

Evaluation of Occupational Safety and Health Risks in Steel Construction Work on E-House Projects in the Modern Steel Construction Industry

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Abstract: The modern steel construction industry presents a relatively high level of Occupational Safety and Health (OSH) risk due to work-at-height activities, heavy material lifting, welding, steel cutting, and heavy equipment operation. E-House projects, as modular steel-based facilities, involve complex construction activities requiring comprehensive risk evaluation. This study aims to evaluate OSH risks in steel construction work on E-House projects using the Hazard Identification, Risk Assessment and Risk Control (HIRARC) approach integrated with Job Safety Analysis (JSA). A quantitative descriptive design was employed through field observations, interviews, documentation studies, and risk assessments covering fabrication, lifting, erection, welding, grinding, and work-at-height activities. The findings identified 35 potential hazards consisting of 8 high-risk, 19 medium-risk, and 8 low-risk categories. The highest risks were associated with steel erection, crane lifting operations, and work-at-height activities with risk ratings exceeding 15. Risk control measures including personal protective equipment, permit-to-work systems, equipment inspections, safety briefings, and supervision significantly reduced risk levels. The study contributes to the enhancement of OSH management systems in modern steel construction projects and provides practical references for improving workplace safety culture.

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INTRODUCTION

The construction industry is one of the strategic sectors that significantly contributes to infrastructure development, economic growth, and industrial area expansion in many countries. However, this sector is also recognized as one of the working environments with relatively high rates of occupational accidents and work-related illnesses compared to other industries. Construction activities involve numerous hazardous tasks, including working at heights, operating heavy equipment, lifting large materials, welding, metal cutting, and interactions between workers, mechanical equipment, and hazardous energy sources. Such complexity increases the likelihood of occupational accidents when hazard identification and risk control processes are not systematically implemented. Faria and Rodolpho (2023) explained that occupational accidents in the construction sector are still predominantly caused by falls from height, struck-by-material incidents, slips, and exposure to unsafe working environments. These conditions indicate that Occupational Health and Safety (OHS) must be integrated into every stage of construction project implementation.

The advancement of modern construction technology has encouraged the increasing use of steel structures in industrial projects due to their advantages, including high strength, construction time efficiency, ease of fabrication, and design flexibility. Steel structures are currently widely employed in

industrial facilities, warehouses, manufacturing plants, energy distribution centers, and modular buildings requiring rapid installation. One application of modern steel construction is the Electrical House (E-House), a modular building designed to accommodate electrical power distribution systems, control panels, automation systems, and various industrial operational support equipment. The modular concept adopted in E-House projects enables fabrication activities to be performed simultaneously with civil works, thereby reducing overall project completion time. Previous studies have emphasized that occupational safety risks in construction projects are strongly influenced by project complexity, equipment utilization, and worker exposure to hazardous environments. Supriyatna et al. (2020) reported that construction projects generally involve significant risks related to work-at-height activities, lifting operations, and unsafe working conditions. Furthermore, Hermawan and Wijaya (2019) argued that occupational safety considerations should be integrated into steel structure planning and design stages to minimize accident potential throughout project implementation. Nevertheless, the intensive fabrication, lifting, erection, welding, grinding, and work-at-height activities involved in E-House construction create risk characteristics that differ from those of conventional construction projects.

Steel construction activities require a high level of precision and complex coordination among workers and equipment. Structural steel erection, for example, involves lifting components using cranes, connecting structural elements at elevated levels, and conducting simultaneous tasks by multiple work teams within the same area. Hidayah (2021) stated that internal risks in steel construction projects are primarily dominated by technical factors related to work methods, equipment conditions, and material characteristics. These risks become even greater when work is conducted in confined spaces or within operating industrial facilities. Therefore, early identification and evaluation of risks are essential to prevent occupational accidents that may result in both material and non-material losses.

The importance of implementing OHS practices in steel construction projects has been highlighted by numerous studies indicating that steel structure activities exhibit relatively higher accident rates than other construction operations. Leu and Chang (2015) found that falls from height constitute the primary cause of fatalities in steel construction projects. Such incidents commonly occur during erection activities performed at elevated levels under restricted movement conditions and dynamic work environments. Nascimento and Alvarenga (2023) demonstrated that steel structure installation in commercial buildings poses substantial hazards because workers directly interact with partially stabilized structures. Furthermore, weather conditions, working surface characteristics, and inadequate fall protection systems may significantly increase the likelihood of fatal accidents. These findings suggest that risk control measures in steel construction activities must be implemented comprehensively and continuously.

