

Digital Transformation of Permit to Work Systems for Work at Height in High-Rise Construction Projects: A Narrative Review

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Abstract

Introduction: High-rise construction projects are high-risk activities and effective occupational safety control systems are needed. Traditional paper-based Permit to Work (PTW) systems are often plagued by delayed approvals, poor documentation and limited monitoring capability. **Objective:** The aim of this study is to analyze the digital transformation of PTW systems in high-rise construction projects for work-at-height activities. **Method:** The study was a narrative review design with 10 references from SCOPUS, Web of Science, ScienceDirect, SpringerLink, Google Scholar, and PubMed. The analysis was on electronic personal timekeeping systems, construction safety management, and occupational risk control. **Result and Discussion:** The review showed that website-based PTW systems enhanced approval efficiency, accessibility, integration of risk assessment, documentation management and permit traceability. Previous studies also reported high usability scores (86.9%-93.3%). But major implementation challenges are organizational readiness, workforce competency and cybersecurity issues. **Conclusion:** Digital PTW systems are highly promising in enhancing the management of occupational safety in work-at-height activities by improving operational efficiency, risk control, and regulatory compliance in high-rise construction projects.

Introduction

The construction industry remains one of the sectors with the highest rates of occupational accidents worldwide, particularly in developing countries experiencing rapid infrastructure growth. In Indonesia, the construction sector contributed approximately 38.5% of total occupational accidents in 2022, showing persistent occupational safety and health challenges within the industry (Deanggi, 2025). Additional data from BPJS Ketenagakerjaan reported that until September 2025, 238,675 workers experienced occupational accidents, consisting of 238,543 work accidents and 132 occupational disease cases (SPSI, 2026). The Ministry of Manpower further reported that 47,300 occupational accident cases occurred from January to April 2025, with 29% originating from the construction sector (Dwi Santosa, 2025). Falls from height remain one of the most frequent and severe incidents in construction projects, alongside struck-by-material accidents, hazardous substance exposure, transportation-related incidents, and confined-space accidents (Dwi Santosa, 2025). High-rise construction projects are particularly vulnerable because work-at-height activities involve dynamic work environments, multiple contractors, changing operational conditions, and significant risks that require systematic occupational safety management through Occupational Safety and Health Management Systems (OSHMS/SMK3) as regulated by Law No. 2 of 2017 and Government Regulation No. 50 of 2012.

Permit to Work (PTW) systems are widely implemented as administrative control mechanisms to manage hazardous activities, particularly work at height, hot work, electrical installation, excavation, lifting operations, and confined-space work. According to Annex II of Government Regulation No. 50 of 2012 concerning SMK3 assessment guidelines, PTW systems are mandatory for high-risk work activities as part of occupational safety implementation. PTW systems function to ensure that hazards are identified, risks are assessed, and control measures are verified before work begins. Previous findings by Deanggi (2025) identified 35 occupational safety and health risks in high-rise construction projects, including falls from height, silica dust exposure, slips, and chemical hazards, with 25 risks categorized as high risk and 10 as moderate risk. The importance of effective permit management systems to reduce occupational accidents and improve safety compliance in construction activities. In work-at-height operations, PTW systems also facilitate communication among supervisors, contractors, and safety personnel while strengthening accountability in safety-critical activities (Lawson, 2026).

Despite their importance, many construction projects still rely on conventional paper-based PTW systems that have several operational weaknesses. Manual permit systems are often associated with delayed approvals, duplicated documents, lost records, limited traceability, and difficulties in monitoring permit status in real time (Sawant & Kewate, 2024). These limitations can reduce the effectiveness of hazard control and delay decision-making processes during high-risk activities. To address these problems, many industries have adopted electronic Permit to Work (e-PTW) systems that integrate automated approval workflows, electronic records, notifications, and audit trail functions to improve efficiency, transparency, and documentation quality. Handyanto *et al.* (2024) reported that a web-based PTW information system improved operational efficiency, permit effectiveness, and document security compared with conventional paper-based systems. In addition, responsive web technologies have increased the feasibility of website-based PTW systems because they can operate across smartphones, tablets, laptops, and desktop computers without requiring separate applications for different operating systems (Turner-McGrievy *et al.*, 2017).

