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Impact of Risk Assessment (RA) and Permit-to-Work (PTW) Linkage on Public Construction Safety

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Abstract

Purpose: The 2022 enactment of the Serious Accidents Punishment Act (SAPA) was intended to pivot South Korea's construction industry toward a self-regulatory safety paradigm; yet, the persistence of conventional accidents remains a sobering reality. **Research design, data and methodology:** This research addresses this gap by examining the empirical effectiveness of systematically aligning Risk Assessment (RA) and Permit to Work (PTW) systems as a proactive strategy to mitigate recurring hazards. Drawing on a dataset gathered from 214 safety managers and Construction Management (CM) professionals in the public sector, the study utilizes Structural Equation Modeling (SEM) analysis to validate hypothesized relationships. **Results:** Findings demonstrate that a cohesive RA-PTW linkage does more than just organize paperwork; it fosters safer and consistent behavioral patterns among workers, which in turn significantly elevates accident prevention performance. Crucially, results highlight the on-site monitoring function of CM personnel as a pivotal moderator that effectively bridges the inherent disconnect between administrative compliance and tangible safety outcomes. **Conclusions:** The study concludes that ensuring the efficacy of safety protocols requires moving beyond a mere bureaucratic veneer of integration toward rigorous, real-time field verification by CM experts. Ultimately, these insights provide a high-reliability governance framework for developing resilient safety management systems capable of thriving within an increasingly high-stakes regulatory environment.

Keywords : Construction Safety, Risk Assessment(RA), Permit-to-Work System(PTW), Construction Management (CM), Accident Prevention Performance.

JEL Classification Code: J28, L74, M11

1. Introduction

1.1. Research Background

The 2022 enactment of the *Serious Accidents Punishment Act (SAPA)* sought to pivot South Korea's construction industry toward a self-regulatory safety paradigm. Yet, a sobering paradox remains: 2025 Ministry of Employment and Labor data reveals that construction fatalities still constitute nearly half of all industrial deaths. The stubborn persistence of "primitive accidents"—falls and entrapments—exposes a profound disconnect between regulatory intent and field-level execution.

This research identifies a critical "systemic decoupling" at the heart of this failure. Risk Assessment(RA) is frequently relegated to a bureaucratic prelude—paperwork completed before a shovel even hits the ground—while the Permit to Work (PTW) system devolves into a fragmented administrative formality (Ahn, 2022). Although existing literature has scrutinized these mandates in isolation, empirical evidence regarding their synergistic integration remains conspicuously absent. To bridge this gap, this study evaluates the operational connectivity between RA and PTW within public construction projects. Crucially, it delineates the moderating role of Construction Management (CM) monitoring as the vital mechanism for driving accident prevention performance. By doing so, this research provides a high-reliability governance model designed to transform bureaucratic compliance into tangible, lifesaving field safety.

2. Literature Review

2.1. Risk Assessment (RA) and Permit to Work (PTW)

Risk Assessment (RA) constitutes a systematic framework for identifying workplace hazards and implementing targeted mitigation strategies—serving as the foundational "Plan" phase in safety management (Oh & Park, 2017). Conversely, the Permit to Work (PTW) system operationalizes this plan by acting as a field-level gatekeeper. It verifies that RA-mandated safety measures are active before work begins, effectively authorizing or halting operations based on real-time compliance. Within the *Plan-Do-Check-Act (PDCA)* framework, PTW serves as a vital bridge between the "Do" and "Check" stages, ensuring that theoretical safety intentions meet practical execution (KOSHA GUIDE, 2020).

Reason's (1997) Swiss Cheese Model provides the critical lens for understanding the danger of keeping these systems in silos. Reason likens organizational defenses to slices of cheese; while each layer is designed to block threats, "holes"—representing latent failures or active errors—exist in every slice. When RA and PTW function as disconnected barriers rather than an integrated whole, these holes are more likely to align, allowing hazards to penetrate the entire defensive stack. This lack of synergistic integration creates catastrophic "systemic gaps"—latent vulnerabilities that significantly escalate the probability of major industrial accidents..