In addition to fall hazards, steel construction activities are exposed to numerous risks associated with material lifting operations, cutting equipment, welding activities, and interactions with electrical and mechanical energy sources. Juniarti and Umar (2022) identified several hazards in steel fabrication environments, including struck-by-material incidents, injuries caused by work equipment, excessive noise exposure, metal dust inhalation, and fire risks resulting from welding operations. Similar findings were reported by Putra et al. (2025), who observed that lifting and erection activities constitute dominant hazard sources capable of causing severe injuries or fatalities. As the utilization of steel

structures continues to increase across modern industrial projects, the need for effective risk management systems capable of identifying and controlling hazards becomes increasingly critical.

Various methods have been developed within construction safety management to assist organizations in identifying and evaluating occupational risks. One of the most widely adopted approaches is Hazard Identification, Risk Assessment, and Risk Control (HIRARC). This method enables systematic hazard identification, followed by risk assessment and the determination of appropriate control strategies. Andriani et al. (2022) demonstrated that the implementation of HIRARC in steel fabrication and building erection activities successfully identified several critical risks requiring priority control measures. Similarly, Haristama et al. (2023) concluded that HIRARC-based approaches assist organizations in classifying risks according to severity and probability levels, thereby enabling organizations to prioritize high-risk activities. Similar findings have also been reported in Indonesian construction projects. Sari et al. (2022) demonstrated that HIRARC effectively identified occupational hazards in hospital construction projects, while Setiawan et al. (2024) found that its implementation improved hazard control practices and safety compliance, allowing resources to be concentrated on high-risk activities.

HIRARC is frequently integrated with Job Safety Analysis (JSA) to improve the accuracy of hazard identification throughout each work stage. JSA breaks down work activities into detailed operational steps, enabling the identification of hazards that might otherwise be overlooked. Jafari et al. (2021) stated that combining JSA with risk assessment provides a more comprehensive understanding of hazard sources and supports the development of more effective control measures. This approach is particularly relevant to E-House projects because their work activities are complex, multidisciplinary, and highly interdependent.

Recent developments in steel construction safety research indicate continuous efforts to enhance risk control effectiveness through various analytical and technological approaches. Song et al. (2007) applied Failure Mode and Effects Analysis (FMEA) to evaluate potential failures in steel frame construction and found that the method effectively supports systematic risk prioritization. Meanwhile, Sharqi and Kaka (2014) developed image-processing-based safety visualization techniques to improve workers' awareness of hazards in steel construction sites. Furthermore, He (2023) identified human factors, equipment, management systems, and environmental conditions as the primary determinants of risk levels in high-rise steel structure construction. However, most existing studies have focused on high-rise buildings, commercial facilities, or general steel construction projects.

A review of the literature reveals that studies addressing OHS risks in E-House projects remain limited compared with research conducted on high-rise buildings and other industrial facilities. Most previous studies have concentrated on steel fabrication, structural installation, or general construction risk assessments without considering the unique characteristics of E-House projects as modular steel-based facilities. In practice, E-House projects involve a combination of construction, mechanical installation, and electrical system activities performed simultaneously within the same work environment. Such conditions generate distinctive risk patterns that require a more specific evaluation approach.

Based on the literature review, two major research gaps were identified. First, there is a lack of studies specifically evaluating occupational health and safety risks in E-House projects using an integrated HIRARC and Job Safety Analysis approach. Second, most previous studies have focused solely on hazard identification without conducting comprehensive risk evaluations across all steel

construction stages involved in modular industrial facility development. These gaps indicate the necessity for research capable of providing a detailed understanding of OHS risk characteristics in E-House projects, thereby supporting decision-making processes in construction safety management.

Accordingly, this study aims to evaluate Occupational Health and Safety (OHS) risks associated with steel construction activities in an E-House project using the HIRARC method integrated with Job Safety Analysis. The study seeks to identify dominant hazard sources, determine risk levels for each work activity, and formulate effective control strategies based on the hierarchy of controls. The novelty of this research lies in its focus on E-House projects as a form of modern modular construction that has received limited attention in occupational risk assessment studies. In addition, this research integrates hazard identification, risk assessment, and risk control across all major steel construction stages, resulting in a more comprehensive evaluation framework. The findings are expected to provide practical contributions to the construction industry by improving the effectiveness of OHS management systems while enriching the scientific literature on risk management in modern steel construction projects.

RESEARCH METHOD

Research Design

This study employed a quantitative approach with a descriptive-evaluative research design to identify, assess, and evaluate Occupational Health and Safety (OHS) risks associated with steel construction activities in an E-House project. The descriptive approach was selected to portray the actual risk conditions present in steel construction operations, while the evaluative approach was applied to assess risk levels and the effectiveness of existing control measures. The primary method utilized was Hazard Identification, Risk Assessment, and Risk Control (HIRARC), integrated with Job Safety Analysis (JSA) to obtain a more detailed hazard identification for each work stage.

