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Original Article

Enhancing Construction Safety of High-Rise Building Under Design-Build Method: A Safety Audit System Development

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Abstract *- Infrastructure development is being carried out massively, but this is accompanied by an increasing number of accidents in the construction industry. This places the construction industry among the most accident-prone sectors compared to others. This trend highlights the ineffectiveness of current construction safety audits in preventing accidents, as these audits are generally concentrated in the construction phase. Audits during the design phase are still very rare, even though everything conducted during the design phase will have a higher effect on the occurrence of accidents than during the construction phase. The limited number of auditors is one of the problems. So, an audit system is needed to make the audit process easier, faster, and more cost-effective. This research aims to develop a risk-based safety audit system for high-rise buildings under the Design-Build (DB) method. The research method was used qualitatively in formulating the development of an integrated audit system. The experimental process was conducted in two phases: (1) formulating a knowledge base for construction safety audit criteria and (2) developing a web-based information system. As a result, the expert assessed that the development of a web-based information system helps the construction safety audit process to be easier, faster, and cost-effective, makes it easier to obtain safety performance data, and facilitates the evaluation of evidence related to construction safety audits so that the audit results can be used for continuous improvement in order to enhance construction safety performance.*

Keywords *- Safety audit, Safety performance, Construction safety, Audit system, Design-build projects.*

1. Introduction

The current government era is considered one of the most aggressive infrastructure project development. In the 2021 state budget for infrastructure, the Minister of Finance allocated Rp417 trillion, an increase of 48% from 2020 [1]. The advantages of infrastructure development are long-term and come with high costs. During the New Order era, infrastructure development was a priority in the national budget; however, in 1998, the monetary crisis halted progress as the government lost its capacity to fund infrastructure construction, maintenance, and rehabilitation. After enduring a recession severely impacting the rupiah's value, the government initiated economic recovery efforts. The realization that Indonesia's infrastructure lagged behind other nations prompted the government to implement various policies to accelerate development [2].

There has been an increase in the construction industry in Indonesia in recent years. Starting in 2014, under President Joko Widodo, Indonesia aims to increase its infrastructure development, particularly through nine priority programs prioritising accelerating infrastructure development [3]. This also includes the construction of the National Capital City (IKN) Nusantara. The construction projects in this new capital city extensively utilize the Design-Build (DB) method.

The DB method demonstrates efficient time performance, ensuring project completion on schedule or ahead of time [4]. Data from the Electronic Procurement Service of the Ministry of Public Works and Housing (PUPR) [5] for the 2022-2024 fiscal year records numerous building projects with DB contracts under the Ministry of PUPR, most of which are developments in IKN, such as ministry office buildings and supporting facilities like multi-story residential buildings (Rusun).

IKN is a strategic project listed in the 2020-2024 National Medium-Term Development Plan (RPJMN) to support the Vision of Advanced Indonesia 2045 [6]; therefore, significant attention is required for its implementation. Ironically, the increase in construction activity was accompanied by a rise in construction accidents [7]. Construction accidents are incidents resulting from negligence during construction work, arising from the inability to comply with safety, security, health, and sustainability standards, leading to property loss, work delays, fatalities, permanent disabilities, or environmental damage [8]. As stated by the Ministry of PUPR [9], the construction sector, together with the manufacturing industry, accounted for 32.00% of work-related accidents in Indonesia, spanning a range of projects, including buildings, roads, bridges, tunnels, and irrigation systems. This figure surpasses those of other sectors, such as transportation (5.30%), forestry (3.80%), and mining (2.60%). Additionally, the International Labour Organization has reported that an estimated 6,000 individuals lose their lives each day as a result of work-related illnesses or occupational accidents [10].

According to data from the National Social Security Agency for Employment (BPJS Ketenagakerjaan) [11], in 2019, the number of claims submitted for Work Accident Insurance (JKK) totaled 182,835 cases. This figure steadily rose in the following years, with 221,740 claims recorded in 2020 and 234,370 claims in 2021. By 2022, the claims had further increased to 297,725 cases. A total of 360,635 work accident issues seeking JKK claims were filed between January and November of 2023.

To prevent and mitigate construction project accidents, the government issued the Regulation of the Minister of PUPR No. 10 of 2021 on Guidelines for the Construction Safety Management System (SMKK). The Ministry of PUPR [8] stipulated that all service users and providers in construction services must implement SMKK, and the SMKK implementation needs to adhere to security, safety, health, and sustainability. Implementation should align with both parties' defined duties, responsibilities, and authorities. Service providers are required to prepare a Construction Safety Plan (RKK), a document that reviews construction safety and incorporates SMKK elements within the contract documents. These elements include (a) Leadership and workforce participation in construction safety, (b) Construction Safety Planning, (c) Construction Safety Support, (d) Construction Safety Operations, and (e) Construction Safety Performance Evaluation.

According to Regulation No. 10 of 2021 [8], the SMKK audit aims to identify weaknesses within each SMKK component to facilitate continuous improvement and prevent operational disruptions, accidents, incidents, and losses. The continued occurrence of construction accidents indicates that the current SMKK audits have yet to effectively prevent these incidents. Arens [12] defined an audit as the process of gathering and assessing evidence related to information to determine and report the level of adherence to established criteria. Auditing is a crucial component of safety management systems, offering a method for thorough and direct monitoring of the system's implementation and effectiveness. The audit process typically includes gathering evidence through interviews, document analysis, and workplace observations based on audit standards or instruments, evaluating the evidence, and summarizing the findings [13]. Safety audit outcomes help organizations develop checklists, recommend improvements, enhance performance in environmental, health, and safety areas, and reduce accident rates [13, 14].

