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A Study on Disaster Prevention and Improvement of Safety Management Systems through Risk Factor Analysis of Temporary Construction Works

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Abstract

Purpose: This study proposes safety management and institutional improvement measures to prevent accidents in temporary construction works. **Methods:** Literature reviews, regulatory analysis, accident case studies, and surveys were conducted. **Results:** Falls, collapses, and falling-object accidents were the most common, mainly caused by inadequate structural review, poor safety management, and insufficient training. **Conclusion:** Strengthening structural safety, systematic management, worker-centered education, smart technologies, and institutional improvements can effectively reduce construction-site accidents.

Keywords : Temporary Construction Works, Construction Site Safety, Structural Safety, Accident Prevention, Safety Management System, Institutional Improvement

JEL Classification Code : K23, D73, L51, L52

1. Introduction

1.1. Research Background

Temporary construction works refer to structures and facilities that are temporarily installed to support permanent construction activities during the construction process. These include scaffolding, shoring systems, gang forms, formwork, working platforms, temporary access routes, hoists, and temporary electrical systems. According to construction accident statistics in Korea, more than 30% of all construction-related accidents occur in temporary construction works, with falls and structural collapses accounting for the majority of fatal accidents (Ministry of Employment and Labor, 2024). Because temporary structures are not permanent facilities, they are inherently vulnerable to structural instability during installation, modification, operation, and dismantling processes. Furthermore, the construction industry in Korea continues to record one of the highest occupational fatality rates among OECD countries. The fatality rate in the Korean construction sector is nearly twice the OECD average, and the overall industrial accident fatality rate remains among the highest within OECD member nations. These statistics indicate that construction remains one of the most hazardous industries in terms of occupational safety and health. In particular, temporary construction works are characterized by their temporary and non-permanent nature, which often results in insufficient structural stability and a higher likelihood of accidents during installation and dismantling operations. Falls, collapses, falling-object incidents, and fire-related accidents frequently occur in temporary works and often lead to severe injuries and fatalities. Therefore, the purpose of this study is to systematically identify and analyze the major risk factors associated with temporary construction works and to propose multidimensional strategies for accident prevention and safety management improvement. To achieve this objective, the study applies Heinrich's Domino Theory and Reason's Swiss Cheese Model as theoretical frameworks and examines the relationships between organizational, managerial, and technical failures and major accident types, including falls, structural collapses, and fire incidents (Heinrich, 1931; Reason, 1990). Through this approach, the study aims to provide practical and policy-oriented recommendations for improving safety performance and reducing industrial accidents in construction sites.

2. Overview of Temporary Construction Works and Accident Cases

2.1. Overview of Temporary Construction Works

Temporary construction works refer to temporary structures and facilities installed to support the construction of permanent structures during construction projects. These structures are essential for ensuring construction safety and improving operational efficiency. Typical temporary structures include scaffolding, shoring systems, formwork, gang forms, working platforms, temporary access routes, temporary electrical facilities, and hoists.

Temporary construction works are characterized by repetitive installation and dismantling processes and play an important role in ensuring both construction quality and worker safety. To improve construction efficiency and productivity, it is necessary to thoroughly review the strength, reusability, structural stability, and maintenance requirements of temporary materials before their use (Kim, 2020). In addition, various temporary facilities such as protective barriers, temporary fences, temporary noise barriers, construction signboards, temporary roads, site offices, and material storage warehouses are installed on construction sites, performing essential functions throughout the construction process.

One of the most significant characteristics of temporary construction works is the coexistence of temporality, repetitiveness, economic efficiency, and risk. Because temporary structures are dismantled after a relatively short period of use, safety management may be neglected compared to permanent structures. Furthermore, in construction environments where project duration reduction and cost minimization are prioritized, productivity and economic efficiency are often emphasized over safety considerations. Consequently, structural instability may increase during installation, operation, and dismantling processes, leading to serious accidents such as worker falls and structural collapses. In particular, repetitive work at heights and the handling of heavy materials in confined workspaces inherently expose workers to significant safety risks (Hinze, 2006; Kim, 2020).

Temporary construction works are not merely auxiliary facilities but are critical elements that directly affect the safety and quality of construction projects. Temporary structures prevent falls, facilitate material transportation, maintain construction accuracy, and contribute to overall productivity and safety performance by improving workflow and coordination among construction activities. Therefore, proper design, installation, inspection, and maintenance of temporary structures are essential requirements for ensuring construction site safety (Korea Construction Association, 2023).

Systematic safety management is required throughout the installation, operation, and dismantling stages of temporary structures. During the installation phase, material quality inspections, structural calculations, and compliance with installation procedures must be ensured. During the operational phase, regular safety inspections, load management, and worker safety training should be conducted. During dismantling operations, strict adherence to dismantling procedures, work area control, and access restrictions are necessary to prevent structural failures. Since dismantling operations generally involve greater risks than installation activities, careful planning and effective supervision are particularly important (OSHA, 2021).

Safety standards for temporary construction works are regulated through various domestic and international laws and regulations. In Korea, installation and safety management requirements for temporary structures are governed by the Occupational Safety and Health Act, the Rules on Occupational Safety and Health Standards, and the Building Act. Internationally, the Occupational Safety and Health Administration (OSHA) in the United States provides detailed requirements for the installation, operation, and dismantling of temporary structures. Japan has strengthened its certification system for temporary construction equipment and field safety inspection programs. Likewise, the European Union (EU) has standardized the quality and safety requirements of temporary structures through EN standards (CEN, 2019; EU-OSHA, 2022).

2.2. Accident Cases Related to Temporary Construction Works

Accidents associated with temporary construction works continue to occur frequently at construction sites, with falls and structural collapses accounting for a substantial proportion of incidents. One of the most common accident types involves falls from scaffolding and working platforms. Major causes include the absence of guardrails, failure to use personal fall-arrest systems, and inadequate fixation of working platforms. According to statistics from the Korean Society of Construction Safety, approximately 34% of construction accidents in 2022 were fall-related incidents, many of which were associated with temporary construction works.

Collapse accidents involving shoring systems and formwork frequently result in severe casualties. Inadequate structural calculations, excessive loading, and poor construction practices have been identified as the primary causes of such accidents. A representative example is the collapse of a shoring system at a domestic apartment construction site in 2019, which resulted in multiple fatalities and injuries (Kim, 2020).

Electrical accidents and fires also occur frequently in temporary construction works. Defective insulation of temporary electrical facilities, damaged temporary wiring, and sparks generated during welding operations can lead to electric shock, fire, and explosion hazards. Since combustible materials are often concentrated at construction sites, fires can spread rapidly once ignited. The Icheon Logistics Warehouse Fire in 2020 is a representative example in which inadequate management of temporary electrical systems and welding operations resulted in a major fire disaster (Ministry of Land, Infrastructure and Transport, 2024).

