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Research Article

Analysis of Occupational Accident Risks (Case Study: Phase 1 Construction Project of the Justice Tower Building, Faculty of Law, Hasanuddin University)

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Abstract

The construction industry is one of the sectors with the highest occupational accident risk. This study was conducted at the Justice Tower Phase 1 Building Construction Project, Faculty of Law, Hasanuddin University, which involves working at height, heavy equipment operation, and activities within an active campus environment. The objectives are to identify potential occupational accident risks, determine dominant risks, and formulate control strategies. A quantitative approach supported by qualitative methods was adopted, with 39 respondents selected from a population of 60 workers using the Slovin formula. Analysis employed Failure Mode and Effect Analysis (FMEA) to calculate the Risk Priority Number (RPN), and IBPRP and AKK methods based on Ministerial Regulation PUPR No. 10 of 2021. Results identified 80 potential occupational accident risks across column work (22 risks), beam work (20 risks), floor slab work (20 risks), and concrete staircase work (18 risks). IBPRP assessment yielded 8 low risks (10%), 65 moderate risks (81.25%), and 7 high risks (8.75%). FMEA analysis identified 56 dominant risks, with the highest RPN value of 366,036 at variable X.3.2.2 (operator failing to observe workers near mobile crane). Control strategies encompass elimination, substitution, engineering controls, administrative controls, and PPE in accordance with the risk control hierarchy.

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Introduction

Infrastructure development is a crucial component in improving the quality of life and economic growth of a nation. The construction industry is recognized as a sector with a high level of occupational accident risk, which can arise at any stage of work, ranging from technical execution aspects to external factors such as working environment conditions. Work accidents have serious consequences, from minor injuries and permanent disability to death, as well as causing decreased productivity, project delays, and increased unplanned costs (Jaya et al., 2021).

To ensure safe construction implementation, the Ministry of Public Works and Housing (PUPR) issued Ministerial Regulation PUPR No. 10 of 2021 concerning the Construction Safety Management System (SMKK) (Peraturan Menteri PUPR, 2021). This regulation emphasizes the protection of workers, the general public, and project assets through the IBPRP approach, which includes hazard identification, risk assessment, and risk control. Factors causing work accidents in construction include human behavior, work environment, work methods, and the tools/materials used (Mufiq & Huda, 2020).

The Phase 1 Construction Project of the Justice Tower Building, Faculty of Law, Hasanuddin University, is executed by PT. Ikram Tiga Berlian and is designed as a nine-story building located within an active campus environment. The complexity of working at height, the use of mobile cranes, and the limited maneuvering space in a densely populated environment create significant potential for work accidents. The Failure Mode and Effect Analysis (FMEA) method is used to identify and prioritize risks based on the Risk Priority Number (RPN) = Severity × Occurrence × Detection. Combining FMEA with IBPRP and AKK yields a comprehensive approach that not only maps risk priorities quantitatively but also designs systematic controls (Popov et al., 2016).

Combining these three instruments is scientifically necessary because each addresses a different, complementary purpose in the risk management cycle rather than duplicating one another. IBPRP, mandated by Ministerial Regulation PUPR No. 10 of 2021, provides the regulatory-compliant screening layer that qualitatively classifies every identified hazard into low, moderate, or high risk, ensuring the analysis satisfies national construction-safety requirements. FMEA then adds a quantitative, activity-level prioritization layer: by decomposing each hazard into a specific failure mode and scoring it on Severity, Occurrence, and Detection, it produces an RPN that ranks risks with far greater resolution than the three-tier IBPRP classification alone, which is essential for allocating limited safety resources to the most critical failure modes. AKK complements both by translating the prioritized risks into a project-specific construction safety implementation document, detailing concrete control measures, responsible parties, and monitoring mechanisms for each work package. Used together, the three methods close the loop from regulatory hazard identification (IBPRP) to quantitative prioritization (FMEA) to operational implementation (AKK), which is why their combination has been adopted in prior construction risk studies rather than relying on any single method in isolation.

