International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V72I1P108

Volume 72 Issue 1, 71-80, January 2024

Original Article

Development of the Construction Safety Goals and Programs During the Design and Construction Phase for the Audit Process to Improve Construction Safety Performance

Muhammad Nouval Akram[1], Yusuf Latief[1], Danang Budi Nugroho[1,2*]

[1]*Department of Civil Engineering, Faculty of Engineering, University of Indonesia, Depok, West Java, Indonesia.*
[2]*National Research and Innovation Agency, South Jakarta, DKI Jakarta, Indonesia.*

[1]*Corresponding Author : muhammad.nouval@gmail.com*

Received: 26 September 2023 Revised: 23 November 2023 Accepted: 19 December 2023 Published: 07 January 2023

Abstract *- In Indonesia, construction service providers need to design and implement a Construction Safety Plan (RKK) as stated in the Ministry of Public Works and Public Housing (PUPR) Regulation No. 10 of 2021. Furthermore, safety goals and programs are currently planned and implemented by contractors only in the construction phase. This becomes a problematic phenomenon in implementing the Construction Safety Management System (SMKK) because it is not comprehensive. Therefore, this study aimed to develop safety goals and programs as the basis for the construction safety audit process on integrated construction using the design-build method as a risk control tool. A qualitative method was used, and additional secondary data were obtained from relevant literature reviews. Risk control was specified for high risk at the WBS level for each work activity. The results showed that risk control for high-risk levels using substitution, engineering controls, administrative controls, and adequate PPE was carried out from the design phase to the project's completion. Meanwhile, RKK, using the design-build method, consisted of 36 main goals and safety programs that controlled high-level risks. This was identified as 3 high risks at the design phase, 2 at the implementation of SMKK, and 3 at the construction phase. In addition, there were successful benchmarks and the person in charge of implementing the risk control. The benefits of this study could become guidelines for preparing safety goals and programs as the basis for the audit process on RKK using the design-build methods in Indonesia.*

Keywords *- Audit process, Construction safety plan, Construction safety performance, Design-build method, Safety goals and programs.*

1. Introduction

Currently, Indonesia is dedicated to improving the development of buildings and infrastructure, as seen in the recent construction of the National Capital (IKN). The government announced plans to relocate the IKN in early 2022 through Law No. 3 2022 concerning the State Capital [1]. Meanwhile, development priorities at the IKN between 2022 and 2027 included infrastructure and government office buildings in the state palace area. Enhancing the volume of construction work in a short time will have an impact on increasing budget and faster execution time, starting from the procurement/auction phase to the project completion. The Minister of Public Works and Public Housing (PUPR) explained regarding the development of the IKN, *"Since the auction follows a design-build approach, we will create the basic design, and the winner will refine both the design and construction. This speeds up the process and is referred to as "design-build"* [2].

Therefore, construction work using the design-build method will consider high risk, complexity, and potential for unexpected situations such as development design changes during project construction. Due to the complexity of this method, Indonesia's construction sector often experiences an increase in construction accidents.

According to the data from BPJS Ketenagakerjaan (Indonesia Worker Insurance), the number of accidents at work sites continues to increase. Since 2017, 123,040 cases have been reported, increasing by 47.48% in 2021 to 234,270. This showed the prevalence of work accidents in the construction industry, especially in high-rise buildings, with a risk that cannot be ignored and must be controlled.

The most fatal work accident that often occurred in high-rise building construction was a fall from a height, which led to disability and even death [3]. Previous research [4] analyzed 224 work accidents and found that 41% could have been prevented through planning. Other research [5] showed that construction safety design included handling the safety of workers in a permanent design on a project. This means the concept of prevention through proactive planning in preventing potential risks is important. It also aimed to eliminate potential risks in the construction phase before the occurrence.

Considering the increasing number of construction accidents, the construction safety audit process is very important. It is also still reactive, carried out after a construction accident has occurred. Based on Symbersky's theory, the potential for construction accidents is due to improper design at the conceptual phase, which is related to non-compliance with standards and regulations [6]. It was concluded that considering safety in the design phase is very important. Hence, the concept of design for construction safety has been formally presented in the global construction research agenda.

This led to a focus on one of the elements of the Construction Safety Management System (SMKK), namely the Construction Safety Plan (RKK). The indicators of this element include safety goals and programs. Also, one of the risk control tools to reduce work accidents in the construction industry was to make a safety plan. The Construction Safety Plan has been regulated by the Ministry of Public Works and Public Housing Regulation No. 10 of 2021 [7].

The plan requires safety goals and programs based on the stages of work activities, namely the Work Breakdown Structure (WBS). To establish safety goals and programs, it is important to identify the hazards and risks highlighted in previous studies.

This involves the identification of hazards and risks based on the WBS level of work activities, starting from the design and implementation of SMKK to construction. Therefore, this study aimed to overcome the problem of construction accidents by developing safety goals and programs as the basis for a more complete and structured construction safety audit process criteria based on high risk and the WBS level of work activities using the design-build method to improve construction safety performance. The benefit of these safety goals and programs as the basis for the construction safety audit process criteria is being a risk control tool and a guideline for preparing construction safety plans for projects using design-build methods.

