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# The Influence of Safety in Design Implementation on Construction Safety Performance in Building Projects

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***Abstract*— The construction industry remains one of the sectors with the highest incidence of occupational accidents, particularly during the project execution phase. To mitigate these risks, the concept of Safety in Design (SiD) has been introduced as a proactive framework that integrates hazard identification and risk mitigation strategies into design stage of construction projects. This study investigates influence of SiD implementation on construction safety performance in building projects within DKI Jakarta. A quantitative research design was adopted, employing a survey of 50 respondents occupying project management positions across four high-rise building projects managed by a state-owned enterprise. The study examined three principal variables: human/engineer factors, managerial aspects, and compliance and technological systems. Data were analyzed using ordinal logistic regression, supported by statistical tests including wald test, goodness-of-fit test, and test of parallel lines. The results reveal that all SiD-related variables significantly contribute to enhancement of construction safety performance. Among these, managerial aspects exert strongest influence, followed by compliance and technology, and finally, human factors. The statistical model demonstrated robust validity and an adequate fit, confirming critical role of incorporating safety considerations from earliest stages of project planning. These findings highlight strategic importance of equipping designers and project managers with safety-oriented competencies, while embedding risk-based decision-making into design process. Such measures are essential to reducing occupational accidents and fostering a culture of safety excellence within the construction industry.**

*Keywords*— Construction safety, logistic regression, project planning, Safety in Design.

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## I. INTRODUCTION

The construction industry represents a critical pillar of Indonesia's economic framework. As a labor-intensive and investment-driven sector, it not only makes a substantial contribution to the national gross domestic product (GDP) but also serves as a catalyst for infrastructure development, employment generation, and capital distribution. The scope of construction activities is broad, encompassing residential developments as well as large-scale public infrastructure projects such as airports, bridges, highways, and water management systems [1]. In 2023, the industry's growth was projected at 5.78%, reflecting continued recovery from the downturn caused by COVID-19 pandemic. Notably, the sector recorded a 4.72% growth rate in fourth quarter of 2022, according to Statistics Indonesia, driven by increased public expenditure and the acceleration of national development programs.

Despite these encouraging economic indicators, construction sector remains one of the most hazardous industries in terms of occupational health and safety (OHS). Construction activities often involve high-risk engineering tasks, dynamic site conditions, operation of heavy machinery, work at significant heights, and complex coordination among multiple stakeholders. Consequently, the sector consistently reports a disproportionately high incidence of workplace injuries and fatalities [2]. In 2022, Indonesian Social Security Agency for Employment documented 265,334 occupational accidents, with the construction industry accounting for 32% of all cases, surpassing both manufacturing and mining sectors [3].

Accidents in the construction industry are driven by multiple factors. These include insufficient training, outdated or non-compliant equipment, unsafe site conditions, improper tool use, weak safety culture, and limited managerial commitment to safety protocols. In addition, many companies view safety management systems as a financial burden, which discourages investment in comprehensive safety planning [4]. However, empirical evidence shows the opposite. The costs of workplace accidents through compensation, project delays, and reputational damage far exceed the expenses of preventive safety measures.

International research has identified early-stage project decisions, particularly those made during planning and design phases, as critical determinants of construction safety outcomes. The European Foundation [5] estimates that up to 60% of construction accidents are directly attributable to design-related decisions. Similarly, Tymvios and Gambatese [6] reported that 42% of site accidents in the United States

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could be attributed to inadequate design planning. These findings have given rise to the concept of Design for Safety (DfS), also known as Safety in Design (SiD), which promotes systematic integration of hazard identification and risk mitigation strategies into the project's conceptual and detailed design stages [7].

Design for Safety (DfS) represents a paradigm shift from reactive to proactive safety management, positioning engineers, architects, and design consultants at the forefront of accident prevention. Instead of relying solely on site-level controls and personal protective equipment (PPE), DfS emphasizes eliminating hazards altogether or reducing their severity and likelihood through deliberate engineering choices. Examples include increasing ceiling heights in service zones, specifying non-slip surfaces, and integrating permanent anchorage points for fall protection all of which significantly enhance construction safety [8].

