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Development of a Framework for Risk-Based Integrated Safety Audit to Enhance Construction Safety Performance

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Abstract

Presently, there is a notable surge in infrastructure development, leading to a heightened occurrence of accidents within the construction sector. This trend has positioned the construction industry as one of the most accident-prone areas compared to other sectors. This suggests that the current construction safety audit procedures have not proven effective in preventing accidents. Typically, audits are conducted primarily during the construction phase, with infrequent assessments during the design phase. According to the Szymberski theory, actions taken during the design phase significantly influence the occurrence of accidents more than those taken during construction. Previous research has discussed a lot about safety management systems. However, it has not discussed how to assure the quality of its implementation. Considering this, the research aims to (a) identify the processes, elements, activities, sub-elements, objectives, criteria, and risks associated with construction safety audits and (b) formulate an integrated, risk-based audit process covering both the design and construction phases. This qualitative research employed the Delphi method to gather insights from construction safety experts, and the developed audit process utilized a risk management approach. The resulting audit process integrates principles from ISO 19011:2018 and Regulation of the Minister of Public Works and Housing Number 10 of 2021. The findings revealed 34 activities in audit program management, 34 activities in audit implementation, and 32 sub-elements in audit criteria. These components are incorporated into a comprehensive construction safety audit framework, organizing audit processes, activities, and criteria. This framework underscores that improving construction safety performance is not solely confined to the construction phase but extends to the design phase as well. The audit results serve as a foundation for continuous improvement, aiding in enhancing safety performance and preventing accidents within the construction industry.

Keywords: Audit; Construction Safety; Safety Performance; Accident; Risk.

1. Introduction

In this era, Indonesia is vigorously pursuing infrastructural development, with the Ministry of Finance reporting an average annual growth of 12.7% in the infrastructure budget from 2015 to 2022 [1]. The government had officially announced the plan to relocate the Indonesian capital with the construction of Nusantara Capital City (IKN), scheduled

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from 2022 to 2024. This initiative started with the construction of essential infrastructure, such as high-rise buildings for the Presidential Palace, the People Consultative Assembly/Parliament facility, etc. [2]. Due to the increasingly dynamic and complex lifecycle of a construction project, it is positioned as a dangerous or highly hazardous industry [3]. Statistics on occupational accidents revealed that high-rise building construction is one of the riskiest workplaces [4].

Accidents ensued as a great burden to the employee and employer in terms of absenteeism, loss of productivity, ergonomic disabilities, high costs incurred, bad company reputation, higher incidence rates of illnesses, and fatalities [5]. Managing this complexity to reduce risks could be achieved through the Construction Safety Management System (CSMS) [6]. Previous research has discussed a lot about safety management systems. However, it has not discussed how to assure the quality of its implementation. To assure the quality of the CSMS implementation, a structured and continuous audit is necessary because it provides a direct and comprehensive means to monitor the realization and effectiveness of the safety management system. Safety audit results also assist diverse companies in developing checklist standards and improved recommendations, enhancing environmental, health, and safety performance, as well as reducing the number of accidents [7, 8]. A safety audit is carried out to ensure that unsafe acts and unsafe conditions are brought to a minimum level so that there is a safe work environment. The purpose of a safety audit is to ensure that there are definitions and safe procedures for work and that the set definitions and safe procedures are practiced [9].

An audit is a systematic and, wherever possible, independent examination to determine whether activities and related results conform to planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the organization's policy and objectives [10]. Audits had been disintegrated and typically confined to a single stage of the project lifecycle, with a focus on the implementation phase, often conducted after accidents. Safety audits during the design phase are infrequent [11]. Despite Szymberski [12] stating that its activities have a more significant influence on the occurrence of accidents compared to the procurement or implementation phases, as shown in Figure 1. In his theory, Szymberski suggests that it is ideal for construction safety to be a prime consideration during the conceptual and preliminary design phases of construction projects, as there is a greater potential for accident reduction than what exists in later construction phases. This implies that efforts to control risks and prevent construction accidents cannot be assured, potentially leading to increased mishaps.

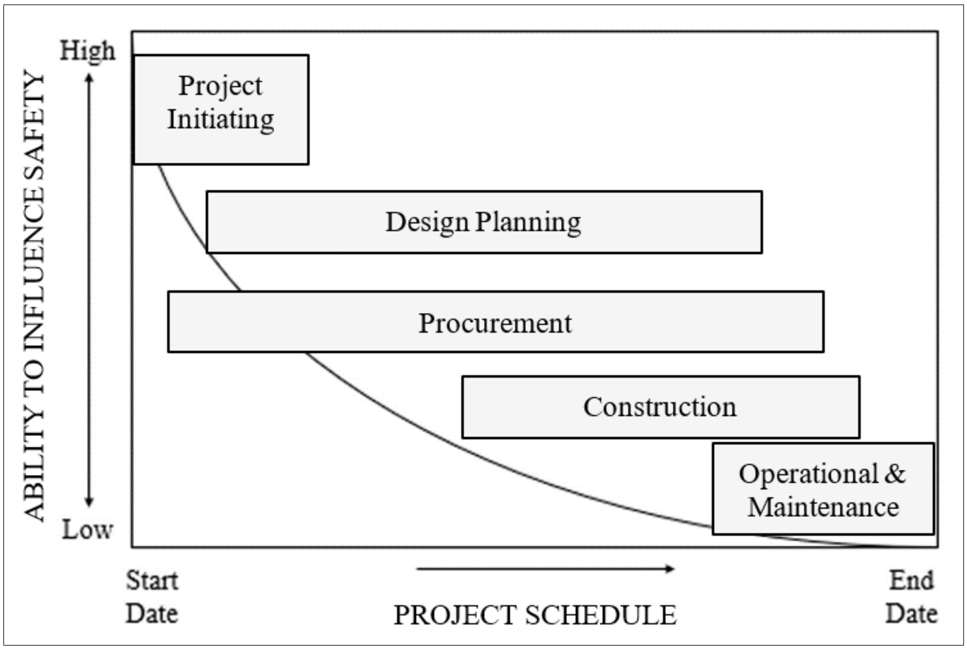

Figure 1. Time-safety influence curve [12]

The construction industry is considered high-risk as it involves dangerous and challenging work such as excavation, the erection of structural steel, and working at substantial heights [13]. Based on the International Labor Organization's (ILO) report [14], construction workers in developed countries are three to four times more likely to experience a fatal accident than workers in other industries; however, workers in less developed countries are six times more likely to suffer and experience a fatal accident than workers in other industries. Employment in the construction industry accounts for approximately 7% of global employment, and 100,000 workers die on construction sites each year, which accounts for approximately 35% of worldwide work-related deaths [15]. Indonesia experienced a significant increase in construction accidents at work sites, as reported by Worker Insurance, with the number rising from 123,040 to 234,270 from 2017 to 2021. Workplace accidents, particularly in the construction and manufacturing sectors, account for the largest contribution at 32%. This comprises all types of projects, such as buildings, roads, bridges, tunnels, irrigation, dams, and others [11].