2. Methodology

The methods used were literature review, case studies, and data collection from safety experts. Furthermore, a literature review of several related sources was conducted to obtain the hazards and risks of each construction work activity using the design-build method along with risk level for risk control to be planned. The literature review was discussed and used to complement the topic of RKK using design-build methods of high-rise building projects based on WBS to improve construction safety performance.

The High-rise building case study approach was also used to comprehensively explain this study and observe new phenomena related to the topic of construction safety. This was based on the WBS of high-rise buildings using the design-build method [8]. Therefore, safety goals and programs as the basis for the construction safety audit process criteria were developed for each WBS level of work activities using the risk controls.

2.1. Construction of High-Rise Buildings using Design-Build Method

2.1.1. Construction of High-Rise Buildings

According to Government Regulation No. 16 of 2021 [9], high-rise buildings are structures with more than 8 (eight) floors. Ministry of Public Works and Public Housing Regulation No. 28/PRT/M/2016 [10] described the scope of work for building construction, including Design Development, Sitework, Structure, Architecture, Mechanical, Electrical, Exterior facilities and Miscellaneous. Also, the regulation explained that design development was included in the construction work scope, especially on integrated construction using the design-build method, which made the design and construction phase part of one unit of the construction contract. The regulation was later supplemented with the Ministry of Public Works and Public Housing Regulation No. 1 of 2022 [11], which explained the scope of work on building and housing, including Preliminaries, Implementation of SMKK, Structure, Architecture, Mechanical, Electrical, Plumbing, Landscape and Area, Exterior and more.

The regulation completed the scope of the previous ones, namely the implementation of SMKK, plumbing, landscaping, and area work. There was a reduction in the scope of work from the previous regulations, namely design development. Therefore, construction work needs to be adjusted to technical specifications and infrastructure type carried out in the following phases: Design Planning, Procurement Planning, Procurement Arrangement, The Selection Implementation of Service Providers and The Implementation of Construction Work.

2.1.2. Design-Build Method

Design-build method is a procurement method that assigns responsibility to one provider. In this case, the provider is responsible for fulfilling all the requirements of design, material, and method of work execution. The design-build method was considered capable of increasing speed and reducing the duration of project completion.

Also, a single responsibility in the design-build method makes the contractor fully responsible for the performance of the implemented project, even though potential errors are caused by the activities of subcontractors involved in the construction process. Other characteristics of the design-build method include work complexity, risk allocation, turnaround time, communication, effective client representation, and use of the latest technological innovations [12].

The Progressive Design-Build (PDB) concept can reduce the overall project completion time because the method does not require the project owner to fully determine the scope of work before tendering. This is because the scope of work is determined during the Detail Engineering Design phase. The design percentage is an approximation, however, it shows that the project owner can involve the designer in the PDB method to proceed with the initial engineering [13]. The difference between the design-build and the conventional methods is shown in Figure 1.

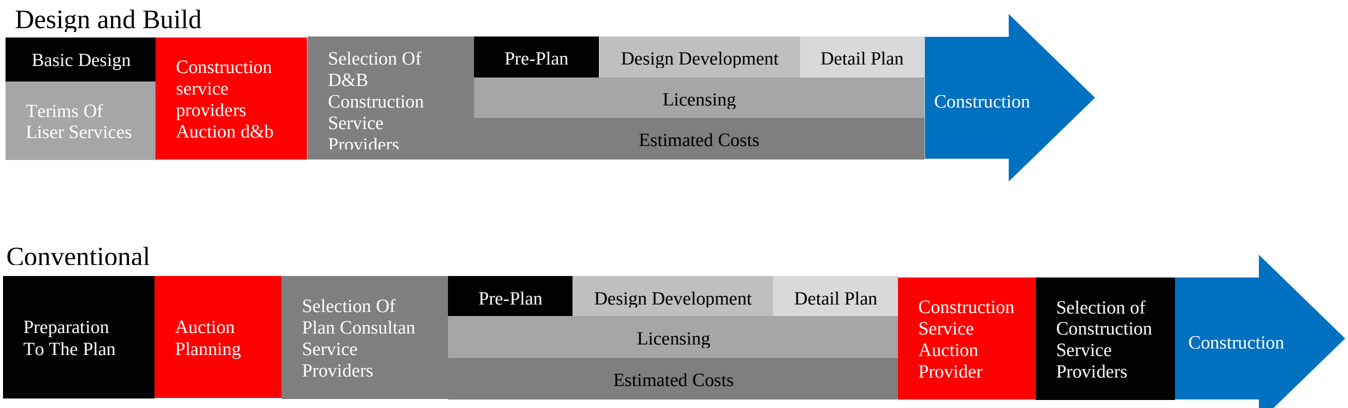

Fig. 1 Design-build method and conventional method [15]

2.2. Construction Safety Performance

Safety performance reflects the outcomes and success rate stemming from safety-related results within a specific job function over a certain period. Therefore, consistent monitoring is needed to determine the extent to which these safety regulations have been complied with and carried out in accordance with the real conditions in the field [14].