The HIRARC approach was chosen because it is one of the most widely used methods in occupational safety management systems for identifying hazards, determining risk levels, and establishing control priorities. Its application is particularly suitable for E-House projects, which involve various high-risk construction activities, including steel fabrication, crane-assisted material lifting, steel structure erection, welding, metal cutting, and work at height. Risk evaluation was conducted systematically by examining the relationship between the likelihood of hazardous events and the severity of their potential consequences.

Research Site and Object

The study was conducted at an E-House construction project forming part of an industrial facility based on steel structure construction. This project was selected because it involves complex work activities and numerous high-risk operations commonly encountered in modern steel construction industries. The research was carried out between January and March 2026, covering fabrication, lifting, erection, welding, grinding, and work-at-height activities.

The research object comprised all major steel construction activities involved in the E-House project. Based on preliminary observations and consultations with the Health, Safety, and Environment (HSE) team, six primary activities were identified as the focus of the study: steel fabrication, material lifting, steel structure erection, welding, grinding, and work at height. These activities were selected

because they possess significant hazard potential and contribute substantially to occupational accident risks throughout project execution. The unit of analysis consisted of hazards identified at each observed work stage.

Data Collection Techniques

Research data were collected through a combination of field observations, structured interviews, and document reviews. Field observations were conducted directly within the project area to identify working conditions, worker behavior, personal protective equipment (PPE) usage, equipment conditions, and hazards emerging during construction activities. Repeated observations were performed across all work categories to obtain representative risk information.

Structured interviews were conducted with personnel directly involved in project implementation, including project managers, field supervisors, HSE officers, crane operators, riggers, welders, and construction workers. These interviews aimed to gather information regarding accident experiences, frequently occurring hazards, the effectiveness of implemented control measures, and compliance with safety procedures.

Additionally, documentation reviews were conducted on various project records related to OHS implementation, including Job Safety Analysis (JSA) documents, work permits, safety inspection reports, near-miss reports, accident records, and standard operating procedures. The use of multiple data sources enhanced research validity through data triangulation, ensuring a more objective representation of actual risk conditions.

HIRARC Risk Analysis

Risk analysis was performed using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method.

The first stage involved hazard identification, which focused on recognizing all potential hazards associated with each steel construction activity. Hazard identification was based on observation findings, interview results, and project JSA documentation.

The second stage involved risk assessment. At this stage, each identified hazard was evaluated using two primary parameters: likelihood and severity. Likelihood represents the probability of a hazardous event occurring, whereas severity represents the magnitude of its consequences should the event occur. Both parameters were assessed using a five-point scale ranging from 1 to 5.

Table 1. Likelihood Scale

Score	Description	Criteria
1	Rare	May occur only in exceptional circumstances
2	Unlikely	Could occur occasionally
3	Possible	Might occur several times during project activities
4	Likely	Expected to occur in many situations
5	Almost Certain	Occurs frequently or repeatedly

Table 2. Severity Scale

Score	Description	Consequence
1	Insignificant	No injury or negligible loss
2	Minor	Minor injury requiring first aid treatment
3	Moderate	Medical treatment required and temporary work restriction
4	Major	Serious injury, permanent disability, or substantial property damage
5	Catastrophic	Fatality, multiple fatalities, or major project loss

The risk value was calculated using the following equation:

$$\text{Risk Rating} = \text{Likelihood} \times \text{Severity}$$

Table 3. Risk Assessment Matrix Used in the HIRARC Method

Severity (S) / Likelihood (L)	1 Rare	2 Unlikely	3 Possible	4 Likely	5 Almost Certain
5 Catastrophic	5 (L)	10 (M)	15 (H)	20 (H)	25 (H)
4 Major	4 (L)	8 (M)	12 (M)	16 (H)	20 (H)
3 Moderate	3 (L)	6 (M)	9 (M)	12 (M)	15 (H)
2 Minor	2 (L)	4 (L)	6 (M)	8 (M)	10 (M)
1 Insignificant	1 (L)	2 (L)	3 (L)	4 (L)	5 (L)

Notes:

L = Low Risk (1–5)

M = Medium Risk (6–12)

H = High Risk (15–25)

Risk assessment was conducted using a 5×5 risk matrix based on the combination of likelihood and severity scores. Likelihood represents the probability of a hazard occurring, while severity reflects the magnitude of the potential consequences. Risk scores were calculated by multiplying likelihood and severity values. The resulting scores were classified into three categories: Low Risk (1–5), Medium Risk (6–12), and High Risk (15–25). This classification was used to determine risk priorities and establish appropriate control measures according to the hierarchy of controls.

The resulting risk scores were classified into three categories: Low Risk (1–5), Medium Risk (6–12), and High Risk (15–25). This classification was adopted from previous HIRARC applications in fabrication and steel-processing industries (Putri et al., 2024; Umam & Suseno, 2025). The risk category served as the basis for determining control priorities and allocating safety resources toward activities with the highest potential consequences. This classification served as the basis for determining control priorities within project management.