Many countries have institutionalized Design for Safety (DfS) through formal legislation and industry-specific guidelines. For instance, New Zealand's Health and Safety at Work Act (2015) requires designers to account for worker safety across all phases of a project [9]. In the United States, the Prevention through Design (PtD) initiative promotes collaborative safety planning among project stakeholders at the early stages of the project lifecycle [10]. Furthermore, Samsudin et al. [11] demonstrated that integrating safety-related design features during preliminary design stage can significantly enhance structural safety performance throughout a building's life cycle.

Despite its demonstrated effectiveness, application of DfS principles in Indonesia remains limited and underutilized. There is a pressing need to increase awareness and capacity among Indonesian design professionals, clients, and contractors regarding the value of upstream safety interventions. Endroyo and Suraji [12] argued that project planning must be realistic, integrative, systematic, and measurable to serve as an effective foundation for construction safety. The planning stage is not only where strategic decisions are made but also where the most impactful safety-related choices can be embedded into project documentation.

In construction projects managed by Indonesian State-Owned Construction Enterprises, the project cycle is generally divided into three key stages: preparation, construction, and maintenance. The preparation stage encompasses development of detailed engineering design (DED), preparation of bridging documents, and formulation of Health, Safety, and Environment (HSE) plans. This stage is critical, as safety planning must be thoroughly integrated into project documentation. However, evidence suggests that safety considerations are often minimally addressed or even overlooked in design documents, thereby reducing the effectiveness of safety measures during project execution.

Amid growing concern over construction-related accidents and a global shift toward proactive safety strategies, this study evaluates integration of Safety in Design (SiD) principles within construction project planning processes in Indonesia. Specifically, the research identifies key factors influencing the adoption of SiD during planning phase, examines their impact on occupational safety performance in construction phase, and develops practical recommendations to support implementation of design-based safety strategies. By analyzing how early-stage design decisions shape downstream safety outcomes, the study seeks to inform and strengthen strategies that enable engineers and project stakeholders to embed safety considerations at outset of a project. Strengthening the implementation of Design for Safety (DfS) is expected to reduce workplace accidents, enhance worker well-being, and ultimately improve both project efficiency and long-term sustainability.

The scope of this research is deliberately focused on planning phase of construction projects, where design decisions are most influential and preventive interventions can be most effective. While the safety performance analyzed pertains to execution stage, the study does not cover safety practices during operation or post-construction phases. Furthermore, data are collected based on the perceptions and professional insights of engineers involved in project planning, obtained through structured questionnaires. As such, the study emphasizes the experiential and perceptual dimensions of SiD implementation, rather than direct field observations or empirical safety audits.

## II. METHOD

This study employed a quantitative research design, utilizing ordinal logistic regression to analyze relationship between Safety in Design (SiD) factors and construction safety performance. Data were obtained through structured questionnaires administered to 50 professionals engaged in construction project management across four construction companies in Jakarta.

This study aims to assess the extent to which Safety in Design (SiD) concept is implemented during the planning phase of construction projects and to examine its impact on construction safety performance. The research framework comprises one dependent variable and three independent variables. The dependent variable, construction safety performance, is defined as collective efforts undertaken to ensure occupational health and safety by preventing work-related accidents and diseases throughout the construction process

The independent variables comprise Human/Designer ($X_1$), Management ($X_2$), and System Compliance & Technology ($X_3$). The Human/Designer variable ($X_1$) refers to members of engineering team directly involved in project planning. Within a leading state-owned construction company in Indonesia, this category includes five key roles: the Method Officer, responsible for planning work methods; the Project Control Officer, who manages budgeting and scheduling; the Drafter Officer, responsible for preparing technical drawings; the BIM Officer, who oversees digital modeling; and the HSE Officer, who develops health, safety, and environmental plans. The Management variable ($X_2$) covers leadership and decision-making roles tasked with establishing policies, ensuring commitments, and resolving project-level issues. These roles include the Project Manager, Site Engineering Manager, Site Operational Manager, and Site Administration Manager, each contributing to different aspects of project oversight. The third variable, System Compliance & Technology ($X_3$), reflects effectiveness of established safety management systems and the integration of digital technologies in safety planning. System compliance is demonstrated through implementation of standards such as Indonesian Occupational Safety and Health Management System, International Standard for Occupational Health and Safety Management Systems 45001, and national construction safety regulations. The technological dimension encompasses tools widely adopted in practice, including Mobile Workforce Technology (MWT) application for field inspections, Quality, Health, Safety, and Environment (QHSE) Passport for centralized worker data management, QHSE Dashboard for real-time safety performance monitoring, and Building Information Modeling (BIM), which enables proactive hazard identification and the integration of safety considerations into design.