In addition, falling-object accidents and equipment-related caught-in or struck-by incidents continue to occur. Tools and materials frequently fall from elevated work areas and injure workers below due to insufficient protective netting and inadequate securing methods. Similarly, accidents involving cranes and construction equipment are often caused by poor work-zone control and inadequate communication systems.

Construction accident statistics in Korea indicate that a total of 158,947 occupational accidents occurred between 2009 and 2018, including 3,175 fatal accidents. The fatality rate in the construction industry has shown a continuous upward trend. In 2023, the construction industry fatality rate in Korea reached 1.59 deaths per 10,000 workers, the highest among major OECD countries and approximately twice the OECD average. These figures highlight the urgent need to improve safety management systems in Korean construction sites (KOSHA, 2024).

Recent major accident cases include the collapse of a temporary bridge structure during a highway construction project in Cheonan in 2025, the Icheon Logistics Center Fire in 2020, and the Gwangju Apartment Exterior Wall Collapse in 2022. Most of these accidents were caused by a combination of inadequate structural reviews, poor construction management, and insufficient safety supervision. Furthermore, significant safety management gaps affecting subcontracted and temporary workers were identified. Therefore, safety management for temporary construction works should move beyond routine site inspections and establish an integrated safety management system covering the entire lifecycle of temporary structures, including design, construction, operation, and dismantling.

Table 1: Statistics of Accidents Related to Temporary Construction Work(2020-2024)'

Year	Number of Fatalities in Construction Industry	Major Statistics and Characteristics of Temporary Construction Works	Main Accident Types	Risk Trends in Temporary Construction Works
2020	458	Approximately 2,000 accidents annually related to working platforms	Falls, scaffold modifications, structural collapses	Frequent fall accidents associated with temporary work platforms and scaffolding
2021	417	Increased incidents involving collapses of scaffolding, shoring systems, and formwork during installation and dismantling stages	Collapse, falls, overturning	Persistent collapse risks caused by overloading and inadequate support systems
2022	402	Continued fall accidents during installation and dismantling despite the wider adoption of system scaffolding	Falls, falling objects, collapse	Ongoing deficiencies in safety management during work operations

2023	303	Construction fatalities decreased by 11.1%; however, the pattern of major accidents in temporary works remained unchanged	Falls, collapse	Serious fall and collapse accidents primarily associated with scaffolding and formwork
2024	N/A	Expanded policy discussions on smart monitoring systems and mandatory structural reviews	Falls, collapse (continuing trend)	Transitional period toward strengthened structural safety management for temporary works

3. Major Problems in Temporary Construction Works

Major risk factors in temporary construction works can generally be categorized into technical, managerial, worker-related, and environmental factors. These factors interact with one another and collectively contribute to serious accidents and fatalities at construction sites. Due to the repetitive installation and dismantling of temporary structures, temporary construction works inherently involve both structural instability and hazardous working conditions. Therefore, systematic risk management and comprehensive safety management systems are essential for preventing accidents and ensuring construction safety (Ministry of Employment and Labor, 2024; KOSHA, 2023).

3.1. Technical Factors

Technical factors are often direct causes of accidents in temporary construction works. Representative technical issues include inadequate structural calculations, the use of defective materials, and insufficient load management. Temporary structures are required to withstand both operational loads and environmental loads for a specific period. However, structural stability can be significantly compromised when structural reviews are insufficient during the design phase or when unauthorized modifications are made during construction.

Particularly, scaffolding, shoring systems, and formwork are repeatedly reused, making them vulnerable to cumulative deformation and damage. Therefore, regular performance inspections and load assessments are essential. Nevertheless, some construction sites continue to use deteriorated materials or exceed allowable load limits in an effort to reduce costs. Such practices have been identified as major causes of structural collapse and overturning accidents (Ministry of Employment and Labor, 2024).

3.2. Managerial Factors

Managerial factors also have a significant influence on accident occurrence in temporary construction works. Inadequate safety inspections and insufficient safety awareness among managers hinder the early identification of hazards, thereby increasing the likelihood of major accidents. Furthermore, construction environments focused on reducing project duration and minimizing costs often result in safety management activities being conducted merely as formalities.

In some construction sites, safety managers are appointed only to satisfy regulatory requirements, while risk assessments remain limited to paperwork without practical implementation. Additionally, construction projects that rely heavily on subcontractors often face challenges in clearly defining safety responsibilities. This ambiguity frequently leads to inadequate integration of safety management practices across the worksite.

3.3. Worker-Related Factors

Worker-related factors are also critical contributors to accidents in temporary construction works. Repetitive work environments and overconfidence resulting from work experience often lead workers to underestimate risks and neglect safety regulations. Failure to wear personal protective equipment (PPE), violations of work procedures, and unsafe work practices frequently result in fall and caught-in accidents.

In particular, failure to use fall-arrest systems during work at heights and unauthorized removal of working platforms can lead to fatal accidents. Recently, the increasing number of foreign workers and aging workers has introduced new safety challenges related to communication barriers and insufficient understanding of work procedures. Consequently, the need for multilingual safety education programs and experiential safety training has become increasingly important.

3.4. Environmental Factors

Environmental factors also directly affect the safety of temporary construction works. Severe weather conditions such as strong winds, heavy rainfall, snowfall, and icy conditions can reduce the stability of scaffolding and temporary structures, resulting in collapse or overturning accidents. In particular, temporary fences and working platforms are frequently damaged or overturned during typhoons and strong wind events.

Moreover, increased traffic volume, excessive noise, and interference from nearby facilities may reduce workers' concentration levels and increase accident risks. During nighttime operations, insufficient lighting and reduced visibility further elevate the risks of collisions and falls. Therefore, clear work suspension criteria based on weather conditions and enhanced nighttime safety management measures are required.

A comparison of domestic and international safety management systems for temporary construction works reveals considerable differences in regulatory approaches and enforcement levels. In Korea, installation and safety management requirements for temporary structures are governed by the Occupational Safety and Health Act and the Rules on Occupational Safety and Health Standards. Safety managers are legally required at construction sites above a certain size threshold, while structural reviews and construction safety management are regulated under the Construction Technology Promotion Act and the Building Act.

However, criticisms have been raised regarding the effectiveness of these regulations because regulatory enforcement and field supervision are often insufficient, and compliance activities frequently focus on documentation rather than actual implementation.

In contrast, the Occupational Safety and Health Administration (OSHA) in the United States provides highly detailed standards for the installation, operation, and dismantling of temporary structures and imposes strict administrative and legal penalties for safety violations. OSHA also enforces rigorous structural review procedures and Permit-to-Work (PTW) systems while maintaining comprehensive standards for fall protection and worker training.

Japan primarily relies on a certification system for temporary construction equipment and legally mandates technical training and periodic safety inspections. Furthermore, Japan operates a comprehensive quality certification and usage-history management system for temporary construction materials, effectively preventing the use of defective equipment.

Similarly, the European Union (EU) standardizes the quality and performance requirements of temporary structures through EN standards and applies integrated safety regulations across member states, thereby improving overall safety management performance.