Safety Performance entails the evaluative actions or behaviors exhibited by individuals across a diverse range of job roles to promote the well-being and safety of workers, clients, the public, and the environment. This facet of safety performance can be measured by assessing safety compliance and participation [15].

Two distinct types of safety indicators are widely used in the safety literature, namely “leading” and “lagging” (measurement safety indicators and after-accident measurement indicators). Main indicators (leading) are specifically preferred by both the academic and industrial world [16].

Traditionally, the construction industry measures safety performance based on lagging indicators such as the Total Recordable Injury Rate (TRIR) and fatality rate. Leading Indicators can be categorized into passive indicators or active indicators [17]. Passive indicators are metrics that cannot be swiftly altered, such as the percentage of management personnel with 10-hour or 30-hour OSHA certifications. On the other hand, active indicators are metrics that can exhibit rapid change, like the percentage of random drug-negative results or safety compliance based on audits [16].

2.3. Hazard and Risk Control

Risk control is determined in accordance with the control hierarchy in ISO 45001: 2018, encompassing elimination, substitution, technical control, administrative control, and personal protective equipment. Risk through elimination stands out as the most effective, reliable, and protective measure. This hierarchical order demonstrates that the substitution, effectiveness, reliability, and level of protection consistently decrease until the use of PPE becomes the lowest effectiveness, as depicted by the smaller triangle in Figure 2 [18].

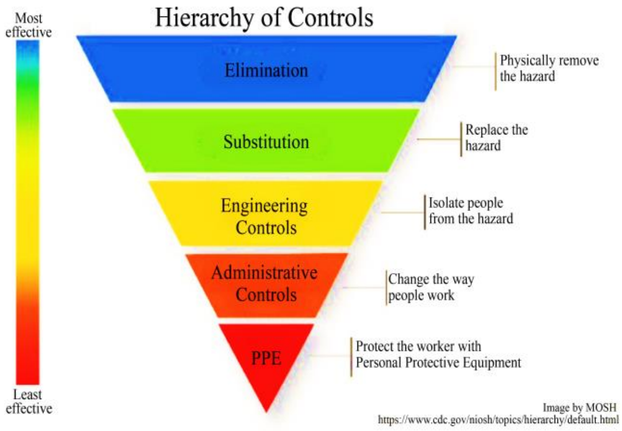

Fig. 2 Hierarchy of controls [20]

The risk control hierarchy is intended to provide a systematic approach to enhancing construction safety, eliminating hazards, and mitigating construction safety risks. Controls at lower levels are considered less effective compared to their counterparts at the preceding levels. Frequently, a combination of multiple controls is employed to successfully reduce construction safety risks to the lowest possible level [17]. Understanding this hierarchy is crucial, as it necessitates a shift from the paradigm of prioritizing PPE as an easy solution for addressing every workplace risk. Safety professionals could adopt innovative strategies to either mitigate or eliminate hazards (elimination) rather than rely solely on PPE to address the risk. This can halt the process at the least effective level of the hierarchy. The primary focus lies in achieving comprehensive risk reduction, as opposed to merely advocating for applying PPE, which squanders valuable time and resources without reducing the underlying risk. Only when elimination control is deemed infeasible should the risk control proceed to the subsequent level within the hierarchy.

2.4. Safety Goals and Programs of Integrated Construction Using Design-Build Method

RKK is a crucial aspect of SMKK. Since it covers all occupational health and safety conditions, a safety plan will prevent possible project delays and most of the risks of work accidents while increasing the potential for success and the confidence of project team members [18].