Collectively, these variables are examined to evaluate their individual and combined contributions to improving construction safety performance from design phase onward, thereby fostering a preventive, systems-oriented approach to occupational safety in the construction industry.

Variable $X_1$, Human/Designer, emphasizes competencies, attitudes, and strategic roles of designers in implementing Safety in Design (SiD) principles during planning phase of construction projects. It encompasses safety knowledge, technical expertise, the use of digital tools (e.g., Building Information Modeling), and commitment to safety. The variable also captures managerial capabilities, including planning, contractor selection, and integration of safety requirements into project documentation. $X_1$ is measured using 25 items that cover a comprehensive range of individual competencies and organizational responsibilities.

Variable $X_2$, Management, emphasizes organizational and institutional factors that influence implementation of Safety in Design (SiD) during planning phase of construction projects. This variable comprises 19 items encompassing a broad range of elements, including community concerns, regulatory requirements, design standards, and integration of safety into design workflows. It captures extent to which risk management practices, team collaboration, and control mechanisms are embedded in design process. Additionally, it addresses availability of design documentation for safety, clarity of responsibilities, and owner-driven safety objectives. Contractual obligations, inclusion of safety requirements in tender documents, and application of risk-based decision-making principles are also key components. Overall, $X_2$ focuses on how project management structures, owner involvement, and procedural frameworks collectively contribute to a proactive and systematic approach to construction safety through the design phase.

Variable $X_3$, Technology and Materials, focused on utilization of digital tools, engineering applications, and regulatory systems that supported integration of Safety in Design (SiD) within construction planning. Comprising eight items, this variable highlighted role of design software, mobile inspection tools, and digital safety dashboards in enhancing hazard identification and performance monitoring. It also reflected application of Building Information Modeling to visualize safety aspects at an early stage of design process. Furthermore, it encompassed adoption of formal safety management systems, such as International Organization for Standardization 45001, Indonesian Occupational Safety and Health Management System, and national construction law, which institutionalized safety protocols across projects.

Variable Y, Construction Safety Performance, represented outcome variable used to evaluate effectiveness of Safety in Design (SiD) practices. It was measured through a single indicator assessing safety performance of construction projects, either ongoing or completed, in which SiD principles had been incorporated during design phase. This variable reflected extent to which safety considerations introduced at design stage translated into measurable improvements in on-site safety outcomes.

This study employed an ordinal measurement scale to assess degree of influence exerted by various factors on improvement of construction safety performance. A five-point Likert-type scale (1–5) was chosen, as a larger number of response categories was considered less practical for certain respondents. To verify, refine, and validate the independent variables (X), an open-ended instrument (First-stage Questionnaire) was administered. Respondents evaluated the influence of each factor using a numerical scale, where a score of 1 denoted “no influence” and a score of 5 denoted “very strong influence.” The development of this measurement scale was adapted from the work of Taiebat and Ku [13].

The sample in this study comprised construction project employees from a state-owned enterprise who were engaged in four ongoing construction projects in Jakarta area. The total population consisted of 100 individuals, and Slovin formula was applied with a 10% margin of error ($e = 0.10$) to determine minimum required sample size, resulting in 50 respondents. The formula employed was $n = N / (1 + Ne^2)$, where n denoted required sample size, N represented population size, and e indicated margin of error.