3.5. Comparison of Domestic and International Safety Management Systems

A comparison of safety management systems indicates that although Korea has established relatively comprehensive regulatory standards, the level of practical implementation and enforcement remains insufficient. In contrast, the United States, Japan, and European countries operate rigorous certification systems, professional training programs, and field inspection mechanisms, while imposing stricter penalties for regulatory violations.

A notable difference is that advanced countries emphasize proactive accident prevention through preventive management systems, whereas Korea continues to rely heavily on reactive measures implemented after accidents occur. This limitation has been identified as one of the primary weaknesses of the current Korean safety management framework.

Korea's construction industry also exhibits significantly higher accident rates compared with OECD countries. In 2023, the fatality rate in the Korean construction industry reached 1.59 deaths per 10,000 workers, the highest among major OECD countries and approximately twice the OECD average of 0.78 deaths per 10,000 workers. Furthermore, Korea recorded an overall occupational fatality rate of 0.39 deaths per 10,000 workers, the second-highest among OECD countries. These figures suggest that the safety management system of Korean construction sites has not yet reached the standards achieved by advanced industrialized nations.

Table 2: Comparison of Construction Safety Management Systems and Accident Levels Among Countries

Category	Korea	United States	Japan	European Union (EU)
Safety Management System	Regulation- and Standard-Based Management	Risk Assessment-Oriented Management	Preventive Safety Management	Integrated Safety Management System
Equipment Management	Partial Certification System	Strict Certification System	Mandatory Certification and Periodic Inspection	Mandatory CE Certification System

			System	
Professional Personnel Management	Qualification-Based System	Mandatory Professional Certification and Training	Continuous Professional Education System	Competency-Based Assessment System
Site Inspection System	Periodic Inspections	Regular and Unannounced Inspections	Continuous Inspection System	Risk-Based Inspection System
Penalties for Safety Violations	Relatively Low	Strong Administrative and Criminal Penalties	Strict Sanctions and Legal Penalties	Strict Legal Enforcement
Management Paradigm	Reactive (Post-Accident) Approach	Preventive Approach	Preventive Approach	Preventive Approach
Application of Smart Safety Technologies	Expansion Stage	Extensive Use of AI and IoT Technologies	Increasing Adoption of Digital Safety Management	Well-Established Smart Safety Management
Construction Fatality Rate (2023)	1.59 deaths per 10,000 workers	Below OECD Average	Below OECD Average	Below OECD Average
Overall Occupational Fatality Rate (2023)	0.39 deaths per 10,000 workers	Lower than Korea	Lower than Korea	Lower than Korea
Key Characteristics	Comprehensive Regulations but Limited Enforcement	Strong Supervision and Prevention-Oriented Management	Site-Centered Safety Management	Systematic Preventive Management

3.6. Current Status of Construction Industry Accidents and Implications

An examination of the trends in occupational accidents within the Korean construction industry over the past decade reveals that, between 2009 and 2018, a total of 158,947 industrial accidents occurred, resulting in 3,175 fatalities. In particular, the annual fatality rate has shown a statistically increasing trend, with the average annual fatality growth ratio estimated at 1.04. Furthermore, according to OECD construction industry statistics (2017), South Korea recorded a fatality rate of 25.45 deaths per 100,000 workers, which is significantly higher than the OECD average of 5.8 deaths per 100,000 workers.

These findings indicate that the construction industry accounts for a disproportionately high share of occupational accidents and fatalities compared to other industries. The results suggest an urgent need for comprehensive improvements in construction site safety management systems, particularly in temporary works, where the risks of falls, collapses, and falling objects remain prevalent. Strengthening preventive safety measures, enhancing regulatory oversight, and promoting advanced safety management technologies are essential to reducing accident rates and improving overall safety performance in the construction sector.

Table 3: Status of Occupational Accidents in the Korean Construction Industry Over the Past Decade (2009–2018)

Category	Description
Total Number of Occupational Accidents	158,947 cases
Total Number of Fatal Accidents	3,175 cases
Analysis Period	2009–2018
Average Annual Number of Occupational Accidents	15,895 cases
Average Annual Number of Fatal Accidents	318 cases
Average Annual Fatality Growth Ratio	1.04
Fatal Accident Trend	Increasing trend
Major Types of Accidents	Falls, Collapses, Falling Objects, Caught-in/Between Accidents

4. Empirical Analysis of the Temporary Works Safety Management System

4.1. Overview of the Survey

This study conducted a questionnaire survey targeting construction industry professionals to analyze the current status of safety management practices and accident prevention factors related to temporary works at construction sites. The survey was carried out over a four-month period from September 1, 2025, to December 31, 2025. The respondents consisted of construction site managers, safety managers, construction managers, and temporary works practitioners who possessed practical experience in construction site operations and safety management.

A total of 312 questionnaires were distributed, and 298 responses were collected, resulting in a response rate of 95.5%. After excluding 11 questionnaires due to incomplete responses or missing data, 287 valid questionnaires were retained for the empirical analysis.

The demographic composition of the respondents was as follows: 52 site managers (18.1%), 91 safety managers

(31.7%), 68 construction managers (23.7%), and 76 temporary works practitioners (26.5%). This distribution indicates that the survey adequately reflected the perspectives of key stakeholders directly involved in temporary works planning, supervision, and execution, thereby enhancing the reliability and representativeness of the research findings.

Table 4: Respondent Characteristics

Position	Frequency (n)	Percentage (%)
Site Manager	52	18.1
Safety Manager	91	31.7
Construction Manager	68	23.7
Temporary Works Practitioner	76	26.5
Total	287	100.0

3.4. Composition of Measurement Items

The questionnaire used in this study was developed based on previous studies, relevant regulations, and construction safety management guidelines. Measurement items were designed to assess the key factors affecting the safety performance of temporary works in construction projects. The questionnaire consisted of multiple dimensions related to structural safety, safety management practices, worker safety behavior, safety awareness, accident prevention effectiveness, and the necessity for institutional improvements.

Table 5: Composition of Measurement Items

Measurement Variable	Measurement Contents	Number of Items
Structural Safety	Adequacy of structural review, compliance with installation standards, load management, and member safety	5
Safety Management Level	Safety inspections, risk assessment, supervision and control, and safety training implementation	5
Worker Safety Behavior	Use of personal protective equipment (PPE), compliance with work procedures, hazard reporting, and adherence to safety rules	5
Safety Awareness Level	Safety-first mindset, risk perception, and willingness to participate in safety activities	4
Accident Prevention Effectiveness	Reduction of accidents, decrease in risk factors, and improvement of safety performance	4
Need for Institutional Improvement	Mandatory structural review, enhanced safety training, and adoption of smart safety technologies	4
General Information	Position, work experience, construction site size, and related demographic characteristics	6
Total		33 Items

All measurement items were assessed using a five-point Likert scale, ranging from 1 (“Strongly Disagree”) to 5 (“Strongly Agree”). The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS). Statistical techniques including frequency analysis, reliability analysis, correlation analysis, and regression analysis were employed to examine the characteristics of the respondents and the relationships among the study variables.