Several previous relevant studies have utilized the FMEA method in construction risk analysis. Ihsan (2022) applied FMEA to the Sigli–Banda Aceh Toll Road project, finding the highest RPN of 158,667 for the risk of workers falling from height during girder erection work. Iman (2018) used FMEA on the New Sembayat II Bridge project in Gresik, identifying dominant risks in over-water activities, and concluded that FMEA is effective for prioritizing risks and supporting decision-making. Gita (2015) combined FMEA and FTA on an apartment project in Surabaya, identifying accident causes from human, management, environmental, and technical factors. Rajab et al. (2024) applied FMEA to a multi-story madrasah project, producing risk control recommendations based on the risk hierarchy. Internationally, Alvand et al. (2023) integrated FMEA with SWARA and WASPAS under a fuzzy environment to prioritize construction risks in Iran, while Zaupa et al. (2023) applied FMEA to prioritize preventive safety measures in Brazilian civil construction, both confirming the RPN-based prioritization approach across different national regulatory contexts. This research extends these studies by integrating FMEA with IBPRP and AKK on a multi-story building project in an active campus environment, thereby producing a more comprehensive risk profile that aligns with national regulations (Peraturan Menteri PUPR, 2021).

Research Method

The research was conducted at the Phase 1 Construction Project of the Justice Tower Building, Faculty of Law, Hasanuddin University, Makassar. This project is designed as a nine-story building, with Phase 1 focused on upper structure work, including columns, beams, floor slabs, and concrete stairs. The study employed a quantitative approach supported by qualitative methods. Primary data were obtained through field observations, interviews with personnel experienced in construction occupational health and safety (OHS), and questionnaire distribution. Secondary data included literature, previous research, and project documents from PT. Ikram Tiga Berlian.

The research population consisted of all 60 project workers. The minimum sample size was determined using the Slovin formula with a tolerance level of e = 10%, yielding a minimum of 38 respondents. A total of 39 respondents were surveyed, slightly above this minimum, using simple random sampling.

$$n = N / (1+N.e^2) = 60 / (1+60\times0{,}1^2) = 60 / 1{,}6 = 37{,}5 \approx 38 \text{ sampel minimum}$$

The respondent profile shows a dominance of ages 20–40 years (66.67%), all male (100%), with the highest education level being senior high school/vocational high school (38.46%), and work experience less than 5 years (46.15%). This profile reflects the general condition of multi-story building construction workers in Indonesia.

Simple random sampling was considered appropriate because the population was occupationally homogeneous: all 60 workers were engaged in the same upper-structure activities (column, beam, floor-slab, and staircase work) under a single contractor, without a formally differentiated supervisory hierarchy (e.g., separate foreman, skilled-worker, and general-laborer registries) that would justify stratification. Work experience was recorded as a proxy for task-specific expertise and hazard familiarity, with respondents spanning less than 5 years (46.15%), 5–10 years (35.90%), 11–15 years (10.26%), and more than 15 years (7.69%), indicating that both novice and experienced workers were represented in the sample. Nonetheless, because respondents were not classified by specific job role (e.g., steel bender, formwork carpenter, crane rigger), the sample may not fully capture role-specific differences in hazard exposure and risk perception; future studies should consider stratified random sampling by occupational role to address this limitation.

In this study, risk refers to the potential for an unwanted event—specifically, an occupational accident—to occur during a construction activity, defined jointly by its likelihood of occurrence and the severity of its consequences for workers. Based on field observation, interviews, and review of project documents covering column, beam, floor slab, and concrete staircase work, 80 risk variables were identified; each variable represents a distinct failure mode (a specific way an accident can occur) together with its associated potential consequence for workers. These 80 identified risk variables form the basis for the severity (S), occurrence (O), and detection (D) assessment described below.

The research variables refer to upper structure work activities, including columns, beams, floor slabs, and concrete stairs. Potential risks for each activity were identified and analyzed using three FMEA indicators: Severity (S), Occurrence (O), and Detection (D). Raw respondent ratings (1–5) were aggregated using SI, as presented in Table 1, Table 2, and Table 3.