Data were collected through a questionnaire administered to personnel directly involved in project planning and safety implementation. The respondents consisted of Project Managers, Site Engineering Managers, Site Operational Managers, BIM Engineers, Site Engineers, Drafters, Method Engineers, and QHSE staff, with approximately 12–13 individuals participating from each project. These roles were selected because of their direct responsibilities in integrating Safety in Design (SiD) principles into construction planning and execution.

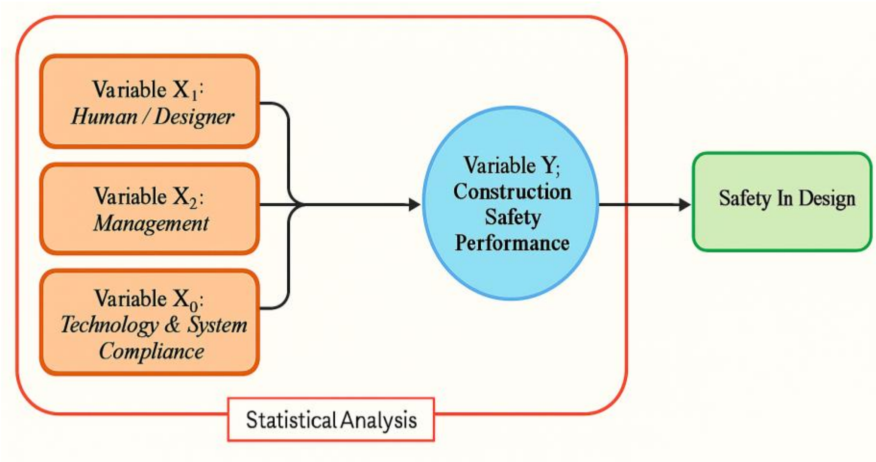


**Figure. 1.** Research Construction Model.

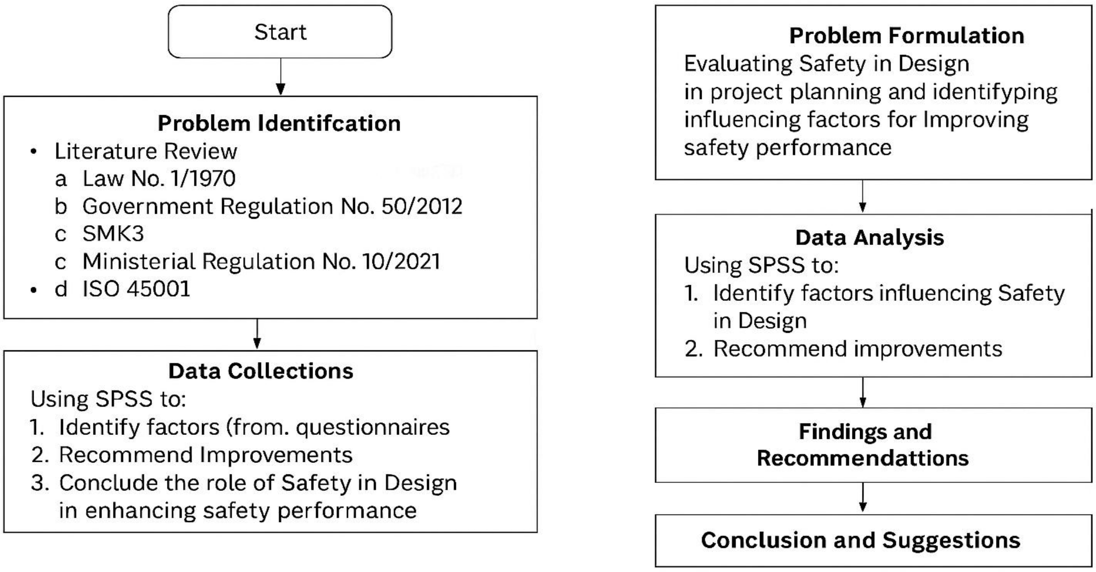


**Figure. 2.** Research diagram

*Data Processing and Analysis*

The data processing stage was carried out after completion of data collection. Quantitative data were analyzed using Statistical Package for Social Sciences (SPSS) through several steps:

*Validity Test*

The validity test was employed to examine accuracy and consistency of questionnaire as a research instrument. The hypotheses for validity test were defined as follows:

- $H_0$: The questionnaire item was not correlated with total score.
- $H_1$: The questionnaire item was correlated with total score;

An item was considered valid if correlation coefficient (r) exceeded critical value in r-table, leading to rejection of $H_0$. Conversely, if r was less than critical value, item was considered invalid.