The third stage involved risk control. Control measures were developed according to the hierarchy of controls, including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). Each recommendation was adjusted according to the characteristics of the work activity and the risk level identified through assessment.

Data Analysis Techniques

The collected data were analyzed using descriptive quantitative methods. All identified hazards were categorized according to work activity and hazard source. Subsequently, risk values were calculated to determine the distribution of risk levels across steel construction activities.

The results were presented in the form of HIRARC tables, risk matrices, and narrative descriptions explaining the risk characteristics of each work activity. Interpretation was conducted by comparing risk levels among activities to determine those requiring priority control measures. Furthermore, the findings were compared with previous studies conducted by Andriani et al. (2022), Haristama et al. (2023), Jafari et al. (2021), Leu and Chang (2015), Putra et al. (2025), and Hidayah (2021) to strengthen the discussion and enhance scientific validity. Through this approach, the study provides a comprehensive evaluation of OHS risks associated with steel construction activities in E-House projects and proposes control recommendations to improve occupational safety performance.

RESULTS AND DISCUSSION

Hazard Identification in Steel Construction Activities of the E-House Project

The results of field observations, interviews with Health, Safety, and Environment (HSE) personnel, and reviews of Job Safety Analysis (JSA) documents indicate that steel construction activities in the E-House project exhibit high-risk characteristics due to the involvement of fabrication, material lifting, steel structure erection, welding, grinding, and work-at-height operations. Across all analyzed activities, a total of 35 potential hazards were identified, originating from human factors, work equipment, materials, and environmental conditions. These hazards included falls from height, struck-by-material incidents, lifting equipment failures, electric shocks, welding burns, injuries caused by cutting tools, and exposure to dust and excessive noise.

Similar hazard characteristics have been reported in steel fabrication and structural construction environments. Umam and Suseno (2025) found that fabrication activities involving cutting, welding, and material handling frequently generate mechanical injury risks and exposure to hazardous physical agents. Likewise, Putri et al. (2024) identified cutting and material processing activities as significant contributors to occupational accidents in steel-related work environments.

These findings suggest that E-House projects possess a high level of operational complexity because multiple construction activities are performed simultaneously within relatively confined working spaces. Such conditions increase the likelihood of hazard interactions that may amplify occupational accident risks if control measures are not adequately implemented. These results are consistent with the findings of Hidayah (2021), who reported that risk characteristics in steel construction projects are influenced by a combination of technical, operational, and environmental factors.

Table 4. Summary of Hazard Potential by Work Activity

Work Activity	Number of Hazards	Percentage (%)
Steel Fabrication	6	17.14
Material Lifting	5	14.29
Steel Structure Erection	8	22.86
Welding	5	14.29
Grinding	4	11.43
Work at Height	7	20.00
Total	35	100

Table 1 indicates that steel structure erection and work-at-height activities account for the highest number of identified hazards compared with other construction activities. This finding suggests that these two activities should become the primary focus of occupational safety management and risk mitigation programs within the E-House project. The high hazard frequency associated with these activities is closely related to the complexity of operations, worker exposure to elevated work environments, and the involvement of heavy structural components requiring precise coordination during installation.

Risk Assessment Results Using the HIRARC Method

Following hazard identification, the next stage involved risk assessment using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method. Risk evaluation was conducted by considering the likelihood of occurrence and the severity of potential consequences associated with each identified hazard. The assessment results revealed that most hazards were classified as medium-risk; however, several hazards fell into the high-risk category and required immediate control measures.

Table 5. Complete HIRARC Risk Assessment Results for E-House Steel Construction Activities

No	Activity	Hazard Potential	L	S	Risk Rating	Category
1	Steel Fabrication	Injury from cutting machine	3	3	9	Medium
2	Steel Fabrication	Falling steel material	3	4	12	Medium
3	Steel Fabrication	Hand trapped between materials	2	3	6	Medium
4	Steel Fabrication	Exposure to sharp steel edges	2	2	4	Low
5	Steel Fabrication	Excessive noise exposure	2	2	4	Low

6	Steel Fabrication	Manual handling strain	2	3	6	Medium
7	Material Lifting	Load falling from crane	4	5	20	High
8	Material Lifting	Sling failure	3	5	15	High
9	Material Lifting	Collision with moving load	3	4	12	Medium
10	Material Lifting	Crane overturning	2	5	10	Medium
11	Material Lifting	Worker struck by lifting equipment	3	4	12	Medium
12	Steel Structure Erection	Fall from height	5	5	25	High
13	Steel Structure Erection	Struck by structural component	4	5	20	High
14	Steel Structure Erection	Structural instability	4	5	20	High
15	Steel Structure Erection	Dropped tools from height	3	4	12	Medium
16	Steel Structure Erection	Pinch points during connection work	3	3	9	Medium
17	Steel Structure Erection	Improper bolt tightening	2	4	8	Medium
18	Steel Structure Erection	Slipping on steel surfaces	3	3	9	Medium
19	Steel Structure Erection	Unstable working platform	4	4	16	High
20	Welding	Welding sparks	3	3	9	Medium
21	Welding	Electric shock	3	4	12	Medium
22	Welding	Eye injury from arc radiation	2	3	6	Medium
23	Welding	Fire hazard	3	4	12	Medium
24	Welding	Welding fume inhalation	2	3	6	Medium
25	Grinding	Grinding wheel fragments	3	3	9	Medium