In addition to the limited number of Construction Safety Committee auditors, audits have often been fragmented. The membership of the Construction Safety Committee, according to the Minister of PUPR's Decree [15], consists of only 28 members. Furthermore, audits have been carried out only at specific stages of the project lifecycle rather than being comprehensive from the design phase through to execution. Audits often focus solely on the execution phase; in some cases, they are conducted only after an accident has occurred [16]. Construction safety audits are seen as a solution to construction accident issues, enabling corrections for non-compliance and performance deficiencies.

However, improvements are needed, such as enhancing the construction safety audit process by implementing an integrated system that covers both the design and construction phases. This approach would make audits more effective, efficient, and optimal, particularly in mitigating construction accidents.

This research aims to develop a Risk-Based Safety Audit System for High-Rise Buildings under the DB Method. Research on construction safety audits has been developed in previous studies. The audit process in earlier research was generally conducted after the occurrence of work accidents or fatalities [17, 18]. Nugroho developed a safety plan standard and an audit process for high-rise building construction projects under the DB method based on WBS and risk. In this study, a knowledge base based on risk causes was developed to enhance the audit process as a learning resource, along with the development of an information system for conducting safety audits on high-rise buildings using the DB method.

2. Materials and Methods

This study uses a qualitative methodology with several research instruments, including a literature study, questionnaires, and interviews. The literature study is conducted to gather data from previous research related to the knowledge base of construction safety audit criteria. The distribution of questionnaires and interviews to experts is carried out to validate and test whether the developed information system aligns with the intended objectives.

In this context, the experimental process was conducted in two phases: (1) formulating a knowledge base for construction safety audit criteria and (2) developing a web-based information system. The research process flow is illustrated in Figure 1.

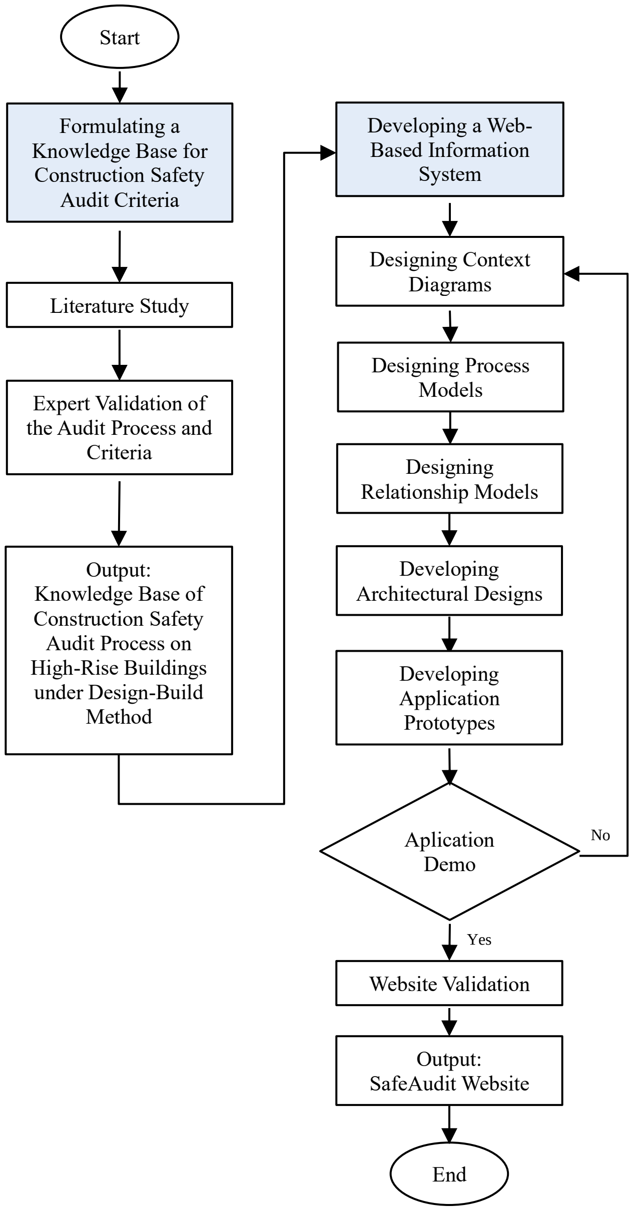

Fig. 1 The research process flow

2.1. Knowledge Base for Construction Safety Audit Criteria

This study uses one of the data sources from research conducted by Akram and Fadli [19], which provides insights into the audit process, audit criteria, along risk control. Expert validation of the audit process and criteria resulted in a standardised construction safety audit process, which became the knowledge base, namely:

(a) Audit Program Management, the development of this audit process stage complements previous research related to audit program management at the organisational level which then refined the targets in each audit process activity which were previously only 26 targets to 65 audit targets carried out by risk response as the development of new audit activities.

(b) Audit Implementation, the development of this audit process stage adds and integrates the ISO 19011:2018 [20] guideline standards for the audit implementation section at the project level with the previous audit process stage at the organisational level, where all process activities, objectives, and audit targets are developed from ISO 19011:2018. Thus, 60 audit objectives were obtained that had the potential to generate risks, and risk responses were carried out in the form of developing new audit activities.