Table 1. Severity Scale

Severity Level	Criteria	Scale
Very High	Very severe failure effect (fatal)	5
High	Severe failure effect (permanent disability)	4
Moderate	Rarely severe failure effect (serious injury)	3
Low	Slightly severe failure effect (minor injury)	2
Very Low	Non-severe failure effect (scrape/abrasion)	1

Table 2. Occurence Scale

Occurence Level	Criteria	Scale
Very Frequent	Unavoidable failure	5
Frequent	Repeated, often occurring failure	4
Occasional	Ordinary occurring failure	3
Remote	Failure that occurs only a few times	2
Very Remote	Very rarely occurring failure	1

Table 3. Detection Scale

Detection Level	Criteria	Scale
Undetectable	No possibility of early failure detection	5
Rarely Detectable	Very low possibility of early failure detection	4
Occasionally Detectable	Low possibility of early failure detection	3
Detectable	High possibility of early failure detection	2
Highly Detectable	Very high possibility of early failure detection	1

The assessment of Severity, Occurrence, and Detection used the Severity Index (SI) method with the formula SI = [Σ(ai×xi) / (5×Σai)] × 100%, which aggregates the ordinal ratings (1–5, per the criteria in Tables 1–3 given by all respondents into a single continuous index (0–100%) per risk variable, reflecting the collective assessment across the sample rather than a single ordinal score. The RPN value was calculated as RPN = S × O × D using these continuous SI percentages, yielding a theoretical range of 0 to 1,000,000 (100 × 100 × 100). Because the priority-level thresholds reported by Melanson and Nadeau (2019) were derived for a conventional 1–10 ordinal Severity/Occurrence/Detection scale (maximum RPN = 1,000), they are not directly applicable to the percentage-based RPN scale used here. Dominant risks requiring priority control action were therefore determined by ranking all 80 risk variables by RPN in descending order and selecting the FMEA-dominant risks based on the top-70% RPN ranking (56 variables), following the prioritization approach used in the underlying field study; in this study, a rank-based cutoff of the top 70% was adopted to fixed RPN thresholds when RPN is derived from a continuous rating scale. Subsequently, risk control was structured using IBPRP and AKK tables according to Ministerial Regulation PUPR No. 10 of 2021 (Peraturan Menteri PUPR, 2021), with the hierarchy: elimination, substitution, engineering controls, administrative controls, and PPE.

Results and Discussion

Identification of Potential Work Accident Risks

The identification of potential risks was carried out through literature review, observation of project activities, and interviews with project executors. From this identification process, 80 potential risks were identified and grouped into 4 work items. The distribution of risk identification per work item is presented in Table 4.

Table 4. Recapitulation of Potential Risk Identification per Work Item

No.	Work Activity	Number of Risks
1	Column Work	22 risks
2	Beam Work	20 risks
3	Floor Slab Work	20 risks
4	Concrete Staircase Work	18 risks
	Total	80 risks

Based on Table 4, column work has the highest number of potential risks (22 risks) due to the complexity of activities, including the fabrication and assembly of reinforcement, transport of steel bars using a mobile crane, formwork installation at height, concreting, and formwork removal. Concrete staircase work has the fewest risks (18 risks), but has the specific characteristic of an inclined work area, which increases the risk of slipping.

Validity Test of Questionnaire Data

The validity test was conducted using Pearson Product-Moment correlation. With n = 39 respondents, df = n−2 = 37, and a significance level of 0.05 (two-tailed test), the critical r value (r table) is 0.316. The processed results showed that all question items were declared valid because the calculated r (r count) ≥ r table (0.316), so all questionnaire items were suitable for use in the research analysis.

Risk Level Assessment (IBPRP)

The risk level assessment used the IBPRP method based on Ministerial Regulation PUPR No. 10 of 2021 [3], where the combination of likelihood and severity values yields the Risk Level (TR = L × S). The distribution of assessment results is presented in Table 5.

