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Factors Affecting Quality Management Failure in Construction Projects

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Abstract : Identifying the root causes of substandard construction projects is crucial considering the social and economic issues structural failures can cause. To date, the focus has predominantly been on identifying and penalizing the culprits rather than uncovering the fundamental reasons. Therefore, this study aims to identify various factors that contribute to failures in construction project quality management, including aspects of substandard construction projects, and determine the relationship between these factors and substandard construction projects. Through a literature review and case analysis, 61 influential factors were identified. A survey targeting participants including structural designers, architectural designers, construction companies, CM, and researchers was conducted to gauge the consensus on these factors. A regression analysis was performed based on data from 724 survey respondents. Ultimately, based on the 17 key influencing factors identified by the regression analysis, 9 preventive measures against substandard construction projects were proposed. This study is significant as it elucidates the reasons behind construction project quality management failures that lead to substandard construction projects and establishes a framework for developing practical solutions to real-world problems rather than theoretical or abstract ones.

Keywords : Substandard Construction Project, Quality Management Failure, Regression Analysis

1. Introduction

1.1 Research Background and Purpose

The construction industry plays a significant role in the national economy. As of 2021, the proportion of construction investment in the GDP was 15%, and the average contribution rate to economic growth was 39.5% from 2015 to 2017 (Bank of Korea, 2022). As of 2015, the production and employment inducement coefficients were 1.15 and 1.10 times the overall industry average, respectively (ISTANS, 2023). Overseas construction is also making a resurgence, with orders expected to exceed $30 billion for the fourth consecutive year (MBC, 2023). According to ENR data, in 2021, the total overseas sales of Korea's 12 major construction companies amounted to $22.7 billion, comparable to the total exports of the shipbuilding industry, which were $23 billion. As of 2022, the number of construction companies in Korea had reached 87,239, of which 15,201 are general construction companies (KOSTAT, 2023). Additionally, approximately 2.1 million people are employed in the construction industry, accounting for 7.5% of the total employed population (27.808 million as of 2022; KOSTAT, 2023).

However, the general perception of the construction industry is negative. Regarding public opinion, including various media reports, not only is there negative content, but the number of students seeking to enroll in construction-related departments such as architectural and civil engineering is decreasing (dnews, 2020.02.10), and survey results indicate that 78% of college students majoring in construction already want to change career paths (koscaj, 2021.06.24). Greatly contributing to this negative image are the unforgettable structural collapse accidents that occur relatively frequently, as shown in

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Table 1. Structural Collapse Accident Statistics (since 2019, Source: CSI)

Divisions		Total	2019	2020	2021	2022	2023
Number of occurrences	Under construction	26	3	8	7	8	7
	In use	14	-	4	7	3	-
Number of Deaths	Under construction	35	2	9	14	10	2
	In use	17	-	-	15	2	-
Number of Injured	Under construction	64	5	23	20	16	12
	In use	11	-	-	10	1	-

〈Table 1〉.

Structural collapse accidents caused by substandard construction projects create social and economic problems. Such substandard construction projects can make buildings less safe, increase maintenance costs, and inconvenience end users. Additionally, such projects may reduce the reliability of the construction industry and have negative consequences for the national economy over time. Therefore, analyzing the root cause of substandard construction projects to prevent them is crucial. However, when a structural collapse occurs due to substandard construction, the focus has been on finding and punishing those responsible rather than identifying the root cause of the collapse.

Therefore, this study aims to identify the fundamental factors that influence quality control failures in construction projects. To achieve this, a literature review and case analysis are used to identify factors leading to quality control failures, and survey data from participants in construction projects is examined using regression analysis to verify the factors' significance. Through this study, by identifying the causes of substandard construction and proposing improvement measures, we aim to contribute to the prevention of substandard construction. By understanding what problems actually occur at construction sites and their causes, we can develop concrete implementation plans for measures that directly address problems at actual sites, rather than theoretical or abstract measures.

1.2 Research Methodology

The flow of the research to achieve the research objectives is as follows. In Section 2, factors affecting substandard construction are derived by reviewing previous studies that define the factors related to quality management failure in companies and projects, as well as analyzing accident investigation reports and press releases to identify the factors affecting substandard construction in Korea. In Section 3, substandard construction and its influencing factors are defined, and a preliminary survey is conducted with academic, research, and industry experts to review the items before the main survey. In Section 4, a survey is presented targeting participants with knowledge and experience relevant to construction projects (structural designers, architects, contractors, CM, academia/research), and the significant factors of substandard construction are identified based on a regression analysis performed on data provided by the main participants. Furthermore, based on the identified influencing factors of substandard construction, measures to prevent substandard construction are presented.