(c) Audit Criteria, the development of these audit criteria improves the audit criteria and composition of the existing SMKK elements in Regulation of the Minister of PUPR No 10 of 2021 [8]. The SMKK audit criteria, which were previously only 86 criteria, have increased to 123 SMKK audit criteria.

In addition, based on the results of expert validation, in construction safety audits, there are 8 causes of audit process risks in the same category at the audit programme management stage, 5 causes of audit process risks at the audit implementation stage, and 9 causes of audit process risks in the audit criteria section.

The data that has been validated is then developed into a knowledge base. The knowledge base serves to store the expertise of expert systems, such as facts and rules, where in its development process, it must be capable of acquiring new information, representing, and storing knowledge in a manner that allows it to be processed by a computer [21].

2.2. Development of a Web-Based Information System

In developing this construction safety audit system, researchers collect data using the construction safety audit process knowledge base as input. The development of information systems for knowledge sharing and the application of knowledge in knowledge management development is through website development. The website development is carried out by following the following steps.

2.2.1. Context Diagram

The context diagram is designed to determine the global flow of data to and from entities in the designed audit system. The BPMN design results for implementing construction safety audits produce an audit system context diagram with two entities, namely Auditee (contractors) and Auditor (Construction Safety Committee).

Where each entity has its role an auditee is an entity that has the role of conducting a self-assessment of construction safety performance on the project being undertaken. In addition, it can also access information on the construction safety knowledge base dashboard. Meanwhile, the Auditor has the role of being able to review and assess the self-assessment carried out by the Auditee. Auditors also access information on the dashboard monitoring safety performance assessment on projects conducting self-assessments.

2.2.2. Process Model: Data Flow Diagram (DFD)

DFD represents the transformation graph of data in a system. This DFD is a derivative form of a context diagram if the context diagram only describes one system at large with a large circle symbol connected to the entity. Then, in the DFD, the description of the system becomes even more detailed, drawing into processes with small circle symbols; the number of entities in the context diagram must be the same as the number of entities in the DFD.

The DFD of this audit system consists of 2 Entities with 2 Processes that produce 2 Datasets. The Auditee entity is connected to Process 1.0 (Project Data Input) and Process 2.0 (Construction Safety Performance Self Assessment) by generating 2 datasets: project data and Self Assessment result data. Meanwhile, the Auditor entity is connected to Process 3.0 (Review of Self Assessment Results) and Process 4.0 (Construction Safety Audit) by generating 1 dataset, namely Construction Safety Audit Results.

2.2.3. Relationship Model: Entity Relationship Diagram (ERD)

ERD is a graphical representation that explains the relationship between entities involved in a system, along with their attributes. A few interconnected tables and views are formed based on the datasets formed in the DFD of this audit system. This ERD is the logic design of the database built to support further system development.

2.2.4. Architectural Design

This audit system is developed with a web-based programming language, and as a data integration model, web service technology (Application Program Interface - API) is used.

The selection of web service technology is because this technology allows for a system to be interconnected with other systems. Java Spring Boot Framework application processes data from the main and temporary tables in each process to create an API, which allows users to make changes and store and delete data in the database through the website interface.

Then, the PHP Codeigniter application processes the model obtained from the API using the ‘Model View Controller (MVC)’ approach before presenting it to the user.

2.2.5. Application Prototype

The development of this audit system prototype is based on the results of system modelling in the previous stage. This application was developed with a web-based programming language, so users only need a web browser to access it. There are several pages/ or menus provided to accommodate user needs when conducting construction safety audits.

2.2.6. Demo

An application demo is the stage of introducing the designed audit system prototype to prospective users, intending to get feedback from prospective users on how to use and the functionality of the built prototype system. This audit system prototype demo is carried out directly to several potential users consisting of Auditors (Construction Safety Committee) and Auditees (Contractors). The demo was conducted offline and online to Auditors (Construction Safety Committee) and Auditees (Contractors).

2.3. Validation of Web-Based Information System Development

Validation of the SafeAudit website was conducted to test the system directly in an actual environment. Users assess the application using a questionnaire. From these results, it can be concluded whether the application developed is in accordance with the objectives. The method used in this validation is done directly to experts by giving questionnaires and interviews.

At this stage, 5 experts are needed, who must meet the criteria of being members of the Construction Safety Committee and/or work safety auditors with at least five years of expertise in integrated construction projects pertaining to high-rise building design and construction. Furthermore, the experts had to possess a minimum of a bachelor's degree. Table 1 presents the profiles of the experts involved in this data collection.

The recapitulation of the expert validation results for the construction safety audit system can be seen in Table 2. In the Perceived Ease of Use aspect, all experts agree that the developed system is easy to learn; all experts agree that this system makes it easy for users to access data and information; and 4 out of 5 experts agree that the stages of using this information system are also easy to remember and practice.

While on the Perceived Usefulness aspect, all experts agreed that the use of this system would speed up and save the cost of conducting construction safety audits; all experts agreed that the use of this system would make it easier to obtain safety performance data needed in conducting construction safety audits; and all experts also agreed that the use of this system would facilitate the process of evaluating construction safety audit evidence.