2.2. Safety Management Role of Construction Management (CM)

Statutory mandates under the Construction Technology Promotion Act empower Construction Managers (CMs) with the rigorous duty to oversee, review, and validate safety management protocols throughout the execution phase. Especially within the public sector, the CM functions as a critical "Gatekeeper," wielding authority delegated by the client to scrutinize contractor safety efforts and grant final clearances for high-risk operations (Lee, 2021).

Existing research underscores that such proactive leadership and stringent field verification serve as essential catalysts; they do not merely enforce rules but actively nurture a resilient safety climate, solidifying compliant behaviors among contractors (Shim, 2019). Accordingly, this study posits that CM monitoring intensity acts as a decisive moderate variable. It ensures that the synergy between Risk Assessment (RA) and Permit to Work (PTW) evolves beyond a perfunctory "paper-and-pencil" exercise, transforming administrative compliance into substantive, high-performance accident prevention on the ground.

2.3. Overview and Definition of Permit to Work (PTW)

The Permit to Work (PTW) system is defined as a formalized, documented control framework designed to proactively identify latent hazards inherent in high-risk operations and ensure that mandatory safety protocols are rigorously verified by supervisors prior to task authorization (HSE,2005). Beyond a mere administrative approval process, the PTW functions as a critical bidirectional communication conduit between the Issuer and the Performer, facilitating the exchange of technical risk intelligence. It serves as an indispensable safety barrier, particularly for non-routine or high-hazard activities where standard operating procedures may be insufficient, thereby ensuring a continuous and verifiable chain of safety responsibility.

Table 1. Safety Management Roles by Phase

Category	Responsible party	Key Tasks and Roles
Preparation of Work Plan	Task Supervisor (Contractor)	objectives, scope, and technical hazard identification
Safety Review	Safety Superintendent, Supervisor (CM)	Review, sign, and authorize the permit document
Permit Issuance	Safety Superintendent, Supervisor (CM)	Review, sign, and authorize the permit document
Patrol Inspection	Supervisor (CM), Safety Manager	Conduct site inspections and initiate corrective actions
Completion Reporting	Task Supervisor	Prepare and submit the final work completion report

2.4. Legal Foundation and Scope of PTW

The operational parameters of the Permit to Work (PTW) system are rigorously delineated by the "Rules on Occupational Safety and Health Standards" in conjunction with *KOSHA Guide G-166-2020*. These regulatory frameworks prioritize high-hazard operations with a significant propensity for catastrophic accidents, specifically mandating PTW protocols for Hot Work, Confined Space Entry, Work at Height, Excavation, and De-energized/Live-line Electrical Work. From a legislative standpoint, *Articles 38 (Safety Measures) and 39 (Health Measures) of the "Occupational Safety and Health Act"* constitute the overarching statutory foundation.

While these articles provide a broad mandate, the legal framework becomes highly prescriptive regarding specific high-risk tasks. For example, the statutory obligations to draft specialized work plans and appoint dedicated safety watchmen for activities such as hot work or confined space entry effectively institutionalize the implementation of the PTW system. Consequently, within the South Korean construction landscape, the PTW transcends its role as a voluntary safety initiative and functions as a critical procedural compliance mechanism that translates abstract legal duties into verifiable onsite safety actions.

Table 2: PTW System Requirements

Timeline	Category	Detailed Requirement
15-day lead time	Submission of Construction Plan & Details (Contractor))	organization chart, manpower/equipment mobilization, work sequences & safety measures.
Prior to Starting High-Risk Work	RA for High-Risk Tasks (Contractor)	Identification of hazards per task and implementation of risk mitigation measures.
1-2 Days Prior to High-Risk Work	Request for PTW Approval (Contractor)	Submission of detailed application including current status of hazard removal/Improvement (with photos).
Prior to Work Initiation	Review and Approval of PTW (CM/Supervisor)	Verification of safety plans vs. site conditions, RA results, onsite safety measures before final authorization.
Before & During Work	Initiation Commencement / Attendance & Verification (Contractor)	Dissemination of PTW safety measures via Tool Box Meeting. Two-person teams for all holiday work. Onsite presence of Task Lead or Safety Manager.
During Work	Monitoring Compliance with Permit Conditions (CM/Supervisor)	Inspection/verification of safety measures (Photos/Videos required). Submission of records to Chief Resident Engineer. Mandatory pre-work safety meetings for holiday shifts. Stop Work Authority exercised upon non-compliance.
Occasionally	Verification of PTW Implementation	Ongoing audits of PTW compliance and derivation of system improvement recommendations.