Table 5. Distribution of Work Accident Risk Levels (IBPRP)

No.	Risk Category	Number of Risk	Percentage (%)
1	Low	8	10.00%
2	Moderate	65	81.25%
3	High	7	8.75%
	Total	80	100.00%

Determination of Dominant Risks (FMEA)Th

The RPN value is calculated as the product of S × O × D for each risk variable. Example calculation for variable X.1.1.1 (hand scratched/pinched): S = 56%, O = 48%, D = 46%, thus RPN = 56 × 48 × 46 = 123,648, ranking 68th of 80 by RPN value. Out of the 80 potential risks analyzed, the 56 risks with the highest RPN values (the top 70%) were identified as dominant risks requiring priority control action. Table 6 presents the ten risks with the highest RPN values.

Table 6. Ten Dominant Risks with the Highest RPN Values

Code	Potential Risk	S	O	D
X.3.2.2	Operator does not see workers near the mobile crane dueto poor operator-worker communication	94	59	66
X.1.2.4	Worn or broken sling falls onto workers	94	52	72
X.3.4.2	Worker falls from the slab edge during concrete pouring due to missing edge protection	97	57	58
X.1.2.3	Falling material strikes workers below the crane's path	79	52	74
X.2.2.2	Worker struck by maneuvering heavy equipment	77	55	69
X.3.1.1	Worker falls from height during formwork installation due to absence of body harness and guardrails	85	57	60
X.1.1.3	Reinforcement shifts and collapses onto workers due to inadequate tying	91	43	71
X.3.4.4	Concrete bucket detaches or moves unexpectedly while being lifted	95	50	58
X.3.5.2	Worker falls from height during formwork removal due to lack of fall protection	75	70	52
X.1.4.6	Worker cannot clearly see the work area due to insufficient lighting during night concreting	79	70	48

Based on Table 6, the risk with the highest RPN value is X.3.2.2 in the wiremesh transport activity for floor slab work, with an RPN of 366,036, the highest among all 80 risk variables and well within the top 70% of RPN-ranked dominant risks. The failure mode is the operator not seeing workers near the mobile crane due to lack of communication, potentially causing workers to be struck by lifted materials or maneuvering heavy equipment. The high RPN value is caused by a combination of three factors: (1) high severity because heavy equipment accidents can be fatal; (2) relatively high occurrence frequency as the mobile crane operates almost daily; and (3) low detection capability due to the absence of a standard communication system between the operator and field workers.

The second highest RPN risk (X.1.2.4, RPN = 351,936) relates to a worn or broken crane sling falling onto workers during column reinforcement transport. This risk is very dangerous because the sudden failure of a sling component is difficult to detect without routine inspection. The third risk (X.3.4.2, RPN = 320,682) is a worker falling from the slab edge during concrete pouring, caused by the absence of slab edge protection or a designated work-area barrier; the severity is compounded by the height of the floor slab work and the difficulty of detecting a fall in time.

Risk Control Strategies (IBPRP and AKK)

Control of dominant risks is structured in the form of IBPRP and AKK tables referring to Ministerial Regulation PUPR No. 10 of 2021. The five levels of the control hierarchy are applied sequentially. A summary of control strategies for the three highest dominant risks is presented in Table 7.

Based on Table 7, controlling risk X.3.2.2 requires a multi-layered approach encompassing the entire control hierarchy. This is due to the complexity of interaction between the crane operator and field workers in a confined work area. Control for X.1.2.4 focuses on engineering controls such as replacing unfit slings and routine load testing, because sling failure is sudden and difficult to detect without strict inspection procedures. Control for X.3.4.2 emphasizes engineering measures, particularly the installation of guardrails and safety nets along the slab edge, combined with a work permit procedure restricting worker access to unprotected edge zones, as the most effective way to prevent falls during concrete pouring.

1. Elimination: Restricting worker access within the crane's working radius using physical barricades and warning signs; arranging separate pedestrian paths away from heavy equipment operation zones; prohibiting activities under the concrete bucket while the crane is operating; stopping work if equipment is unsafe; and preventing simultaneous formwork removal.