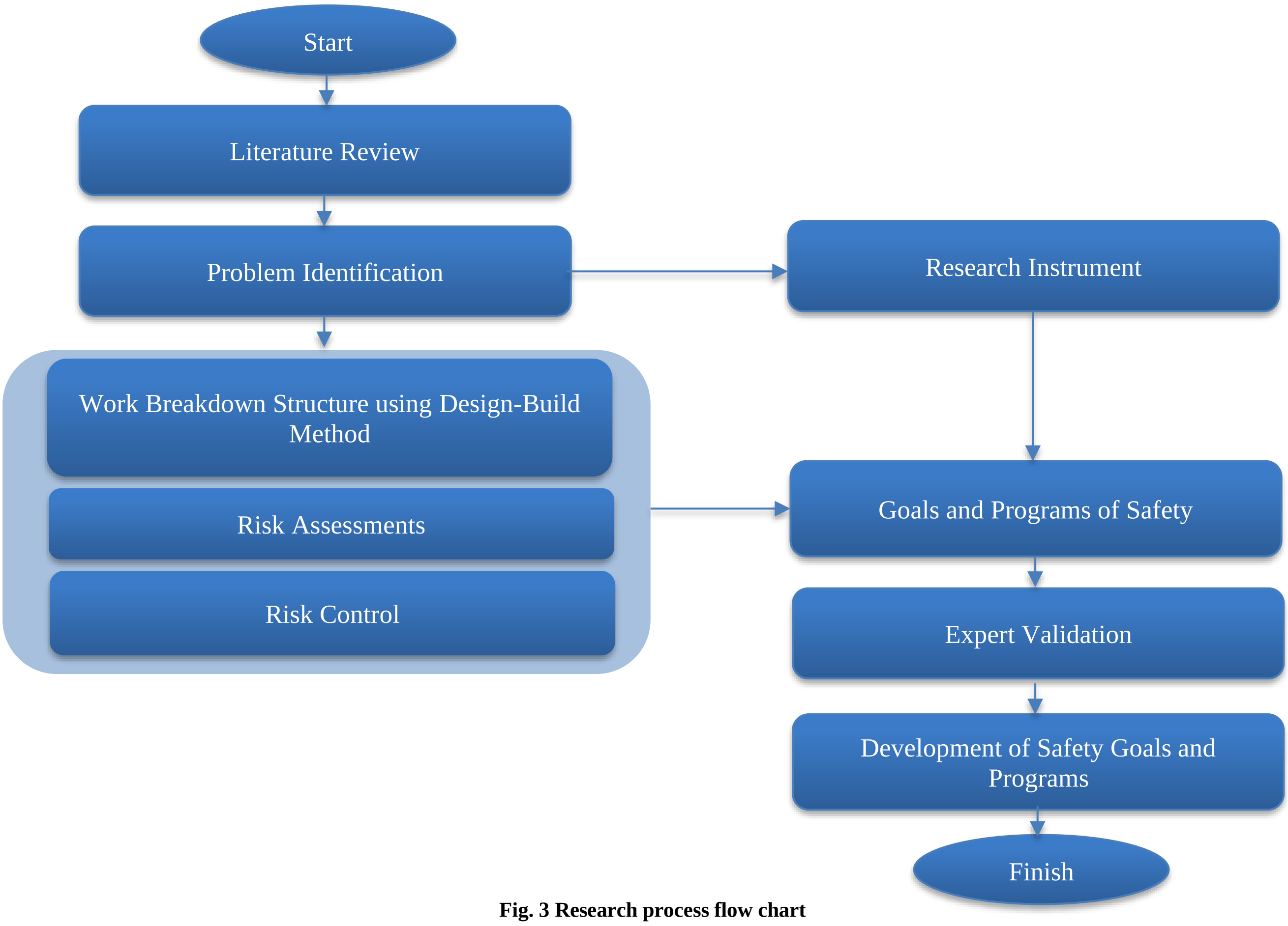

Fig. 3 Research process flow chart

The presence of a safety plan aids in identifying potential risks that can occur as a result of potential hazards. Therefore, identifying potential hazards and associated risks is a paramount task within construction jobs aimed at minimizing the occurrence of work accidents [19]. The occupational health and safety management plan, an important document, delineates construction hazards and risks, along with their corresponding control and prevention measures in the project work area [20].

This document is also used to develop an effective work safety program through goals, objectives and work methods oriented toward certain achievement indicators [21]. Ministry of Public Works and Public Housing Regulation No. 10 of 2021 contains a Safety Plan in the form of engineering goals and programs based on each work activity.

This framework controls the hazards and risks that may exist in each work activity of integrated construction, leveraging the design-build method.

The process of developing safety goals and programs as the basis for the construction safety audit process criteria entails collaborating with construction safety experts and the construction safety committee, who subject each phase to validation through the Delphi Method. This method culminates in creating RKK for integrated high-rise building construction, utilizing the design-build approach. The collected data were subsequently analyzed using descriptive analysis with a qualitative approach. Figure 3 shows a flowchart of the research process.

3. Result and Discussion

The results corresponded with a previous study, which developed the WBS level of work activities for high-rise buildings using the design-build method. The implementation phase of the high-rise building project encompassed; Design Phase, the Implementation of SMKK and the Construction Phase.The identification of hazards and risks from work activities was extensively carried out in previous studies for high-rise projects using conventional methods. Therefore, this study will have a gap by integrating hazards and risks from work activities in the previous study to develop safety goals and programs for high-rise projects using design-build methods.

3.1. Defining Hazards and Risks

The initial step included the identification of hazards and risks in all work activities that stem from the development of the WBS for high-rise buildings using the design-build method. This study focused primarily on the management of high-level risks, encompassing hazard and risk levels in each work activity. The hazards and risks in the design phase and the implementation of SMKK were derived from previous research regarding developing the risk-based WBS level of work activities for high-rise buildings. Similarly, the hazards and risks at the execution phases of construction work were derived from previous studies.