The most effective strategies for preventing accidents involve avoiding risks, assessing those risks that cannot be avoided, tackling the risks at source, implementing innovation, prioritizing improvement actions, replacing hazardous substances with some less dangerous ones, and implementing global policies that integrate organizational values [16]. These programs should be continuously monitored and evaluated. Based on the theory proposed by Suraji et al. [17] stated that evaluation should be conducted in the initial phases of a construction project. It was specifically proposed that audits conducted during the design phase should prioritize prevention. Therefore, auditors need to thoroughly examine the constructability of design, ensuring it prioritizes structural strength and integrates safety considerations. Globally, various accident prevention strategies have been developed, focusing on the significant influence of professional design on construction safety. Meanwhile, data obtained from Oregon, Washington, and California showed that 22% of 226 injuries were recorded between 2000 and 2002, and 42% of 224 deaths in the US between 1990 to 2003 were attributed to design [18, 19]. On average, 6.9% of serious and fatal accidents in the construction industry could be prevented through proactive measures in equipment design [20]. Contract methods, such as design-build and interaction between planners and contractors before construction, provide opportunities for these individuals to contribute to safety measures [21]. Conducting work safety audits from the planning stage to the handover stage is effective in enforcing and monitoring compliance with work safety legislation and guidelines [22]. According to Alruqi et al. [23], there is a relationship between leading indicators in construction and safety performance. Through a meta-analysis of eight studies, they found that safety auditing had a strong relationship to injuries when measured as an active indicator (when including site safety observations and inspections). Furthermore, regulatory inspections, if considered part of auditing, may contribute to improved health and safety outcomes in specific circumstances [24]. While there is a clear statistical association between audit measures and safety performance, there is no strong evidence to suggest that audits directly cause performance improvements.

Meanwhile, the Regulation of the Minister of Public Works and Housing Number 10 of 2021 addresses risk management in construction projects, covering safety aspects in four dimensions, namely human (workers), assets or technology, public, and the environment [6]. This research aims to (a) identify the processes or elements, activities or sub-elements, objectives or criteria, goals, and risks of construction safety audit, as well as (b) develop an integrated risk-based audit process covering both design and construction phases. The influence of regulation, effective application of standards, policies, and business models on auditor judgment is increasingly important in understanding and improving the quality of the resulting audit and serves as a consistent reference for continuous improvement [25]. Previous research has discussed a lot about safety management systems. However, it has not discussed how to assure the quality of its implementation. Therefore, this development of an integrated construction safety audit process will optimize the audits, enhancing their effectiveness in improving safety performance. This proactive method and principles of sustainable development lead to early identification and resolution of construction safety issues and accident prevention.

2. Research Material

2.1. Audit Process on Design and Construction Phase of High-Rise Buildings Project

An audit is an effort to examine nonconformities in the outcomes of work and confirm or compare these outcomes with predetermined criteria or plans, with the main aim of achieving continuous improvement. Its integration brings about various benefits, including optimization of business and resources, fostering organizational unity towards integrated goals, lightening workloads, and reducing certification time, costs, and documentation requirements [26]. Recognized as an important management tool and control system, auditing plays a significant role in organizational processes. As safety audits are quite costly and burdensome, an attempt should be made to achieve maximum rule compliance with the maximum level of safety audits. One starting point for optimization is the timing of audits [27]. ISO 19011:2018 provides comprehensive principles and methods for auditing management systems, specifying the competencies required by auditors. Audit operates on the fundamental principle of evidence-based assessment, perceived as a rational method to draw reliable and reproducible conclusions systematically [28]. The management of audit programs is shown in Figure 2, and ISO 19011:2018 also guides the preparation and implementation of related activities as part of these programs.

