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Determinant Factors Affecting Design for Safety in Planning Stage of High-Rise Building

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ABSTRACT

The Indonesian construction sector is experiencing rapid growth, particularly in high-rise buildings. However, this growth is accompanied by significant challenges, including a high incidence of workplace accidents and construction failures. To address these concerns, this research focused on Design for Safety (DfS), a proactive approach that prioritizes safety considerations from the initial planning stages of construction projects. The study aimed to conduct a thorough review of the factors influencing the successful implementation of DfS in high-rise building projects, guided by the principles outlined in the Indonesian Minister of Public Works and Housing Regulation Number 10 of 2021. The literature review was rigorously validated and refined through the Delphi method, involving a panel of experts in the field of construction safety. The research identified ten key factors and thirty-six sub-factors that significantly impact the effective implementation of DfS. These findings provide crucial insights for developing and implementing more effective DfS strategies, ultimately contributing to a substantial improvement in safety performance within the Indonesian high-rise building construction sector.

1. INTRODUCTION

Indonesia's construction industry, particularly in high-rise buildings, is experiencing rapid growth fueled by urbanization and investment [1, 2]. However, this growth is accompanied by a concerning increase in work accidents and building failures. Work injury claims have surged, and data from the Ministry of Manpower highlights the significant involvement of construction workers [3, 4]. Furthermore, a previous study documented nine building failures between 2017 and 2020 [5]. These incidents underscore the critical need to enhance safety measures within the sector.

Construction accidents and failures result in substantial financial losses, including medical expenses, compensation claims, and project delays [6-9]. Research suggests that many accidents stem from design errors and deficiencies, emphasizing the importance of addressing design-related issues to improve construction safety [10-13].

Design for Safety (DfS) provides a proactive approach to prevent accidents by prioritizing worker safety during the design stage [14, 15]. This involves identifying and mitigating risks early on, as advocated by Szymberski [16], who emphasized the effectiveness of early intervention in safety efforts. By integrating safety considerations throughout the design process, DfS empowers designers to play a crucial role in achieving safer construction projects [10, 17].

This research aimed to investigate the factors influencing the implementation of DfS in Indonesian high-rise building construction. The study was guided by the Conceptual Design of the Construction Safety Management System (RK-SMKK), as outlined in Minister of Public Works and Housing Regulation Number 10 of 2021, which emphasizes the integration of DfS as a fundamental element for establishing a robust safety management system. The findings of this research are expected to contribute to the development of strategies for enhancing DfS implementation and improving overall safety performance within the Indonesian construction industry.

1.1 Gap and related research of DfS

Previous studies have highlighted the critical role of industry practitioners' knowledge, supportive policies, and effective regulations in successfully implementing DfS. However, challenges such as limited knowledge and training, inconsistent regulatory enforcement, and negative stakeholder attitudes often hinder its effective adoption [15, 18-23]. While Building Information Modeling (BIM) technology offers significant potential for supporting DfS, concerns regarding increased costs remain a significant barrier [15, 24, 25].

This research sought to delve deeper into the implementation of DfS within the Indonesian construction context. Specifically, it focused on exploring the influence of key components outlined in the Indonesian Minister of Public Works and Housing Regulation Number 10 of 2021, which governs the Conceptual Design of the Construction Safety Management System (RK-SMKK). Unlike previous studies that examined general factors, this research aimed to investigate the impact of specific RK-SMKK components, such as inspection standards, traffic management, and risk assessment, on actual construction safety performance. The findings of this research were expected to provide more targeted and actionable recommendations for policymakers to enhance DfS implementation in Indonesia by emphasizing the significance of each individual RK-SMKK component.

1.2 Research purpose and objective

This research aimed to conduct an in-depth investigation of factors influencing the successful implementation of DfS based on RK-SMKK in high-rise building projects. The findings of this research were intended to provide valuable insights for developing effective strategies to enhance safety performance in future high-rise building construction projects.

2. METHOD

2.1 Research strategy

A well-defined research strategy is crucial for guiding the entire research process, from initial question formulation to the analysis of collected data [26, 27]. The choice of research methods, such as experiments, surveys, or case studies, is contingent upon the specific research questions and considerations such as the need for variable control and the temporal focus of the study [27].

Table 1. Research strategy

Research Question	Type of Question	Research Strategy
What are factors influencing the implementation of DfS based on RK-SMKK in high-rise building construction projects in Indonesia?	What	Literature Review and Expert Validation using the Delphi Method

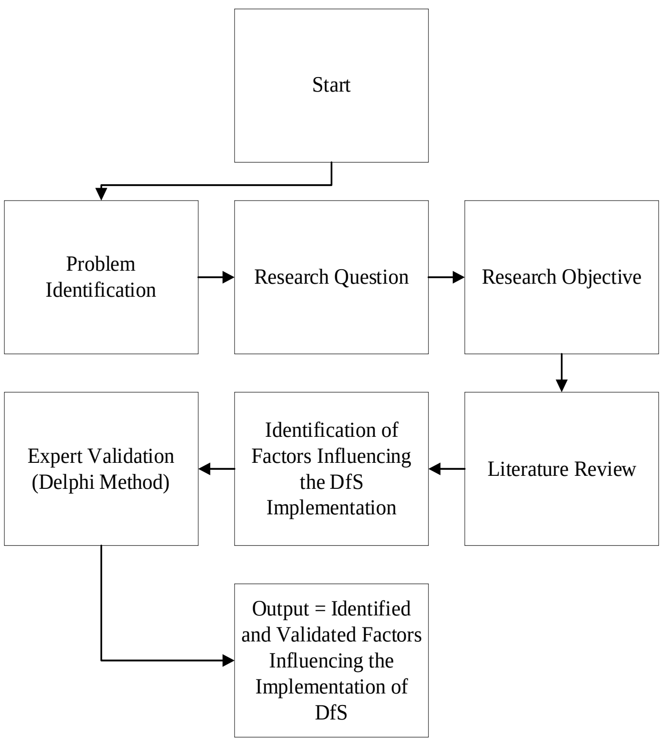

Figure 1. Research flow

This research employs a systematic approach to investigate the implementation of DfS in high-rise building projects, as outlined in Table 1. The research process begins with a clear definition of the research problem and the formulation of specific research objectives. A comprehensive literature review is then conducted, followed by expert validation using the Delphi method to identify and refine the key factors that influence the successful implementation of DfS, as visualized in Figure 1.

