1 was determined by multiplying the factor weight (0.25) by the sub-element weight (0.27) and the element weight (0.16), yielding a result of 0.0108. The scores for elements, sub-elements, and factors served as inputs for the development of the web-based information system, wherein the scores were multiplied by the user-selected rating scale to produce the project's safety performance score.

Table 2. The Weighting of Construction Safety Rating Tools Indicators

Element	Sub-element	Factor
Leadership and Worker Participation in Construction Safety (0.16)	Top Management Ensuring Their Concern for External and Internal Issues (0.27)	F1-F4 (0.25)
	Forming an Organizational Structure for CSMS (0.25)	F5-F8 (0.25)
	Establishing Construction Safety Commitments and Worker Participation (0.25)	F9-F13 (0.25)
	Carry out Supervision, Training, Accountability, Resources, and Support (0.23)	F14-F16 (0.33)
The Construction Safety Planning (0.31)	Establishing Hazard Identification, Risk Assessment, Control, and Opportunities (HIRACO) (0.26)	F17-F22 (0.17)
	Determining Engineering, Management, and Manpower Action Plans as Outlined in Safety Goals and Programs (0.27)	F23-F30 (0.13)
	Ensuring Compliance with The Standards and Regulations of Construction Safety (0.22)	F31-F34 (0.25)
	Design Control and Contract Reviews (0.25)	F35-FF36 (0.50)
The Support of Construction Safety (0.14)	Determining Resources in the form of Technology, Equipment, Materials, and Costs (0.22)	F37-F39 (0.33)
	Establishing Minimum Standards for Worker Competency (0.20)	F40-F46 (0.14)
	Ensuring Concern for the Organization of Work Implementation (0.20)	F47-F51 (0.20)
	Establish Communication Management for All Stakeholders (0.20)	F52-F55 (0.25)
	Establishing Documented Information (0.20)	F56-F58 (0.33)
The Operations of Construction Safety (0.20)	Carrying out Construction Safety Plan Implementation Planning (0.25)	F59-F64 (0.17)
	Carrying out Construction Safety Operations Control (0.26)	F65-F98 (0.03)
	Determining Preparedness and Response to Emergency Condition (0.26)	F99-F104 (0.17)
	Establishing Construction Accident Investigation (0.23)	F105-F107 (0.33)
Performance Evaluation of The Implementation of CSMS (0.19)	Performing Monitoring and Inspections (0.22)	F108-F112 (0.20)
	Conducting Safety Audits (0.20)	F113-F114 (0.50)
	Conducting Evaluations (0.19)	F115-F117 (0.33)
	Establishing Management Reviews (0.20)	F118-F120 (0.33)
	Establish Construction Safety Performance Improvements (0.19)	F121-F123 (0.33)

The web-based information system for assessing safety performance in building projects utilizing design-build contracts, employing safety rating tools indicators, is accessible at https://safetyratingtools.id/. The Project Safety Rating on this website is derived from self-assessments conducted by contractors and evaluations performed by committee members. Contractors are permitted to perform self-assessments on their projects, whereas committee members have the ability to review all projects that have been self-rated by contractors and validate the outcomes. The workflow depicted in Figure 3 outlines this process. Figure 4 illustrates the initial interface of the Safety Rating Tools website. The "About SRT" menu is accessible to the public without the need for login credentials. This menu outlines key information and critical elements related to safety performance measurement in building projects utilizing design-build contracts. Users must log in with their username and password to conduct measurements. Individuals without an existing account may register to obtain access. Upon successful login, contractor users are presented with the "My Project" interface, which displays their respective projects, as illustrated in Figure 5.