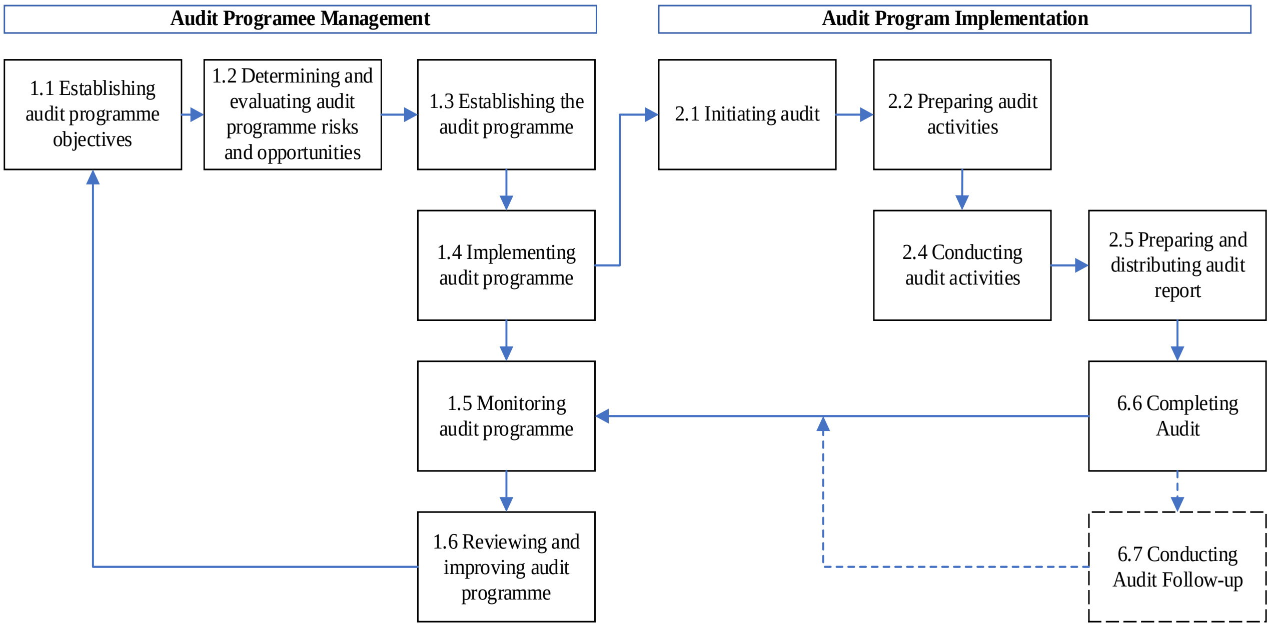

Figure 2. Process flow for managing audit programs

According to the Ministry of Public Works and Housing [6], the elements of CSMS implementation were analyzed in the audit process, namely leadership and workforce participation (sub-elements: leadership concern for external and internal issues, CSMS management organization, construction safety commitment, workforce and employee participation, as well as surveillance, learning training, responsibility, resources, and support). The audit also examines the construction safety plan, focusing on sub-elements including Hazard Identification, Risk Assessment, Determination of Risk, and Opportunity Control (HIRADC). It also assesses the engineering management and personnel action plans outlined in safety goals and programs along with ensures compliance with construction safety standards and regulations. An audit evaluates construction safety resources by considering sub-components such as resources in the form of technology, equipment, materials, costs, personnel skills, organizational awareness, management communication, and information documentation. The Construction Safety Operations focuses on addressing not only the implementation of the Construction Safety Plan (RKK) but also sub-elements such as construction accident investigation, operational management preparation, and actions in emergency situations. Lastly, audit comprised evaluation of CSMS performance implementation consists of sub-elements that include monitoring or inspection, management review, evaluations, and improvements to security measures.

High-rise buildings are defined as structures with more than eight floors [29], resulting in a comprehensive construction scope outlined by the Ministry of Public Works and Housing [30]. This scope comprised various aspects, including (a) site work preparation, (b) CSMS implementation, (c) structural, (d) architectural, (e) mechanical, (f) and electrical works, including (g) exterior building facilities, and (h) miscellaneous activities, collectively referred to as the WBS. In the context of construction methods, the design-build method is a significant method for delivering infrastructure and buildings. This method mandates the service provider to take unified responsibility for both design and construction, known for its efficiency in accelerating project timelines and reducing the general duration. Therefore, an integrated audit is needed to check deviations in design documentation and detect conscious degradation in final product quality. The audit will allow for evaluating and managing a construction firm's or their contractor’s activity. All these kinds of works are made through only one procedure utilization. Moreover, audits may be used in different phases (planning, design, construction, and exploration of facilities). The engineering audit objects are constructional structures. The subjects are report information, design plans, technical and economic decisions, activity on different stages of engineering investigations, measurements of engineering defense, and risk decline [31].

2.2. Construction Safety Management System

The Ministry of Public Works and Housing [6] provides a comprehensive perspective on construction safety, defining it as all engineering activities to achieve compliance with Security, Safety, Health, and Sustainability Standards. These standards are crucial for ensuring safety in construction engineering, protecting public welfare, preserving the environment, and maintaining occupational health. Based on this, Regulation of the Minister of Public Works and Housing Number 10 of 2021 outlined specific criteria for assessing construction safety risks, including the magnitude of job risks, contract value, number of workers, types of heavy equipment used, and the level of technology application. Safety risks are assessed through a systematic calculation of their potential magnitude by determining the likelihood of events that could result in losses, pose risks to human lives, impact public safety, and harm the environment.

According to Nugroho and Latief [32], construction safety systems develop an integrated governing protocol that includes planning, engineering, controlling, organization, financing, assurance, and the investigation of narrowly avoided incidents or accident causation. This comprehensive procedure is an essential part of the general organizational process and construction project management, with the main aim of preventing deficiencies, defects, failures, and potential hazards within construction projects that could cause harm to people, the public, society, property, and the environment. It can also damage business and corporate value. CSMS needs to be implemented early, starting from the feasibility research stage of the project, ensuring adherence to Health, Safety, Security, and Environment Sustainability Standards that comprise construction engineering, public, environmental, and occupational health and safety. Suraji et al. [17] mentioned two reasons for the influence of society on construction safety. First, workers themselves can be directly influenced by external factors, e.g., pressures from the social, economic, or political climate or environmental conditions. As a result, these factors can distract them from their work, potentially leading to accidents. Second, the client is under a number of distal factors, e.g., economic, social, and political pressures, during the conceptual development of a project. This cause-and-effect process has the potential to increase workers' constraints directly or indirectly through inappropriate construction planning or inappropriate construction control procedures, leading to inappropriate site conditions, inappropriate worker actions, or inappropriate construction operations. Consequently, regular monitoring is essential to assess the extent of compliance with safety regulations as well as ensure its implementation is in accordance with the actual field conditions [33, 34]. There are two types of safety performance indicators: leading and lagging indicators (output and post-accident measurements), with lead indicators being preferred in industry and academia [35].

2.3. Enhancing Construction Safety Performance through An Integrated Risks-Based Audit

To ensure enhanced safety performance, all parties, including users and service providers, must implement a risk management process during the design and implementation phases of construction projects. The main objective is to reduce or even eliminate accidents, one of the most significant safety performance indicators. These comprehensive risk management methods include identifying and analyzing risks, hazards, controls, or responses, as well as establishing objectives and programs for each work activity, specifically those with medium- and high-risk values. The integration of risk management into construction safety planning from design to the implementation phase is crucial [6]. The systematic risk management process requires identifying, analyzing, responding to, and controlling potential risks during program implementation. Its core purpose is to enhance the likelihood and impact of positive risks while contemporarily reducing the possibility and effect of negative threats, optimizing the success of the program [36]. Risk management plays a crucial role in the decision-making process in construction project management, influencing scope, time, integration, quality, human resources, cost, communications, and project procurement. Therefore, WBS should be categorized based on work packages, methods or design, activities, material resources, equipment, labor, and the environment to identify risks. This systematic method enables the identification of risk events that might impact safety performance objectives [32].

A safety audit plays a crucial role in conducting a comprehensive safety assessment, thereby enabling contractors to reflect, strengthen, and maintain current best practices while reducing risks continually [37, 38]. According to Barretto et al. [39], the risk-based audit process aims to achieve several objectives, namely (a) verifying compliance with established requirements, (b) assessing the effectiveness of management practices, (c) identifying weaknesses in operational and management aspects to reduce accident risks, and (d) fostering a culture of continuous learning and improvement. ISO 19011:2018 introduced a risk-based method to audit principles to support these objectives. This addition enhances general competencies for auditors and adjusts terminology to reflect audit processes accurately. Furthermore, the standard extends guidelines for conducting this process, specifically focusing on the design phase [26]. For enhancing safety performance, audits should be conducted from the beginning, just after a new rule has been prescribed, and audits should be conducted continuously and should not be stopped after a certain period [40].