2.2 Delphi method

The Delphi method is an iterative process for gathering and refining expert opinions on a specific subject [28]. This method helps achieve consensus and has proven valuable in various fields, including construction management, for decision-making and forecasting [28, 29]. In this study, a two-round delphi process was employed, with consensus defined as agreement among 70-75% of the participating experts on a specific factor [30, 31].

2.3 Experts criteria

This research utilized a panel of expert validators comprising experienced construction safety professionals with a minimum of 15 years of practical experience and a bachelor's degree [32]. This stringent selection criterion ensured the inclusion of highly qualified and knowledgeable experts, thereby enhancing the credibility and validity of the research findings.

3. RESULTS AND DISCUSSION

3.1 Propose of DfS factors

A literature review was conducted on relevant previous research. The results showed that there were several factors influencing the implementation of DfS in construction projects.

3.1.1 Scope of designers' responsibilities (X.1)

Designers play a pivotal role in construction projects, encompassing tasks such as preparing and modifying designs and delegating these tasks to others [33]. Their primary responsibility is to ensure the safety and success of the project through comprehensive design development and effective coordination with all stakeholders [33].

3.1.2 Construction method (X.2)

The construction method outlines the step-by-step process for building a structure, encompassing all phases from planning to completion [34]. The chosen method significantly influences the project's quality, timeline, and overall cost-effectiveness [34].

3.1.3 Testing and inspection standards (X.3)

Testing and inspection standards provide detailed guidelines for evaluating the quality of construction work [35]. International standards such as AISC, ACI, BS, AWS, and ISO 9001 serve as crucial frameworks for ensuring quality control and assurance throughout the construction process [36].

3.1.4 Environmental Management Plan (EMP) (X.4)

An Environmental Management Plan (EMP) is a crucial document that outlines strategies for mitigating environmental impacts during construction [37]. It details how construction activities will be managed to minimize environmental disturbances and ensure compliance with environmental regulations.

3.1.5 Traffic management plan (X.5)

A Traffic Management Plan is a critical safety document that outlines strategies for managing traffic flow around the construction site [35]. This plan ensures safe passage for both workers and the public while minimizing disruptions to traffic flow.

3.1.6 Risk management (X.6)

Risk management is defined as a coordinated activity to direct and control an organization with regard to the identification, analysis, evaluation, treatment, monitoring and review of risk [38]. In the context of construction project management, risk management is a comprehensive and systematic approach to identifying, analyzing, and responding to risk in order to achieve project objectives [39].

3.1.7 DfS regulations (X.7)

Regulation is a process of ensuring that standards are met as a legal requirement for a particular service or public activity so that policies are fulfilled [40]. Examples include the UK's CDM 2015 and Australia's WHS Act, which encourage the integration of safety considerations into the design process while providing legal safeguards for designers [41, 42].

3.1.8 Risk level (X.8)

Risk level refers to the magnitude of a risk or a combination of risks expressed as a combination of their consequences and likelihood of occurrence [38]. Risk level is determined by two factors: frequency level and consequence level. Frequency level (probability) is the magnitude of the likelihood of a risk occurring or the frequency of a risk event, while consequence level refers to the magnitude of the negative impact of a risk [43].

3.1.9 Costs and personnel requirements for construction safety (X.9)

The cost of construction safety, in the context of construction safety management systems (SMKK), refers to the expenses incurred in implementing SMKK in construction services [35]. Construction safety personnel are individuals who possess specific competencies in the field of construction safety in implementing and supervising the application of SMKK, as evidenced by a Construction Work Competency Certificate [35].

3.1.10 Safety guidelines design (X.10)

Construction operation and maintenance safety manual is a review document prepared by a construction design consultant that provides a narrative description of the operation and maintenance methods for buildings or civil structures, according to the specific work package being designed [35].

3.2 Explanation of factors

This section provides a detailed explanation and information on factors influencing DfS.

Table 2. Factors explanation

Factor	Indicators	Description
Scope of designers' responsibilities (X.1)	Safety Knowledge Integration X.1.1	Designers integrate DfS knowledge into their design decisions [14, 15].
	Collaboration and Communication X.1.2	Effective collaboration is crucial for integrating safety considerations throughout the design process [44].
	Design Tools and Guidelines X.1.3	Designers can use design tools and guidelines in applying DfS [14, 44].
	Motivation and Mindset X.1.4	Designers prioritize safety and motivate others to implement the same method [14, 45].
	Training and Education X.1.5	Ongoing training improves designers' ability to DfS [45].
Construction method (X.2)	Technology Use X.2.1	Designers use BIM to automate safety processes and identify, assess, and control risks [46].
	Multi-criteria Analysis X.2.2	Designers use multi-criteria mathematical methods for safety evaluations [47].
	Regulatory Compliance X.2.3	Designers understand legal requirements and develop HSPs based on design documentation [48].
	Continuous Monitoring X.2.4	Strengthening monitoring and measurement to guide safety practices [49].
Testing and inspection standards (X.3)	Compliance Inspection X.3.1	Effective pre-construction inspections ensure design safety and reduce risks [50].
	Standard Procedures X.3.2	Routine inspections and tests follow international codes such as NFPA 101 [51].
	Quality Control X.3.3	Designers ensure building materials meet quality and safety standards through rigorous testing [52].
Environmental management plan (X.4)	HSE Principles X.4.1	Early HSE integration is essential to identify risk and develop a robust HSE management plan for the entire project lifecycle [53].
	Performance Indicators X.4.2	Designers use PIs to assess EMP performance and identify areas for improvement. Critical PIs include public safety, highway safety risks, construction waste, chemical spills, soil erosion, and water quality changes [54, 55].
	Integrated HSE Management System X.4.3	Designers and stakeholders identify, evaluate, and prioritize HSE activities for risk management [56].
	Compliance with Regulations X.4.4	Adherence to ISO9001, ISO14001, and GB/T28001 ensures project quality, environmental protection, and occupational health and safety [57].