Then, regarding Attitudes Towards Using the system, 3 out of 5 experts agreed that they were happy with using the SafeAudit system, and 4 out of 5 experts agreed that they thought using the SafeAudit system was a good idea. Furthermore, regarding Behavioural Intention to use the system, 4 out of 5 experts agreed on their willingness to use the SafeAudit system for conducting construction safety audits, and 4 out of 5 experts agreed on suggesting the SafeAudit system develop some features so that its use is not only for conducting construction safety audits.

Table 1. List of experts on the validation

Code	Occupation	Experience	Education
P1	Ministry of Public Work and Housing	19 Tahun	Doctor
P2	Safety Committee	15 Tahun	Master
P3	Safety Committee	38 Tahun	Doctor
P4	Contractors	18 Tahun	Master
P5	Safety Committee	13 Tahun	Master

Table 2. Recapitulation of the results of expert validation of the safeaudit

No.	Assessment Aspect	Indicator	Agree	Neutral	Disagree
1	Perceived Ease of Use	The developed system is easy to learn	5	0	0
2	Perceived Ease of Use	This information system makes it easy for users to access data and information	5	0	0
3	Perceived Ease of Use	The stages of using this information system are easy to remember and put into practice	4	1	0
4	Perceived Usefulness	The use of this system will speed up and save the cost of conducting construction safety audits	5	0	0
5	Perceived Usefulness	The use of this system will make it easier to obtain safety performance data needed in conducting audits	5	0	0
6	Perceived Usefulness	The use of this system will facilitate the evaluation process of construction safety audit evidence	5	0	0
7	Attitudes Towards Using	I feel happy using this SafeAudit system	3	2	0
8	Attitudes Towards Using	I think using this SafeAudit system is a good idea	4	1	0
9	Behavioural Intention	I want to use this SafeAudit system in conducting construction safety audits	4	1	0
10	Behavioural Intention	I would like to suggest that this SafeAudit system develop some features so that its use is not only for conducting construction safety audits.	4	1	0

3. Results and Discussion

SafeAudit is a web-based information system created for high-rise building safety performance audits using the DB technique.

The website can be accessed via https://safeaudit.id/. The system can be used for:

- Obtain information about the construction safety audit process and its associated risk management strategies,
- To guide the construction safety audit process for high-rise buildings with DB contracts,
- Storage of documents that support the construction safety audit process, along with the outcomes of safety audits on previous projects,
- Conduct self-assessment of construction safety performance conducted by the Auditees,
- Review the results of the self-assessment of construction safety performance and provide an assessment of the results of the construction safety audit conducted by the Auditors.

3.1. The Page View of the Construction Safety Audit Knowledge Base

Figure 2 shows the front page of SafeAudit. On the Knowledge Base page, the public can access information about the construction safety audit process without the need to log in. Meanwhile, to access the Construction Safety Audit page, users must log in.

On the login page, users need to enter a username and password that has been registered, as shown in Figure 3. Users who do not have an account can sign up first. Users must fill in data to get a username and password.

Figure 4 shows the knowledge base page that displays the knowledge base of the risk cause-based audit process from the categories:

(a) Audit Programme Management,

(b) Audit Implementation, and

(c) Audit Criteria.