Table 1. Risk assessment and control using the design-build method

No.	Potential Risk	Risk Control	Hierarchy	Reference
Potential Risk in the Design Phase				
1	Design implementation method is not based on field conditions, leading to non-constructible designs.	Change the design implementation method and conduct a re-design	Substitution	Expert Judgment
		Design verification	Engineering Control	
		Evaluate the competence of designer experts and refresh the organizational structure.	Administrative Control	
2	Deficiencies in determining the scope of work, resulting in design defects.	Design verification	Engineering Control	Expert Judgment
		Evaluate the competence of designer experts and refresh the organizational structure.	Administrative Control	
3	Errors in calculating the dimensions and mass planning of buildings that are not in accordance with design safety rules/standards.	Change the calculating dimension methods and designing the mass of the building and conduct a re-design	Substitution	Expert Judgment
		Design verification	Engineering Control	
		Evaluate the competence of designer experts and refresh the organizational structure.	Administrative Control	
Potential Risk on Implementation of SMKK				
1	Error in hazards and risk identification in the preparation of IBPRP.	Evaluate the Hazard Identification, Assessment, and Risk Control (IBPRP) drafting result	Administrative Control	Expert Judgment
		Organize SMKK training and evaluate the personnel competencies.		
2	Implementation of risk response is not in accordance with hazard identification in IBPRP.	Evaluate the implementation of risk response for each work activity	Administrative Control	Expert Judgment
Potential Risk in the Construction Phase				
1	Workers fall from heights.	Install a strong and wide platform.	Engineering Control	Project Document
		Install safety fence.		
		Install dividing area/horizontal safety net.		
		Install lighting in the opening area.		
		Install a body line to attach the safety body harness.		
		Display “Watch Your Steps” and “Careful” signs.	Administrative Control	
		Conduct Tool Box Meeting.		
		Patrol by SHE officers every 2 hours.		
		Conduct Health, Safety and Environment (HSE) training at height on a regular/periodic basis.		
		Ensure the workers are healthy and not height-phobic.		
		Periodically inspect high-work facilities.		
		Complete use of PPE	Adequate PPE	
2	Crushed by construction materials.	Carefully handling and bonding materials	Engineering Control	Project Document
		Establish a safe zone/green zone in the work area.		
		Display “Beware of Falling Materials” signs	Administrative Control	
		Using Handy Talkie communication devices		
		Assign flagman/rigger personnel.		
		Complete use of PPE	Adequate PPE	
3	Workers collide with falling and sharp objects.	Display “Careful” signs	Administrative Control	Project Document
		Conduct Tool Box Meeting		
		Conduct socialization of work methods.		
		Certify all heavy equipment operators.		
		Complete use of PPE	Adequate PPE	

Table 2. Development of safety goals and programs using the design-build method

No.	Goals		Programs				
	Activity	**Benchmark**	**Resource**	**Dur.**	**Indicator**	**Monitoring**	**PIC**
Potential Risk: Design implementation method is not based on field conditions, leading to non-constructible designs							
1	Design of execution methods and assumptions used are in accordance with site condition and safety design standards.	Design of the execution method is accurate, and the assumptions used are in accordance with site conditions and safety design standards.	Checklist forms, Design benchmarking, Design for safety standards/ guidelines, Verification facilities and officers.	Determined before design and implemented during the design execution.	Design process is going well and appropriately, and the execution method is in accordance with the design for safety and site conditions.	Checklist of inspection reports and monitoring systems for design execution.	Designer Expert Supervisor.
2	Verify the design results for execution methods and assumptions used according to safety design standards and guidelines.	Design results for the execution method and assumptions used are accurate and in line with safety design standards and guidelines.	Checklist forms, Design benchmarking, Design for safety standards/ guidelines, Verification facilities and officers.	During the design execution period.	Design process is going well and appropriately in accordance with safety design standards.	Work inspection and monitoring reports.	Designer Expert Supervisor and Team of Individual and External Consultants.
3	Design experts are competent in designing safe execution methods and design assumptions according to standards and guidelines.	Design of the execution method is accurate, and the assumptions used are in accordance with safety design standards.	Inspection and evaluation form, Organizational structure of designer experts.	Determined before design and in accordance with the competency requirements..	Design process is going well and appropriately. Design for safety can be implemented.	Work inspection and monitoring reports.	Human Capital Manager.
Potential Risk: Error in hazards and risk identification in the preparation of IBPRP							
1	Check the progress of the IBPRP preparation periodically.	IBPRP preparation errors can be controlled without missing the risk factors for each work activity and its risk controls.	Document checklist form.	During the execution of the work.	The IBPRP preparation process is going well; errors resulting from risk identification and action plans could be limited to zero.	Supervision reports for each work activity, Management Report.	QHSE Manager
2	Organize training and evaluation for workers and employees for the preparation of IBPRP.	All workers and employees understand and are competent to prepare a complete IBPRP, including the risk factors.	Inspection and evaluation forms, SOP/training modules.	Determined before the work begins and in accordance with the requirements.	The preparation process is going well, and the results were accurate as expected.	Checklist, Supervision reports for each work activity, Management Report	Human Capital Manager
Potential Risk: Workers collide with falling and sharp objects							
1	Install a strong and wide platform	The platform is used to carry out work adequately.	Workbench/ Platform	Before the execution of the work.	Available when effectively carrying out	There are supervisors	HSE Inspector, Supervisory Officer