2. Preliminary Review

2.1 Results of Literature Review on Failure Factor Analysis

This study reviewed the literature defining the factors of quality management failure in companies or projects to define the influencing factors of substandard construction 〈Table 2〉.

Tuane et al. (2013) identified the factors leading to failures in quality management performance in Brazilian manufacturing companies. Through a literature review, 17 failure factors were identified, and their validity was verified through two case studies and expert interviews.

Hamad et al. (2015) identified the most influential causes of defects at construction sites to prioritize strategies for preventing construction defects. Thirty failure factors derived through the literature review were classified into organizational influences, defective

Table 2. Failure factors of quality management in existing literature

Divisions	Failure factors of quality management
Tuane et al. (2013)	Bureaucracy during the implementation Lack of communication Lack of leadership support Complexity of implementation Lack of training and employee development Lack of time to implement more complex practices Lack of sense of urgency Lack of technical knowledge Resistance to change Lack of shared responsibility among sectors Lack of links between quality, strategy and operations Lack of implementation planning Existence of different subcultures Using preset models, bumping into macro cultural differences Lack of credibility of who is implementing Do not disseminate positive result Negative history of other implementations
Hamad A. et al. (2015)	Organizational culture Time pressure and constraints Workplace quality system Financial constraints on operational expenses Inadequate employee training or learning opportunities.
Mohammad et. al. (2021)	Lack of mentorship Lack of commitment Imbalanced knowledge/experience Conflict of interest Lack of freedom of action Unclear authorization Lack of infrastructure and financial resources Inadequate monitoring program Lack of management review Nonconformance to procedures Deficient supplier management
Qi, Y. et al. (2021)	Poor operational skilled workers Lack of experienced project managers Poor checking procedures of site supervisors Use of poor materials Inadequate equipment performance Inaccurate design work Incomplete construction site survey Unauthorized changes in design documents Incomplete building information in projects Wrong construction flow Unsettled plan or lack of construction plan Poor site management Poor onsite coordination

supervision, and preconditions for defective acts. A survey conducted through the Project Pathogens Network (PPN) with 106 industry experts presented the five most pathogenic failure factors.

Mohammad et al. (2021) identified success and failure factors in implementing quality management systems in small and medium-sized enterprises. Through 21 expert interviews, 27 success and 12 failure factors were extracted, and factor analysis was conducted based on a survey with 298 respondents. Ultimately, 26 success and 11 failure factors were identified.

Qi et al. (2021) identified the failure factors of quality management in Chinese construction projects. Thirteen failure factors were derived through a literature review and expert opinions, and their validity and priority were verified through ISM and MICMAC and 22 focus group interviews.

This analysis of prior studies revealed that the barriers to quality management system operation can be broadly classified into problems related to (1) the quality management system itself, (2) organizational-level issues, and (3) individual-level issues.

2.2 Case Analysis of Collapses Due to Quality Management Failure

The most recent structural collapse incidents were analyzed to identify the hidden reasons for the apparent direct causes and potential underlying causes. The conditions leading up to the collapse incidents are summarized below (Yu, 2023).

First, the structural design errors revealed in the accident investigation reports were critical, these were errors in the initial design information. The structural calculation document omitted the shear check for some columns, while some columns had discrepancies with the shear reinforcement as per the structural calculation basis and actual shear reinforcement detailed in the document. It was also discovered that some beams and columns had discrepancies between the reinforcement based on the structural calculation basis in the document and the actual reinforcement details. Although the review committee deemed the structural design adequate, a discrepancy between the "reinforcement according to calculation basis" and "reinforcement in the member list" in the same structural calculation document is a serious issue. Additional discrepancies were found in the reinforcement of some structural members between the structural calculation document and structural drawings. The error in initial design information not only reflects the architectural structural engineers' lack of technical competence but also indicates problems with the design quality management system of the architectural structural design offices.