Traffic management plan (X.5)	Traffic Management Plan X.5.1	Designers communicate traffic control measures to ensure safety and review the TCP periodically [58].
	Stakeholder Inclusion X.5.2	Involving all relevant stakeholders in the development and implementation of a TMP [59].
	Performance Assessment X.5.3	The continuous evaluation of the effectiveness of the traffic management plan [60].
Risk Management (X.6)	Risk Source Identification X.6.1	Designers identify risks, consider site conditions and external factors, and evaluate how design options impact safety [61-63].
	Risk Assessment Methods X.6.2	Risk assessment methods such as AHP and Risk Matrix prioritize risks. Quantitative Risk Assessment calculates possibility, consequence, and exposure to assess risks quantitatively [61].
	Mitigation Strategies X.6.3	Mitigation strategies prevent and reduce risks, addressing those that cannot be eliminated during design [63, 64].
	Risk Assessment Tools X.6.4	Tools such as Safety in Design Risk Evaluator (SliDeRulE) help designers assess and mitigate construction safety risks [62].
	Documentation X.6.5	Designers document risks, mitigation measures, and residual risks, integrating with BIM for better visualization and management [64].
DfS Regulations (X.7)	Compliance with Regulations X.7.1	Designers and stakeholders understand and apply CDM regulations to ensure compliance and avoid legal interventions [44].
	Documentation and Review X.7.2	Proper documentation and regular reviews ensure compliance and maintain safety standards [44].
	Specific Regulations X.7.3	Regulations such as NFPA 59A and EU Directive 92/57/EEC mandate specific safety measures and designer responsibilities [23].
	Legal Responsibilities X.7.4	Designers have a legal responsibility to ensure that their design consider health and safety at all stages of construction [44, 65].
Risk Level (X.8)	Design Elements X.8.1	Specific design features and related construction activities have varying levels of risk. For example, elements such as roofs, beams, and foundations are considered to be the riskiest to construct [66].
	Environmental Factors and Systems X.8.2	Construction environment and existing risk management systems influence safety [63, 67].
	Methodologies and Tools X.8.3	WBS and SliDeRulE can meticulously identify and assess the level of risk at every phase of the project [62, 67].
Costs and Personnel Requirements for Construction Safety (X.9)	Budget Allocation X.9.1	Implementing effective HSE requires a clear budget allocation, which is often insufficient. HSE costs typically range from 3 to 5% of the total project value [68-70].
	Cost Estimation Models X.9.2	Accurate cost estimation models are crucial. Methods such as fuzzy and neural networks can improve accuracy. Standardized pricing frameworks can help accurately price HSE elements [68, 70].
	Competence X.9.3	Design staff must be knowledgeable in risk management and HSE principles [71].
	Training X.9.4	Maintaining high safety standards in construction requires regular training for workers [72, 73].
Safety guidelines Design (X.10)	Regulatory Framework X.10.1	A strong regulatory framework and clear guidelines are essential to promote safety practices. For example, Malaysian guidelines emphasize legislation and client influence in adopting safety measures [74].
	Safety Training X.10.2	Training for designers and workers is essential to ensure awareness of safety protocols and effective implementation. This is because a lack of safety expertise among designers is a significant barrier [15, 20].
	Design and Planning X.10.3	Design for Maintainability (DfM) ensures safety throughout the project lifecycle, including maintenance [75].
	Site-Specific Safety Plan X.10.4	Site-specific safety plans help workers anticipate and avoid problems. Including subcontractors ensures their compliance with safety measures [76].

Table 3. Validator expert identity description

Categories	Expert 1	Expert 2	Expert 3
Name	DA	LN	BP
Gender	Male	Male	Male
Age	38 years old	59 years old	57 years old
Company/Institution	PT. KAI (Persero)	Indonesian Occupational Health Association (PAKKI)	PT. Citra Marga Lintas Jabar
Position	Manager	Chairman	Director
Experience in Construction Industry/Occupational Safety and Health (OSH)	> 15 years	> 15 years	> 15 years

Based on the experts' validation of all factors, recommendations were given to make the descriptions more specific.

Table 2 provides a comprehensive list of factors identified through a thorough literature review, each accompanied by specific indicators and detailed descriptions. To ensure the relevance and completeness of these factors, a rigorous expert validation process was conducted. Table 3 summarizes the qualifications of the expert panel, all of whom were deemed competent to participate in the validation process. Based on the expert feedback, several refinements were made, including the addition of further explanations to enhance the comprehensiveness of certain factors. Furthermore, some factors were deemed less relevant and were subsequently eliminated, as outlined in Table 4.