*Reliability Test*

Reliability testing was conducted to measure internal consistency of questionnaire using Cronbach's Alpha. The hypotheses for reliability test were defined as follows:

- $H_0$: The item was not correlated with total score.
- $H_1$: The item was correlated with total score.

An instrument was considered reliable if Cronbach's Alpha value exceeded 0.60, which indicated the rejection of $H_0$.

*Ordinal Logistic Regression*

Ordinal logistic regression was employed to examine influence of various factors on implementation of Safety in Design (SiD). The analytical procedure consisted of the following steps:

1. Conducting descriptive analysis to obtain an initial overview;
2. Specifying ordinal logistic regression model to identify significant influencing factors;
3. Performing following analysis:
   - Estimating parameters using Maximum Likelihood
   - Estimation (MLE) method;

- Applying Wald test to assess significance of individual predictors;
- Evaluating model fit to determine its appropriateness;
- Interpreting model using odds ratio.

## III. Results and Discussion

The data in this study were obtained from questionnaires completed by 50 respondents who were involved in four state-owned construction projects in Jakarta area. The analysis was conducted using one dependent variable, namely Construction Safety Performance (Y), and three independent variables representing Safety in Design (SiD) concept: Human/Engineer (X1), Management (X2), and System Compliance & Technology (X3)

Validity testing was conducted to ensure that questionnaire items accurately and consistently measured intended variables. As shown in Table 1, all items demonstrated a Pearson correlation coefficient (r) greater than critical value of 0.279, based on a sample size of 50 respondents and a 5% significance level. Specifically, the r values for Human/Engineer variable (X1) ranged from 0.769 to 0.899, those for Management variable (X2) ranged from 0.563 to 0.865, and those for System Compliance & Technology variable (X3) ranged from 0.834 to 0.943. These results confirmed that all questionnaire items were statistically valid and suitable for further analysis. The validity assessment indicated that instrument effectively captured constructs under investigation with both precision and consistency.

Table 1.
Validity and Reliability Variable

| Variabel | r-value | r-table | note | r-alpha | cutt-of- value | note |
|---|---|---|---|---|---|---|
| Human/Engineer (X1) | 0.769 to 0.899 | 0.279 | valid | 0.980 | 0.60 | reliable |
| Management (X2) | 0.563 to 0.865 | 0.279 | valid | 0.966 | 0.60 | reliable |
| System Compliance & Technology (X3) | 0.834 to 0.943 | 0.279 | valid | 0.964 | 0.60 | reliable |

Reliability testing was conducted on all questionnaire items that had previously been validated. Similar to validity test, reliability test involved 50 respondents and was performed using statistical software to calculate Cronbach's alpha coefficient for each research variable. A questionnaire was considered reliable if Cronbach's alpha value exceeded 0.60. As shown in Table 1, Cronbach's alpha values for variables were: Human/Engineer (X1) = 0.980, Management (X2) = 0.966, and System Compliance & Technology (X3) = 0.964. All of these values were significantly higher than the threshold, indicating a very high level of internal consistency. Therefore, instrument was concluded to meet reliability requirements and was suitable for use as a measurement tool in this study

Parameter estimation in ordinal logistic regression analysis was performed using the Maximum Likelihood Estimation (MLE) method, which is widely applied to estimate unknown parameters in statistical models. The analysis was conducted with SPSS version 16, incorporating all independent variables into the model. The resulting parameter estimates, as produced by software, are presented in Table 2.

Table 2 presented estimated coefficients for each indicator within three main independent variables: Human/Engineer (X1), Management (X2), and System Compliance & Technology (X3). The estimated values varied, indicating both positive and negative effects of respective indicators on the dependent variable, Construction Safety Performance (Y).