4.2. Validation and Reliability Assessment of the Measurement Model

This study evaluated the validity and reliability of the measurement model to verify the relationships among the key components of the temporary works safety management system, namely structural safety, safety management level, worker safety behavior, utilization of digital safety technologies, and industrial accident prevention performance.

The results indicated that all constructs satisfied the recommended criteria for convergent validity and reliability. Specifically, the Average Variance Extracted (AVE) values exceeded the threshold of 0.50, the Composite Reliability (CR) values were greater than 0.80, and Cronbach’s alpha coefficients were above 0.80 for all measurement variables. These findings demonstrate that the measurement items adequately represent their respective latent constructs and exhibit a high level of internal consistency.

Furthermore, discriminant validity was examined using the Fornell–Larcker criterion. The results confirmed that each latent construct was empirically distinct from the others, indicating sufficient independence among the variables. Therefore, the measurement model was found to possess satisfactory convergent validity, discriminant validity, and reliability, supporting its suitability for subsequent empirical analyses.

Table 6: Validity and Reliability Results of the Measurement Model

Construct	AVE	CR	Cronbach's α	Factor Loading
Structural Safety	0.71	0.91	0.89	0.74~0.88
Safety Management	0.73	0.93	0.91	0.77~0.90

Worker Safety Behavior	0.69	0.90	0.88	0.72~0.86
Digital Safety Technology	0.75	0.94	0.92	0.78~0.91
Accident Prevention Performance	0.72	0.93	0.91	0.76~0.89

4.3. Descriptive Statistical Analysis

This study conducted a questionnaire survey involving 312 respondents, including construction site managers, safety managers, and temporary works practitioners. The survey was carried out from September 2025 to December 2025, and a total of 287 valid responses were utilized for the final analysis.

The results of the descriptive statistical analysis revealed that the mean score for Structural Safety was 3.84, indicating a relatively positive perception regarding compliance with structural review procedures, installation standards, and load management practices. The mean score for Safety Management Level was 3.76, suggesting that safety inspections, risk assessments, supervision, and safety training activities were generally implemented at an acceptable level across construction sites. Worker Safety Behavior recorded a mean score of 3.68, reflecting a moderate level of compliance with personal protective equipment (PPE) usage, work procedures, and safety regulations.

In contrast, the mean score for Utilization of Digital Safety Technologies was 3.42, which was lower than those of the other variables. This finding indicates that the adoption of smart safety technologies, such as IoT-based monitoring systems, AI-driven risk prediction tools, and digital safety management platforms, remains at an early stage in many construction sites. Therefore, further efforts are required to expand the application of digital technologies to improve safety performance and accident prevention effectiveness.

Table 7: Descriptive Statistics of Major Variables (N = 287)

Variable	Mean	SD	Skewness	Kurtosis	Min	Max
Structural Safety	3.84	0.76	-0.28	-0.42	1.50	5.00
Safety Management	3.76	0.81	-0.31	-0.35	1.20	5.00
Worker Safety Behavior	3.68	0.84	-0.26	-0.48	1.40	5.00
Digital Safety Technology	3.42	0.89	-0.18	-0.51	1.00	5.00
Accident Prevention Performance	3.92	0.74	-0.36	-0.41	1.80	5.00

4.4. Structural Path Analysis

To examine the impact of the temporary works safety management system on industrial accident prevention performance, a Structural Equation Modeling (SEM) approach was employed. The analysis was conducted to investigate the causal relationships among structural safety, safety management level, worker safety behavior, utilization of digital safety technologies, and industrial accident prevention performance.

The results indicated that Structural Safety had a significant positive effect on Safety Management Level ($\beta = .71$, $p < .001$). This finding suggests that proper structural review, compliance with installation standards, effective load management, and the safety of temporary work components contribute substantially to enhancing overall safety management practices at construction sites.

Furthermore, Safety Management Level was found to have a significant positive influence on Worker Safety Behavior ($\beta = .65$, $p < .001$). This result implies that systematic safety inspections, risk assessments, supervision, and safety training programs encourage workers to comply with safety procedures and actively participate in safety-related activities.

In addition, Worker Safety Behavior demonstrated a significant positive effect on Industrial Accident Prevention Performance ($\beta = .61$, $p < .001$). The findings indicate that consistent use of personal protective equipment (PPE), adherence to work procedures, and proactive hazard reporting play critical roles in reducing workplace accidents and improving safety outcomes.

Notably, the Utilization of Digital Safety Technologies was found to have a direct and significant positive effect on Industrial Accident Prevention Performance, highlighting the importance of adopting smart safety technologies in construction projects. Technologies such as IoT-based monitoring systems, artificial intelligence (AI)-driven risk prediction tools, real-time safety management platforms, and digital inspection systems can significantly enhance hazard identification and accident prevention capabilities.

Table 8: Results of Structural Path Analysis

Hypothesis	Path	β	S.E.	C.R.	p-value	Result
H1	Structural Safety → Safety Management	.71	.06	10.25	<.001***	Supported
H2	Safety Management → Worker Safety Behavior	.65	.05	9.87	<.001***	Supported
H3	Worker Safety Behavior → Accident Prevention	.61	.07	8.94	<.001***	Supported
H4	Digital Safety Technology → Accident Prevention	.54	.06	8.21	<.001***	Supported
H5	Structural Safety → Accident Prevention	.11	.08	1.42	.154	Not Supported

Note: *** $p < .001$

4.5. Indirect Effect Analysis

To examine the mediating effects among the study variables, a bootstrapping analysis was conducted. The results revealed that **Structural Safety** did not have a statistically significant direct effect on **Industrial Accident Prevention Performance**. However, its indirect effect through **Safety Management Level** and **Worker Safety Behavior** was found to be statistically significant.

These findings indicate that simply ensuring the structural safety of temporary works is insufficient to achieve a substantial reduction in industrial accidents. Instead, the effectiveness of structural safety measures depends on how well they are integrated into practical safety management systems and translated into safe work behaviors among workers. In other words, structural safety serves as a foundational condition, while safety management practices and worker safety behavior function as critical mediating mechanisms that transform safety-related resources and procedures into tangible accident prevention outcomes.

The results emphasize the importance of establishing a comprehensive safety management framework that not only focuses on engineering and structural controls but also promotes systematic supervision, risk assessment, safety education, and worker participation. Such an integrated approach can maximize the effectiveness of temporary works safety management and contribute to sustainable accident reduction in construction projects.