Table 4. Improvement results according to recommendations from validator experts

Factor	Indicators	Description
Scope of designers' responsibilities (X.1)	Design Tools and Guidelines X.1.3	Designers are able to select and use design tools and guidelines in implementing DfS [14, 44].
Construction method (X.2)	Multi-criteria Analysis X.2.2	Designers use multi-criteria mathematical methods such as MCDM for safety evaluations [14, 47].
	Regulatory Compliance X.2.3	Designers understand legal conditions such as PUPR Ministerial Decree no. 10 of 2021 and develop Construction Safety Plans (RKK) based on design documentation [35, 48].
Testing and inspection standards (X.3)	Standard Procedures X.3.2	Routine inspections and testing include examining the functions and commissioning practices associated with planning and design stages of construction projects. These practices are guided by international codes and standards, such as the NFPA 101 Life Safety Code, which determines the frequency and requirements of inspections [52, 77].
	Quality Control X.3.3	The designers ensure that the quality of building materials and work safety methods meet the required standards through rigorous testing to maintain project quality and safety [14, 53].
Environmental management plan (X.4)	QHSE Principles X.4.1	Early QHSE integration is essential to identify risks and develop a robust QHSE management plan for the entire project lifecycle [53].
	Performance Indicators X.4.2	Designers use PIs to assess EMP performance and identify areas for improvement. Critical PIs include construction waste, chemical spills, soil erosion, and water quality changes [54, 78].
	Integrated QHSE Management System X.4.3	Designers and stakeholders collaborate to identify, evaluate, prioritize, and follow up on QHSE activities for risk management [56].
	Compliance with Regulations X.4.4	Comply with standards (ISO 9001, ISO 14001, ISO 45001, GB/T28001) and regulations (PUPR Ministerial Decree no. 10 of 2021) to ensure quality, environmental protection, and occupational health and safety [35, 57].
Traffic management plan (X.5)	Stakeholder Inclusion X.5.2	Eliminated.
	Performance Assessment X.5.3	Continuously assess planning consultants' performance in designing effective TMP [60].
DfS Regulations (X.7)	Compliance with Regulations X.7.1	Designers and stakeholders understand and apply CDM (Construction (Design and Management) Regulations), which mandate comprehensive planning and continuous review. This is carried out to avoid legal interventions and ensure compliance with Construction Safety standards [44].
	Specific Regulations X.7.3	Regulations such as EU Directive 92/57/EEC and Minister of Manpower Regulation 2018 mandate safety measures and designer responsibilities [23, 79].
	Legal Responsibilities X.7.4	Designers have a legal responsibility to ensure their design consider Construction Safety at all stages of construction [44, 65].
Risk Level (X.8)	Design Elements X.8.1	Certain design features and related construction activities carry varying degrees of risk. For example, elements such as foundations are considered risk to build [66].
Costs and Personnel Requirements for Construction Safety (X.9)	Budget Allocation X.9.1	Effective implementation of construction safety requires clear budget allocation, which is often insufficient, leading to financial losses and increases in the initial budget. Construction Safety costs typically range between 3-5% of the total project value, depending on scale [68-70].
	Cost Estimation Models X.9.2	Eliminated.
	Competence X.9.3	Design staff must be knowledgeable in risk management and Construction Safety principles [71].
	Training X.9.4	Regular training and retraining programs for construction employees on construction safety practices are essential to maintain high safety standards and improve worker performance [72, 73].
Safety guidelines Design (X.10)	Site-Specific Safety Plan X.10.4	Eliminated.

3.3 Explanation of recommendations by experts

The "Design Tools and Guidelines" sub-variable (X.1.3) within the "Designers' Scope of Responsibility" (X.1) was refined by emphasizing the importance of designers being able to not only utilize, but also effectively select appropriate design tools and guidelines based on specific safety requirements.

The "Construction Method" variable (X.2) underwent several refinements. The "Multi-Criteria Analysis" sub-variable (X.2.2) was enhanced by incorporating examples of Multi-Criteria Decision Making (MCDM) methods to enrich the discussion. The "Compliance with Regulations" sub-variable (X.2.3) was clarified by including specific examples of applicable Indonesian regulations, such as the Ministry of Public Works and Housing Regulation Number 10 of 2021. Additionally, the term "Health and Safety Plan" was replaced with "Construction Safety Plan" to align with current terminology.

The "Testing and Inspection Standards" variable (X.3) underwent refinement. The "Standard Procedures" sub-variable (X.3.2) was enhanced to emphasize the importance of considering functional and commissioning practices during the planning and design stages, as highlighted by Ellis (2008). This expanded the scope of inspection to encompass physical, functional, and operational aspects of construction. Additionally, the "Quality Control" sub-variable (X.3.3) was broadened to include the assessment of the quality of applied safety work methods.

The "EMP" variable (X.4) underwent significant refinement. The HSE concept was expanded to include Quality, Health, Safety, and Environment (QHSE) to encompass quality aspects within construction project implementation. The "Performance Indicators" sub-variable (X.4.2) was refined to align with the research focus on the planning stage of substructure work, leading to the removal of irrelevant indicators. Furthermore, the "Integrated QHSE Management System" (X.4.3) and "Compliance with Regulations" sub-variable (X.4.4) were strengthened by incorporating references to ISO 45001 standards and the Ministry of Public Works and Housing Regulation Number 10 of 2021.

The "TMP" variable (X.5) underwent refinement. The "Stakeholder Inclusion" sub-variable (X.5.2) was eliminated as it was deemed less relevant to the perspective of planning consultants within the scope of this research. The "Performance Evaluation" sub-variable (X.5.3) was reformulated to emphasize the crucial role of evaluating the performance of planning consultants in the effective design and implementation of TMPs.

The "DfS Regulation" variable (X.7) underwent significant refinement. The "Compliance with Regulations" sub-variable (X.7.1) was enhanced by emphasizing the importance of adhering to Construction Safety standards. The "Specific Regulations" sub-variable (X.7.3) was expanded to include the Ministry of Manpower Regulation Number 5 of 2018, which mandates designers to incorporate occupational safety considerations into their designs. Furthermore, the "Legal Liability" sub-variable (X.7.4) was adjusted by replacing "Occupational Health and Safety (OHS)" with "Construction Safety" to ensure a more specific focus on construction-related safety concerns.