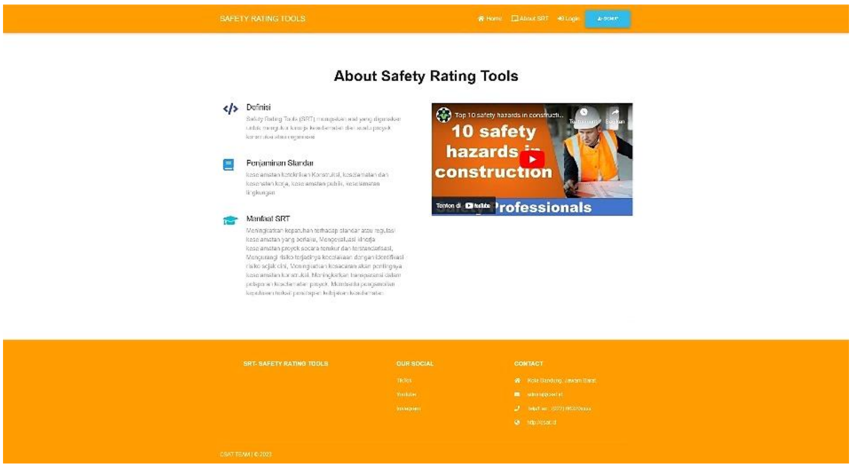

Figure 4. Homepage of the Safety Rating Tools Website

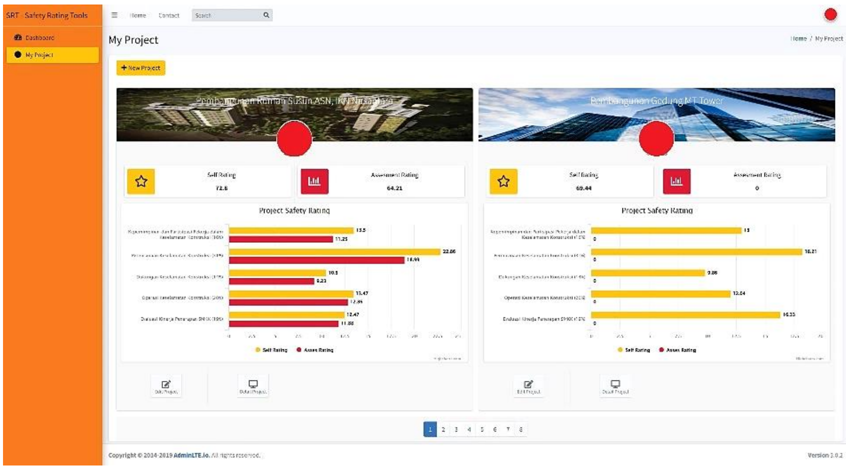

Figure 5. "My Project" Menu

Contractor users may initiate a new measurement by selecting "New Project" and providing the necessary project information. The subsequent step involves inputting the project's performance rating scale by utilizing the indicators from safety rating tools to implement construction safety management. Values are categorized on a scale: very good (score 1), good (score 0.75), fair (score 0.5), poor (score 0.25), and very poor (score 0). Each indicator is assigned a weight, as presented in Table 2. The weights are multiplied by the chosen rating scale provided by the contractor. The website analyzes this data and generates a final score, which serves as the self-rating score for the project. Figure 6 illustrates the score interface for contractors. Committee members may assess and validate the self-rating results submitted by contractors through an evaluation process. Values are assigned according to a scale that includes very good, good, fair, poor, and very poor. Figure 7 illustrates the score interface for committee members.