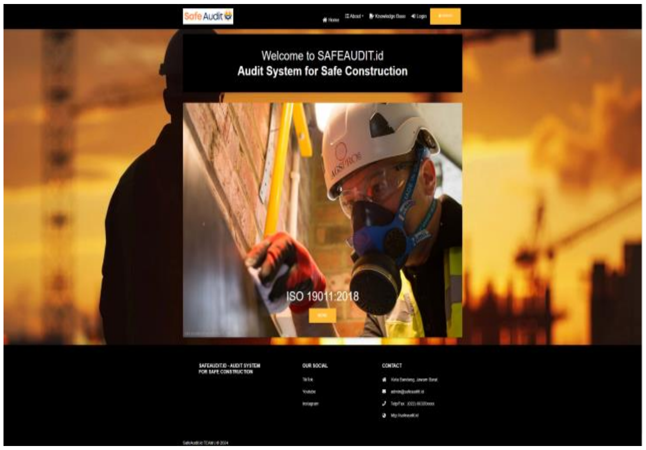

Fig. 2 Website main page

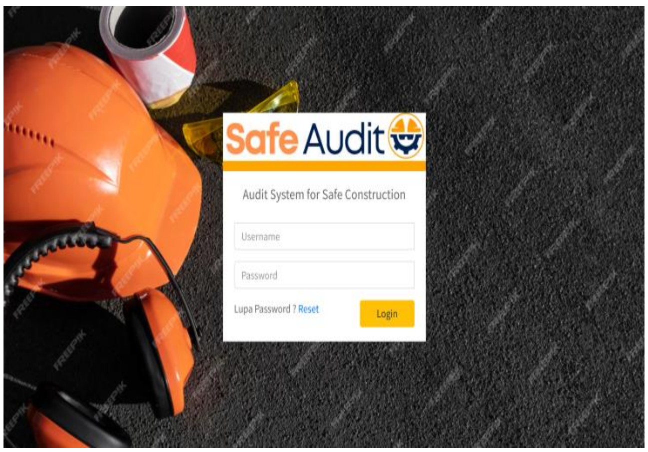

Fig. 3 Login page

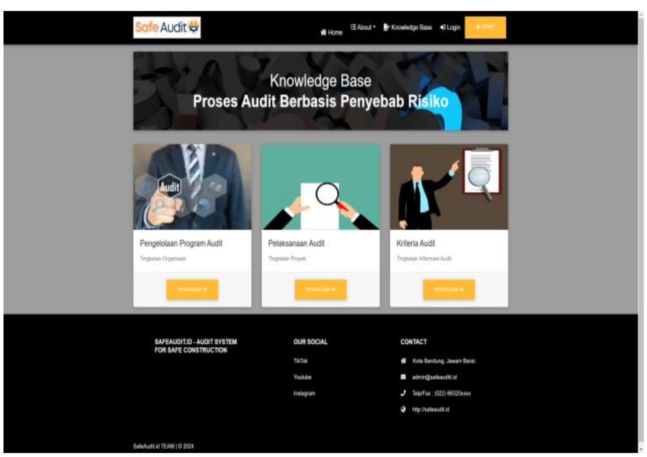

Fig. 4 Menu options on the knowledge base page

Then, in Audit Programme Management, the web page will display 8 knowledge of the same risk cause category in audit programme management. After the user selects one of the details of the risk causes of audit programme management, the pattern recognition of audit activities, risks, causes, and preventive actions will be displayed as shown in Figure 5.

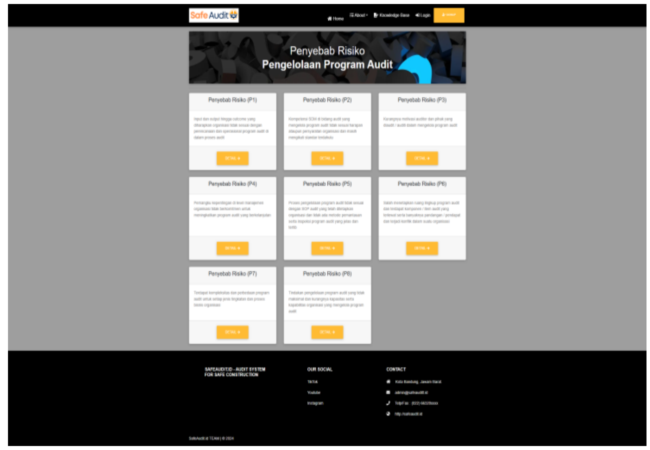

Fig. 5 Page of risk cause-based audit process information on audit programme management

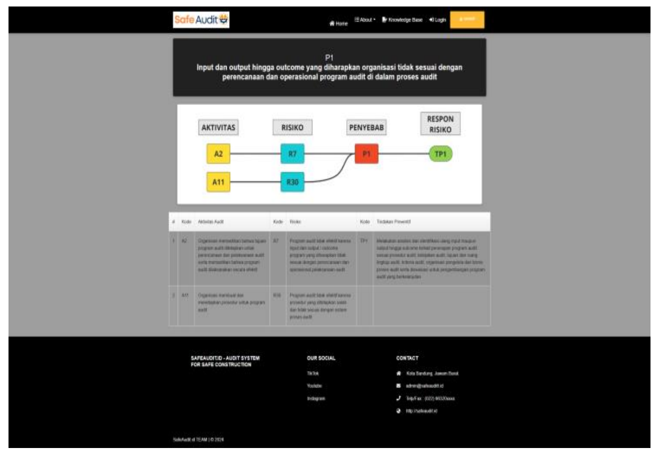

Fig. 6 Pattern recognition of audit activities, risks, causes, and risk responses

The display of audit activities, risks, and preventive actions is also available for each risk to cause details in audit implementation and audit criteria, as shown in Figure 6.

3.2. The Page View for Self-Assessment of Construction Safety Performance

The SafeAudit website testing was conducted using real data on The Integrated Design and Build Construction Project for the Development of a Multi-story Residential Building (Rusun) in IKN, with the contractor being PT X. PT X, as an auditee, will perform the self-assessment process on the SafeAudit website using the construction safety plan document and supporting data from the project.

Contractors need to login using the username and password that have been registered to be able to access the Dashboard and My Project menus. The Dashboard view after the user logs in is shown in Figure 7. On the 'My Project' menu page, projects that carried out the self-assessment process for construction safety performance by the Contractor will be displayed.

If the Contractor wants to start the assessment process for a new project, click Add Project. Then, the data that needs to be filled in will appear, including the project's name, owner, location, value, start and end dates, CM consultant, planning consultant, main contractor, project address, active/inactive status, and upload project images, as shown in Figure 8.