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Although electronic PTW systems have been increasingly implemented in several industrial sectors, research specifically discussing website-based e-PTW systems for work-at-height activities in high-rise construction projects remains limited. Previous studies have mainly focused on system design, workflow automation, and usability evaluation within industries such as transportation, shipbuilding, manufacturing, and palm oil processing rather than construction-specific work-at-height activities. Existing studies also provide limited evidence regarding the extent to which e-PTW systems improve occupational safety performance compared with manual PTW systems. Comprehensive narrative reviews discussing the contribution of digital PTW systems to risk management, operational effectiveness, and occupational safety enhancement in high-rise construction projects are still lacking. Considering the high incidence of work-at-height accidents and the growing demand for digital transformation in construction safety management, a review is necessary to synthesize current evidence and identify research gaps. Therefore, this narrative review aims to analyze the digital transformation of Permit to Work systems for work-at-height activities in high-rise construction projects, particularly regarding occupational risk control, operational efficiency, and safety management improvement.

Method

In this study, a narrative review design was adopted to provide a comprehensive analysis of the digital transformation of Permit to Work (PTW) systems for work-at-height activities in high-rise construction projects. The choice of narrative review approach is because the aim of this study was not to measure one statistical relationship but to synthesize and critically interpret multidisciplinary evidence about electronic Permit to Work (e-PTW) system as part of occupational safety management in construction industries. Previous works on PTW digitalization have addressed different aspects like website development, workflow automation, usability evaluation, risk assessment integration, and safety documentation management in a wide range of industrial sectors. However, the present literature is fragmented and has not holistically studied PTW digital transformation specifically for high-rise construction and work-at-height operations. As reported by Larasati *et al.* (2022), Maulana *et al.* (2024), Handyanto *et al.* (2024), and Nuzula *et al.* (2023), web-based permit systems have shown potential to improve operational efficiency, accessibility, and documentation management. However, the broader implications of such systems for construction occupational safety management remain under-researched.

The review was conducted systematically in stages including identification of literature, screening, assessment of eligibility, critical appraisal and synthesis of narrative. Sources of literature were obtained from internationally recognized scientific databases such as SCOPUS, Web of Science, ScienceDirect, SpringerLink, Google Scholar and PubMed. In addition, government regulations, occupational safety guidelines, institutional reports and construction safety standards were incorporated to strengthen the regulatory and operational perspectives discussed throughout the review. However, some basic references like Amm (2021) and Turner-McGrievy *et al.* (2017) were also included, as they provided significant theoretical input on PTW systems, electronic permit flaws and benefits, and responsive website usability ideas. The literature selection process was based on works related to high-risk construction work, work-at-height management, digital permit systems, construction safety management systems, occupational risk assessment, and electronic workflow integration in hazardous operational environments.

The literature search process utilized combinations of the keywords: “Permit to Work system,” “electronic Permit to Work,” “digital PTW,” “work at height safety,” “construction safety management,” “high-rise construction safety,” “construction risk assessment,” “occupational safety digitalization,” “website-based permit system,” “electronic work permit,” “responsive PTW system,” and “construction safety compliance.” Additional searches were performed using terms such as “Job Safety Analysis integration,” “construction digital transformation,” “online permit approval,” “occupational risk management,” “safety audit documentation,” “construction hazard control,” and “work-at-height permit systems” to obtain wider comparative perspectives on the implementation of PTW in diverse industries. The specificity and relevance of search was refined by the use of fundamental of Boolean operators (AND, OR, NOT). The inclusion criteria were peer-reviewed journal articles, conference proceedings, government regulations, construction safety standards and occupational safety guidelines that discussed permit systems, digital occupational safety management or work-at-height operational controls. The review excluded studies that dealt only with unrelated topics in software engineering without relevance to occupational safety, or publications that did not cover operational safety..