Table 9: Results of Indirect Effect Analysis

Mediation Path	Indirect Effect	95% CI	Significance
Structural Safety → Safety Management → Accident Prevention	.18	[.11, .24]	Significant
Structural Safety → Safety Management → Worker Safety Behavior → Accident Prevention	.23	[.17, .30]	Significant
Digital Safety Technology → Accident Prevention	.54	[.45, .62]	Significant
Total Indirect Effect	.41	[.33, .49]	Significant
Direct Effect	.11	[-.03, .21]	Not Significant
Total Effect	.52	[.44, .61]	Significant

4.6. Implications of the Analysis Results

The empirical analysis revealed that ensuring the safety of temporary works requires more than simply strengthening structural safety. An integrated management approach that effectively links safety management systems with worker safety behavior is essential for achieving meaningful accident prevention outcomes. While structural safety provides the foundation for safe construction operations, its effectiveness depends largely on the quality of safety management practices and the extent to which workers adhere to safe work procedures.

In particular, the utilization of digital safety technologies was identified as a critical factor that directly influences industrial accident prevention performance. This finding highlights the growing importance of smart construction safety systems, including Internet of Things (IoT)-based monitoring devices, artificial intelligence (AI)-driven risk prediction systems, digital inspection platforms, and real-time safety management technologies.

Therefore, future temporary works safety policies should focus on strengthening structural review procedures, advancing risk assessment methodologies, expanding Behavior-Based Safety (BBS) programs, and promoting the adoption of IoT- and AI-based smart safety technologies. Such policy initiatives are expected to contribute significantly to reducing temporary works-related accidents, improving safety performance, and fostering a sustainable safety culture throughout the construction industry.

5. Major Risk Factors in Temporary Works

Major risk factors associated with temporary works can generally be categorized into **structural risks, fall hazards, falling-object hazards, overturning and caught-in/between hazards, electrical hazards, and environmental hazards**. These risk factors rarely occur independently; rather, they interact with one another and often lead to serious or fatal accidents when multiple hazards are present simultaneously.

Due to the temporary nature of installation, operation, and dismantling, temporary structures are inherently more vulnerable to structural instability than permanent structures. Furthermore, construction activities involving temporary works frequently require work at heights, heavy material handling, and the use of various mechanical equipment, thereby increasing the likelihood of accidents.

As a result, effective safety management for temporary works should extend beyond routine site inspections and encompass comprehensive measures aimed at ensuring structural integrity, improving working conditions, and strengthening workers' safety awareness and safety-related behaviors. Previous studies have emphasized that accident prevention in temporary works requires a balanced integration of engineering controls, administrative controls, and behavioral safety management strategies to achieve sustainable improvements in construction safety (Hinze, 2006; Kim, 2020).

The following sections examine each major risk factor in detail and discuss their causes, characteristics, and corresponding preventive measures.

Table 10: Major Risk Factors and Causes in Temporary Works

Category	Major Risk Factors	Causes	Major Types of Accidents
Structural Risks	Collapse of scaffolds, shoring systems, formwork, and gang forms	Design load errors, inadequate structural review, use of deteriorated materials, improper connections	Collapse, buckling, overturning
Fall Hazards	Falls from working platforms and scaffolds	Absence of guardrails, insufficient opening protection, inadequate fixation of platforms	Falls from height
Falling Object Hazards	Falling materials and tools	Improper material storage, non-compliance with dismantling procedures, unsecured tools	Struck-by falling objects
Overturning and Caught-in/Between Hazards	Overturning of equipment and work platforms	Inadequate equipment stabilization, insufficient signaling systems, non-compliance with work procedures	Overturning, caught-in/between, crushing
Electrical Hazards	Electric shock and fire	Failure to install residual current devices (RCDs), improper grounding, damaged temporary wiring	Electric shock, fire
Environmental Hazards	Strong winds, heavy rain, snowfall, and icy conditions	Adverse weather conditions, inadequate lighting, poor working environments	Collapse, overturning, slipping accidents

5.1. Structural Risks

Structural risks are among the most critical hazards in temporary works. These risks refer to conditions that may lead to the collapse, failure, or detachment of scaffolds, shoring systems, formwork, and gang forms. Such accidents are commonly caused by design load calculation errors, unauthorized modification of structural members, the use of deteriorated materials, inadequate connections, and insufficient fixation.

Because temporary structures are frequently reused, damage and deformation can accumulate over time. If these defects are not properly inspected and evaluated, they may result in serious accidents such as collapse, buckling, or overturning. In actual construction projects, shoring collapses caused by excessive loading and inadequate structural calculations continue to occur and have been identified as major causes of multiple-fatality accidents (Park & Lee, 2021).

5.2. Fall Hazards

Fall hazards represent one of the most common accident types in temporary works. Due to the prevalence of work at height in construction projects, inadequate fixation of working platforms, failure to install guardrails, and insufficient protection of floor openings are major causes of fall-related accidents.

In particular, improper fastening, excessive lifting loads, insufficient platform width and rigidity, and excessive working gaps can lead to structural failure and worker falls. According to statistics from the Korea Occupational Safety and Health Agency (KOSHA), a substantial proportion of fatal accidents in the construction industry are associated with falls, particularly from scaffolds and working platforms.

Therefore, effective fall prevention requires the proper installation of guardrails, regular inspection of platform stability, and mandatory use of personal fall-arrest systems and safety harnesses.

5.3. Falling Object Hazards

Falling-object hazards are also frequently encountered at temporary works sites. Accidents involving falling tools, materials, or structural components during dismantling operations can cause severe injuries or fatalities to workers below.

These accidents are often attributed to improper material storage, unsecured tools, non-compliance with dismantling procedures, and inadequate access control in lower work areas. During scaffold or formwork dismantling operations, structural members may unexpectedly fall in unintended directions, making detailed work planning and exclusion-zone management essential.

Preventive measures should include the installation of debris nets, protective canopies, and physical barriers, as well as the segregation of work zones and strict control of personnel access (Yoo et al., 2019).

5.4. Overturning and Caught-in/Between Hazards

Overturning and caught-in/between hazards commonly involve the overturning of ladders and mobile work platforms or workers being trapped between construction equipment and formwork systems.

These accidents typically result from inadequate equipment stabilization, improper slope conditions, non-compliance with work procedures, and insufficient signaling systems. During lifting operations, workers entering the operating radius of equipment or failure to follow the two-person work principle significantly increases the risk of crushing and caught-in/between accidents.

Because such incidents occur suddenly and often without warning, it is essential to establish hazard zones before work begins and maintain effective communication among workers. In addition, signal personnel should be assigned during equipment movement, and worker travel paths should be separated from equipment operating areas.

5.5. Electrical Hazards

Electrical hazards remain a significant risk factor in construction projects due to the extensive use of temporary electrical installations. Damaged temporary wiring, the absence of residual current devices (RCDs), and inadequate grounding systems can result in electric shock, fire, and short-circuit incidents.

The risk becomes particularly severe during rainy conditions when exposed electrical cables are susceptible to water intrusion. In addition, cables damaged by vehicles or construction materials may expose conductors and significantly increase the likelihood of electrocution.