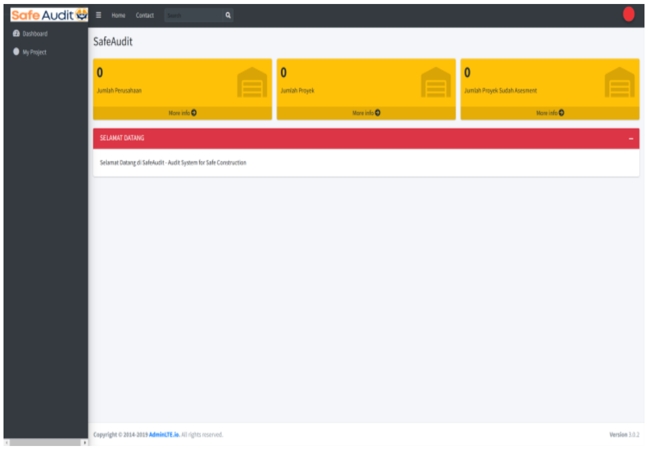

Fig. 7 Page of auditee user dashboard

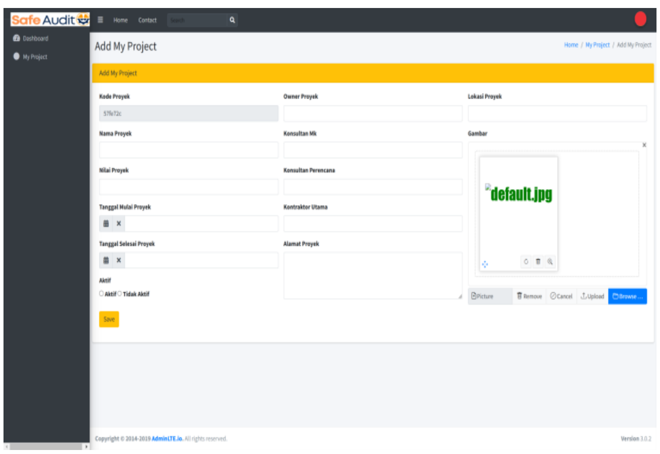

Fig. 8 Page of project data fill

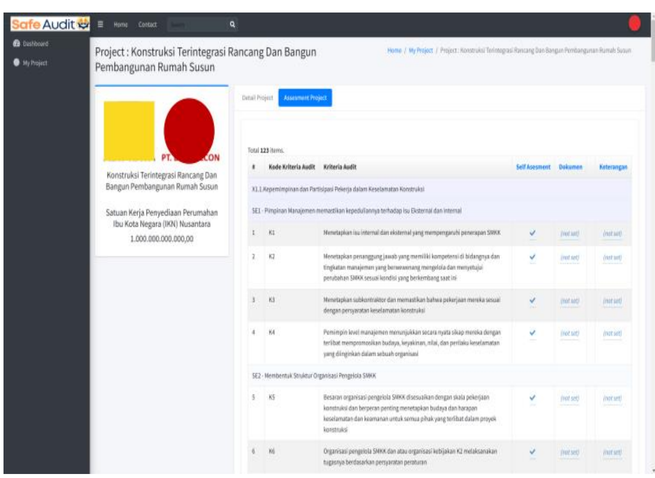

Fig. 9 Page of self-assessment process by auditee user

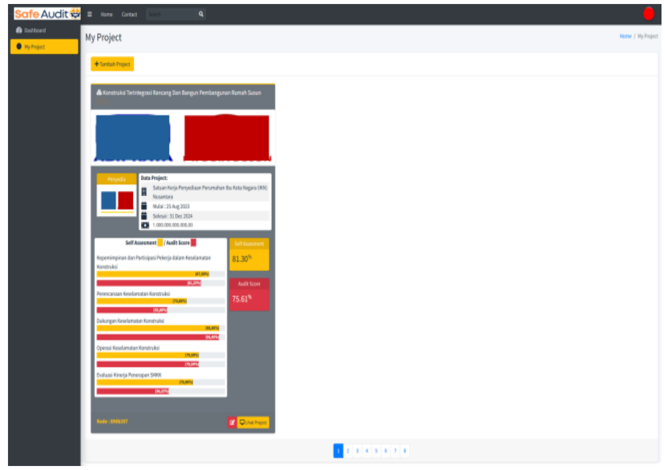

Fig. 10 View of self-assessment results score

After the new data is created, the Auditee user can perform the self-assessment process. In the Project Assessment tab, a self-assessment can be made regarding construction safety performance on a project by assessing each audit criterion. Auditee users can select "Yes/No" in the Self Assessment column to assess whether the audit criteria have been implemented/implemented or not. The auditee can select "Yes" if the implementation of the audit criteria has been carried out properly in the field and is supported by complete documentation. Conversely, the auditee can select "No" if the implementation of the audit criteria has not been carried out properly and is not supported by complete documentation. Supporting documents for each audit criterion can be uploaded in the Documents column. Auditee users can also add remarks in the column provided, as shown in Figure 9. Then, the self-assessment results score can be seen in the My Project menu, as shown in Figure 10.

Figure 10 shows that the self-assessment result score of PT X for constructing the Multi-story Residential Building (Rusun) in IKN is 81.30%. The implementation of worker leadership and participation in construction safety scored 87.50%, the implementation of construction safety planning scored 70.00%, the implementation of construction safety support scored 95.45%, the implementation of construction safety operations scored 79.59%, and the implementation of construction safety performance evaluation scored 75.00%. Based on these scores, PT X, as the contractor, has implemented the audit criteria for constructing the Multi-story Residential Building (Rusun) in IKN at a rate of 81.30%.

3.3. The Page View of the Construction Safety Audit

The audit process is conducted by the Auditor (Construction Safety Committee). Auditor users need to login using their registered username and password to access the Dashboard and Project List menus. The Dashboard view after the user logs in is shown in Figure 11. In the 'Project List' menu, all projects that have been self-assessed by the Auditee are displayed.