2.5. Global PTW Case Studies

Advanced nations with sophisticated safety management infrastructures utilize the PTW system as a pivotal instrument that bridges statutory regulation with autonomous safety management.

Table 3: International Case Studies of the Permit to Work (PTW) System Implementation

Country	UK	US	Singapore
Legal Framework	Focuses on practical standards based on guidance (HSG250) rather than statutory regulations.	Specific PTW obligations are explicitly mandated under Federal Law (29 CFR).	PTW for work at heights is mandated as a legal obligation under WSH regulations.
Purpose & traits	System and procedure-oriented to mitigate human errors.	Liability & compliance focus	Serves as a field hazard control and a potent enforcement tool.

Organizational Structure & Roles	Cross-verification through subdivided roles, such as Authorizers and Persons in Charge.	Prescribed Issuer/ Entrant duty	PM holds ultimate responsibility; site supervisors and safety officers execute operational tasks.
Scope of High-Risk Work	High-risk tasks voluntarily designated by the workplace (e.g., confined spaces, hot work, electrical work).	Statutory high-risk tasks specified by law, such as confined spaces and hot work.	Work at heights (specifically 3m or above), high-risk construction tasks, etc.
LOTO Integration	Integrated as a core component within the PTW procedures.	Stringently linked with independent LOTO.	Utilized as a fundamental control measure for PTW in work at heights and equipment maintenance
Enforcement & Sanctions	Focuses on accident investigations, audits, and corrective/improvement requests.	Severe sanctions (Citations, fines,criminal liability for non-compliance.	Immediate Stop Work Orders, fines, & revocation permits/ licenses for violations.

2.5.1 International Industry Standards and Digital Transformation of PTW Systems

Global energy sectors, including major corporations such as Shell and BP, adhere to the Report 603 standards published by the International Association of Oil & Gas Producers (IOGP). To overcome the spatial and temporal limitations of traditional paper-based permits, the industry is rapidly transitioning toward electronic Permit to Work (e-PTW) systems. These digital platforms facilitate real-time monitoring of site activities and provide systemic interlocks to prevent Simultaneous Operations (SIMOPS), where conflicting tasks could lead to catastrophic interference.

2.6. Conceptual Definition and Significance of Risk Assessment

Risk Assessment (RA) is defined as a systematic process in which an employer identifies hazardous and risky factors inherent in construction structures, machinery, equipment, and work behaviors. This process involves estimating and determining the probability (frequency) and severity (intensity) of potential injuries or illnesses caused by such factors, followed by the establishment of risk mitigation measures (Occupational Safety and Health Act, Article 36). Rather than being a reactive safety management tool, Risk Assessment serves as a core mechanism for proactive safety management.

2.7. Risk Assessment Procedures by Timing

In May 2023, the Ministry of Employment and Labor (MOEL) promulgated a significant revision to its Risk Assessment notification, strategically introducing the 'Constant Assessment' framework. This policy shift was designed to bolster on-site operationality and narrow the persistent empirical gap between rigid regulatory mandates and the fluid realities of field execution. Under this revised paradigm, the risk assessment process is systematically demarcated into three distinct operational stages based on their specific temporal triggers and safety objectives:

(a) Initial Assessment, which serves as a foundational baseline evaluation conducted across all comprehensive work stages prior to the establishment of a workplace or the commencement of construction activity to identify fundamental hazard factors at the project's inception.

(b) Occasional Assessment, which is triggered by specific environmental or operational fluctuations, such as the introduction of new machinery, modifications in technical work methods, or the occurrence of industrial accidents, ensuring that newly emerged risks are promptly addressed through adaptive countermeasures; and

(c) Constant Assessment, a newly institutionalized model that prioritizes continuous risk management through a structured cycle of monthly joint labor-management patrols, weekly safety review meetings, and Daily -Tool Box Meetings (TBM).

By facilitating the real-time dissemination of hazard information and mitigation strategies directly to the frontline workforce, this integrated framework is specifically engineered to supersede the conventional 'Regular Assessment' model. It is increasingly recognized as a highly adaptive safety management paradigm for the construction industry, where site conditions are inherently volatile and subject to dynamic transformations.