					the work process.		
2	Install safety fence	Every opening area is provided with an adequate safety fence.	Safety fence	Before the execution of the work.	All working areas with openings have safety fences.	HSE officers inspect the work area.	HSE officers, Supervisors, Executors
3	Install dividing area/horizontal safety net	All working area is delimited, and the opening area is restricted with an adequate horizontal safety net.	Water barriers, Traffic cones, Police lines and Safety nets.	Before the execution of the work.	100% according to safety standards. All working area was restricted.	Report checklist: there is an officer in charge of the checklist.	HSE officers, Supervisors, Executors
4	Install lighting in the opening area	All opening area in the working area is provided with adequate lighting.	Lighting	Before the execution of the work.	No dark working area.	HSE officers inspect the working area.	HSE officers, Supervisors, Executors
5	Install body line to attach the safety body harness.	The outer boundary of the building is provided with a safety body line to link safety body harnesses.	Standard safety body lines.	Before installation and execution of work.	100% according to safety standards.	Report checklist: there is an officer in charge of the checklist.	HSE officers, Supervisors, Executors
6	Display “Watch Your Steps” and “Careful” signs.	Related signs are installed in place before working..	Information, appeals and warning signs.	Before and during the execution of the work.	The working process is safe, and no injury was recorded by related resources.	Supervision reports for each work activity, HSE Report.	HSE officers, Supervisors, Executors
7	Conduct Tool Box Meeting	Conduct Tool Box Meetings before working to provide job descriptions based on SOP.	Safety Tool Box Meeting officers, Management personnel.	Implemented before starting and after work.	100% according to safety standards, all personnel understand how to work safely.	Report checklist: there is an officer in charge of the checklist.	HSE officers, Supervisors, Executors
8	Patrol by HSE officers every 2 hours	Workers are monitored and notified in case of danger threat.	Patrol Officer, loudspeaker.	During the execution of the work.	The working process is going safely, and no injury was recorded by related resources.	There are officers in charge of surveillance patrols.	HSE officers, Supervisors, Executors
9	Conduct HSE training at height on a regular/ periodic basis.	All related resources, administrative and technical units understand and are competent.	Examination forms, safety equipment for working at height.	Should be ready before and during the work process.	The execution is going safely without any material, tools or workers falling from a height.	Checklist, Supervision reports for each work activity, Management Report.	HSE officers, Supervisors, Executors
10	Ensure the workers are healthy and not height-phobic.	All related resources were physically and mentally prepared for work at height,	Health examination form.	Should be ready before and during the work process.	The working process is going safely, and workers are not injured.	Checklist, Supervision reports for each work activity, Management Report.	HSE officers, Supervisors, Executors

		and no one was injured.					
11	Periodically inspect high-work facilities.	All working tools are conditionally and administratively appropriate for use during work at height.	License for operation, stationery, and checklist report form.	Before and after the work, the results are subsequently evaluated.	Working tools used to function properly and optimally, work is safe and secure.	Supervision reports for each work activity, HSE report, and Management Report.	HSE officers, Supervisors, Executors
12	Use a safety belt/body harness before and during work.	All related resources used PPE according to standards before and during the work execution.	Safety belt/body harness according to International Standards.	Before the execution and during the working process.	The working process is going safely, and no injuries occurred to any related resources.	Supervision reports for each work activity, HSE report.	HSE officers, Supervisors, Executors

3.2. Determining Risk Control

Hazard and risk controls are arranged to align with acceptable benchmarks or predetermined achievement indicators. The requisite resources for executing these controls were also identified. Using the design-build method, these controls were subsequently used to develop building project construction safety goals and programs. Hazard and risk control for each phase of work activities was structured in accordance with the control hierarchy based on ISO 45001:2018.

This hierarchy encompassed elimination, substitution, engineering control, administrative control, and personal protective equipment. The determination of hazard and risk control was based on the level of potential risk. It was imperative to recognize that both controls were frequently grouped together, particularly to determine and prioritize high levels of risk in the workplace. Meanwhile, this study specifically focused on applying controls to mitigate high-level risks during each phase of work activities.

3.3. Develop Safety Goals and Programs

According to previous studies, a total of 29 potential high-level risk factors were identified in high-rise building construction using the design-build method. A total of 29 identified high risks were not grouped into each phase of the construction work. Then, these risks were categorized into the design phase with a total of 6 high risks, implementation of SMKK with a total of 2 high risks, and construction phase with a total of 21 high risks.

Construction safety experts and the construction safety committee subsequently validated the risk control of each work activity with a total of 3 highest risks in each phase, as shown in Table 1, along with safety goals and programs, as shown in Table 2, with a total of 36 primary goals and safety programs to manage all highest risk in each phase. Accidents can occur due to lack of training, inappropriate work equipment and platforms, wrong safety attitudes, failure to use personal Protective Equipment (PPE), as well as Procurement methods problems and sub-contracting methods [3]. Due to insufficient safety knowledge and technology training, workers lacked the ability and knowledge to predict potential risks or avoid work accidents.

This included not following standard safety procedures, making arbitrary decisions about building, and choosing to continue working in unsafe conditions. Poor coordination, lack of proper instructions, and misunderstandings between job trades all contributed to construction accidents [23]

Using unsafe work platforms could also place workers at risk when equipment is not properly used, maintained, or stored. Inadequate housekeeping at the workplace was considered a risk factor for work-related injuries [25]. Working without adequate PPE significantly increased the likelihood of accidents. Various reasons contributed to workers refusing to wear PPE while working.

These included feeling uncomfortable with gears when working on-site and considering them as items interfering with work output. The International Labor Organization (ILO) showed that some workers feel uncomfortable when wearing any type of PPE, indirectly reducing their performance [26]. The safety attitudes of construction workers were influenced by their understanding and awareness of risks, management, safety rules, or work procedures [27].