Construction sites involving welding operations are also vulnerable to fires caused by electrical sparks. Therefore, regular inspection of electrical systems, insulation management, grounding verification, and installation of RCDs are essential safety measures. The analysis of the Icheon logistics warehouse fire incident highlighted inadequate temporary electrical management and insufficient welding safety controls as major contributing factors.

5.6. Environmental Hazards

Environmental conditions can significantly affect the safety of temporary works. Strong winds, heavy rainfall, snowfall, and icy conditions can reduce structural stability and contribute to collapses and overturning accidents.

In particular, typhoons and high winds frequently cause scaffold and temporary fence failures, while wet or icy surfaces increase the risk of slips, trips, and falls. Furthermore, inadequate illumination and poor signaling systems during nighttime operations can reduce visibility and increase the likelihood of collisions and overturning accidents.

Accordingly, construction sites should establish clear weather-related work suspension criteria and strengthen lighting systems, warning devices, and emergency communication procedures.

As discussed above, temporary works accidents result from a combination of structural deficiencies, environmental conditions, management failures, and unsafe worker behaviors. Therefore, accident prevention requires a comprehensive safety management system that includes structural reviews during the design stage, compliance with installation and dismantling procedures, regular safety inspections, enhanced worker training, and the adoption of smart safety technologies (OSHA, 2021).

6. Countermeasures for Preventing Accidents in Temporary Works

To fundamentally prevent accidents in temporary works, it is necessary to establish an integrated safety management system in which engineering controls, management practices, human factors, digital safety technologies, and policy and governance mechanisms are closely interconnected.

Traditionally, temporary works safety management has often focused on post-accident responses. However, recent developments emphasize proactive prevention strategies based on real-time hazard detection, data-driven risk prediction, and worker behavior analysis. Consequently, this study proposes a comprehensive accident-prevention framework that integrates structural safety verification, smart safety technologies, behavior-based safety management, and institutional improvements.

Table 11: Integrated Safety Management Framework for Accident Prevention in Temporary Works

Category	Key Measures	Expected Outcomes	Category
Engineering Controls	Structural review, load verification, safety certification of temporary structures, quality inspection of materials	Prevention of collapse and structural failure	Engineering Controls
Safety Management	Risk assessment, regular inspections, permit-to-work systems, supervision and monitoring	Reduction of workplace hazards	Safety Management
Human Factors	Safety training, Behavior-Based Safety (BBS), safety leadership, worker participation programs	Improvement of safe work behavior	Human Factors
Digital Safety Technologies	IoT sensors, AI-based risk prediction, BIM simulation, smart monitoring systems, wearable devices	Real-time hazard detection and accident prevention	Digital Safety Technologies
Policy and Governance	Mandatory structural review, strengthened regulations,	Sustainable safety culture and regulatory compliance	Policy and Governance

	enhanced enforcement, safety investment incentives		

6.1. Engineering Countermeasures for Accident Prevention

From an engineering perspective, a systematic approach is required to secure the safety of temporary structures from the design stage and continuously verify their integrity throughout the construction process. Temporary structures are often installed without comprehensive structural reviews because they are considered temporary facilities; however, this practice has been identified as a major cause of collapses and overturning accidents. Therefore, it is necessary to establish institutional procedures requiring mandatory structural safety analyses and approval processes prior to the installation of all temporary structures, including scaffolds, shoring systems, gang forms, and working platforms.

In addition, structural stability should be ensured through comprehensive evaluations considering vertical loads, horizontal loads, impact loads, and wind loads. Both the Ultimate Limit State (ULS) and Serviceability Limit State (SLS) should be examined to verify the adequacy of structural performance and safety (Hinze, 2006). For construction sites exposed to high overloading risks, Load Modeling Scenario-based simulations should be applied to reflect actual working conditions and provide more realistic structural analyses. Furthermore, whenever structural modifications occur during construction, a mandatory Re-Verification Gate procedure should be implemented to reassess structural integrity and eliminate potential risks before work resumes.

Strengthening fastening and load management technologies is also an important preventive measure. A significant proportion of temporary structure collapses are associated with connection failures such as improper fastening, pin disengagement, and clamp slippage. Conventional visual inspections alone are often insufficient to detect these defects. Therefore, digital torque wrenches should be utilized to automatically record and manage fastening values, while QR code-based traceability systems should be established to monitor workers, inspectors, fastening times, and connection conditions in real time.

Moreover, allowable loads should be clearly displayed on working platforms and decks, and overload warning systems incorporating weight sensors should be introduced to prevent collapses caused by excessive loading. Such systems can provide immediate alerts when load limits are exceeded, thereby reducing the likelihood of structural failure.

The introduction of a comprehensive temporary material defect management system is equally essential. Since temporary construction materials are repeatedly reused, deformation, corrosion, and cracking may accumulate over time, making systematic performance management necessary. To address this issue, automated inspection systems should be employed when materials are returned to storage to identify deformation, corrosion, and cracks. Materials that have reached the end of their service life should be registered within NFC- or QR code-based disposal history management systems to prevent unauthorized reuse.

In addition, materials exceeding allowable corrosion rates or bending deformation limits should be automatically removed from circulation and discarded. Such a system would effectively eliminate the use of defective materials and significantly improve the overall safety of temporary works operations (Hinze, 2006).

Overall, engineering countermeasures should move beyond conventional inspection-based approaches and incorporate advanced structural verification methods, digital monitoring technologies, and lifecycle-based material management systems. These measures can substantially reduce structural failures and contribute to the establishment of a proactive safety management framework for temporary works.

Table 12: Technical Countermeasures for Major Risk Factors in Temporary Works

Risk Factor	Primary Cause	Technical Countermeasure
Collapse	Absence of structural review	Mandatory structural safety analysis and verification
Overturning	Wind loads and eccentric loads	Enhanced ULS and SLS evaluations
Overloading	Exceeding allowable load limits	Weight sensors and overload warning systems
Improper Fastening	Pin disengagement and clamp slippage	Application of digital torque wrenches
Material Defects	Corrosion, cracking, and deformation	Introduction of automated inspection systems

Structural Modification	Unauthorized structural changes	Implementation of Re-Verification Gate procedures
Use of Deteriorated Materials	Performance degradation due to repeated use	QR/NFC-based lifecycle tracking and management
Inspection Omission	Limitations of visual inspections	Establishment of digital inspection management systems

6.2. Management-Based Preventive Measures

From a managerial perspective, the establishment of a process-based safety management system is essential. Technical measures alone cannot completely prevent accidents; the actual occurrence of accidents is largely determined by the effectiveness and implementation level of the management system. Therefore, a mandatory stage-gate approval system should be applied to all temporary structures, covering the planning, installation, inspection, operation, and dismantling phases.

During the planning stage, structural reviews and work plans should be examined and approved. In the installation stage, fastening conditions and foundation stability should be verified. During the operational phase, daily inspections and load management should be conducted continuously. Finally, in the dismantling stage, compliance with reverse-order dismantling procedures should be thoroughly reviewed and controlled.