3. Research Method

3.1. Research Design

The method is a systematic and scientific method designed to gather data for specific purposes. In selecting this method, three influencing factors play a significant role, namely the type of questions posed, the level of control over the behavioral events under investigation, and the focus on contemporary incidents as opposed to historical activities [41]. This research adopts a qualitative method to identify the audit process, activities, objectives, goals, risk details, levels, causes, and preventive actions. Literature reviews and the Delphi method were primary data collection sources. The Delphi method, widely used as a forecasting method, provides projections for complex or uncertain future situations. It includes collecting opinions and knowledge from multiple expert panels with relevant expertise. The Delphi survey was conducted to gather information and obtain the best conclusions from experts [42, 43].

The research design structure, as shown in Figure 3, requires a two-step process. Initially, the results of the archive analysis contributed to the formulation of content and constructs for the construction safety audit procedure. These were then subjected to validation by experts using the Delphi method. In this stage, experts provided valuable feedback on the audit process, activities, objectives, goals, and risk details, specifically in the design and construction stages of high-rise buildings using the design-build method. Subsequently, the content and constructs validated by experts are further evaluated through archive analysis, focusing on identifying risk levels, causes, and preventive actions. Experts provide feedback on risk levels, causes, and preventive actions in the construction safety audit process using the Delphi method. The research was concluded with a final validation of the results obtained using the Delphi method.

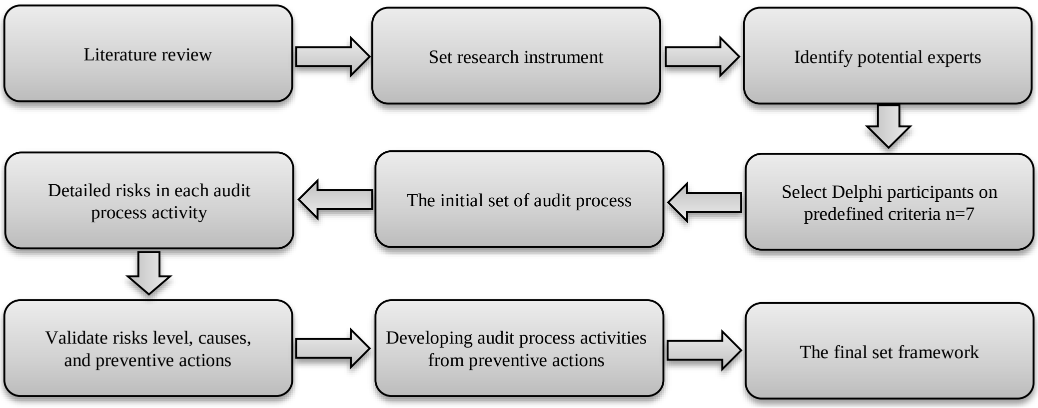

Figure 3. The research design

This research follows specific criteria for expert selection, targeting individuals who are either members of the Construction Safety Committee or possess expertise in construction with a minimum of 10 years of experience in high-rise building construction using the design-build method. Furthermore, these experts must possess a minimum educational qualification equivalent to a master's degree (S2).

3.2. The Initial Set of Construction Safety Audit Process

The instrument for the construction safety audit process was carefully designed based on archive analysis from prior research, regulations, and relevant international standards. It integrated all variables and components obtained from various literature sources, categorizing the audit process into three distinct groups, namely audit program management, implementation, and criteria, as shown in Figure 4. The instrument used secondary sources from previous research [6, 28, 44] to provide comprehensive insights into audit processes and activities. It comprises the program management phase at the organizational level, the implementation stage of a project, and criteria, risks, causes, and preventive actions. The output of this instrument included six processes in the audit and the implementation phases, as well as five elements in the criteria. An overview of audit process items used as benchmarks in developing the research instrument is shown in Table 1.

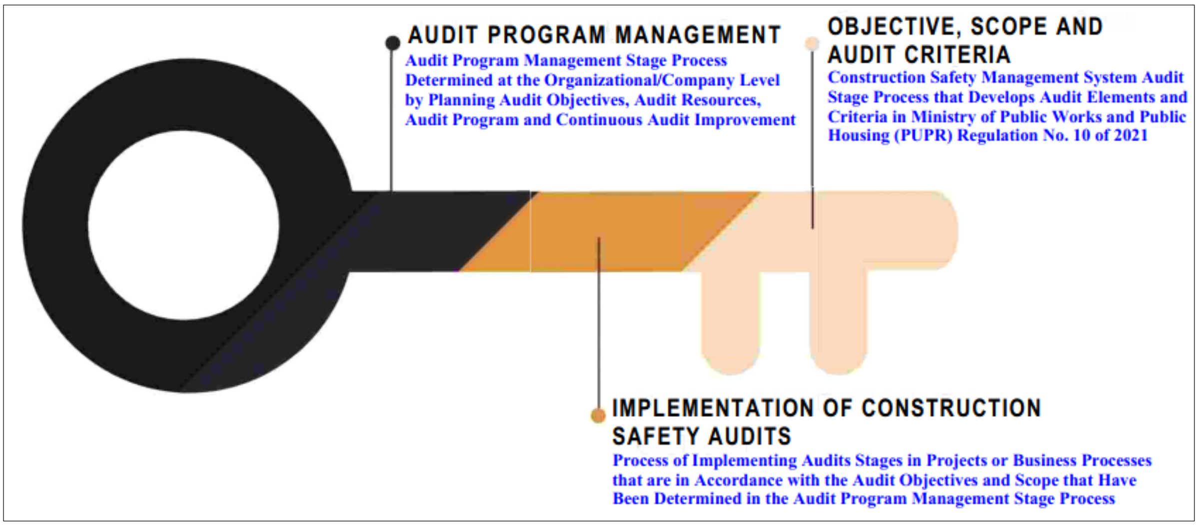

Figure 4. Construction safety audit process

Table 1. Construction Safety Performance Audit Process

Code	Audit Process/Elements
	Audit Program Management
X1.1	Establishing audit program objectives
X1.2	Determining and evaluating audit program risks and opportunities
X1.3	Establishing audit program
X1.4	Implementing audit program
X1.5	Monitoring audit program
X1.6	Reviewing and improving audit program
	Audit Implementation
X2.1	Initiating audit
X2.2	Preparing audit activities
X2.3	Conducting audit activities
X2.4	Preparing and distributing audit report
X2.5	Completing audit
X2.6	Conducting audit follow-up
	Audit Criteria
X4.1	Leadership and Worker Participation in Construction Safety
X4.2	Construction Safety Planning
X4.3	Construction Safety Support
X4.4	Construction Safety Operations
X4.5	Performance Evaluation of CSMS Implementation

3.3. The Delphi Process

The Delphi method, recognized as a standardized and interactive research method, plays a significant role in gathering perceptions or assessments from a group of experts on a specific topic. This effective method is particularly beneficial for reaching a consensus on new and complex concepts across interdisciplinary research [45]. This is likely due to variation among studies that implement Delphi and ambiguity in the literature that provides guidance for the specific parameters associated with the method. In carrying out the Delphi method, we have to: (1) understand the merits, appropriate application, and appropriate procedure of the traditional Delphi process; (2) identify and qualify potential expert panelists according to objective guidelines; (3) select the appropriate parameters of the study, such as the number of panelists, number of rounds, type of feedback, and measure of consensus; (4) identify potential biases that may negatively impact the quality of the results; and (5) appropriately structure the surveys and conduct the process in such a way that bias is minimized or eliminated [46]. The application of the Delphi method in this research is shown in Figure 5, which comprises four distinct phases, namely questionnaire design and validity examination, expert selection, survey, and data analysis.