As a result, 10 references were identified and cited throughout this narrative review on their direct relevance to Permit to Work systems, occupational safety management, construction risk control, digital transformation and work-at-height safety management. References were international journal articles, observational studies, usability evaluations, conceptual system development studies, occupational safety regulations and institutional safety frameworks. Core references were studies by Larasati *et al.* (2022), Maulana *et al.* (2024), Istiyanto and Novianti (2019), Handyanto *et al.* (2024), and Nuzula *et al.* (2023) that directly discussed website-based PTW systems, permit management workflows, and usability evaluations in various industrial sectors. Further references such as Mubarak *et al.* (2025), Turner-McGrievy *et al.* (2017), Amm (2021), and Gamage (2021) have been incorporated to bolster the discussions on digital transformation, responsive system accessibility, operational weaknesses of paper-based permits, and organizational challenges with technology adoption. Regulatory references such as Government Regulation Number 50 of 2012 concerning Occupational Safety and Health Management Systems (SMK3) and Regulation of the Minister of Public Works and Housing Number 10 of 2021 concerning Construction Safety Management Systems (SMKK) were also integrated to provide legal and operational perspectives of PTW implementation in the Indonesian construction industries. Moreover, supporting references on occupational risk assessment, electronic documentation systems and safety compliance management were integrated for enhancing the multidisciplinary analysis in the whole review.

This framework enabled the study to interpret how electronic PTW systems could automate hazard categorization, approval escalation, and safety control validation in high-risk construction settings. In this narrative review, data analysis was qualitative and involved thematic synthesis and interpretation of findings across the selected literature. The analysis reviewed the common themes that emerged from the review of the operational weaknesses of manual PTWs systems, digital workflow automation, integration of risk assessment, management of safety documentation, usability evaluation, responsive website accessibility, multi-level approval systems, occupational safety compliance and challenges of organisational transformation. The results of different studies were classified into several analytical dimensions such as technological

infrastructure, occupational risk control, safety management integration, human and organizational factors, cybersecurity concerns, and operational monitoring capability. Comparative analysis was also made between different industrial sectors such as transportation services, fertilizer industries, oil and gas operations, shipbuilding and palm oil processing for the identification of transferable practices which are relevant to high-rise construction projects.

Result and Discussion

The digital transformation of Permit to Work (PTW) systems for work-at-height activities in high-rise construction projects should be regarded not only as an administrative modernization initiative but also as a strategic element of occupational safety management that can impact overall safety performance, operational efficiency, and regulatory compliance. Previous research on PTW systems has been concentrated on system development, interface design and digitization of workflow, without an overall assessment of their wider contribution to construction safety management systems. According to Larasati *et al.* (2022), web-based PTW reporting systems can accelerate approval processes and improve accessibility by online workflows and integrated databases. Similarly, Maulana *et al.* (2024) found that responsive web-based PTW systems allowed supervisors, managers and HSE personnel to approve simultaneously, which made permit processes more efficient than sequential paper-based procedures. However, most of the studies still focused on the technical design of systems rather than discussing digital PTW systems as integrated operational risk control mechanisms in high-risk construction environments. PTW digitalization should be seen not only as an innovation in information technology but as part of a wider change in the management of construction occupational safety.