2. Substitution: Replacing worn or non-compliant slings with slings certified to a capacity higher than the actual load according to SNI standards, accompanied by a load test before use.
3. Engineering Controls: Implementing standard scaffolding; installing guardrails and safety nets at slab edges and height areas; installing crane alarms and visual signals; adding shore bracing to high-risk formwork; and using lifting materials that meet SNI specifications.
4. Administrative Controls: Safety induction for new workers; daily toolbox meetings; implementation of SOPs for high-risk activities; periodic inspections by OHS officers; appointment of a signalman to guide the crane operator; and maintaining a logbook for lifting equipment maintenance.
5. Personal Protective Equipment (PPE): Mandating the use of body harnesses for work at height, safety helmets, safety shoes, safety glasses, gloves, and reflective vests for all workers in the project area.

Table 7. Summary of Control Strategies for the Highest Dominant Risks

Risk Code	Potential Risk	Control Strategy
X.3.2.2 (RPN=366,036)	Operator does not see workers near mobile crane	Elimination: crane zone barricade; Substitution: automatic crane alarm; Engineering: visual signals & two-way radio (HT); Administrative: appointment of signalman, toolbox meeting; PPE: reflective vest, helmet
X.1.2.4 (RPN=351,936)	Worn or broken sling falls onto workers	Elimination: prohibition of using unfit slings; Substitution: SNI-certified sling with higher capacity; Engineering: routine load tests; Administrative: daily sling inspection logbook; PPE: helmet, gloves
X.3.4.2 (RPN=320,682)	Worker falls from the slab edge during concrete pouring	Elimination: keep workers away from unprotected slab edges by adjusting the work method and positioning during pouring; Substitution: use formwork systems with built-in edge protection (guarded work platforms/scaffolding); Engineering: install guardrails (90-120 cm) and toe boards along slab edges plus safety nets below the work area; Administrative: mark and restrict access to edge zones with warning signs/barriers and a work permit procedure, plus toolbox meetings; PPE: body harness

The Construction Safety Analysis (AKK) details work items in more depth than the IBPRP, covering the safety aspects of workers, equipment, materials, environment, and the public. The AKK document has been endorsed by the project owner as a binding safety commitment. Dewi (2023) concluded on a similar toll road project that risk hierarchy-based control proved effective in reducing risk categories from high to moderate or low. Consistent with Dewi (2025), the IBPRP on structural work successfully eliminated high risks after engineering and administrative controls were consistently applied. Ghuzdewan (2025) adds that the Pareto principle in construction management supports focusing control on the 20% highest risks that contribute to 80% of potential losses, aligning with the finding of 56 dominant risks from the total 80 identified risks in this study.

Several patterns in these findings differ from earlier construction FMEA studies and merit further explanation. First, the dominance of mobile-crane and lifting-related risks (X.3.2.2, X.1.2.4) rather than fall-from-height risks alone, as reported in single-activity studies such as Ihsan (2022), reflects the specific hazard profile of this project: a nine-story building erected within a spatially constrained, active campus environment where the crane's working radius repeatedly overlaps with pedestrian routes used by students and staff. Because the campus remains operational throughout construction, worker exposure to heavy-equipment movement is more frequent and less controllable than on a closed construction site, which plausibly elevates both the Occurrence and Detection scores for equipment-interaction risks relative to projects in isolated locations. Second, the concentration of high-RPN risks in floor-slab and column work (X.3.4.2, X.1.2.4, X.1.2.3) rather than being evenly spread across all structural elements is consistent with the nine-story height of the building: slab-edge and reinforcement-transport activities are repeated at every floor level, compounding both frequency of exposure and the severity of a potential fall or struck-by incident as the building rises. Third, cross-tabulating the IBPRP and FMEA outputs at the item level shows how the two methods relate: all 7 risks IBPRP classified as high (100%) are also among the FMEA-dominant risks, confirming agreement at the upper end of the risk spectrum; however, IBPRP's moderate category is far less discriminating of its 65 variables, 47 (72.3%) are FMEA-dominant while 18 (27.7%) are not, and even within the low category, 2 of 8 variables (25%) are FMEA-dominant despite being screened as low risk by IBPRP. This demonstrates that IBPRP's three-tier qualitative classification is too coarse to differentiate priority within its moderate and low categories, whereas FMEA's continuous RPN ranking resolves these sub-groups into a precise order; the two methods are therefore complementary rather than redundant, with IBPRP performing the initial regulatory-compliant screening and FMEA refining prioritization within and, in some cases, across IBPRP's risk levels. This item-level correspondence directly informs the AKK control document: the 47 IBPRP-moderate/FMEA-dominant variables received the same five-hierarchy control treatment (Table 7) as the IBPRP-high risks, ensuring that FMEA-identified priorities are not overlooked simply because IBPRP's coarser classification placed them in the moderate tier.