The "Risk Level" variable (X.8) underwent refinement. Specifically, the "Design Element" sub-variable (X.8.1) was refined to focus exclusively on foundation elements, which were identified as the most critical and risky components within the substructure of high-rise buildings. This refinement aligns the analysis with the specific research focus.

The "Construction Safety Costs and Personnel Requirements" variable (X.9) underwent refinement. The term "Occupational Health and Safety (OHS)" was replaced with "Construction Safety" in the sub-variables related to Budget Allocation, Competence, and Training to ensure a specific focus on construction projects. Furthermore, the "Cost Estimation Model" sub-variable was eliminated as it was deemed to be adequately addressed within the provisions of the Ministry of Public Works and Housing Regulation regarding the allocation of budget for Construction Safety and construction safety management systems (RK-SMKK).

The "Safety Guideline Design" variable (X.10) underwent refinement. The "Specific Site Safety Plan" sub-variable (X.10.4) was eliminated as it was deemed more relevant to the scope of work of contractors, specifically involving direct on-site inspections. This adjustment was made to ensure that the focus of this variable remained on design aspects relevant to the project planning stage.

4. CONCLUSIONS

This research investigated the impact of RK-SMKK components on safety in Indonesian high-rise construction. Using a systematic approach and expert input (Delphi method), the study identified ten key factors crucial for successful DfS implementation. These factors include designers' roles, construction methods, testing standards, environmental and traffic management plans, risk management, regulations, risk levels, safety costs and personnel needs, and safety guideline design. Expert feedback further refined these factors, incorporating practical examples and decision-making methods.

While the Delphi method is a valuable tool for eliciting expert opinions, it's crucial to acknowledge its limitations. The representativeness of the expert panel can influence the generalizability of the findings, as the perspectives may not fully capture the diverse realities of the construction industry.

This research provides a valuable framework for understanding and implementing DfS in high-rise building projects in Indonesia. The identified factors can serve as a guide for policymakers, designers, and construction professionals in developing and implementing effective safety strategies, ultimately contributing to safer and more efficient construction practices.

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REFERENCES

[1] Annur, C.M. RI Masuk Daftar Negara dengan Gedung Pencakar Langit Terbanyak. databoks.katadata.co.id. https://databoks.katadata.co.id/properti/statistik/fe882dcb153cdc9/ri-masuk-daftar-negara-dengan-gedung-pencakar-langit-terbanyak, accessed on Jan. 26, 2025.

[2] Annur, C.M. Peringkat 12 Dunia, Jakarta Miliki 149 Gedung Pencakar Langit. databoks.katadata.co.id. https://databoks.katadata.co.id/properti/statistik/e9f41e7d8d02198/peringkat-12-dunia-jakarta-miliki-149-gedung-pencakar-langit, accessed on Jan. 26, 2025.

[3] Yonatan, A.Z. Indonesia Catat Lebih dari 160 Ribu Kecelakaan Kerja pada 2024. goodstats.id. https://goodstats.id/article/indonesia-catat-lebih-dari-160-ribu-kecelakaan-kerja-pada-2024-ZPCSs, accessed on Jan. 26, 2025.

[4] Kasus Kecelakaan Kerja, Mei Tahun 2024. Kementerian Ketenagakerjaan Republik Indonesia. https://satudata.kemnaker.go.id/data/kumpulan-data/1881, accessed on Jan. 26, 2025.

[5] Amal, A. (2023). Kecelakaan Konstruksi Dan Kegagalan Bangunan: Paradikma Baru Keselamatan Konstruksi Dan Penerapan Sesuai Regulasi. Journal of Sustainable