The comparative synthesis of the previous studies, shown in Table 1, also demonstrates that the research on electronic Permit to Work (e-PTW) systems is still scattered over different industrial sectors. Larasati *et al.* (2022) studied the transportation service industries and Maulana *et al.* (2024) the fertilizer manufacturing environments with chemical and fire hazards. Istiyanto and Novianti (2019) investigated the contractor permit system in the oil and gas industries, while Handyanto *et al.* (2024) and Nuzula *et al.* (2023) explored the shipbuilding and palm oil processing industries, respectively. While these industries differ in their operations, all studies found the same weaknesses in conventional permit systems, such as delayed approvals, poor document management, limited monitoring capability and difficulties during audits. The majority of the studies also emphasized the importance of centralized databases, online approval systems, and integrated Job Safety Analysis (JSA) functions to enhance safety documentation and permit traceability. Work at height is one of the highest risk construction activities related to fatal falls and serious injuries (Long Peng *et al.*, 2023; Anantharaman *et al.*, 2023). However, there is a lack of extensive discussions specifically related to work-at-height control in high-rise construction projects

Table 1
 Previous Studies Related to Digital Permit to Work Systems

Authors	Year	Main Findings	Major Limitation
Larasati <i>et al.</i>	2022	Web-based PTW reporting system accelerated approval and online access	Limited to conceptual design without implementation evaluation
Maulana <i>et al.</i>	2024	Responsive PTW system enabled simultaneous approvals and greater efficiency	No empirical effectiveness testing
Istiyanto & Novianti	2019	Contractor permit system improved data centralization and workflow management	Did not evaluate K3 performance improvement
Handyanto <i>et al.</i>	2024	PTW website achieved usability score of 86.9% and integrated JSA features	No detailed accident reduction analysis
Nuzula <i>et al.</i>	2023	Multi-level web-based permit system achieved usability score of 93.3%	Limited discussion regarding cybersecurity and long-term impacts

The literature reviewed in this study consistently shows that high-rise construction projects have complex operational characteristics, thus requiring more adaptive and integrated permit management systems. Often construction work has to be performed by several contractors, in changing working environments, with concurrent hazardous activities and short schedules for completing the project, which increase occupational safety risks. Penyedia jasa konstruksi wajib melaksanakan Analisis Keamanan Konstruksi (AKK) untuk kegiatan yang memiliki risiko menengah dan tinggi, berdasarkan Peraturan Menteri Pekerjaan Umum dan Perumahan Nomor 10 Tahun 2021 tentang Sistem Manajemen Keamanan Konstruksi (SMKK). In this context, PTW systems are used not only as administrative procedures, but also as operational control mechanisms to ensure that hazard identification, risk assessment and preventive measures are implemented prior to the work commencing. Mubarak *et al.* (2025) also emphasized that digital systems could improve compliance through automatic alerts on safety non-conformities and preparation of safety documentation for audits. Digital PTW systems can therefore significantly enhance regulatory compliance and improve operational safety management in construction environments with dynamic hazards and high uncertainty.

One of the most important themes identified throughout the reviewed studies was risk assessment integration. PT ABC's risk evaluation procedures are based on quantitative assessment using Likelihood/Frequency and Consequence/Severity factors to establish overall risk levels prior to the issuance of permits. The basic risk calculation method is as follows (1):

$$R = L \times C \tag{1}$$

where *R* is Risk value, *L* is Likelihood, the probability or frequency of a hazard occurring, and *C* is Consequence, the severity of the impact if the hazard occurs. The approach enables organizations to rank risks into several priority levels with varying controls. Electronic PTW systems can automate risk calculations and reduce the inconsistencies often seen in manual assessment processes. Automated calculations also help speed up permit approval because supervisors and HSE staff can immediately see whether work activities fall into the acceptable, moderate, high or extreme risk categories. Integrated

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digital risk assessment systems can deliver significant operational benefits for work at height where hazards such as falls, falling objects, unstable platforms and electrical exposure can quickly become fatal, ensuring that no permit can be approved without proper checks on hazard assessment and control. Table 2 shows PT ABC Risk Categories.