The development of these safety goals and programs focused on controlling risk factors related to workers, materials, equipment, and the environment/public. RKK, an element of the safety plan within SMKK, could significantly influence the promotion of a prevention culture in construction projects, serving as a leading indicator of construction safety [28].

This study result is more comprehensive than previous studies because it develops risk control along with safety goals and programs to mitigate hazards and risks in construction work. For example, the risk of workers colliding with falling and sharp objects in the previous studies did not identify the most effective to the least effective risk control along with safety goals and programs that were not optimal enough to control the risk, whereas in this study all risk controls along with safety goals and programs have been identified systematically and have been validated by experts for the effectiveness of the implementation of safety goals and programs. Likewise, in the previous studies, risk control at the construction design phase was not considered at all. However, in this study, it has been identified to be able to implement the design for safety where the design can be implemented in the construction stage safely and securely.[29] [30]

4. Conclusion

In conclusion, this study showed improvements in developing safety goals and programs as the basis for audit process criteria based on risk and WBS. Initially, RKK was in accordance with the Ministry of Public Works and Public Housing Regulation No. 10 of 2021. It was also developed using the design-build method based on the WBS levels of work activities for high-rise buildings. This indicated that the developed safety goals and program as the basis for the audit process could be implemented by the Project Owner or Contractor in high-rise buildings or similar projects using the design-build method. In the process of developing safety goals and programs, the project phases using this approach held significant importance due to their impact on the effectiveness of the implemented risk control. The results showed that risk control for high-risk levels, involving substitution, engineering controls, administrative controls, and adequate PPE, was carried out throughout the design phase to project completion. RKK, using the design-build method, had 36 primary goals and safety programs to manage high-level risks. Specifically, there were 3 high risks identified during the design phase, 2 during the implementation of SMKK, and 3 during the construction phase. Successful benchmarks were established, and individuals responsible for implementing risk control were designated. This study could serve as a guide for contractors engaged in integrated high-rise construction projects using the design-build method. This could potentially foster improvement in construction safety performance, particularly concerning leading indicators.

Funding Statement

The authors are grateful for the financial support the Ministry of Education, Culture, Research and Technology provided through the PPS-PTM Grant scheme for the Year 2023, with Decree Number: 0557/E5.5/AL.04/2023.

Acknowledgment

The authors are grateful to all construction safety audit research group members who assisted, advised or provided suggestions and responses throughout the drafting and completion of this study and to construction safety experts and the construction safety committee who helped the author validate this research process.

References

[1] People's Representative Council of the Republic of Indonesia, Law No. 3 of 2022 about State Capital, Jakarta, Indonesia, 2022. [Online]. Available: https://jdih.pu.go.id/detail-dokumen/2949/1#div_cari_detail

[2] DetikFinance.com, Listen! This is the IKN Development Plan Whose Contract was Signed on July 15, 2022. [Online]. Available: https://finance.detik.com/properti/d-6173282/simak-begini-rencana-pembangunan-ikn-yang-kontraknya-diteken-15-juli

[3] Kai Chen Goh et al., "Accidents Preventive Practice for High-Rise Construction," *MATEC Web of Conferences, The 3rd International Conference on Civil and Environmental Engineering for Sustainability (IConCEES 2015)*, vol. 47, pp. 1-6, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[4] Michael Behm, "Linking Construction Fatalities to the Design for Construction Safety Concept," *Safety Science*, vol. 43, no. 8, pp. 589-611, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[5] John A. Gambatese, Michael Behm, and Jimmie W. Hinze, "Viability of Designing for Construction Worker Safety," *Journal of Construction Engineering and Management*, vol. 131, no. 9, pp. 1029-1036, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[6] R.T. Szymberski, "Construction Project Safety Planning," *Tappi Journal*, vol. 80, no. 11, pp. 69-74, 1997. [Google Scholar] [Publisher Link]

[7] Ministry of Public Work and Housing of the Republic of Indonesia, Regulation of Minister of Public Work and Housing No. 10 of 2021: Concerning Guidelines for Construction Safety Management System, Jakarta, Indonesia, 2021. [Online]. Available: https://jdih.pu.go.id/detail-dokumen/2884/1#div_cari_detail

[8] Robert K. Yin, *Case Study Research: Design and Methods*, Sage Publications, 2009. [Google Scholar] [Publisher Link]

[9] Government Regulation of the Republic of Indonesia, Government Regulation No. 16 of 2021: Concerning Implementation Regulations of Law No. 28 of 2002 Concerning Buildings, Jakarta, Indonesia, 2021. [Online]. Available: https://jdih.pu.go.id/detail-dokumen/2851/1#div_cari_detail

[10] Ministry of Public Work and Housing of the Republic of Indonesia, Regulation of Minister of Public Work and Housing No. 28/PRT/M/2016: Concerning Guidelines for Analysis of Unit Prices in the Public Works Sectors, Jakarta Indonesia, 2016. [Online]. Available: https://jdih.pu.go.id/detail-dokumen/2201/1#div_cari_detail