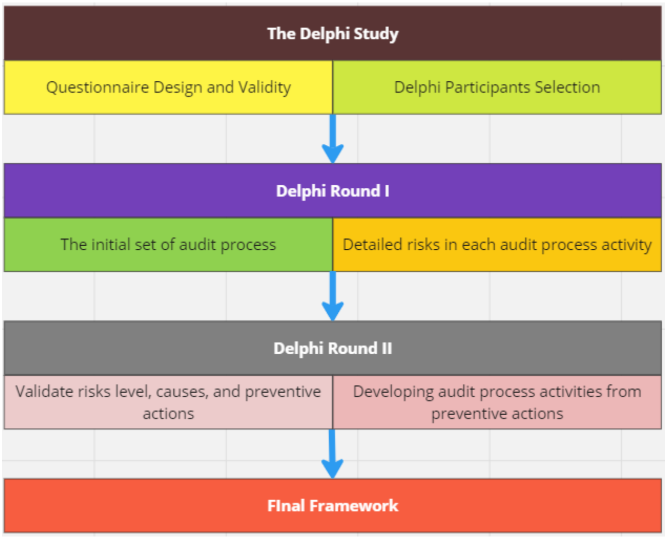

Figure 5. The Delphi process flowchart

The Delphi survey engages a total of seven experts, including members of the Construction Safety Committee and other seasoned professionals. The combined experience of these experts varies from 12 to 38 years, with three of them having over 30 years of expertise. Among the group, three experts hold a doctoral degree (S3), while the remaining four possess a master's degree (S2). Table 2 shows a comprehensive profile of these experts, who play a critical role in validating the development of the construction safety audit process.

Table 2. The Delphi Participants' Demographics

User	Position	Organization	Experience	Education
Expert 1	Committee member	Ministry of Public Works and Housing	14 years	Doctoral
Expert 2	Chairman, Committee member	Construction Safety Experts Association (PAKKI)	31 years	Master
Expert 3	Associate Professor, Committee member	Academics	38 years	Doctoral
Expert 4	Director, Committee member	Ministry of Public Works and Housing	38 years	Doctoral
Expert 5	Committee member	Ministry of Public Works and Housing	12 years	Master
Expert 6	Senior Vice President QHSE	Construction Organizations	29 years	Master
Expert 7	Vice President QHSE	Construction Organizations	20 years	Master

4. Result and Discussion

In this section, the discussion of the results is presented in two parts: (1) analyzing the initial set of processes or elements, activities or sub-elements, objectives or criteria, goals, and risks of a construction safety audit, as well as (2) a framework for an integrated risk-based audit process covering both design and construction phases.

4.1. Analyzing The Initial Set of Process/Elements, Activities/Sub-elements, Objectives/Criteria, Goals, and Risks of Construction Safety Audit

The validation outcomes obtained from expert evaluations on various facets of construction safety audits are systematically shown in Table 3. The audit program management segment includes six processes, 28 activities, 38 objectives, 65 goals, and 65 risks. Meanwhile, the audit implementation phase showed six processes, 21 activities, 54 objectives, 61 goals, and 61 risks. In audit criteria, experts identified five elements, 22 sub-elements, and a comprehensive set of 123 criteria, goals, and risks. Moreover, the validation process was extended to a thorough examination of risk details, in which experts contributed valuable insights. This collaborative effort aimed to derive cause-based preventive actions and establish distinct risk levels. Wolff et al. [47] extensively reviewed psychometric risk research and provided a general overview of perceived risk conceptualization and measurement. Specifically, subjective risks are defined as the severity level of negative outcomes measured based on their likelihood, in accordance with the widely accepted definition in psychometric and general economic literature [48, 49].

Table 3. Process/Elements, Activities/Sub-elements, Objectives/Criteria, Goals, and Risks of Construction Safety Audit

No.	Audit Process/Elements	Audit Activities /Sub-elements	Audit Objectives / Criteria	Audit Goals	Audit Risks
	Audit Program Management				
X1.1	Establishing audit program objectives	2 Activities	6 Objectives	8 Goals	8 Risks
X1.2	Determining and evaluating audit program risks and opportunities	4 Activities	4 Objectives	4 Goals	4 Risks
X1.3	Establishing audit program	6 Activities	10 Objectives	27 Goals	27 Risks
X1.4	Implementing audit program	6 Activities	8 Objectives	9 Goals	9 Risks
X1.5	Monitoring audit program	5 Activities	5 Objectives	9 Goals	9 Risks
X1.6	Reviewing and improving audit program	3 Activities	5 Objectives	8 Goals	8 Risks
	Audit Implementation				
X2.1	Initiating audit	2 Activities	11 Objectives	11 Goals	11 Risks
X2.2	Preparing audit activities	4 Activities	12 Objectives	18 Goals	18 Risks
X2.3	Conducting audit activities	9 Activities	22 Objectives	22 Goals	22 Risks
X2.4	Preparing and distributing audit report	2 Activities	5 Objectives	5 Goals	5 Risks
X2.5	Completing audit	2 Activities	2 Objectives	2 Goals	2 Risks
X2.6	Conducting audit follow-up	2 Activities	2 Objectives	3 Goals	3 Risks
	Audit Criteria				
X3.1	Leadership and Worker Participation in Construction Safety	4 Sub-elements	16 Criteria	16 Goals	16 Risks
X3.2	Construction Safety Planning	4 Sub-elements	20 Criteria	20 Goals	20 Risks
X3.3	Construction Safety Support	5 Sub-elements	22 Criteria	22 Goals	22 Risks
X3.4	Construction Safety Operations	4 Sub-elements	49 Criteria	49 Goals	49 Risks
X3.5	Performance Evaluation of CSMS Implementation	5 Sub-elements	16 Criteria	16 Goals	16 Risks

4.2. Developing a Framework for an Integrated Risks-Based Construction Safety Audit

Conducting a relative assessment of perceived risks requires evaluating whether hazard A is deemed more or less risky compared to hazard B, even when the precise measurement of these risks is challenging. This evaluation requires a careful method, ensuring that hazards A and B are both assessed for risks in exactly the same way. Consistency is achieved by assessing them under similar conditions and at the same specificity level [50]. In the adoption of a qualitative risk assessment method that uses descriptive language, risk mapping is structured into low, medium, and high categories. The validation results obtained from experts regarding risk levels, causes, and preventive actions are systematically shown in Table 4.