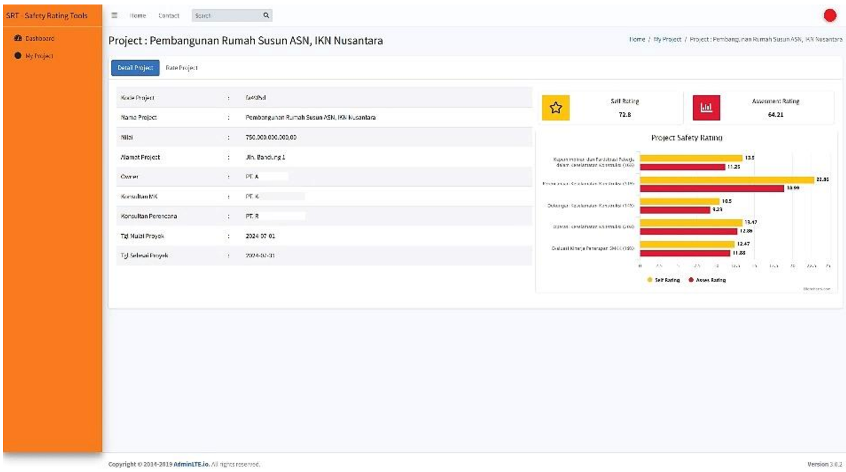

Figure 6. Score Display on the SRT Website for Self-Rating Stage

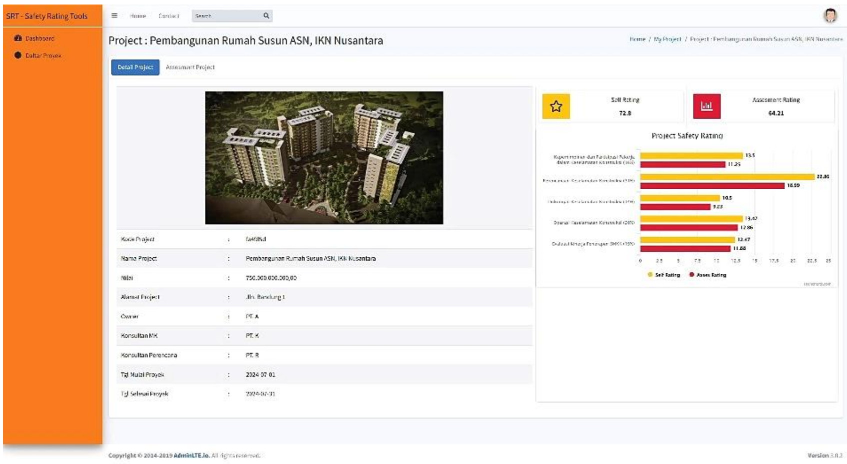

Figure 7.Score Display on the SRT Website for Assessment Rating Stage

Following the development of the website, validation was performed with the participation of experts. Data were analyzed through descriptive methods. The responses from each expert were quantified based on indicators, assigning a score of 3 for "good," 2 for "sufficient," and 1 for "poor." The results were averaged for each indicator, leading to the following conclusions: a rating of 2-3 is considered good, 1-2 is deemed sufficient, and 0-1 is classified as poor. Table 3 presents a summary of the website validation results.

Table 3. Summary of the Website Validation Results

No.	Evaluation Aspect	Indicator	Expert Answers			Total	AVG	Conclusion
			Good	Sufficient	Poor			
1	Usability	This information system facilitates access to data concerning measurements (safety rating tools) for building projects utilizing design-build contracts.	4	1	0	14	2.80	Good
		This information system provides a framework for the measurement process of safety rating tools in building projects utilizing design-build contracts.	3	2	0	13	2.60	Good
		This information system offers supporting data and case studies related to the measurement process of safety rating tools.	4	1	0	14	2.80	Good
2	Operational performance	The website is easy to use.	4	1	0	14	2.80	Good
		The output information's format is simple to comprehend.	4	1	0	14	2.80	Good
		The alignment between the requested input and the output.	4	1	0	14	2.80	Good
		System's speed at responding to user input.	4	1	0	14	2.80	Good
3	Design	The arrangement of features and content is simple to comprehend.	3	2	0	13	2.60	Good
		The design that was chosen.	4	1	0	14	2.80	Good
		The arrangement of colors.	3	1	1	12	2.40	Good

The findings indicated that the average scores for usability, operational performance, and design across all indicators ranged from 2 to 3, suggesting that the SRT website's performance was satisfactory. This facilitates the measurement of safety performance in building projects utilizing design-build contracts, particularly aiding the committee by removing the necessity for manual safety performance evaluation and offering a more systematic process. Experts offered recommendations for future development, including the implementation of a live feature during the measurement process to enable direct monitoring by the committee.

The safety performance scores produced by the measurement process on the SRT website indicate the degree of implementation of construction safety management within a project. The scores indicate the extent to which the project has effectively implemented safety management in accordance with relevant regulations. The safety performance scores of projects enable the committee to aggregate safety performance data for contractor-led projects. Average safety performance scores for each contractor can be derived from the data of their ongoing or completed projects. These data may subsequently inform the bidding process for project tenders.

The safety rating tools, structured as an information system to assess construction safety performance, are intended to enhance sustainable safety outcomes in construction projects. This system guarantees compliance with safety procedures in accordance with the Ministry of Public Work and Housing Regulation No. 10 of 2021, and it is readily accessible at all times and locations. This is consistent with Anggraini [7], who asserted that measurement is essential for evaluating the implementation of construction safety regulations. Dakhli et al. [39] highlighted the critical role of information systems in the construction industry, which consistently manages substantial volumes of information. Consequently, information systems must be structured to facilitate efficient, organized, and secure access to information. The SRT standardizes safety performance measurement. Hinze & Godfrey [25] noted that safety performance measurement offers a comprehensive assessment of a project's performance and is frequently utilized to benchmark projects or companies against industry standards. Park et al. [14] demonstrated that a construction safety management information system effectively enhanced safety management in construction companies in Korea, leading to a consistent decline in injury rates over a three-year period.