Table 4. Risk Assessment (RA) Procedures and Key Content

CURRENT		REVISED
Purpose of Risk Assessment Notification Purpose unclear	→	**Define Purpose of Risk Assessment Notification** Concretized as “to prevent industrial accidents”
Definition Rule Definition includes estimation/ determination of frequency/ severity, making it difficult for workplaces to understand	→	**Clarify Definition Rule** Excludes obligation to measure possibility/severity of injury/illness, focuses on identifying risk factors and establishing countermeasures
Assessment Method Possibility and severity for using matrix/ multiplication/ addition for quantitative calcit require, field application for difficult for influration	→	**Diversify Assessment Method** Improved frequency/level without calculating risk to judge to improved (Checklists, OPS, etc. are also suggested)
Assessment Timing Consists of Initial, Regular, Occasional assessments **[Initial]** Timing after workplace establishment ambiguous **[Regular]** Every 1 year after initial assessment **[Occasional]** Introduction/change of machinery/equipment	→	**Clarify Assessment Timing** Reformed to ensure constant risk assessment summary **[Initial]** Within a month after workplace establishment **[Occasional]** New introduction/change due to new additional hazards/risks for each conducted **[Regular]** Re-examine adequacy of entire risk assessment results annually re-enqually and implement reduction measures if needed **[Constant]** Monthly proposals through monthly proposals, near-miss checks, worker-participating workplace patrols; exempt from occasion/regular assessment if daily TBM is after occasional/regular assessment exempt
Limited Worker Participation Participate only in identifying hazards/risk factors, establishing reduction measures, implementing reduction measures	→	**Guarantee Worker Participation in Entire Process** Workers participate in the entire risk assessment process
Lack of Result Sharing Rules Requires notifying workers only when residual risks exist when notifying requires	→	**Share Risk Assessment Results with Workers** Share all risk assessment results with workers Establish provision for dissemination efforts through TBM

2.8. Limitations and Necessity of the Separate Operation of the System

According to Korea Occupational Safety and Health Agency (KOSHA), domestic construction sites exhibit a distinct trend toward the bifurcated operation of Risk Assessment (RA) and the Permit to Work (PTW) system, failing to achieve meaningful mutual integration. This systemic separation manifests primarily through an information gap, where specific hazard factors and countermeasures identified during the planning-oriented RA phase are frequently omitted at the PTW issuance stage, often being replaced by perfunctory checklists or routine "no abnormalities" remarks. Furthermore, a significant implementation gap persists as RA is largely relegated to an administrative formality for safety managers, while PTW is dismissed as a routine procedural requirement for site supervisors, effectively severing the "Last Mile" of safety communication where critical risk information must reach the actual workers.

Analyzing this phenomenon through the lens of Reason’s Swiss Cheese Model (1997), RA serves as a defensive barrier in the "Planning" phase to identify latent hazards, whereas PTW acts as a critical barrier in the "Execution (Do/Check)" phase to control identified risks immediately prior to work commencement. The structural "holes" between these defensive layers can only be bridged when RA outcomes are institutionalized as mandatory conditions for approval for the PTW process, establishing a rigorous operational logic that any risk not addressed in the Risk Assessment cannot be authorized in the Work Permit. Such integration is particularly vital for the effectiveness of Tool Box Meetings (TBM) within the "Constant Assessment" framework; by utilizing safety measures verified during the PTW approval process as the core content of the TBM, a virtuous cycle of 'RA-PTW-TBM' can be established, ultimately transforming high-level risk management into practical, real-time preventive actions at the site level.

Table 5: Summary of Revised and New Risk Assessment Guidelines

Risk Assessment Implementation Process		
Core Points	**Process Step**	**Main Content**
Hazard Identification	Preliminary Preparation	Establish implementation rules Define risk criteria Pre-survey of safety info
	Hazard Identification	Identify via patrol inspections Utilize near-miss data
Worker Participation	Risk Determination	Judge risk levels Decide on tolerability
	Establish & Implement Mitigation Measures	Implement measures by priority Reduce risk to ALARP Re-verify tolerability
Sharing of Results	Sharing of Risk Assessment Results	Post & notify results Share via Tool Box Meetings (TBM)