Second, a contractor violated the standards related to aggregate testing in the quality management plan. The frequency of concrete aggregate testing was applied uniformly across all aggregate sources, contrary to the relevant standards, and the frequency of aggregate testing was changed from 7 to 0 times when the quality management plan was revised. The contractor also substituted direct testing with documents submitted by the ready-mix concrete company, contrary to standard procedures. The supervisor reviewed this as being "no problem," and the client approved it without special reasons for adjusting the test frequency. Meanwhile, the contractor and supervisor did not check the record content of the aggregate testing items during the preliminary inspection of 10 out of 13 ready-mix concrete companies (5 government-supplied and 5 privately supplied) and proceeded to pour the ready-mix concrete without considering adjustments or changes to the mix, despite the test results from one of the three sites that conducted aggregate testing showing a significant change in the fine aggregate ratio (0.31) compared to the standard (0.2).

Third, landscaping work involving heavy machinery was conducted on the upper section of an underground parking lot, and both the contractor and supervisor failed to review and plan for all possible working loads.

Fourth, the project management system included several stages of review and approval processes (gateway review processes); however, design and construction errors were not filtered out during these processes, indicating that the project management system did not function properly. Thus, the issue was not so much the inadequacy of the project management system as its failure to operate correctly.

The causes identified above are categorized by responsible parties in 〈Table 3〉.

Table 3. Responsible person by direct cause

Divisions	Structural designer	Architectural designer	Constructor	Supervisor
Error in writing initial design information	V	V		
Violation of initial management standards			V	
Gateway review operation failure			V	V
Insufficient construction management skills			V	

Below, Section 3 defines substandard construction and its influencing factors, and Section 4 aims to provide significant influencing factors through regression analysis based on the responsible parties identified previously: structural designers, architects, contractors, and supervisors.

3. Derivation of Substandard Construction and its Influencing Factors

3.1 Substandard Construction

The government diagnosed that the direct causes of collapse incidents are comprehensive deficiencies due to design errors, poor construction, and inadequate supervision (Joint of Related Ministries, 2023). Accordingly, this study defines substandard construction as a comprehensive consequence of poor design, poor construction, and inadequate supervision resulting from the failure of construction project quality management due to the competency and attitude of project participants or the project management system not functioning properly.

- Poor design: Omission of design elements, inconsistencies between design documents, interference among design elements, etc.
- Poor construction: Construction that differs from the design documents, construction that does not meet quality standards, etc.
- Inadequate supervision: Omissions, oversights, misjudgments related to supervision tasks such as inspections/tests, etc.

3.2 Influencing Factors of Substandard Construction

In this study, by organizing the literature review on quality management failure in construction projects and accident investigation reports and press materials (100 cases in total) regarding nine structural collapse accidents that occurred between 2017 and 2023, the influencing factors leading to substandard construction were identified.

Although the existing literature discusses problems with the quality management system itself, organizational-level issues, and individual-level issues as main factors, the domestic construction industry is heavily influenced by regulations that are inseparable from changes in the macro-industrial and social environments. Therefore, this study categorizes the influencing factors of substandard construction into four main factors: (1) competence and attitude of the participating technicians or organizations, (2) project management system structure and operation, (3) institutional environment, and (4) construction industry and social environment. Initially, 50 detailed items were derived, and following a review by 10 industry and academic experts (average career experience: 19.2 years), 11 more items were added, resulting in 61 items in total.

3.2.1 Competence and Attitude of the Participating Technicians and Organizations

This includes a lack of technical competence related to quality, safety, processes, or costs, such as engineering knowledge, skills, and experience; a lack of professional attitude and responsibility, such as ethical consciousness, effort to fulfill duty, safety consciousness, quality consciousness; lack of a management system and insufficient review and approval outcomes at each work phase, and insufficient personnel input with required qualifications and competence 〈Table 4〉.

Table 4. Evaluation items for the capabilities and attitudes of engineers or organizations

Div.	Evaluation items
CA1	Functional decline of skilled personnel
CA2	Lack of technical competence in architectural design company personnel
CA3	Lack of technical competence in structural design company personnel
CA4	Lack of technical competence in construction company personnel
CA5	Lack of technical competence in supervisory company personnel
CA6	Lack of technical competence in personnel of ordering organizations and supervisory authorities
CA7	Lack of attitude and responsibility in skilled personnel
CA8	Lack of professional attitude and responsibility in architectural design company personnel
CA9	Lack of professional attitude and responsibility in structural design company personnel
CA10	Lack of professional attitude and responsibility in construction company personnel
CA11	Lack of professional attitude and responsibility in supervisory company personnel
CA12	Lack of professional attitude and responsibility in personnel of ordering organizations and supervisory authorities
CA13	Absent or inadequate internal design management system in architectural design companies
CA14	Absent or inadequate internal design management system in structural design companies
CA15	Absent or inadequate internal construction management system in construction companies
CA16	Absent or inadequate internal supervision management system in supervisory companies
CA17	Absent or inadequate internal construction management system in specialized construction companies
CA18	Lack of qualified and competent technical personnel in design tasks
CA19	Lack of qualified and competent technical personnel in construction tasks
CA20	Lack of qualified and competent technical personnel in supervisory tasks