Civil Engineering (JOSCE), 5(1): 7-17. https://doi.org/10.47080/josce.v5i01.2349
[6] Feng, Y., Zhang, S., Wu, P. (2015). Factors influencing workplace accident costs of building projects. Safety Science, 72: 97-104. https://doi.org/10.1016/j.ssci.2014.08.008
[7] Alkaissy, M., Arashpour, M., Wakefield, R., Hosseini, R., Gill, P. (2022). The cost burden of safety risk incidents on construction: A probabilistic quantification method. Risk Analysis, 42(10): 2312-2326. https://doi.org/10.1111/risa.13865
[8] Othman, I., Azman, A. (2020). Safety misbehaviour and its effect towards safety performance of construction projects. In the 3rd International Conference on Architecture and Civil Engineering (ICACE 2019), Kuala Lumpur, Malaysia, pp. 193-200. https://doi.org/10.1007/978-981-15-1193-6_22
[9] Ahzahar, N., Karim, N.A., Hassan, S.H., Eman, J. (2011). A study of contribution factors to building failures and defects in construction industry. Procedia Engineering, 20: 249-255. https://doi.org/10.1016/j.proeng.2011.11.162
[10] Tymvios, N., Gambatese, J.A. (2016). Perceptions about design for construction worker safety: Viewpoints from contractors, designers, and university facility owners. Journal of Construction Engineering and Management, 142(2): 04015078. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001067
[11] Love, P.E., Lopez, R., Edwards, D.J., Goh, Y.M. (2012). Error begat error: Design error analysis and prevention in social infrastructure projects. Accident Analysis & Prevention, 48: 100-110. https://doi.org/10.1016/j.aap.2011.02.027
[12] [Larsen, G.D., Whyte, J. (2013). Safe construction through design: Perspectives from the site team. Construction Management and Economics, 31(6): 675-690. https://doi.org/10.1080/01446193.2013.798424
[13] Love, P.E.D., Lopez, R., Goh, Y.M., Tam, C.M. (2011). What goes up, shouldn't come down: Learning from construction and engineering failures. Procedia Engineering, 14: 844-850. https://doi.org/10.1016/j.proeng.2011.07.107
[14] Gambatese, J.A., Behm, M., Hinze, J.W. (2005). Viability of designing for construction worker safety. Journal of Construction Engineering and Management, 131(9): 1029-1036. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:9(1029)
[15] Murtaza, I., Rashid, M.U., Asad, M. (2024). Construction safety challenges and opportunities at design stage for building industry. Proceedings of the Institution of Civil Engineers-Management, Procurement and Law, 178(1): 3-15. https://doi.org/10.1680/jmapl.23.00010
[16] Tymvios, N., Hardison, D., Behm, M., Hallowell, M., Gambatese, J. (2020). Revisiting Lorent and Szymberski: Evaluating how research in prevention through design is interpreted and cited. Safety Science, 131: 104927. https://doi.org/10.1016/j.ssci.2020.104927
[17] Gao, R., Chan, A.P., Utama, W.P., Zahoor, H. (2016). Multilevel safety climate and safety performance in the construction industry: Development and validation of a top-down mechanism. International Journal of Environmental Research and Public Health, 13(11): 1100. https://doi.org/10.3390/ijerph13111100
[18] Poghosyan, A., Manu, P., Mahdjoubi, L., Gibb, A.G., Behm, M., Mahamadu, A.M. (2018). Design for safety implementation factors: A literature review. Journal of Engineering, Design and Technology, 16(5): 783-797. https://doi.org/10.1108/JEDT-09-2017-0088
[19] Hosseinian, S.S., Torghabeh, Z.J., Ressang, A. (2013). Relative importance of factors affecting construction hazards in the design phase. Applied Mechanics and Materials, 330: 862-866. https://doi.org/10.4028/www.scientific.net/AMM.330.862
[20] Toole, T.M. (2005). Increasing engineers' role in construction safety: Opportunities and barriers. Journal of Professional Issues in Engineering Education and Practice, 131(3): 199-207. https://doi.org/10.1061/(ASCE)1052-3928(2005)131:3(199)
[21] Al-Bayati, A.J., Jensen, E., Bazzi, K. (2024). Prevention Through Design (PtD): Addressing engineers' knowledge gaps. In 2024 ASEE Annual Conference & Exposition, Portland, Oregon. https://doi.org/10.18260/1-2--47873
[22] Christermaller, F., Che Ibrahim, C.K.I., Manu, P., Belayutham, S., Mahamadu, A.M., Yunusa-Kaltungo, A. (2022). Implementation of design for safety (DfS) in construction in developing countries: A study of designers in Malaysia. Construction Economics and Building, 22(2): 1-26. https://doi.org/10.5130/AJCEB.v22i2.8105
[23] Martínez-Aires, M.D., Rubio Gámez, M.C., Gibb, A. (2016). The impact of occupational health and safety regulations on prevention through design in construction projects: Perspectives from Spain and the United Kingdom. Work, 53(1): 181-191. https://doi.org/10.3233/WOR-152148
[24] Rodrigues, F., Alves, A. (2015). Contribution of BIM for hazards' prevention through design. Occupational Safety and Hygiene, 3: 67-69. https://doi.org/10.1201/b18042
[25] Zulkifli, A.R., Ibrahim, C.K.I.C., Belayutham, S. (2021). The integration of Building Information Modelling (BIM) and Prevention Through Design (PtD) towards safety in construction: A review. In 4th International Conference on Architecture and Civil Engineering (ICACE 2020), Kuala Lumpur, Malaysia, pp. 271-283. https://doi.org/10.1007/978-981-33-6560-5_28
[26] Andersen, J. (2018). Research Strategy. The European Research Management Handbook, Elsevier, pp. 109-145. https://doi.org/10.1016/B978-0-12-805059-0.00005-5
[27] Yin, R.K. (2014). Case Study Research Design and Methods (5th ed.). Canadian Journal of Program Evaluation, 30(1): 108-110. https://doi.org/10.3138/cjpe.30.1.108
[28] Lyonnais, É. (2021). À la recherche d'un consensus professionnel, la méthode Delphi. Sages-Femmes, 20(6): 52-54. https://doi.org/10.1016/j.sagf.2021.09.013
[29] Vernon, W. (2009). The Delphi technique: A review. International Journal of Therapy and Rehabilitation, 16(2): 69-76. https://doi.org/10.12968/ijtr.2009.16.2.38892
[30] Jaam, M., Awaisu, A., El-Awaisi, A., Stewart, D., El-ssHajj, M.S. (2022). Use of the Delphi technique in pharmacy practice research. Research in Social and Administrative Pharmacy, 18(1): 2237-2248.