[11] Ministry of Public Work and Housing of the Republic of Indonesia, Regulation of Minister of Public Work and Public Housing No. 01 of 2022: Guidelines for Preparation of Cost Estimates for Construction Work in the Public Works and Public Housing Sector, Jakarta, Indonesia, 2022. [Online]. Available: https://jdih.pu.go.id/detail-dokumen/2932/1#div_cari_detail

[12] MM Gambo, and C.P. Gomez, "Project Characteristics for Design and Build Procurement in Malaysian Construction Industry," *Journal of Engineering and Technology*, vol. 6, no. 1, pp.144-154, 2015. [Google Scholar] [Publisher Link]

[13] Douglas D. Gransberg, and Keith R. Molenaar, "Critical Comparison of Progressive Design-Build and Construction Manager/General Contractor Project Delivery Methods," *Transportation Research Record*, vol. 2673, no. 1, pp. 261–268, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[14] Kin Dorji, and Bonaventura H.W. Hadikusumo, "Safety Management Practices in the Bhutanese Construction Industry," *Journal of Construction in Developing Countries*, vol. 11, no. 2. pp. 53-75, 2006. [Google Scholar] [Publisher Link]

[15] Andrew Neal, and Mark A. Griffin, "Safety Climate and Safety at Work," *American Psychological Association*, pp. 15–34, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[16] Elyas Jazayeri, and Gabriel B. Dadi, "Construction Safety Management Systems and Methods of Safety Performance Measurement: A Review," *Journal of Safety Engineering*, vol. 6, no. 2, pp. 15-28, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[17] Jimmie Hinze, Samuel Thurman, and Andrew Wehle, "Leading Indicators of Construction Safety Performance," *Safety Science*, vol. 51, no. 1, pp. 23-28, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[18] Hubungi Kami, "*Development of Construction Safety Cost Model for Flats Construction in Indonesia*," Doctoral Dissertation, University of Indonesia, Depok, Indonesia, 2022. [Online]. Available: https://eng.ui.ac.id/en/ftui-doctor-develops-a-construction-safety-cost-model-for-flats-construction-in-indonesia/

[19] Hierarchy of Controls, The National Institute for Occupational Safety and Health (NIOSH), CDC: Centers for Disease Control and Prevention, 2023. [Online]. Available: https://www.cdc.gov/niosh/topics/hierarchy/default.html

[20] Badan Standardisasi Nasional, Sistem Manajemen Keselamatan dan Kesehatan Kerja (SMK3) Berbasis SNI ISO 45001:2018 - Persyaratan dan Pedoman Penggunaan, 1st ed., Jakarta, Indonesia, 2019. [Online]. Available: https://perpustakaan.bsn.go.id/repository/5c963c3bb81c996466ddccfc1845ff0a.pdf

[21] Gary A. Morris, and Ryan Cannady, "Proper Use of the Hierarchy of Controls," *Professional Safety*, vol. 64, no. 8, pp. 37-40, 2019. [Google Scholar] [Publisher Link]

[22] Project Management Institute, *Project Management Body of Knowledge*, 6(PMBOK(R) Guide-Sixth Edition / Agile Practice Guide Bundle (JAPANESE), 2018. [Google Scholar] [Publisher Link]

[23] Phoya Sarah, "*Health and Safety Risk Management on Building Construction Sites In Tanzania: The Practice of Risk Assessment, Communication and Control*," Thesis for the degrees of Licentiate of Engineering, Chalmers University of Technology, Gothenburg, Sweden, 2012. [Google Scholar] [Publisher Link]

[24] Matthew R. Hallowell, and John A. Gambatese, "Construction Safety Risk Mitigation," *Journal of Construction Engineering and Management*, vol. 135, no. 12, pp. 1316-1323, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[25] British Standard Institution, ISO 45001: 2018 Occupational Health and Safety Management Systems, 2018. [Online]. Available: https://www.iso.org/standard/63787.html

[26] Zhenghui Chen, and Yaoxing Wu, "Explaining the Causes of Construction Accidents and Recommended Solutions," *International Conference on Management and Service Science*, Wuhan, China, pp. 1-5, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[27] Seokho Chi, Sangwon Han, and Dae Young Kim, "The Relationship between Unsafe Working Conditions and Workers' Behavior and their Impacts on Injury Severity in the US Construction Industry," *Journal of Construction Engineering and Management*, vol. 139, no. 7, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[28] Vincent M Dufort, and Claire Infante-Rivard, "Housekeeping and Safety: An Epidemiological Review," *Safety Science*, vol. 28, no. 2, pp. 127-138, 1998. [CrossRef] [Google Scholar] [Publisher Link]

[29] A.S. Ali, S.N. Kamaruzzaman, and G.C. Sing, "A Study on Causes of Accident and Prevention in Malaysian Construction Industry," *Journal of Design + Built*, vol. 3, pp. 95-104, 2010. [Google Scholar]

[30] S. Mohamed, T.H. Ali, and W.Y.V. Tam, "National Culture and Safe Work Behaviour of Construction Workers in Pakistan," *Safety Science*, vol. 47, no. 1, pp. 29–35, 2009. [CrossRef] [Google Scholar] [Publisher Link]