4.2. Investigation of the Relationship Model Between Information Systems and Safety Rating Tools in Relation to Construction Safety Performance

The questionnaire results regarding the relationship between information systems (X1) and safety rating tools (X2) with construction safety performance (Y) were analyzed post-distribution. The participants included individuals from the Ministry of Public Work and Housing as well as contractors, all possessing at least a bachelor's degree and a minimum of five years of experience in high-rise design-build construction projects. Statistical analyses were performed on the collected data, encompassing homogeneity tests, data adequacy assessments, validity evaluations, reliability assessments, correlation analysis, and regression analysis utilizing SPSS software. The homogeneity test for the institution utilized the Mann-Whitney U test, whereas the Kruskal-Wallis test was applied for education and work experience. The results of the homogeneity test revealed significance values of 0.148 for institutions, 0.059 for education, and 0.101 for work experience. Given that the significance values exceeded 0.05, no differences were observed in the perceptions of respondents based on institutions, education levels, or work experience levels. The data adequacy test employed the Kaiser Meyer Olkin Measure (KMO), yielding a KMO value of 0.689, which exceeds the threshold of 0.5, thereby confirming that the data satisfies the adequacy criteria. The validity test results indicated that the minimum Corrected Item-Total Correlation value for the X1 indicator was 0.405, for X2 it was 0.667, and for Y it was 0.562.

The values exceeded the R table value of 0.349, indicating that the items for indicators X1, X2, and Y were valid. The reliability test results indicated Cronbach's Alpha values of 0.852 for variable X1, 0.970 for X2, and 0.926 for Y. The Cronbach's Alpha values exceeding 0.60 indicate that the data for X1, X2, and Y are reliable. The analysis of correlation was performed utilizing the Spearman method. The results indicated that all variables were significant, demonstrating a robust relationship among variables X1, X2, and Y. The results of the regression analysis encompassed R-squared, F-test, and T-test statistics. The Adjusted R Square value was 0.596, suggesting that about 59.6% of the variation in variable Y is accounted for by variables X1 and X2. The F-test results indicated a significance value in the ANOVA output of less than 0.05 and a F value of 22.420, which exceeds the F table value of 3.34, demonstrating that variables X1 and X2 collectively influenced variable Y. The T-test results indicated significance values of 0.004 for the effect of X1 on Y and 0.003 for the effect of X2 on Y. Given that the significance values for X1 and X2 were less than 0.05, it was determined that variables X1 and X2 significantly influenced variable Y.

The results of the multiple regression analysis indicated the relationship model for the leading indicator (Y1) as follows:

$$Y1 = 2.678 + (0.239)X1 + (0.100)X2 \quad (1)$$

The constant value was 2.678, suggesting a direct relationship between the independent and dependent variables. The regression coefficient for variable X1 was 0.239, suggesting a positive effect of X1 on Y1. An increase of 1 unit in variable X1 results in a 0.239 increase in Y1, assuming all other variables are held constant. The regression coefficient for variable X2 was 0.100, suggesting a positive effect of X2 on Y1. If variable X2 increases by 1 unit, Y1 is expected to increase by 0.100, assuming all other variables remain constant.

The relationship model for the lagging indicator (Y2) as follows:

$$Y2 = -0.124 + (0.289)X1 + (0.095)X2 \quad (2)$$

The constant value was -0.124, suggesting a potential negative influence between the independent and dependent variables when the independent factors were not contributory. The regression coefficient for variable X1 was 0.289, signifying a positive effect of X1 on Y2. If variable X1 increases by 1 unit, Y2 will rise by 0.289, if all other variables are held constant. The regression coefficient for variable X2 was 0.095, showing a positive effect of X2 on Y2. If variable X2 were to grow by 1 unit, Y2 would rise by 0.095, provided that other variables remained unchanged. When X1 > 0 and X2 > 0, the value of the lagging indicator (Y2) will enhance, or the accident rate will diminish. Conversely, when X1 = 0 and X2 = 0, the accident rate would be elevated, indicating inadequate safety, as denoted by the negative constant value of -0.124.

The relationship model was subsequently validated by experts. Experts had favorable opinions regarding the proposed mathematical model. Experts underscored the importance of emphasizing the leading indicator because of its direct influence on risk mitigation and the proactive enhancement of safety performance. The information system was emphasized as the primary focus for enhancing documentation, accessibility, and risk response. The leading indication serves to detect potential hazards and issues prior to their escalation. Consequently, improving the quality of the leading indication is essential for mitigating future accidents. Experts indicated that the trailing indicator assesses previous unpleasant occurrences and contributes to alleviating their already manifested impacts. Information systems are utilized to enhance response times and optimize safety assessment outcomes. Nevertheless, the lagging indicator is contingent upon the efficacy of the leading indicator. The trailing indication demonstrates the performance of the leading indicator; therefore, prioritizing the leading indicator is essential to avert negative occurrences from the beginning. Information systems are essential for enhancing the lagging indicator by mitigating adverse effects and increasing safety outcomes.