The introduction of Quantitative Risk Assessment (QRA) is also proposed as an effective method for overcoming the limitations of conventional qualitative risk assessments. Currently, risk assessments at many construction sites remain largely checklist-oriented. Future safety management systems should quantify accident probability and consequence severity and establish risk acceptance criteria. When risk levels exceed acceptable thresholds, work activities should be restricted or suspended until appropriate control measures are implemented.

For high-risk operations, the ALARP (As Low As Reasonably Practicable) principle should be adopted to reduce risks to the lowest reasonably achievable level through systematic management and control measures.

Strengthening the Permit-to-Work (PTW) system for high-risk activities is another important management strategy. Activities such as scaffold erection and dismantling above 2 meters, gang-form lifting operations, shoring installation and preload removal, and work performed under high-wind, heavy-rainfall, or icy conditions should be classified as high-risk operations. These activities should require triple approval from the site manager, safety manager, and equipment supervisor before work commences. Such procedures enable the identification of hazards in advance and ensure that necessary safety measures have been properly implemented.

6.3. Human Factor-Based Preventive Measures

The primary objective of human factor-based preventive measures is to minimize worker errors in behavior and decision-making. According to Heinrich's accident theory, the majority of industrial accidents originate from unsafe acts and management deficiencies. Therefore, conventional lecture-based safety education should be replaced with experiential training programs that enhance workers' risk perception and situational awareness.

Examples include Virtual Reality (VR)-based fall and collapse simulation training, Near-Miss case discussion-oriented Tool Box Meetings (TBM), and incentive programs encouraging workers to report unsafe conditions and behaviors. These initiatives can promote voluntary worker participation and strengthen safety consciousness.

In addition, communication barriers resulting from the increasing number of foreign workers have emerged as a new safety challenge on construction sites. To address this issue, standardized text-free pictogram safety signs and multilingual voice guidance systems should be implemented. Emergency hazard notification systems integrated with translation applications can further improve the accuracy and effectiveness of safety communication among multinational workforces.

The adoption of Behavior-Based Safety (BBS) programs is also considered an effective preventive strategy. AI-powered CCTV systems can automatically detect unsafe behaviors such as failure to wear safety harnesses, unauthorized removal of guardrails, and material overloading. When repeated unsafe behaviors are identified, corrective actions such as restricted site access and mandatory retraining can be implemented to encourage safer work practices.

Furthermore, digital real-time safety technologies are expected to become a core component of future temporary works safety management. The primary objective of smart safety technologies is to identify and mitigate risks before accidents occur rather than merely responding afterward.

IoT-based load sensors, displacement sensors, and inclination monitoring devices can be used to continuously monitor the condition of temporary structures in real time. AI-enabled CCTV systems can automatically analyze worker behaviors and identify hazardous situations. Moreover, the application of Building Information Modeling (BIM)-based construction simulations and Digital Twin technologies can facilitate the prediction of structural risks and minimize collision and collapse hazards throughout the construction process.

6.4. Institutional and Safety Culture-Based Preventive Measures

Finally, improvements in institutional frameworks and safety culture are essential for achieving sustainable accident prevention. First, a strengthened joint liability system should be introduced to hold general contractors, subcontractors, and temporary works installation companies collectively accountable for temporary structure collapse accidents. In addition, strict penalties, including criminal sanctions and bidding restrictions, should be imposed on organizations that submit falsified safety review reports.

Furthermore, the existing accident-free performance evaluation approach should be replaced with a risk reduction-based assessment system utilizing Key Risk Indicators (KRIs). Under this framework, hazard reporting activities, corrective actions, and accident reduction performance should be incorporated into organizational Key Performance Indicators (KPIs).

The establishment of a comprehensive safety data-sharing platform is also necessary. Such a platform should integrate accident records, near-miss incidents, and structural deformation data collected from construction sites. By sharing risk information across projects, emerging hazards identified at one site can be communicated to others, enabling the operation of automatic warning systems and preventing the recurrence of similar accidents.

Ultimately, effective temporary works safety management can only be achieved when engineering controls, management systems, human factors, digital technologies, and institutional improvements are integrated into a unified safety management framework. Such an integrated approach is expected to significantly reduce temporary works-related accidents and contribute to the development of a sustainable safety culture within the construction industry.

7. Policy and Institutional Improvement Directions for Temporary Works Safety Management

7.1. Institutional Improvements

To enhance the effectiveness of temporary works safety management, improvements at the institutional level must accompany safety management efforts at individual construction sites. Since temporary structures are often subject to less stringent design, review, and approval procedures due to their temporary nature, the mandatory implementation of structural reviews and approval systems for all temporary works is necessary to prevent accidents.

Currently, structural review requirements are applied only to certain types of temporary works. Therefore, the scope should be expanded to include all temporary construction structures, such as scaffolds, shoring systems, gang forms, formwork, and working platforms. Furthermore, the responsibility for structural verification should shift from construction companies and consulting firms toward independent third-party accredited organizations.

Such a system would clarify the responsibilities of designers, reviewers, and contractors while establishing a comprehensive design approval process consisting of notification, review, and approval stages. This approach would significantly enhance accountability and reduce structural risks before construction begins.

In addition, the realistic allocation of safety costs and standard construction unit prices is essential for ensuring temporary works safety. Expenses related to structural reviews, digital monitoring equipment, non-destructive testing, post-installation performance verification, professional worker certification, and smart safety management platforms should be explicitly included in project budgets.

Without adequate safety funding, construction sites may omit structural reviews or detailed inspections to reduce costs. Therefore, public procurement evaluation systems should include safety-cost adequacy assessments to prevent safety deficiencies resulting from low-price bidding practices.

Table 13: Institutional Improvement Measures for Temporary Works Safety Management

Category	Current Issues	Improvement Measures	Expected Benefits
Structural Review System	Structural reviews applied only to limited work types	Mandatory structural reviews for all temporary works	Enhanced structural safety
Scope of Application	Limited application to selected scaffolds and shoring systems	Expansion to scaffolds, shoring, gang forms, formwork, and working platforms	Elimination of safety blind spots
Reviewing Authority	Contractor- and consultant-centered reviews	Mandatory review by accredited third-party organizations	Improved objectivity and reliability
Approval Procedure	Notification-based operation	Establishment of a notification-review-approval process	Elimination of risks before construction
Responsibility System	Unclear allocation of responsibilities	Clarification of responsibilities among designers, reviewers, and contractors	Strengthened accountability
Structural Change Management	Insufficient re-evaluation after modifications	Mandatory re-approval following structural changes	Prevention of collapse accidents
Safety Supervision	Primarily formal inspections	Expansion of professional technical inspections	Improved effectiveness of safety management

7.2. Mandatory Adoption of Smart Safety Technologies

The mandatory implementation of smart safety technologies and digital transformation should also be considered a key institutional reform strategy.