Table 2
PT ABC Risk Categories

Risk Category	Risk Level
Extreme risk, operations must stop	E
High risk, immediate corrective action required	T
Major risk, corrective improvement required	M
Potential risk requiring attention	R

The reviewed consistently identified the operational weaknesses of conventional paper-based Permit to Work (PTW) systems in construction environments. Amm (2021) showed several critical limitations of manual permit systems, including inadequate training, poor shift handovers, weak leadership commitment, ineffective audit practices, and vulnerabilities associated with paper documentation. Similar findings were reported in previous studies where manual PTW systems frequently caused delayed approvals, document loss, inefficient monitoring processes, and difficulties in retrieving historical permit records. These weaknesses become more problematic in high-rise construction projects because work conditions are dynamic and hazardous activities often require rapid operational decisions. Environmental conditions such as rain, dust, heat, and operational disturbances can also physically damage paper permits and reduce the reliability of documentation systems on construction sites. Consequently, electronic PTW systems provide significant advantages through centralized databases, automatic backups, searchable records, and real-time accessibility for supervisors, HSE personnel, and management teams, thereby improving operational efficiency and hazard control.

Usability and accessibility are major factors influencing the successful implementation of electronic PTW systems. Handyanto *et al.* (2024) reported that a web-based PTW system achieved a usability score of 86.9%, categorized as “very feasible,” while Nuzula *et al.* (2023) reported an average usability score of 93.3%, indicating high effectiveness, ease of learning, and strong user satisfaction. These findings suggest that construction personnel generally perceive website-based PTW systems as more practical and efficient than conventional paper-based approaches. Turner-McGrievy *et al.* (2017) explained that responsive-design websites are cost-effective and can function efficiently across multiple platforms, including smartphones, tablets, laptops, and desktop computers. This flexibility is highly relevant in construction environments where workers and supervisors frequently move across operational areas and require immediate access to permit systems regardless of the device or operating system used. In addition, previous studies showed that electronic PTW systems can integrate Job Safety Analysis (JSA), PPE verification, inspection checklists, activity logs, and multi-level approval systems, thereby improving consistency in hazard control and reducing the likelihood of human error during work-at-height activities (Handyanto *et al.*, 2024; Nuzula *et al.*, 2023).

Despite these advantages, organizational, human, and cybersecurity factors remain major challenges in the digital transformation of PTW systems within the construction industry. Gamage (2021) emphasized that successful digital transformation depends on organizational capabilities related to technology adoption, data management, operational processes, and change management. However, many construction companies still face barriers such as limited digital competencies, insufficient training, financial constraints,

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and worker resistance toward technological changes. In some cases, employees perceive digital PTW systems as additional administrative burdens rather than tools that improve occupational safety performance. Amm (2021) warned that generic electronic permit systems may not adequately address site-specific operational hazards and may introduce security vulnerabilities related to unauthorized access, data manipulation, or system downtime. Therefore, future development of electronic PTW systems should incorporate stronger cybersecurity frameworks, secure authentication systems, encrypted databases, and reliable backup mechanisms to ensure operational continuity, regulatory compliance, and protection of sensitive occupational safety information in high-rise construction projects.

Conclusion

The digital transformation of Permit to Work (PTW) systems for work-at-height activities in high-rise construction projects has significant potential to improve occupational safety management, not just in terms of administrative efficiency. The literature reviewed consistently shows that electronic PTW systems enhance permit accessibility, approval efficiency, documentation quality, audit readiness, risk assessment integration and hazard control verification through features such as online approvals, integrated Job Safety Analysis (JSA), PPE verification and automated monitoring systems. Digital PTW systems also help ensure compliance with regulations and visibility into operations on construction sites where hazards change, multiple contractors work and activities are high-risk. However, successful implementation depends not only on technological infrastructure, but also on organizational commitment, workforce competency, leadership support, effective safety culture and cybersecurity protection. But the existing studies are limited in their assessment of the long-term effect of electronic PTW systems on accident reduction and overall safety performance. Therefore, future research should focus on longitudinal effectiveness evaluation, cyber resilience, predictive risk monitoring, and integration with advanced technologies, such as Internet of Things (IoT) systems and real-time operational analytics, to further enhance proactive occupational safety management in construction industries.

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