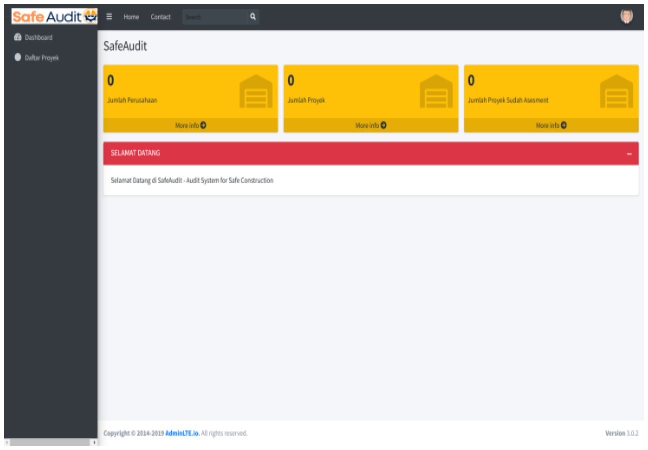

Fig. 11 Page of auditor user dashboard

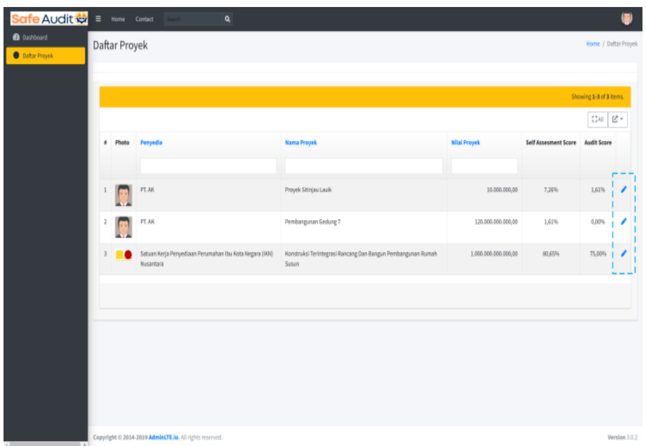

Fig. 12 View of project list on auditor user

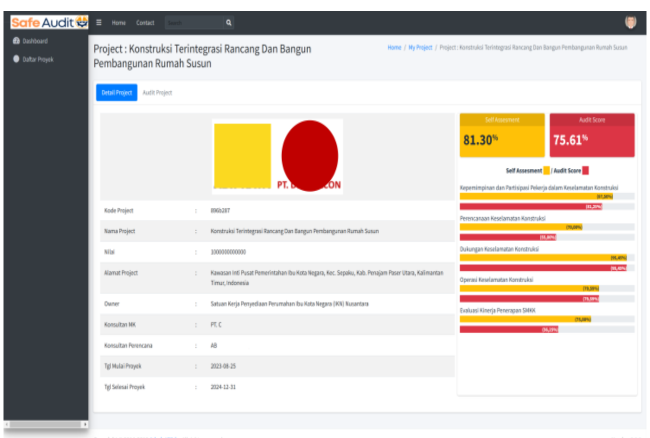

Fig. 13 Menu view of projects that have been self-assessed

Auditors can view project data and perform the audit process by clicking the pencil button on each project, as shown in Figure 12. The Detail Project tab displays project data that has been self-assessed, as shown in Figure 13. Auditors can view self-assessment results and perform audit checking by clicking the Audit Project tab. On the Audit Project tab, there are 5 audit criteria. The first tab focuses on Worker Leadership and Participation in Construction Safety; the second tab covers Construction Safety Planning; the third tab addresses Construction Safety Support; the fourth tab relates to Construction Safety Operations; and the final tab focuses on Construction Safety Performance Evaluation, each of which has audit criteria as shown in Figure 14.

The Auditors can view and check the results of the self-assessment inputted by the Auditee. The Auditors can select Yes/No in the Audit Check column to assess whether or not the audit criteria have been applied/implemented. The Auditor can select "Yes" if the implementation of the audit criteria has been carried out properly and is supported by documented evidence uploaded by the auditee.

Conversely, the Auditor can select "No" if the implementation of the audit criteria has not been carried out properly and is not supported by documented evidence. Supporting documents in the Documentary Evidence column can be downloaded to help the checking process. The Auditors can also add remarks in the Audit Notes column. The result of the Audit Score can be seen in the Project Detail tab view, as shown in Figure 15.