26	Grinding	Flying metal particles	3	3	9	Medium
27	Grinding	Hand injury from grinder	2	3	6	Medium
28	Grinding	Noise exposure	2	2	4	Low
29	Work at Height	Loss of balance	5	5	25	High
30	Work at Height	Lifeline failure	4	5	20	High
31	Work at Height	Scaffold instability	4	4	16	High
32	Work at Height	Falling objects	3	4	12	Medium
33	Work at Height	Adverse weather conditions	2	3	6	Medium
34	Work at Height	Improper use of full-body harness	2	2	4	Low
35	All Work Areas	Failure to use PPE	4	3	12	Medium

Summary of Risk Categories:

- High Risk = 8 Hazards (22.86%)
- Medium Risk = 19 Hazards (54.28%)
- Low Risk = 8 Hazards (22.86%)
- Total Hazards = 35 (100%)

The assessment results demonstrate that the highest risk levels originated from steel structure erection and work-at-height activities, each obtaining a risk rating of 25. These hazards possess a substantial probability of causing severe injuries or fatalities, making them the highest priority for risk control implementation. The findings emphasize the importance of implementing rigorous fall protection systems, continuous supervision, and strict compliance with safety procedures during elevated work operations.

Furthermore, material lifting activities also generated several high-risk hazards, particularly crane load failure and sling breakage. These findings indicate that lifting operations require enhanced inspection procedures, competent operators, and effective communication systems among lifting personnel to minimize accident potential.

Risk Category Distribution

Based on the hazard identification and risk assessment results, all identified hazards were subsequently classified into low-, medium-, and high-risk categories.

Table 6. Distribution of Risk Categories

Risk Category	Number of Risks	Percentage (%)
High	8	22.86
Medium	19	54.28
Low	8	22.86
Total	35	100

The results presented in Table 3 show that medium-risk hazards dominate the overall risk profile, accounting for 54.28% of all identified hazards. This finding indicates that although most activities can still be managed through existing safety measures, continuous monitoring and improvement efforts remain necessary to prevent risk escalation.

Nevertheless, the presence of 22.86% high-risk hazards demonstrates that the E-House project continues to face substantial potential for serious occupational accidents. These high-risk hazards are primarily associated with work-at-height activities, steel structure erection, and material lifting operations, all of which involve exposure to severe consequences, including permanent disability and fatality.

The predominance of medium-risk hazards is consistent with findings reported by Andriani et al. (2022) and Haristama et al. (2023), who observed that steel construction projects generally exhibit moderate risk levels across most activities while maintaining several critical hazards requiring priority intervention. The existence of high-risk hazards within the present study further highlights the necessity of implementing comprehensive risk control strategies based on the hierarchy of controls, including engineering improvements, administrative controls, worker competency enhancement, and the mandatory use of appropriate personal protective equipment (PPE).

Overall, the risk distribution pattern indicates that while existing safety management practices have contributed to reducing the occurrence of extremely hazardous conditions, additional preventive measures are still required to effectively mitigate critical risks associated with steel construction activities in E-House projects.

Figure 1. HIRARC Risk Category Distribution

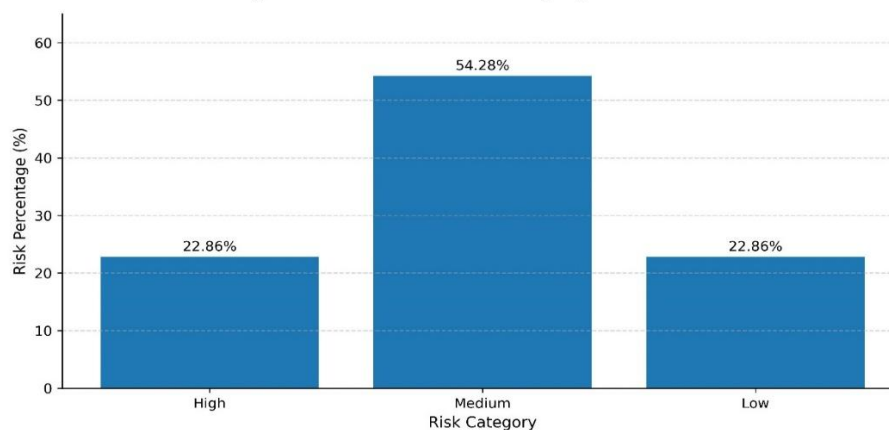


Figure 1. Distribution of HIRARC Risk Categories

Discussion of Dominant Risks

The findings of this study indicate that the dominant risks in the E-House project originate from steel structure erection, material lifting, and work-at-height activities. These hazards obtained risk rating values ranging from 20 to 25, placing them within the high-risk category. Such results highlight the critical nature of these activities and the urgent need for effective risk control measures to prevent severe occupational accidents.