3. Research Methodology

3.1. Research Framework and Hypothesis Development

In the proposed empirical model of this study, the integrated connectivity between Risk Assessment (RA) and the Permit to Work (PTW) system is established as the independent variable, while disaster prevention performance serves as the dependent variable. To further examine the contextual dynamics within construction safety management, the monitoring intensity of Construction Management (CM) is incorporated as a moderating variable. This research design aims to verify not only the direct causal impact of system integration on safety outcomes but also how the oversight activities of CM personnel can strategically augment this relationship in actual field operations. Based on the theoretical framework and the conceptual model developed for this study, the following hypotheses are formulated:

H1: The degree of integration between Risk Assessment (RA) and the Permit to Work (PTW) system will have a significant positive effect on accident prevention performance.

H2: The intensity of monitoring by Construction Management (CM) will positively moderate the relationship between the integration of RA-PTW systems and accident prevention performance.

3.2. Data Collection and Analysis Methods

To provide an empirical basis for the proposed research model, data collection was conducted over a three-month period from May to July 2024. The target population for this study consisted of safety managers and Construction Management (CM) personnel stationed at 50 publicly funded construction sites in South Korea, encompassing both civil engineering and architectural projects. A self-administered survey method was employed to ensure objective data acquisition from professionals directly involved in on-site safety operations.

Table 6: Overview of Data Collection and Analysis

Category	Content
Survey Period	2024 Feb ~ Apr 2024 (3 months)
Target Population	50 domestic public construction sites (Civil/Architecture)
Respondent Composition	Safety Managers and Construction Management (CM) Personnel
Survey Method	Self-administered questionnaire
Distributed Questionnaires	230 copies
Collected Questionnaires	214 copies (Effective rate: 93.0%)
Final Sample for Analysis	214 valid questionnaires
Analysis Techniques	Structural Equation Modeling (SEM), Multi-Group Analysis (MGA), Confirmatory Factor Analysis (CFA)

Statistical processing of the collected data was conducted using IBM SPSS Statistics v.26.0 and AMOS v.26.0 in parallel. The specific analysis procedures were as follows: IBM SPSS v.26.0 was utilized to perform frequency analysis and descriptive statistics to identify the demographic characteristics of the sample. To verify the internal consistency of the measurement scales, reliability analysis was conducted by calculating Cronbach's alpha coefficients. Confirmatory Factor Analysis (CFA) was performed using AMOS v.26.0 to evaluate the structural validity of the latent variables. Subsequently, convergent and discriminant validity were verified through the assessment of Composite Reliability (CR) and Average Variance Extracted (AVE) values.

Third, a Structural Equation Model (SEM) was ultimately constructed to test the proposed research hypotheses and elucidate the causal relationships between the independent, mediating, and dependent variables.

4. Results and Analysis

4.1. Validity and Reliability Analysis

To verify the validity of the measurement tools, Confirmatory Factor Analysis (CFA) was conducted. The results indicated an overall favorable model fit, with the following indices: $\chi^2/df = 2.14$, CFI = 0.92, TLI = 0.91, and RMSEA = 0.06.

These values satisfy the standard thresholds for a good model fit. Regarding the convergent validity of the measurement items, the standardized factor loadings for all items were found to be 0.6 or higher. Furthermore, the Composite Reliability (CR) and Average Variance Extracted (AVE) values for all latent variables exceeded the required criteria (CR > 0.7 and AVE > 0.5), thereby securing convergent validity.

In terms of reliability, Cronbach's alpha (α) coefficients for all variables were above 0.8, confirming that the internal consistency of the measurement tools was fully satisfied.

4.2. Hypothesis Testing Results

According to the results of the Structural Equation Modeling (SEM) analysis, Hypothesis 1 (H1), which posited that "the connectivity between Risk Assessment (RA) and the Permit to Work (PTW) system will exert a significant positive influence on disaster prevention performance," was statistically supported ($\beta = 0.642$, $p < .001$). This empirical finding implies that as Risk Assessment (RA) outcomes are operationalized into specific approval conditions for the Permit to Work (PTW) and effectively disseminated through Tool Box Meetings (TBM), the identification of near-misses and the rate of compliance with safety regulations at construction sites are significantly enhanced. Ultimately, the integration of these two systems serves as a critical mechanism for transforming planning-phase risk data into active on-site preventive measures. Table4:Confirmatory Factor Analysis (CFA) Results for Validity and Reliability Verification