For the Human/Engineer (X1) variable, estimated coefficients ranged from –2.574 (X1.22) to 4.315 (X1.13), reflecting a broad spectrum of influence across the 25 indicators. Positive coefficients suggested stronger contributions to safety performance, whereas negative coefficients implied inhibitory effects. For Management (X2) variable estimates were predominantly positive, with highest value recorded at 2.235 (X2.19). This pattern indicated that effective management components generally enhanced construction safety performance. In contrast, System Compliance & Technology (X3) variable exhibited more moderate coefficient values, ranging from –0.453 (X3.3) to 0.570 (X3.4), with several values approaching zero. Such findings suggested a more limited or nuanced role of technological systems in directly influencing safety outcomes. Overall, these estimates clarified relative influence of each indicator on construction safety performance and formed the basis for further hypothesis testing.

The Wald test was applied to assess significance of each parameter in the ordinal logistic regression model. As shown in Table 2, predictors with p-values below 0.05 were deemed statistically significant, confirming rejection of the null hypothesis ($H_0$) and indicating a meaningful influence on construction safety performance.

For the Human/Engineer (X1) dimension, 22 of 25 indicators (e.g., X1.1 = 0.027; X1.2 = 0.004; X1.13 = 0.001) exhibited significant effects, with p-values ranging from 0.001 to 0.051. The remaining indicators (e.g., X1.8 = 0.054; X1.10 = 0.458; X1.23 = 0.051) exceeded 0.05 threshold and therefore did not demonstrate a significant influence on response variable.

I Management (X2) category, 16 of 19 indicators (e.g., X2.3 = 0.017; X2.5 = 0.003; X2.18 = 0.038) were statistically significant, whereas three indicators (X2.4 = 0.417; X2.9 = 0.344; X2.15 = 0.106) were not. These results indicated that managerial practices and organizational decision-making processes played a critical role in shaping occupational safety performance.