The findings are consistent with those reported by Leu and Chang (2015), who identified falls from height as the leading cause of fatal accidents in steel construction projects. Similarly, Nascimento and Alvarenga (2023) demonstrated that steel structure installation activities expose workers to substantial hazards because operations are frequently conducted at elevated locations where structural components may not yet have achieved full stability. Under such conditions, Workers are vulnerable to falls, structural collapse, and struck-by-object incidents, all of which may result in severe injuries or fatalities. Similar conclusions were reported by Fitrialitya (2021), who identified work-at-height activities as one of the most critical sources of construction accidents. All of which can result in severe injuries or fatalities.

The material lifting risks identified in this study are also in agreement with the findings of Putra et al. (2025), who reported that crane-assisted lifting operations represent one of the most critical activities in steel construction projects. Errors in load rigging, sling failure, equipment malfunction, and communication breakdowns between crane operators and riggers can significantly increase the likelihood of serious accidents. Consequently, the implementation of comprehensive lifting plans, routine inspection of lifting equipment, operator certification programs, and effective communication protocols are essential elements for reducing lifting-related risks.

In contrast, fabrication, welding, and grinding activities were predominantly classified within the medium-risk category. These findings support the study conducted by Juniarti and Umar (2022), which identified various mechanical and physical hazards in steel fabrication environments, including injuries caused by machinery, exposure to welding sparks, metal dust inhalation, and excessive noise levels. Although the severity of these hazards is generally lower than those associated with erection and work-at-height activities, their relatively high frequency of occurrence necessitates continuous monitoring and control. Without adequate preventive measures, repetitive exposure to such hazards may contribute to occupational injuries and long-term health problems among workers.

Furthermore, the predominance of high-risk hazards in erection and work-at-height activities reflects the unique characteristics of E-House construction projects, where multiple construction processes are often conducted simultaneously within confined workspaces. This situation increases the probability of hazard interaction and creates additional safety challenges that require integrated risk management approaches. Therefore, project managers should prioritize safety interventions in these activities to achieve meaningful reductions in accident rates.

Evaluation of Risk Control Measures

The evaluation of existing control measures revealed that the use of personal protective equipment (PPE), permit-to-work systems, safety induction programs, toolbox meetings, equipment inspections, and field supervision were among the primary factors contributing to risk reduction within

the project. These measures have helped improve workers' awareness of hazards, strengthen compliance with safety procedures, and minimize unsafe behaviors during project execution.

This approach is consistent with the hierarchy of controls framework, which emphasizes the implementation of engineering and administrative controls before relying on personal protective equipment as the final layer of protection. Although PPE remains essential in mitigating residual risks, its effectiveness largely depends on proper selection, worker compliance, and continuous supervision. Therefore, PPE should be integrated with broader risk management strategies rather than being used as the sole control measure.

The findings of this study support the conclusions of Andriani et al. (2022) and Haristama et al. (2023), who reported that systematic HIRARC implementation improves the effectiveness of occupational safety management systems. Similar conclusions were reported by Susanti et al. (2026), who found that HIRARC-based controls significantly reduced occupational hazards in bridge construction projects. This finding reinforces the effectiveness of systematic risk assessment and control approaches in large-scale construction projects. who reported that the consistent implementation of HIRARC significantly improves the effectiveness of Occupational Health and Safety (OHS) management systems. Through systematic hazard identification, risk assessment, and control planning, organizations can allocate resources more efficiently toward activities that present the highest levels of risk.

Moreover, Zehro (2020) emphasized that successful risk control is strongly influenced by organizational commitment to fostering a sustainable safety culture. Safety performance cannot be achieved solely through procedures and regulations; it also requires active participation from management and workers in promoting safe work practices. Continuous safety training, leadership commitment, worker engagement, and effective communication are therefore essential components of a successful safety management system.

Based on the findings of this study, several strategic recommendations can be proposed to further reduce occupational risks in future E-House projects. These include enhancing worker competency through regular training and certification programs, strengthening supervision of high-risk activities, improving inspection and maintenance procedures for lifting equipment, and implementing technology-based safety monitoring systems such as digital permit-to-work platforms, real-time worker tracking, wearable safety devices, and automated hazard detection systems. The integration of these measures is expected to improve risk control effectiveness and contribute to the development of safer and more sustainable modular construction projects.