Table 4. Validation Results of Risks Levels, Causes, and Preventive Actions

Code	Audit Activities / Sub-elements	Code	Risks Details	Risks Levels	Causes	Preventive Actions
X1. Audit Program Management						
X1.1. Establishing audit program objectives						
A1	The organization creates audit program objectives that consistently support audit process policies and objectives and are by its business processes	R1	Audit program objectives are not achieved and are wrong due to the many perspectives and opinions/ conflicts within an organization, as well as overlooked audit components/items.	High	Mistakenly defining audit program scope and overlooking components/items, along with numerous perspectives/opinions and conflicts within an organization.	Mistakenly defining audit program scope, overlooking components/items, and encountering numerous perspectives/ opinions as well as conflicts within an organization.
		R2	The combination of the program and audit process is not achieved according to plan due to many perspectives being combined incorrectly.	High	Mistakenly defining audit program scope and overlooking components/items, along with numerous perspectives/opinions and conflicts within an organization.	Developing detailed and straightforward policies, regulations, and procedural systems for audit program management from the initial phase to completion, including the responsible organization and adequate resources.
		R3	The unity of audit program objectives is not established, and goals are not achieved because personnel still adhere to outdated standards.	High	The competencies of the human resources managing audit program do not fulfil the organization's expectations and still adhere to outdated standards.	Implementing training programs and conducting socialization with a clear explanation of audit program implementation standards, along with creating a selection scheme for auditors through expert certification.
		R4	Audit program fails to adopt changes and lacks integration from the beginning to the end due to insufficient socialization and periodic reviews.	High	Mistakenly defining audit program scope and overlooking components/items, along with an unclear understanding of program integration by the organization.	Communicating and socializing the policy of separating audit program within audit process for each organizational level that is in accordance with the organization's goals and business.
		R5	Audit program is not properly managed because the program priority setting within the organization is inaccurate.	Medium	Mistakenly defining audit program scope and overlooking components/items, along with the program priority within the organization that is not in accordance with the objectives.	Developing detailed and straightforward policies, regulations, and procedural systems for audit program management from the initial phase to completion, including the responsible organization and adequate resources.
		R6	Audit program management is not optimal because the organization lacks interconnected process activities that function as a coherent system.	Medium	Mistakenly defining audit program scope, overlooking components/ items, and integrating process activities that are not interconnected and do not function as a coherent system.	Developing standardized business process procedures for audit program that are simple to understand yet detailed and comprehensive, accompanied by regulations supporting the program.
				⋮		
A69	Establishing Construction Safety Performance Improvement	R246	The CSMS audit does not depict the actual conditions in the field because the improvement in safety performance is not in accordance with the organization's business scale	Medium	Suboptimal management actions in the CSMS audit as well as the lack of capacity and capability among safety auditors and all parties that participated in the project to enhance safety performance in accordance with the organization's business scale.	Conducting analysis and re-identification of inputs, outputs, and outcomes related to CSMS implementation in accordance with procedures, policies, goals and scope, criteria, management organization, and business process along with performing evaluation for the sustainable development of CSMS.
		R247	The CSMS audit has no follow-up for improvement and enhancement because the identification of factors influencing safety and health performance improvement in the workplace are not in accordance with with the needs analysis results	Medium	The inputs, outputs, and expected outcomes related to the identification of factors influencing improvement in workplace safety and health performance is not in accordance with with the needs analysis results for CSMS implementation.	Conducting analysis and re-identification of inputs, outputs, and outcomes related to CSMS implementation in accordance with procedures, policies, goals and scope, criteria, management organization, and business process along with performing evaluation for the sustainable development of CSMS.
		R248	The CSMS audit has no follow-up for improvement and enhancement because both internal and external influences are ignored and not used as learning points to enhance safety performance	Medium	Suboptimal management actions in the CSMS audit as well as the lack of capacity and capability among safety auditors and all parties participating in the project to manage internal and external influences as learning points to improve safety performance.	Following up on the results of CSMS implementation by reporting to relevant authorities and responsible parties regarding the benefits of CSMS that generate added value along with providing rewards or penalties based on the ranking determination through the assessment of standardized parameters.

The recapitulation of risk levels shows that in the audit program management section, there are specifically 24, 36, and five high, medium, and low risks. Meanwhile, the audit implementation section has 44, nine, and seven high, medium, and low risks. In the audit criteria section, the distribution includes 85, 35, and three high, medium, and low risks. For each risk detail with identified levels, cause-based preventive actions were established. The experts also explained the causes of each risk in detail, along with their preventive actions. Additionally, a systematic pattern recognition process was conducted, grouping risks based on their underlying causes, as shown in Table 5.