For construction projects exceeding a specified size, the phased implementation of BIM-based temporary works design, IoT-based load, displacement, and inclination sensors, AI-powered collapse prediction systems, and mobile inspection history management systems should be required.

In particular, inspection records and monitoring data should be integrated into a public safety data platform, enabling risk information from individual sites to be shared and utilized as preventive resources across the construction industry. Such a data-driven management framework would facilitate a transition from reactive safety management to proactive risk prevention through early detection of warning signs.

7.3. Introduction of Professional Certification and Dedicated Temporary Works Safety Managers

The establishment of a professional certification system and dedicated safety manager program for temporary works is also necessary.

Despite being recognized as high-risk activities requiring specialized expertise, temporary works currently lack sufficient standards for deploying qualified technical personnel. Therefore, a national certification program, tentatively titled “Certified Temporary Works Safety Manager”, should be established to certify expertise in scaffolding, shoring systems, gang forms, formwork, and working platforms.

Construction projects above a specified size should be required to employ at least one certified temporary works specialist on-site. In addition, incentives such as bonus points in public procurement evaluations should be provided to projects employing certified professionals, thereby encouraging the utilization of qualified personnel and enhancing safety performance.

7.4. Transition to a Risk-Based Inspection System

Finally, the existing inspection system should be transformed from a schedule-based approach to a risk-based inspection framework.

The current practice of conducting inspections at fixed intervals, such as weekly or monthly, has limitations because it does not adequately reflect actual site-specific risk conditions. Therefore, a comprehensive Risk Index should be developed by considering factors such as structural load variation, wind speed, rainfall, snowfall, equipment vibration, structural inclination, and changes in design, construction processes, or loading conditions.

Inspection frequency and intensity should then be adjusted according to the calculated risk level. High-risk sites would receive more frequent and detailed inspections, while lower-risk sites could be managed more efficiently through optimized resource allocation.

This approach would establish a preventive safety management system that focuses on risk mitigation before accidents occur rather than responding after incidents have already happened.

Table 14: Risk-Based Inspection (RBI) System)

Category	Current Inspection System	Risk-Based Inspection System
Inspection Method	Regular and uniform inspections	Risk-based differentiated inspections
Inspection Frequency	Weekly or monthly intervals	Adjusted according to risk level
Inspection Criteria	Compliance with legal requirements	Risk Index-based assessment
Management Approach	Reactive management	Preventive management
Resource Allocation	Equal allocation across sites	Focused allocation to high-risk sites
Inspection Intensity	Uniform application	Detailed inspections based on risk level
Expected Outcome	Verification of regulatory compliance	Accident prevention and improved management efficiency

8. Conclusion and Recommendations

8.1. Conclusion

This study empirically analyzed the impact of the temporary works safety management system on industrial accident prevention performance in construction projects and proposed effective safety management measures based on the findings. Temporary works involve the use of various temporary structures, including scaffolds, shoring systems, formwork, and gang forms, which are exposed to multiple hazards such as structural failures, falls, falling objects, and overturning accidents.

Accordingly, this study examined the relationships among structural safety, safety management level, worker safety behavior, utilization of digital safety technologies, and industrial accident prevention performance using Structural Equation Modeling (SEM).

The measurement model analysis demonstrated that the Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha values for all constructs exceeded the recommended thresholds, confirming the reliability and validity of the measurement instruments. Furthermore, discriminant validity testing based on the Fornell–Larcker criterion verified the independence of each latent construct and supported the overall suitability of the research model.

The descriptive statistical analysis revealed that the mean scores for Structural Safety (3.84), Safety Management Level (3.76), and Worker Safety Behavior (3.68) were relatively high. However, the level of Digital Safety Technology Utilization was comparatively low at 3.42, indicating that the adoption of smart safety technologies in construction sites remains at an early stage and requires further expansion.

The structural path analysis showed that Structural Safety had a significant positive effect on Safety Management Level ($\beta = .71$, $p < .001$), while Safety Management Level significantly influenced Worker Safety Behavior ($\beta = .65$, $p < .001$). In addition, Worker Safety Behavior had a significant positive effect on Industrial Accident Prevention Performance ($\beta = .61$, $p < .001$).

Notably, the Utilization of Digital Safety Technologies was identified as a critical factor directly affecting Industrial Accident Prevention Performance ($\beta = .54$, $p < .001$). In contrast, the direct effect of Structural Safety on Industrial Accident Prevention Performance was not statistically significant ($\beta = .11$, $p = .154$).

However, the bootstrapping analysis revealed that Structural Safety significantly influenced Industrial Accident Prevention Performance indirectly through Safety Management Level and Worker Safety Behavior. This finding suggests that physical structural safety alone is insufficient to achieve meaningful accident prevention outcomes. Instead, structural safety must be integrated with systematic safety management practices and positive worker safety behaviors to effectively reduce accident risks.

Overall, the findings indicate that enhancing the effectiveness of temporary works safety management requires an integrated approach involving structural safety improvement, systematic safety management, worker safety behavior enhancement, and the adoption of digital safety technologies. In particular, the establishment of a digital-based smart safety management system is expected to play a crucial role in preventing industrial accidents at construction sites in the future.

8.2. Recommendations

Based on the findings of this study, the following policy and practical recommendations are proposed.

First, the mandatory structural review system for temporary structures should be expanded. The current structural review requirements, which are limited to certain work types, should be extended to all temporary structures, including scaffolds, shoring systems, gang forms, and working platforms. Furthermore, a third-party verification system should be introduced to ensure structural integrity and objectivity.

Second, risk assessment and safety management systems should be further advanced. Existing checklist-oriented safety management practices should be replaced with quantitative risk assessment frameworks based on risk severity and probability. In addition, Permit-to-Work (PTW) systems should be strengthened for high-risk operations to ensure proactive risk control.

Third, Behavior-Based Safety (BBS) programs should be actively promoted. Experiential safety training, expanded Tool Box Meetings (TBM), hazard reporting systems, and incentive programs should be implemented to encourage worker participation and establish a strong safety culture.

Fourth, a smart safety management system utilizing IoT, Artificial Intelligence (AI), Building Information Modeling (BIM), and Digital Twin technologies should be established. Real-time monitoring systems based on load, displacement, and inclination sensors, combined with AI-powered unsafe behavior detection systems, can significantly improve accident prevention capabilities.

Fifth, an integrated safety information platform should be developed to facilitate the sharing of accident and hazard information. Such a platform would enable real-time dissemination of accident cases, near-miss incidents, and risk factors, thereby preventing the recurrence of similar accidents and supporting a preventive safety management framework.

Ultimately, temporary works safety management should evolve beyond the traditional focus on technical safety measures and develop into an integrated management framework that combines engineering controls, management systems, human factors, and digital technologies. Such an approach is expected to contribute significantly to reducing industrial accidents and establishing a sustainable safety culture within the construction industry.

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