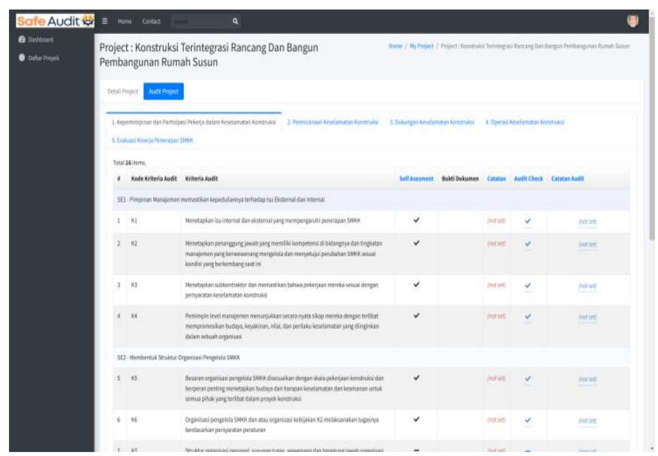

Fig. 14 View of construction safety audit process conducted by auditor users

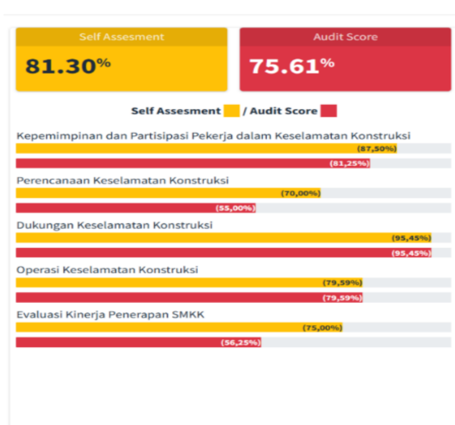

Fig. 15 Display of construction safety audit result scores

Figure 15 shows that the construction safety audit score of PT X for constructing the Multi-story Residential Building (Rusun) in IKN is 75.61%. The implementation of Worker Leadership and Participation in Construction Safety scored 81.25%, the implementation of Construction Safety Planning scored 55.00%, the implementation of Construction Safety Support scored 95.45%, the implementation of Construction Safety Operations scored 79.59%, and the implementation of Construction Safety Performance Evaluation scored 56.25%. Based on these scores, PT X, as the contractor, has achieved a construction safety compliance level of 75.61% based on the established audit criteria.

Table 3. Assessment score

Assessment	Score
Agree	3
Neutral	2
Disagree	1

Table 4. Average range of assessment results

Average Range	Result
1,5 - 3	Agree
0 - 1,5	Disagree

Table 5. Validation results of the construction safety audit system

No.	Indicator	Mean	Result
1	The developed system is easy to learn	3	Agree
2	This information system makes it easy for users to access data and information	3	Agree
3	The stages of using this information system are easy to remember and put into practice	2,4	Agree
4	The use of this system will speed up and save the cost of conducting construction safety audits	3	Agree
5	The use of this system will make it easier to obtain safety performance data needed in conducting audits	3	Agree
6	The use of this system will facilitate the evaluation process of construction safety audit evidence	3	Agree
7	I feel happy using this SafeAudit system	1,8	Agree
8	I think using this SafeAudit system is a good idea	2,4	Agree
9	I want to use this SafeAudit system in conducting construction safety audits	2,4	Agree
10	I would like to suggest this SafeAudit system to develop some features, so that its use is not only for conducting construction safety audits.	2,4	Agree

5 experts then validated the information system to determine whether it functions properly and meets user needs. Based on the results of expert validation, a descriptive analysis method is carried out to determine the results of the assessment of each aspect related to the system that has been developed. From the results of expert validation in Table 2, The conclusion is obtained by finding the average value of the assessment, with each assessment having a score as in Table 3 and Table 4. After scoring, data analysis was performed on the validation of the use of the construction safety audit system, the results of which are presented in Table 5.

The data analysis conducted on the evaluation of the developed website is presented in the table above. Based on the four assessment aspects encompassing ten indicators, the results show that the average score of all indicators falls within the range of 1.5 to 3. Referring to Table 4, this indicates that the assessment results have been approved. Regarding Perceived Ease of Use, the developed system is easy to learn, which makes it easy for auditors/users to access data and information. The stages of using this information system are also easy to remember and practice. Meanwhile, in the aspect of Perceived Usefulness, using this system will speed up and save costs for conducting construction safety audits, make it easier to obtain safety performance data needed in conducting construction safety audits and facilitate the process of evaluating construction safety audit evidence. Then regarding attitudes towards using the system (Attitude Toward Using), users feel happy to use this safeaudit.id system, and they think using this safeaudit.id system is a good idea. Furthermore, regarding Behavioural Intention, users want to use this safeaudit.id system in conducting construction safety audits and want to suggest this safeaudit.id system develops several features so that its use is not only for conducting construction safety audits.

The research results show that the developed information system has been validated and approved by experts. This study produced a standardized construction safety audit system and a knowledge base designed based on risk causes in the construction safety audit process. The web-based information system is designed to perform safety audits on high-rise building projects using the DB method to evaluate their safety performance levels. Safety performance can be assessed through safety compliance and also safety participation [22]. The audit score result on the information system is presented as a percentage of the implementation of construction safety in the project. Quantitative audit results are often used by organizations as a performance metric [23]. Rajaprasad [24] emphasized that safety performance is evaluated through audits, and the data collected is used to identify the most effective corrective actions. The information system for construction safety audits makes the audit process more structured and efficient. The audit process no longer needs to be conducted manually, and data is directly stored in the system's database, which can be accessed anytime and anywhere. This aligns with Turban [25], who stated that information systems are a combination of information technology and human activities that function to collect, process, generate, distribute, and store data to support organizational needs or strategies. This system certainly supports the Auditor (the Construction Safety Committee) in carrying out their duties, such as monitoring and evaluating construction work and investigating construction accidents, as stipulated in the Minister of PUPR Decree [15]. In addition, the knowledge base based on risk causes in the construction safety audit process from expert validation results is presented in the information system. This is in line with Tan [21], who explains that a knowledge base is used to store expert system expertise that can be processed by a computer. Atymtayeva [26] states that a knowledge base is an effective tool to support the audit process. The knowledge base provides systematic and structured information to facilitate decision-making. The knowledge base's objective is to provide domain-specific information in a way that computers can efficiently handle [26].

4. Conclusion

Developing the SafeAudit Website as a web-based information system simplifies the construction safety audit process, making it faster, more cost-effective, and easier to access safety performance data while streamlining the evaluation of construction safety audit evidence. So that the audit results can be used for continuous improvement in order to enhance construction safety performance, future research ought to concentrate on creating a performance-based audit system on construction projects so that the safety rating value of the construction project can be known.

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