Both independent variables, information systems and safety rating tools, exert a favorable influence on the leading indication. This suggests that enhancements in both variables favorably influence the value of the leading indicator. Likewise, the lagging indicator is significantly influenced by information systems and safety rating tools, suggesting that enhancements in both factors positively affect the value of the lagging indicator. When executed proficiently, both leading and trailing indicators enhance construction safety performance. Safety performance denotes the degree of safety in a project from inception to conclusion and is regarded as a primary indicator of overall project success [40, 41].

The information system exerts a greater impact on enhancing the leading indicator than the safety rating tools. This underscores the importance of enhancing the quality and reliability of the information system utilized for inspections and audits to improve the leading indication. The information system exerts a greater influence on the lagging indicator than the safety rating tools, underscoring its significance in the assessment process aimed at mitigating future negative outcomes. The lagging indicator is affected by initial negative contributions, reflecting trends for detrimental outcomes such as accidents, sickness, environmental degradation, or security breaches. Consequently, information systems and safety rating tools are essential to elevate the lagging indicator to a positive or neutral state. The absence of their role would increase the probability of hazards or negative consequences.

The integration of a proficient information system and comprehensive safety rating tools will produce ideal outcomes for both leading and trailing indicators. While the safety rating tools contribute less than the information system, they should not be disregarded. Safety rating instruments guarantee the adherence to safety requirements. Improving safety rating tools is essential for bolstering the leading indication, particularly in increasing safety awareness during the project's first phases. Safety rating tools also have a role in the lagging indicator, albeit to a lower degree, by diminishing the probability of occurrences quantified by the trailing indicator. The lagging indicator is extensively utilized and readily available owing to its documentation and application as a report to health and safety authorities [42, 43]. Neamat [43] and Bhagwat & Delhi [20] observed a transition from a reactive approach to a proactive approach due to its effectiveness in preventing injuries or accidents. Expert opinions from the validation results indicate that the leading indication should be prioritized, since it directly influences the lagging indicator and overall construction safety performance. Safety is paramount for construction firms, requiring a dependable system for assessing safety performance. Rajaprasad [44] asserted that the construction sector needs an appropriate framework to evaluate safety performance at the project level. The integration of information systems with safety rating tools has demonstrated a beneficial impact on both leading and lagging indicators. This corresponds with Bhagwat & Delhi [20], who elucidated that effective measurement facilitates the assessment, monitoring, control, and enhancement of current safety performance.

5. Conclusion

The deployment of information systems and safety rating instruments is crucial in the construction sector to assess and enhance safety performance. This necessity arises from the persistently elevated incidence of accidents in the construction industry, necessitating efficient and standardized measurement instruments grounded on information systems. The validation results reveal the following weights for the elements: Leaders and Workers Participation in Construction Safety at 16%, Construction Safety Planning at 31%, Construction Safety Support at 14%, Construction Safety Operations at 20%, and Construction Safety Performance Evaluation at 19%. The results informed the creation of a web-based information system, leading to the Safety Rating Tools website, which assesses construction safety performance on design-build contract projects. The project safety rating on the SRT website comprises two evaluation phases: self-assessment by contractors and assessment by committee members. Users must first log in to the website to do these assessments. The SRT website underwent professional validation, revealing commendable performance in usability, operational efficiency, and design elements. Experts also offered recommendations for enhancement, including the incorporation of a live feature during the measuring procedure by contractors, allowing committees to oversee the process in real time.

An inquiry into the correlation between information systems, safety rating tools, and construction safety performance indicated a positive relationship between information systems and safety rating tools and construction safety performance. Enhancements in the two independent variables, specifically information systems and safety rating tools, positively influenced both leading and lagging indicators. The anticipated result of creating a web-based information system to assess safety performance is enhanced adherence to relevant safety standards and regulations, ultimately resulting in improved construction safety performance.

6. Declarations

6.1. Author Contributions

Conceptualization, Y.L., M.A.W., and D.B.N.; methodology, D.B.N. and Y.L.; software, Y.L. and N.A.N.; validation, D.B.N., M.A.W., and N.A.N.; formal analysis, F.L.; investigation, Y.L.; resources, R.A.; data curation, D.B.N.; writing—preparation of original draft, D.B.N., N.A.N., and Y.L.; writing—review and edit, D.B.N., N.A.N., and Y.L.; visualization, R.A.; supervision, F.L.; project administration, D.B.N. and N.A.N.; funding acquisition, D.B.N. and Y.L. All the authors have read and agreed to publish this manuscript.

6.2. Data Availability Statement

Data sharing is not applicable to this article.

6.3. Funding

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6.5. Conflicts of Interest

The authors declare no conflict of interest.

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