Table 7: Hypothesis Results

Category	Factor loading	CR	AVE	Cronbach's α	Model Fit Indices
Thresholds (Minimum)	≥ 0.60	≥0.70	≥0.50	≥ 0.80	
Actual Values	All items ≥ 0.60	0.83–0.91	0.56–0.78	0.81–0.89	χ^2/df=2.14, CFI=0.92, TLI=0.91, RMSEA=0.06
Evaluation	Criteria Met	Criteria Met	Criteria Met	Criteria Met	Good Fit

Table 8: Summary of Hypothesis Testing Results

Hypothesis	Content	Method	Path Coeff. (β)/ Δχ²	P- value	Result
H1	RA-PTW connectivity positively influences disaster prevention performance.	SEM	0.642	< .001	Supported
H2	CM field monitoring activity moderates the disaster prevention effect.	MGA	High=0.715, Low=0.432 (Δχ²=4.12)	< .05	Supported

To verify Hypothesis 2 (H2), a Multi-group Analysis (MGA) was conducted by categorizing the groups into "High" and "Low" based on the frequency of on-site verification by Construction Management (CM) personnel. The results revealed that the group with high CM monitoring activity ($\beta = 0.715$) exhibited a significantly higher path coefficient than the low-activity group ($\beta = 0.432$) ($\Delta\chi^2 = 4.12$, $p < .05$). This finding implies that even when systemic connectivity is firmly established, the disaster prevention effect is further maximized when CM personnel directly monitor the implementation of safety protocols on-site. Ultimately, this suggests that human-led field verification acts as a critical catalyst in enhancing the practical effectiveness of the RA-PTW integrated system.

5. Conclusion and Recommendations

This study has verified, through both domestic and international case analyses, that the integrated operation of the Permit to Work (PTW) system and Risk Assessment (RA) yields substantial efficacy in disaster prevention. The findings confirm that the PTW system serves as a pivotal mechanism for mitigating construction accidents. Specifically, the results underscore the critical importance of conducting exhaustive technical and administrative reviews of core safety elements—including pre-work risk assessments—across all construction phases, while maintaining rigorous adherence to operational standards during the implementation and execution stages.

5.1. Research Summary and Implications

This research provided an empirical investigation into the impact of the linked operation of RA and PTW on safety performance within public construction sites, while simultaneously elucidating the moderating role of Construction Management (CM) activities. The results affirm that a "chemical synthesis" of these two institutional frameworks is an essential prerequisite for accident prevention. Furthermore, the study confirms that the on-site inspection functions performed by CM personnel are vital for ensuring the integrity and effectiveness of this systemic integration.

5.2. Polic y and Practical Recommendations

First, from a policy perspective, the Ministry of Land, Infrastructure and Transport (MOLIT) and the Ministry of Employment and Labor (MOEL) should incorporate the implementation of RA-PTW integrated systems—including electronic linkages—as a formal evaluation criterion during the bidding process for public works. Additionally, sub-regulations of the Construction Technology Promotion Act should be amended to mandate the inclusion of "Risk Assessment reflection" as a compulsory requirement in CM inspection checklists for high-risk operations, such as hot work or confined space entry.

Second, in practical terms, the adoption of smart safety technologies is imperative to facilitate this linkage. Project workflows should be enhanced to allow workers to verify daily RA results via QR codes on mobile devices during Tool Box Meetings (TBM).

Such a system should be designed so that these verification steps are automatically recorded as mandatory approval logs within an Electronic Permit to Work (e-PTW) system (Ministry of Employment and Labor, 2025).

5.3. Limitations and Future Research Directions

Although the current findings yield meaningful insights into safety management, the cross-sectional design of this survey-based study naturally limits our capacity to confirm direct causality between the observed variables. To move beyond these snapshot-in-time constraints, future scholarly efforts should prioritize longitudinal investigations. Specifically, by monitoring longitudinal accident rate data from construction projects that have fully institutionalized integrated RA-PTW systems, researchers will be able to more robustly evaluate the enduring efficacy and long-term protective impact of these safety-critical interventions.

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