TABLE 2.
WALD TEST ESTIMATOR

| Variable | Item | Estimate | Wald | df | Sig. | Note |
|---|---|---|---|---|---|---|
| Human/Engineer (X1) | X1.1 | 0.060 | 0.014 | 1 | 0.027 | significant |
| | X1.2 | 2.025 | 8.361 | 1 | 0.004 | significant |
| | X1.3 | 1.509 | 4.043 | 1 | 0.044 | significant |
| | X1.4 | -1.269 | 2.208 | 1 | 0.037 | significant |
| | X1.5 | 2.572 | 7.637 | 1 | 0.006 | significant |
| | X1.6 | -1.962 | 7.903 | 1 | 0.005 | significant |
| | X1.7 | -0.454 | 0.459 | 1 | 0.048 | significant |
| | X1.8 | -2.444 | 3.714 | 1 | 0.054 | not significant |
| | X1.9 | -0.346 | 0.249 | 1 | 0.018 | Signifikan |
| | X1.10 | -0.390 | 0.551 | 1 | 0.458 | not significant |
| | X1.11 | -0.631 | 0.703 | 1 | 0.002 | significant |
| | X1.12 | -0.750 | 0.010 | 1 | 0.021 | significant |
| | X1.13 | 4.315 | 10.090 | 1 | 0.001 | significant |
| | X1.14 | 0,602 | 0.972 | 1 | 0.024 | significant |
| | X1.15 | 1.629 | 4.341 | 1 | 0.037 | significant |
| | X1.16 | -0.142 | 0.026 | 1 | 0.036 | significant |
| | X1.17 | 1.223 | 5.381 | 1 | 0.02 | significant |
| | X1.18 | 1.982 | 8.266 | 1 | 0.004 | significant |
| | X1.19 | -0.410 | 0.210 | 1 | 0.047 | significant |
| | X1.20 | -1.563 | 4.299 | 1 | 0.038 | significant |
| | X1.21 | 1.326 | 1.605 | 1 | 0.005 | significant |
| | X1.22 | -2.574 | 7.895 | 1 | 0.025 | significant |
| | X1.23 | 1.413 | 3.809 | 1 | 0.051 | significant |
| | X1.24 | -0.807 | 1.630 | 1 | 0.02 | significant |
| | X1.25 | -0.141 | 0.066 | 1 | 0.033 | significant |
| Management (X2) | X2.1 | 0.113 | 0.082 | 1 | 0.024 | significant |
| | X2.2 | 0.168 | 0.251 | 1 | 0.037 | significant |
| | X2.3 | 0.997 | 2.495 | 1 | 0.017 | significant |
| | X2.4 | 0.853 | 0.659 | 1 | 0.417 | not significant |
| | X2.5 | 1.458 | 9.029 | 1 | 0.003 | significant |
| | X2.6 | 1.486 | 1.926 | 1 | 0.047 | significant |
| | X2.7 | 0.736 | 2.976 | 1 | 0.029 | significant |
| | X2.8 | 0.634 | 1.948 | 1 | 0.005 | significant |
| | X2.9 | 0.801 | 0.896 | 1 | 0.344 | not significant |
| | X2.10 | 0.785 | 0.322 | 1 | 0.037 | significant |
| | X2.11 | 0.214 | 0.159 | 1 | 0.043 | significant |
| | X2.12 | 0.711 | 0.827 | 1 | 0.018 | significant |
| | X2.13 | 0.945 | 0.496 | 1 | 0.021 | significant |
| | X2.14 | 0.273 | 0.375 | 1 | 0.039 | significant |
| | X2.15 | 1.128 | 2.613 | 1 | 0.106 | not significant |
| | X2.16 | 0.338 | 0.662 | 1 | 0.016 | significant |
| | X2.17 | 0.497 | 0.824 | 1 | 0.024 | significant |
| | X2.18 | 0.838 | 0.972 | 1 | 0.038 | significant |
| | X2.19 | 2.235 | 5.829 | 1 | 0.016 | significant |
| System Compliance & Technology (X3) | X3.1 | 0.205 | 0.415 | 1 | 0.025 | significant |
| | X3.2 | 0.129 | 0.079 | 1 | 0.039 | significant |
| | X3.3 | -0.453 | 2.006 | 1 | 0.037 | significant |
| | X3.4 | 0.570 | 1.932 | 1 | 0.016 | significant |
| | X3.5 | 0.412 | 1.075 | 1 | 0.031 | significant |
| | X3.6 | 0.138 | 0.103 | 1 | 0.048 | significant |
| | X3.7 | 0.000 | 0.368 | 1 | 0.057 | not significant |
| | X3.8 | 0.075 | 0.044 | 1 | 0.035 | significant |

Regarding System Compliance & Technology (X3) dimension, 7 of 8 indicators (e.g., X3.1 = 0.025; X3.3 = 0.037; X3.4 = 0.016) were statistically significant, while X3.7 ($p = 0.057$) was not. These results underscored critical role of compliance systems and technological infrastructure in enhancing construction safety performance.

Collectively, the results confirmed that multiple aspects across human, managerial, and technological domains significantly contributed to safety performance outcomes in construction sector. Integrating these factors into planning and operational strategies was therefore essential for improving safety-related behavior and reducing risks across project environments. Overall, the findings indicated that Human/Engineer factor had a statistically significant impact on construction safety performance. Several indicators served as strong positive contributors, whereas others exerted negative effects on likelihood of achieving higher safety performance categories. These results underscored critical importance of effectively managing human-related factors to enhance safety performance in construction projects.

The ordinal logistic regression analysis of Management factor revealed that the model was statistically valid and appropriate for data, with a significance value of 0.012 (< 0.05), indicating that the inclusion of management variable significantly improved the model's ability to explain variations in safety performance. The model also satisfied parallel lines assumption ($p = 0.398$), confirming consistent effects across safety performance categories. Most management indicators exerted a significant and positive influence, with X2.5, X2.6, X2.8, and X2.19 contributing the most. These findings underscored critical role of effective management in enhancing occupational safety performance within construction settings.