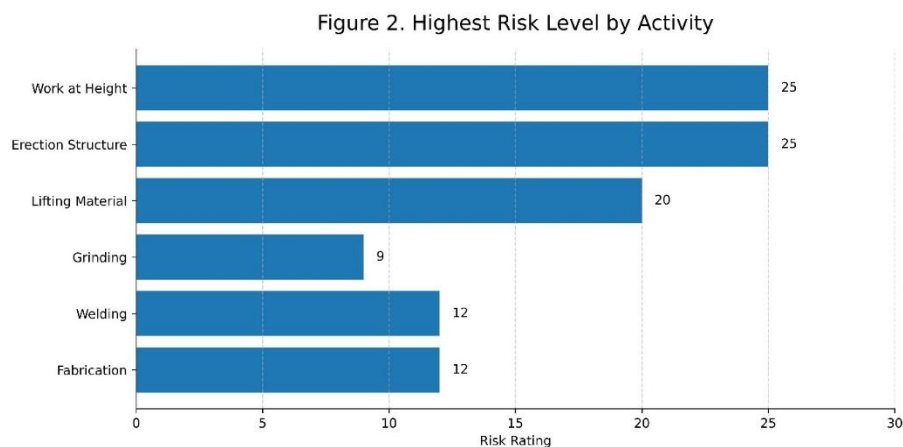


Figure 2. Highest Risk Levels by Work Activity

The visualization results indicate that **Steel Structure Erection** and **Work-at-Height** activities exhibit the highest risk rating values (25), followed by **Material Lifting** activities with a risk rating of 20. These activities therefore represent the primary priorities for risk control programs within the E-House construction project. The findings highlight the need for enhanced preventive measures, strict supervision, and continuous monitoring to minimize the likelihood of severe occupational accidents associated with these high-risk operations.

CONCLUSION

This study successfully evaluated Occupational Health and Safety (OHS) risks associated with steel construction activities in an E-House project using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method supported by the Job Safety Analysis (JSA) approach. The findings reveal that E-House projects possess high-risk characteristics due to the integration of steel fabrication, material lifting, steel structure erection, welding, grinding, and work-at-height activities within a complex working environment. A total of 35 potential hazards were identified, consisting of 8 high-risk hazards, 19 medium-risk hazards, and 8 low-risk hazards. The highest risk levels were observed in steel structure erection, crane-assisted material lifting, and work-at-height activities, with risk rating values reaching 25, indicating the potential for severe injuries and fatalities.

The study further demonstrates that the primary contributors to elevated risk levels include falls from height, struck-by-material incidents, structural collapse hazards, lifting equipment failures, and non-compliance with occupational safety procedures. The implementation of risk control measures through the use of personal protective equipment (PPE), permit-to-work systems, equipment inspections, safety induction programs, toolbox meetings, and field supervision proved to be essential in reducing risk levels and improving worker safety performance.

From a practical perspective, the findings provide valuable insights for the development of risk management strategies and the strengthening of Occupational Health and Safety programs in modern steel construction projects, particularly E-House developments. The results can serve as a reference for project managers, safety practitioners, and construction organizations in prioritizing preventive measures and allocating safety resources more effectively.

From an academic perspective, this study contributes to the growing body of knowledge on occupational risk management in modular steel-based construction projects, a topic that remains relatively underexplored in the existing literature. The novelty of this research lies in the application of an integrated HIRARC-JSA framework to evaluate risks across all major stages of E-House steel construction activities, providing a comprehensive understanding of hazard characteristics and control requirements.

Future studies are recommended to integrate HIRARC with other quantitative risk assessment techniques, such as Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), and safety-oriented Building Information Modeling (BIM). Such integration may facilitate the development of more comprehensive, accurate, and adaptive risk evaluation models capable of addressing the increasing complexity and technological advancements of modern construction projects.