Table 5. Mapping of Cause-Based Audit Activities and Risks Details

Code	Audit Activities/Sub-elements	Code	Risks Details	Code	Causes	Code	Preventive Actions
			X1. Audit Program Management				
			X1.1. Establishing audit program objectives				
A2	The organization ensures that audit program objectives are established for audit design and implementation. Furthermore, it ensures that the program is carried out effectively	R7	Audit program is ineffective because the expected inputs and outputs/outcomes are not in accordance with design and operational implementation	P1	The inputs, outputs, and expected outcomes of the organization is not in accordance with audit program design and operation within audit process	TP1	Conducting an analysis and re-identification of inputs, outputs, and outcomes related to the implementation of audit program in accordance with procedures, policies, goals and scope, criteria, management organization, and business process along with performing evaluation for the sustainable development of the program
A11	The organization creates and establishes procedures for audit program	R30	Audit program is ineffective because the established procedures are incorrect and are not in accordance with audit process system				
A1	The organization sets consistent audit program objectives that support the policies and goals of audit process are not in accordance with the business process of the organization	R3	The unity of audit program objectives is not established, and goals are not achieved because personnel still adhere to outdated standards	P2	The competencies of the human resources managing audit program do not fulfil the organization's expectations or requirements and still adhere to outdated standards.	TP1	Conducting an analysis and re-identification of inputs, outputs, and outcomes related to the implementation of audit program in accordance with procedures, policies, goals and scope, criteria, management organization, and business process along with performing evaluation for the sustainable development of the program
A2	The organization ensures that audit program objectives are established for audit design and implementation. Furthermore, it ensures the program is carried out effectively	R8	Communication within audit program is ineffective due to a lack of understanding related to digital technology advancements			TP2	Implementing training programs and socializing a re-explanation of audit program implementation standards, along with creating a selection scheme for auditors through expert certification
A7	The organization defines the roles and responsibilities of individuals managing audit program as well as audit team/auditors	R13	Audit program management is not in accordance with the roles and responsibilities of the selected personnel because it is not their task			TP3	Conducting specialized development and mentoring through a professional education program for engineering specialist auditors capable of managing audit program in line with objectives and standards
A8	The organization specifies the competencies of individuals managing audit program and audit team/auditors	R14	The organization struggles and makes mistakes in determining personnel who can manage audit program according to the expected competencies			TP4	Conducting a review and evaluation of audit program objectives against the expected results, with a monitoring process for program implementation
		R15	Standards and performance of audit program show no improvement because the selected personnel are not responsibly executing their tasks				
A9	The organization appoints individuals who manage and are responsible for audit program as well as audit team/auditors	R20	The quality of audit program results is poor and incorrect because the selected personnel cannot manage and are not accountable for the program				
A10	The organization establishes levels for audit program	R25	Audit program is not managed properly due to the selection of weak audit team partners who do not possess the required competencies				
		R27	The organization does not produce a high-quality audit program because performance indicators are unclear				
A11	The organization creates and establishes procedures for audit program	R31	Audit program is not managed properly because the socialization is poorly executed and cannot be measured				
A12	The organization identifies resources for audit program	R37	Audit program results are incorrect and cannot be accounted for because the allocated resources do not match the needs				

		R38	Audit program is not managed properly due to a lack of competent human resources as per requirements
		R39	Audit program objectives are not achieved because there are no financial resources according to the needs
A15	The organization appoints audit team members	R43	The quality of audit program results is poor and incorrect because the personnel assigned to audit team cannot adapt and communicate effectively with each other
A18	The organization manages and maintains records of audit program results	R48	Audit program is mismanaged due to a lack of competent resources in the field of archiving
A20	The organization monitors performance results of audit team members	R50	Audit program is not managed properly because audit team's performance does not fulfil expectations
A21	The organization monitors audit team's ability to conduct audit in accordance with the plan	R52	Audit program is not managed properly because audit team cannot resolve issues that arise during implementation
A22	The organization obtains feedback from top management, audited parties, auditors, and other relevant stakeholders	R54	The quality of audit program results is poor and incorrect because some parties do not work well or to their maximum capacity
A24	The organization reviews audit program to assess whether its objectives have been achieved	R58	Audit program objectives are not achieved and are incorrect because the results are not associated with performance, policies, and goals

After identifying cause-based preventive actions, a total of 37 such measures were classified, with 9, 13, and 15 specifically related to audit program management, implementation, and criteria. These preventive actions were then integrated into additional activities or criteria as part of the development of a risk-based construction safety audit process. The subsequent analysis of these 37 additional indicators was carried out using the Delphi method. The results showed that four indicators are considered inappropriate by experts, namely (i) re-identifying audit program implementation, followed by analysis and evaluation for the sustainable development of the program; (ii) communicating and socializing the CSMS implementation policy in the audit process for each project level in line with the goals and business process; (iii) conducting daily inspections during implementation integrated into the work; and (iv) planning a complete and orderly schedule for construction safety audit implementation with a designated responsible party for each process or activity. According to the experts, the risk response results associated with the cause-based construction safety audit process should not be eliminated because they offer additional information.

The developed framework of the construction safety audit process, as shown in Figure 6, comprised (a) 34 activities in audit program management at the organizational level, which increased goals in each process or activity from 26 to 65; (b) 34 activities in audit implementation at the project level, including the integration of ISO 19011:2018 standards, which merged with the previous process phases at the organizational level to obtain 60 goals; (c) 32 sub-elements in audit criteria were refined by adjusting the audit form in Regulation of the Minister of Public Works and Housing Number 10 of 2021 with the addition of 37 new criteria, thereby leading to a total of 123. The identification of risk factors in the audit criteria section suggested that a properly executed CSMS implementation can significantly improve construction safety performance. This observation is also consistent with preliminary research [37, 38, 50], showing that organizations with robust safety management systems and effective audits had better hazard control and safer working conditions, thereby reducing workplace accidents and improving project management.