The ordinal logistic regression analysis of the analysis of Technology and System Compliance factor confirmed that the model was statistically valid and appropriate for data. The comparison between intercept-only model and the model showed a significant improvement, with the -2 Log Likelihood decreasing from 108.650 to 90.000, resulting in a Chi-Square value of 18.650 (df = 7; p = 0.009). This result indicated that the inclusion of predictors significantly enhanced the model's explanatory power. Out of eight predictor variables, seven (X3.1, X3.2, X3.3, X3.4, X3.5, X3.6, and X3.8) significantly influenced safety performance categories ($p < 0.05$), while X3.7 was marginally significant ($p = 0.057$). The model also satisfied the proportional odds assumption ($p = 0.987$), confirming the consistency of predictor effects across all levels of safety performance. Overall, the findings underscored that technology and system compliance factors played a crucial role in determining construction safety outcomes.

Based on analysis, a recommended integration scheme for construction safety was formulated, as presented in Table 1. This scheme was embedded into design workflow at project planning stage and was developed with reference to the Regulation of the Minister of Public Works and Public Housing of Republic of Indonesia No. 10/2021 on Construction Safety Management Systems. The safety-in-design implementation framework began with a conceptual structure aligned with construction work stages, aimed at identifying potential hazards and establishing appropriate risk controls, particularly for high-risk activities. This framework served as foundation for the Health, Safety, and Environment Plan and the Division of Responsibility, both structured in accordance with Article 23 of the same regulation.

The Health, Safety, and Environment Plan served as a strategic instrument for systematically managing health, safety, and environmental risks across all phases of the project. It encompassed key components, including the project overview, scope of work, geographical boundaries, definitions, references, leadership and worker participation, construction safety planning, resource requirements, operational control procedures, performance evaluation mechanisms, and supporting documentation. The plan was developed in alignment with relevant national and international standards, specifically Law No. 1/1970, Ministerial Regulation No. 10/2021, Government Regulation No. 50/2012, and International Organization for Standardization 45001.

The Division of Responsibility matrix ensured that all safety, health, and environmental requirements were verified and fulfilled prior to commencement of each project activity. The DOR was aligned with Agile and Scrum methodologies, serving as a readiness criterion to confirm compliance with health, safety, and environmental standards. It encompassed planning documents, commitment letters, competency certifications, labor documentation, and adherence to health, safety, and environmental General Rules, including the use of personal protective equipment, safe operation of heavy equipment, lifting tools, power tools, electrical systems, as well as protocols for working at heights, confined spaces, and hazardous activities. In addition, it incorporated requirements for temporary facilities, access control systems, and communication equipment to support field operations and safety oversight. Collectively, this integrated safety design framework reinforced proactive risk mitigation and fostered a consistent safety culture throughout all phases of construction project.

## IV. CONCLUSION

This study identified three primary factors that influenced effective implementation of Safety in Design (SiD) during construction planning phase: Human/Engineer (X1), Management (X2), and Technology/System Compliance (X3). Each factor consisted of multiple indicators that significantly affected construction safety performance. Among these, key human-related indicators including knowledge of safety standards, technical competence, and a safety-oriented mindset were particularly dominant. Management-related indicators, such as managerial control, coordination, and monitoring, also contributed positively. Similarly, technological aspects, including adherence to safety codes and system integration, further strengthened safety outcomes in construction projects.

The ordinal logistic regression analysis confirmed that these three variables collectively and significantly influenced safety outcomes, with the model demonstrating a strong statistical fit and meeting proportional odds assumption. These findings underscored critical importance of integrating safety considerations from design stage through involvement of competent human resources, effective management practices, and strict compliance with safety technologies and standards.

Moreover, the study highlighted specific human factors such as familiarity with SiD concepts, mental and physical resilience, and safety-oriented decision-making skills as key contributors to safer design practices. Positive associations were identified with collaborative communication and regulatory enforcement, whereas negative influences emerged from inadequate safety systems, limited technical knowledge, and resistance to safety measures due to perceived creative constraints.

Based on these insights, the study recommended development of integrated safety management systems within design phase, the enhancement of risk assessment procedures, the mandating of safety-related education for design professionals, and the strengthening of regulatory frameworks. Future research was encouraged to examine application of SiD in subsequent project stages and to advance the safety competence of construction personnel throughout the project lifecycle.

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