Systematically comparing these results with prior FMEA-based construction studies further clarifies this study's contribution. Ihsan (2022) reported a highest RPN of 158,667 for a fall-from-height risk during girder erection on the Sigli–Banda Aceh toll road, a project executed on an isolated, single-purpose corridor with minimal third-party foot traffic. The highest RPN in the present study (366,036, for a mobile-crane/worker-interaction failure) is more than double that figure and, unlike the fall-from-height risk identified by Ihsan (2022), is an equipment-interaction risk—a difference attributable to the constrained, pedestrian-active campus setting rather than to a generic worsening of construction hazards. Gita (2015), studying an apartment project in an urban but non-institutional setting, attributed dominant accident causes to human, managerial, environmental, and technical factors rather than to interaction with an active third-party population, since that site was not concurrently occupied by non-construction personnel. This comparison indicates that the specific contribution of the present study is twofold: empirically, it provides quantitative evidence that an active, occupied institutional environment (rather than project scale or structural complexity alone) can elevate equipment-interaction risk above the fall-from-height risk found dominant in Ihsan (2022), a project executed on an isolated corridor; and methodologically, it demonstrates a percentile-rank (top-70%) approach to determining FMEA-dominant risks from a continuous, SI-based RPN scale, offering a replicable alternative to fixed RPN thresholds for studies using survey-derived rather than expert-panel S/O/D ratings—a scenario likely to recur in other Indonesian IBPRP-integrated FMEA studies, given the widespread use of the SI method in this research context (Iman, 2018; Ihsan, 2022; Gita, 2015).

Conclusion

Based on the research results on the Phase 1 Construction Project of the Justice Tower Building, Faculty of Law, Hasanuddin University, three conclusions are drawn. First, 80 potential work accident risks were identified in structural work with the following distribution: column work (22 risks), beam work (20 risks), floor slab work (20 risks), and concrete staircase work (18 risks). The IBPRP assessment yielded 8 low risks (10%), 65 moderate risks (81.25%), and 7 high risks (8.75%), indicating that most risks fall into the moderate category. Second, based on the FMEA method, 56 dominant risks (the top 70% by RPN ranking) were identified from the 80 potential risks analyzed. The risk with the highest RPN value is X.3.2.2 (operator does not see workers near the mobile crane due to lack of communication) with an RPN of 366,036, which has the potential to cause severe to fatal accidents. Third, the control strategies for dominant risks encompass five hierarchy levels: elimination (restricting crane work area, warning signs), substitution (using SNI-standard slings), engineering controls (scaffolding, safety nets, crane alarms), administrative controls (safety induction, toolbox meetings, SOPs, periodic inspections), and the use of PPE (body harnesses, helmets, safety shoes, gloves, reflective vests). These strategies are structured with reference to Ministerial Regulation PUPR No. 10 of 2021 (Peraturan Menteri PUPR, 2021) and are documented in the IBPRP and AKK documents, which have been endorsed by the project owner.

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Author Contributions

Conceptualization, I.D and M.D.A.P.; Methodology, M.S.A.; Software, U.; Validation, M.S.A and U.; Formal Analysis, M.S.A.; Investigation, M.D.A.P.; Resources, M.S.A and U.; Data Curation, U.; Writing – Original Draft Preparation, I.D and M.D.A.P.; Writing – Review & Editing, I.D and M.D.A.P.; Visualization, M.S.A.; Supervision, I.D.; Project Administration, U.; Funding Acquisition, I.D.

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Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

The datasets generated during and/ or analyzedduring the current study are available from the corresponding author on reasonable request.

Use of Generative AI

No generative AI was used.

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