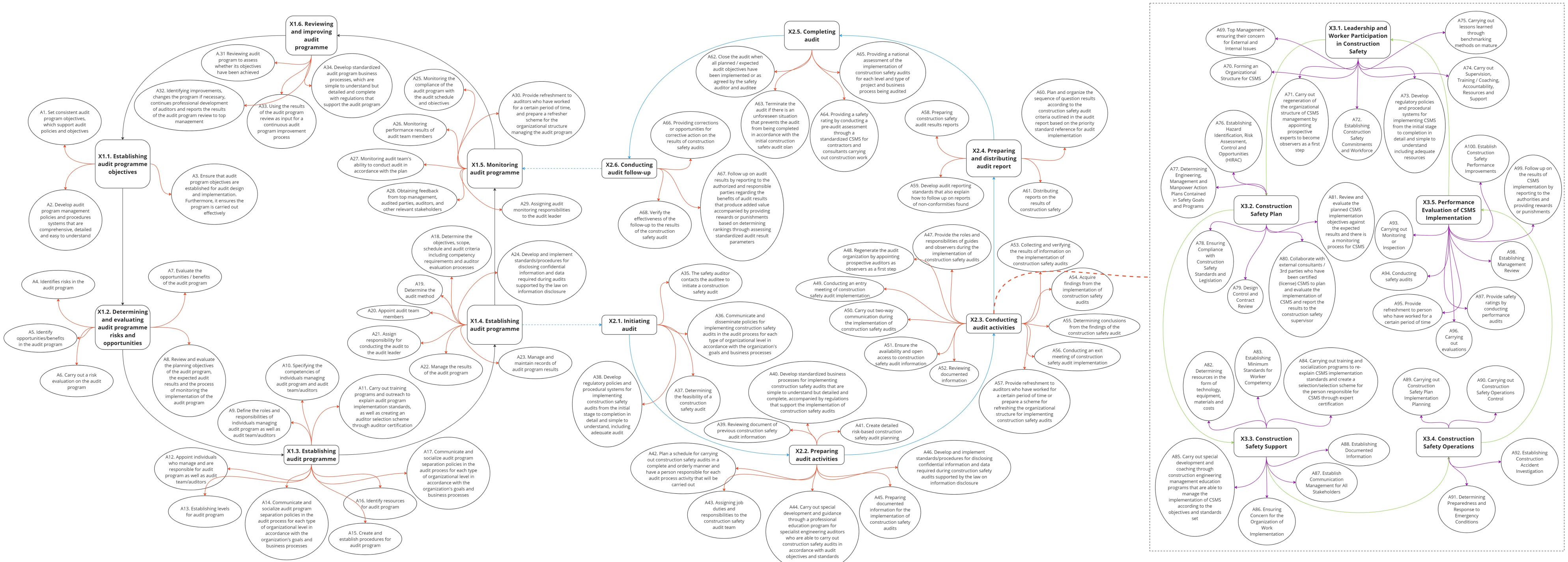

Figure 6. The framework of construction safety audit process

Construction safety audits would optimally improve construction safety performance when audits of CSMS implementation could be mitigated as well as possible. Several preventive actions or risk responses have been mapped to mitigate the detailed risks of the cause-based construction safety audit process, including conducting regular audits to evaluate the CSMS on the project and detailing a more regular audit schedule to evaluate construction safety performance. Each stage of the construction safety audit process is carried out with an assessment system so that risk prevention can be carried out as early as possible through audits that describe actual conditions in the working zone. Audit risk based along with risk control and causes, can be explained in more detail so that auditors and auditees are more aware of the potential risks that will occur in the implementation of construction safety audits. Implementing risk responses in the development of construction safety audit standards can reduce work accidents by identifying deviations earlier, thereby improving safety performance. The development of risk responses to detailed cause-based audit risks refers to the needs of each organization/company, the project's business operations, and the criteria to be audited.

Data analysis of the relationship between the development of construction safety audit process standards and construction safety performance using regression analysis. Based on the results of expert validation related to the development of construction safety audit process standards, as shown in Table 6, data was obtained which explains that the development of construction safety audit process standards, especially in the audit criteria section, has an influence and relationship with key indicators for enhancing construction safety performance, especially leading indicators such as those found in Regulation of the Minister of Public Works and Housing Number 10 of 2021, namely the implementation of Leadership and Worker Participation in Construction Safety, Implementation of Construction Safety Policy Elements, Construction Safety Programs, Construction Safety Support, and Inspections & Audits. In addition, leading indicators can also change in a short time. For example, the percentage of negative random drug results or the percentage of safety compliance based on audits. Leading indicators directly measure aspects of the CSMS, such as the frequency or timeliness of audits. The results of the construction safety audit can be further developed by the organization to become a standard inspection list, recommend improvements, improve environmental, health, and safety performance, and reduce the number of accidents.

Table 6. Influence of Construction Safety Audits on Construction Safety Performance

No.	Audit Process / Audit elements	Leading Indicators	Influence
1	Establishing audit program objectives	Application of Leadership in Construction Safety	High
		Implementation of Construction Safety Policy Elements	High
2	Determining and evaluating audit program risks and opportunities	Construction Safety Program	Medium
		Implementation of Construction Safety Policy Elements	High
3	Establishing audit program	Construction Safety Program	High
		Inspection & Audit	High
4	Implementing audit program	Construction Safety Program	Medium
		Inspection & Audit	High
5	Monitoring audit program	Inspection & Audit	High
		Construction Safety Support	Medium
6	Reviewing and improving audit program	Inspection & Audit	High
		Construction Safety Program	Medium
		Construction Safety Support	Low
7	Initiating audit	Construction Safety Program	High
8	Preparing audit activities	Construction Safety Program	High
		Inspection & Audit	Medium
9	Conducting audit activities	Inspection & Audit	High
		Construction Safety Support	Medium
10	Preparing and distributing audit report	Inspection & Audit	High
		Construction Safety Support	High
11	Completing audit	Inspection & Audit	High
		Construction Safety Support	High
12	Conducting audit follow-up	Implementation of Construction Safety Policy Elements	High
		Inspection & Audit	Medium
13	Leadership and Worker Participation in Construction Safety	Application of Leadership in Construction Safety	High
14	Construction Safety Planning	Implementation of Construction Safety Policy Elements	High
		Construction Safety Program	High
		Construction Safety Support	Medium
15	Construction Safety Support	Construction Safety Support	High
		Construction Safety Program	Medium
16	Construction Safety Operations	Construction Safety Program	High
17	Performance Evaluation of CSMS Implementation	Construction Safety Program	High
		Inspection & Audit	High

So, developing a framework for the construction safety audit process is very influential in enhancing construction safety performance. The results of the construction safety audit process can be developed as an innovative method to move away from traditional methods of records and information management to enable better management and organization of workflow processes. In practice, the current audit process is only carried out when an accident has occurred and only for certain purposes. The audit process is an important element of the CSMS because audit activities are carried out to review and evaluate the performance and effectiveness of the applicable safety management system.

5. Conclusion

In conclusion, the newly devised construction safety audit process facilitates early identification of deviations during the design phase. Given the escalating number of construction accidents, the implementation of construction safety audits has gained paramount importance. This audit process was developed by integrating principles from ISO 19011:2018 and Regulation of the Minister of Public Works and Housing Number 10 of 2021, resulting in an enhanced construction safety audit framework compared to the existing procedures. The findings revealed 34 activities in audit program management, 34 activities in audit implementation, and 32 sub-elements in audit criteria, all of which are integrated into the construction safety audit framework, systematically organizing audit processes and criteria.

This framework emphasizes that the improvement of construction safety performance extends beyond the construction phase to include the design phase. The audit results play a crucial role in continuous improvement efforts, aiming to enhance safety performance and prevent accidents in the construction industry. The analysis provided by auditors is deemed reliable when following this established audit process. The construction safety audit process framework was developed based on 21 causes of risk, leading to the identification of 37 risk responses. These responses translate into additional activities and new audit criteria, serving as a strategic approach to advancing standards in the construction safety audit process. The envisioned outcome of this construction safety audit process is an improvement in safety performance, particularly in the context of high-rise buildings using the design and build method. For future research, it is recommended to explore aspects such as the inclusion of responsible individuals and the assignment of value weights for each audit process and criterion. This suggests a shift towards a performance-based approach rather than solely adhering to conformance in construction safety audits.

6. Declarations

6.1. Author Contributions

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

6.2. Data Availability Statement

Data sharing is not applicable to this article.

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6.5. Conflicts of Interest

The authors declare no conflict of interest.

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