REFERENCES

- Andriani, D., Ratnaningsih, A., & Putra, P. A. P. (2022). HIRARC analysis of occupational health and safety risks in steel fabrication and erection for the construction of Loji Kridanggo Hotel, Boyolali. *RekaRacana: Civil Engineering Journal*, 8(2), 151–162. <https://doi.org/10.26760/rekaracana.v8i2.70>
- Faria, R. A., & Rodolpho, D. (2023). Occupational health and safety in civil construction. *Information in Focus*, 21(1), 1–12. <https://doi.org/10.31510/infa.v21i1.1847>
- Fitrialita, A. (2021). Work accident risk analysis for height workers using the HIRARC method in the MTH 27 Office Suite Project PT X in 2021. *Indonesian Scholar Journal of Medical and Health Science*, 1(04), 140–147.
- Haristama, I. S., Zacoeb, A., & Susanti, L. (2023). Risk analysis of occupational hazards using HIRADC approach in the implementation of occupational safety and health management system. *Journal of Engineering Research and Reports*, 25(6), 48–61. <https://doi.org/10.9734/JERR/2023/v25i6940>
- He, H. (2023). Safety risk analysis of high-rise steel structure building construction. *Highlights in Science, Engineering and Technology*, 62, 496–502. <https://doi.org/10.54097/hset.v62i.10664>
- Hermawan, S., & Wijaya, G. B. (2019). The new design criteria for steel construction concerning occupational health and safety. *Borneo Project Innovation*, 2(2), 80–88. <https://doi.org/10.20527/BPI.V2I2.41>
- Hidayah, S. (2021). Project risks identification of steel construction on industrial buildings: A systematic literature review. *International Journal of Integrated Engineering Management*, 2(3), 149–160. <https://doi.org/10.22441/IJIEM.V2I3.11895>
- Jafari, B., Nezamodini, Z. A., Sari, H., & Mohammadi, A. (2021). Risk assessment by job safety analysis and William Fine method and comparison with workers' risk perception results. *Annals of Occupational Health*, 5(4), 357–369. <https://doi.org/10.18502/aoh.v5i4.7972>
- Juniarti, S., & Umar, A. F. (2022). Overview of occupational hazards and accident potential and risk assessment analysis in steel fabrication plant PT Wika Industri dan Konstruksi. *Jurnal Persada Husada Indonesia*, 9(34), 1–12. <https://doi.org/10.56014/jphi.v9i34.349>
- Leu, S.-S., & Chang, C.-M. (2015). Bayesian-network-based fall risk evaluation of steel construction projects by fault tree transformation. *Journal of Civil Engineering and Management*, 21(3), 330–340. <https://doi.org/10.3846/13923730.2014.890643>
- Nascimento, S. S. S., & Alvarenga, G. A. C. Q. (2023). Working at height: Risk analysis in commercial warehouse construction with metal roof structures. *Zenodo Repository*, 1(1), 1–15. <https://doi.org/10.5281/zenodo.7557225>

- Putra, A. S., Ramdan, M., & Putri, I. M. M. (2025). Application of occupational health and safety management through job safety analysis in steel structure installation: A case study of PT Ultra Sakti workshop construction. *Jurnal Teknik Sipil*, 24(4), 1543–1554. <https://doi.org/10.26418/jts.v24i4.86895>
- Putri, A. E. L., Rupiwardani, I., & Subhi, M. (2024). Work accident risk analysis using the HIRARC method in iron cutting work. *Jurnal Kesehatan Tambusai*, 5(2). <https://doi.org/10.31004/jkt.v5i2.29734>
- Sari, K. P., Chairi, M., & Helin, R. P. (2022). Occupational health and safety risk analysis in RSUD Pasaman Barat building project using the HIRARC method. *Jurnal Rivet*, 2(1). <https://doi.org/10.47233/rivet.v2i01.491>
- Setiawan, L., Rahmatullah, A., Muhammad, I., Rini, A. S., Hanan, S., & Pratama, T. R. H. (2024). Implementation of occupational health and safety using HIRARC (Hazard Identification Risk Assessment and Risk Control) in construction companies in Cilegon. *Industrika: Industrial Engineering Scientific Journal*, 8(2). <https://doi.org/10.37090/indstrk.v8i2.1516>
- Sharqi, R., & Kaka, A. P. (2014). Health and safety visualization in steel construction projects through image processing. In *Construction Research Congress 2014* (pp. 1047–1056). American Society of Civil Engineers. <https://doi.org/10.1061/9780784413616.102>
- Song, J.-W., Yu, J.-H., & Kim, C.-D. (2007). Construction safety management using FMEA technique: Focus on steel frame work cases. *Journal of Asian Architecture and Building Engineering*, 6(1), 77–84.
- Supriyatna, H., Kurniawan, W., & Purba, H. H. (2020). Occupational safety and health risk in building construction projects: A literature review. *Organization, Technology and Management in Construction: An International Journal*, 12(1), 2201–2208. <https://doi.org/10.31181/ORESTA200134S>
- Susanti, B., Dinata, A. S., Juliantina, I., Indriyati, C., & Said, B. F. (2026). Occupational safety and health risk analysis in segmental box girder bridge installation using the HIRARC method. *TAPAK: Construction Application Technology*, 15(2), 111–123. <https://doi.org/10.24127/tp.v15i2.5185>
- Umam, K., & Suseno. (2025). Occupational safety analysis in plate tank fabrication workers using the HIRARC method at PT XYZ. *Journal of Mechanical, Industrial, Electrical and Informatics Engineering*, 4(1). <https://doi.org/10.55606/jtmei.v4i1.4797>
- Zehro, K. (2020). Identification, determination, and control of health, safety, and environmental hazards associated with construction projects: State-of-the-art. *International Journal of Advanced Engineering Science and Applications*, 1(4), 1–8. <https://doi.org/10.47346/IJAESA.V1I4.42>