https://doi.org/10.1016/j.sapharm.2021.06.028
[31] Diamond, I.R., Grant, R.C., Feldman, B.M., Pencharz, P.B., Ling, S.C., Moore, A.M., Wales, P.W. (2014). Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. Journal of Clinical Epidemiology, 67(4): 401-409. https://doi.org/10.1016/j.jclinepi.2013.12.002
[32] Murti, C.K., Muslim, F. (2023). Relationship between functions, drivers, barriers, and strategies of building information modelling (BIM) and sustainable construction criteria: Indonesia Construction Industry. Sustainability, 15(6): 5526. https://doi.org/10.3390/su15065526
[33] CDM. Managing health and safety in construction. London, 2015. https://www.hse.gov.uk/pubns/books/l153.htm, accessed on Jan. 26, 2025.
[34] Technocrat Education Institute. Metode Konstruksi: Panduan Lengkap untuk Membangun Bangunan yang Berkualitas. Teknik Sipil Universitas Teknokrat Indonesia. https://tekniksipil.teknokrat.ac.id/metode-konstruksi-panduan-lengkap-untuk-membangun-bangunan-yang-berkualitas/, accessed on Jan. 26, 2025.
[35] Kementerian Pekerjaan Umum Dan Perumahan Rakyat Republik Indonesia. PEDOMAN SISTEM MANAJEMEN KESELAMATAN KONSTRUKSI. Indonesia, 2021. https://peraturan.bpk.go.id/Details/216875/permen-pupr-no-10-tahun-2021, accessed on Jan. 26, 2025.
[36] El-Reedy, M.A. (2013). Concrete and Steel Construction. CRC Press. https://doi.org/10.1201/b16310
[37] EPA. Construction Environmental Management Plan (CEMP). South Australia, 2024. https://www.epa.sa.gov.au/files/12330_guide_cemp.pdf, accessed on Jan. 26, 2025.
[38] Vorst, C.R., Priyarsono, D.S., Budiman, A. Manajemen Risiko Berbasis SNI ISO 31000. Badan Standardisasi Nasional (BSN), 2018. https://perpustakaan.bsn.go.id/repository/ca09e618c360ecd38f4f0ccfc828a2ff.pdf, accessed on Jan. 26, 2025.
[39] ICE, Risk Analysis and Management for Projects (RAMP), 2nd ed. London: Thomas Telford Ltd., 2005. https://www.icevirtuallibrary.com/doi/abs/10.1680/ramp.33900.fm, accessed on Jan. 26, 2025.
[40] Stewart, J., Walsh, K. (1992). Change in the management of public services. Public Administration, 70(4): 499-518. https://doi.org/10.1111/j.1467-9299.1992.tb00952.x
[41] Mahamadu, A.M., Manu, P., Poghosyan, A., Mahdjoubi, L., Gibb, A., Behm, M. (2017). Organisational attributes that determine design for occupational safety and health capability. In CRIOCM 2017 22nd International Conference on Advancement of Construction Management and Real Estate, pp. 964-971.
[42] Bong, S., Rameezdeen, R., Zuo, J., Li, R.Y.M., Ye, G. (2015). The designer's role in workplace health and safety in the construction industry: Post-harmonized regulations in South Australia. International Journal of Construction Management, 15(4): 276-287. https://doi.org/10.1080/15623599.2015.1094850
[43] Rachmina, D. Penilaian Risiko – In General. Indonesia Risk Management Professional Association. https://irmapa.org/penilaian-risiko-in-general/, accessed on Jan. 26, 2025.
[44] Summerhayes, S.D. (2010). Design Risk Management Contribution to Health and Safety. Wiley. https://doi.org/10.1002/9781444318890
[45] Öney-Yazıcı, E., Dulaimi, M.F. (2015). Understanding designing for construction safety: the interaction between confidence and attitude of designers and safety culture. Architectural Engineering and Design Management, 11(5): 325-337. https://doi.org/10.1080/17452007.2014.895697
[46] Othman, I., Harahap, M.I.P., Mohamad, H., Shafiq, N., Napiah, M. (2018). Development of BIM-based safety management model focusing on safety rule violations. MATEC Web of Conferences, 203: 02007. https://doi.org/10.1051/matecconf/201820302007
[47] Dėjus, T. (2011). Safety of technological projects using multi-criteria decision making methods. Journal of Civil Engineering and Management, 17(2): 177-183. https://doi.org/10.3846/13923730.2011.576809
[48] Obolewicz, J., Baryłka, A., Szota, M. (2023). The impact of human behaviour on the (un) safety of the construction site. Journal of Achievements in Materials and Manufacturing Engineering, 119(1): 35-41. http://dx.doi.org/10.5604/01.3001.0053.8697
[49] Yang, H., Kong, H. (2019). Basic principles of a design and construction method for open excavation technology under complex conditions. Tunnel Construction, 1147-1151.
[50] Li, X., Zhang, X., Liu, Q., Zhang, Y., Gu, X., Qiu, Z. (2022). Research on coal mine building compliance inspection system based on accident causation and BIM in China. International Journal of Environmental Research and Public Health, 19(24): 16466. https://doi.org/10.3390/ijerph192416466
[51] Lovell, V., Frame, A. (2009). Life safety damper inspections. Consult Specif Eng, 20-21. https://www.csemag.com/articles/life-safety-damper-inspections/.
[52] Wang, N., Xu, C. (2019). Analysis of common problems in testing of building engineering materials. In AIP Conference Proceedings, 2073(1): 020009. https://doi.org/10.1063/1.5090663
[53] Edwards, V.H., Ray, M.A., English, A., Ellis, R., Chosnek, J., Geaslin, E., Jones, S.L. (2013). Integrate health, safety, and environment into engineering projects. Chemical Engineering Progress, 109(4): 50-55.
[54] Radzi, A.R., Farouk, A.M., Romali, N.S., Farouk, M., Elgamal, M., Rahman, R.A. (2024). Assessing environmental management plan implementation in water supply construction projects: Key performance indicators. Sustainability, 16(2): 600. https://doi.org/10.3390/su16020600
[55] Dahalan, N.H., Rahman, R.A., Ahmad, S.W., Che Ibrahim, C.K.I. (2023). Public monitoring of environmental management plan implementation in road construction projects: Key performance indicators. Journal of Engineering, Design and Technology. https://doi.org/10.1108/JEDT-06-2023-0225
[56] Brusn Patricia, A. (2004). Using an integrated approach to manage Health, Safety, and Environmental (HSE) activities on Engineering, Procurement, and Construction (EPC) projects. In Proceedings of the Air and Waste Management Associations, Annual Meeting and Exhibition, pp. 4489-4495.
[57] Huang, Q.M., Zhang, Q. (2009). Construction management scheme conformed to the quality,

environmental and safety standards. Shenzhen Daxue Xuebao (Ligong Ban)/Journal of Shenzhen University Science and Engineering, 98-101.
[58] Gambatese, J., Johnson, M. (2014). Impact of design and construction on quality, consistency, and safety of traffic control plans. Transportation Research Record, 2458(1): 47-55. https://doi.org/10.3141/2458-06
[59] Scriba, T., Symoun, J., Beasley, K.A. (2010). To lessen work zone impacts: Try TMPs. Public Roads, 74(2): 10-17.
[60] Gallo, A.A., Dougald, L.E., Demetsky, M.J. (2013). Formalized process for performance assessment of work zone transportation management plans in Virginia. Transportation Research Record, 2337(1): 50-58. https://doi.org/10.3141/2337-07
[61] Youli, Y., Yingjian, P., Xiaoxia, L. (2018). Research on safety risk management of civil construction projects based on risk matrix method. IOP Conference Series: Materials Science and Engineering, 392(6): 062080. https://doi.org/10.1088/1757-899X/392/6/062080
[62] Dharmapalan, V., Gambatese, J.A., Fradella, J., Moghaddam Vahed, A. (2015). Quantification and assessment of safety risk in the design of multistory buildings. Journal of Construction Engineering and Management, 141(4): 04014090. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000952
[63] Wang, Y.Q., Bian, G.Y., Li, Y. (2014). Risk assessment of construction organization plans for bridge projects. Advanced Materials Research, 831: 370-375. https://doi.org/10.4028/www.scientific.net/AMR.831.370
[64] Hossain, M., Abbott, E.L., Chua, D.K. (2017). Design for safety knowledge-based BIM-integrated risk register system. In 9th International Structural Engineering and Construction Conference: Resilient Structures and Sustainable Construction. https://doi.org/10.14455/ISEC.res.2017.46
[65] Nassif, A.Y., Ward, R.N. (2011). An investigation into the effectiveness of the construction health and safety regulations in the United Kingdom: Designers role. In 6th International Structural Engineering and Construction Conference: Modern Methods and Advances in Structural Engineering and Construction, pp. 461-466. Research Publishing Services. https://doi.org/10.3850/978-981-08-7920-4_S1-CS06-cd
[66] Barrie, A., Rohani, J.M., Redzuan, N. (2020). Risk estimation of construction activities of buildings. AIP Conference Proceedings, 2217(1): 020001. https://doi.org/10.1063/5.0004435
[67] Damanik, M.F., Latief, Y., Nugroho, D.B. (2023). Development of risk-based Work Breakdown Structure (WBS) standards for integrated design and construction phase on design-build contract of mechanical and electrical works of high-rise building to improve construction safety performance. International Journal of Engineering Trends and Technology, 71(8): 119-130. https://doi.org/10.14445/22315381/IJETT-V71I8P210
[68] Sari, F.A.K., Latief, Y. (2021). Safety cost estimation of building construction with fuzzy logic and artificial neural network. Journal of Physics: Conference Series, 1803(1): 012020. https://doi.org/10.1088/1742-6596/1803/1/012020
[69] Harianja, A.S., Latief, Y. (2020). Structural Equation Model (SEM) between risk, safety control systems of risk, and OHS programs on OHS costs in Rusunawa projects. IOP Conference Series: Materials Science and Engineering, 930(1): 012030. https://doi.org/10.1088/1757-899X/930/1/012030
[70] Akawi, J., Musonda, I. (2021). Costing of health and safety elements in construction projects in Gauteng, South Africa. In Collaboration and Integration in Construction, Engineering, Management and Technology: Proceedings of the 11th International Conference on Construction in the 21st Century, London 2019, pp. 315-320. Springer International Publishing. https://doi.org/10.1007/978-3-030-48465-1_53
[71] Manu, P., Poghosyan, A., Mahamadu, A.M., Mahdjoubi, L., Gibb, A., Behm, M., Akinade, O.O. (2019). Design for occupational safety and health: Key attributes for organisational capability. Engineering, Construction and Architectural Management, 26(11): 2614-2636. https://doi.org/10.1108/ECAM-09-2018-0389
[72] Bourahla, A., Fernandes, G., Ferreira, L.M.D. (2024). Managing occupational health and safety risks in construction projects to achieve social sustainability–A review of literature. Procedia Computer Science, 239: 1053-1061. https://doi.org/10.1016/j.procs.2024.06.269
[73] Abdi, M.A., Hareru, W.K. (2024). Assessment of factors affecting the implementation of occupational health and safety measures in the construction industry in Somaliland. Advances in Civil Engineering, 2024(1): 8324294. https://doi.org/10.1155/2024/8324294
[74] Ibrahim, C.K.I.C., Manu, P., Belayutham, S., Cheung, C., Mohamad, M.Z., Yunusa-Kaltungo, A., Ismail, S., Hussain, A. (2023). Factors influencing DfS adoption: The case of Malaysian construction organisations. In Thirty-Ninth Annual Conference, pp. 237-246.
[75] Stiegert, I., Hippert, A., Borges, M. (2016). Design for Maintenance guidelines: Safety height work. In Occupational Safety and Hygiene IV-Selected, Extended and Revised Contributions from the International Symposium Occupational Safety and Hygiene, pp. 173-178.
[76] Reid, C. (2007). Developing a culture of safety. Workplace HR and Safety Magazine, pp. 27-28.
[77] Ellis, R. (2008). Design delays. Engineered Systems, 25(1): 24.
[78] Dahalan, N.H., Rahman, R.A., Hassan, S.H., Ahmad, S.W. (2023). Performance indicators for public evaluation of environmental management plan implementation in highway construction projects. International Journal of Disaster Resilience in the Built Environment, 15(3): 425-449. https://doi.org/10.1108/IJDRBE-02-2023-0025
[79] Permenaker Republik Indonesia, 2018. https://www.peraturan.go.id/id/permenaker-no-5-tahun-2018, accessed on Jan. 26, 2025.