3.2.2 Project Management System Structure and Operation

Regardless of how outstanding an individual's competence may be, it can only be utilized within the project management system; thus, individual capabilities cannot exceed the system's performance level. The structure and operation of the project management system include deficiencies that imply Plan-Do-Check-Action procedures for various reviews/inspections/tests/investigations/measuring/approvals at each construction project stage and deficiencies in the role-responsibility-authority sharing and collaboration system among project participants such as the client, architectural designer, structural designer, various specialized designers, and licensing authorities 〈Table 5〉.

Table 5. Evaluation items for the composition and operation of the project management system

Div.	Evaluation items
PMS1	Absent or inadequate project management system in ordering organizations and supervisory authorities
PMS2	Confusion due to different project management systems among ordering organizations and supervisory authorities
PMS3	Unclear or unreasonable role-responsibility-authority sharing system among participating entities
PMS4	Lack of coordination, collaboration, and communication among participating entities
PMS5	Decreased the effectiveness of project management tasks due to redundant/unnecessary work
PMS6	Poor or formalistic project management system operation
PMS7	Shortage of labor/infrastructure/resources for operating the project management system

3.2.3 Institutional Environment

There is a saying that the domestic construction industry is an institutional business, meaning it is heavily controlled by regulations. Especially for projects commissioned by public clients such as LH, they must proceed according to the process defined by regulations from beginning to end. Therefore, since the institutional environment has a significant impact on the construction industry, any problems within it must be found and

Table 6. Evaluation items for institutional environment

Div.	Evaluation items
IE1	Reduced construction/service fees due to price-focused contractor selection
IE2	Reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting
IE3	Irrational contractor-selection methods (e.g., favoring connections over technical ability, considering sales activities)
IE4	Unequal contract structures
IE5	Inappropriate design and construction periods
IE6	Design and construction period delays not recognized despite the client being at fault
IE7	Delays in design and construction due to external factors (e.g., unions, permits, supply of materials)
IE8	Insufficient size of supervisory staff relative to the volume of supervisory tasks according to placement standards
IE9	Inadequate effectiveness of the construction technician grading system related to supervisory staff placement standards
IE10	Excessive and duplicate intervention by ordering organizations and supervisory authorities hindering autonomous and effective construction
IE11	Poor quality or timely procurement of government-supplied materials
IE12	Hindrance of autonomous and effective construction due to excessive standard segmentation in laws (e.g., personnel placement standards, construction cost items)
IE13	Insufficient punishment for contract breach or poor design/poor construction/inadequate supervision
IE14	Inadequate re-education system and content for construction personnel
IE15	Inadequate school education system and content for construction personnel
IE16	Absence of a qualification or competence management system for construction skilled labor
IE17	Absence of a qualification or competence management system for construction technical personnel
IE18	Formalistic operation in reviews of engineering areas such as building permits or project plan approvals

Table 7. Evaluation items for the construction industry environment and social environment

Div.	Evaluation items
ISE1	Shortage of construction skilled labor supply
ISE2	Aging and shortage of skilled workers (e.g., forepersons, lead workers)
ISE3	Increase in foreign skilled labor
ISE4	Lack of qualified architects in the design phase
ISE5	Lack of qualified structural engineers in the design phase
ISE6	Aging of supervisory staff
ISE7	Misuse/abuse of authority to replace supervisory staff by the client
ISE8	Misuse/abuse of replacing supervisory staff deployed by the supervisory company
ISE9	Excessive reliance on outsourcing in specialized areas of the design phase (e.g., structure/civil/mechanical/landscaping/estimating/construction)
ISE10	Excessive reliance on outsourcing in specialized trades during the construction phase
ISE11	Increase in job switching among technicians per project (increase in contract positions)
ISE12	Excessive sales activities for winning contracts
ISE13	Backward practices such as solicitation, favoritism, and collusion
ISE14	Social culture of disregarding contracts
ISE15	Lack of problem awareness regarding practices that were conventionally followed
ISE16	Authoritarian and bureaucratic project culture (e.g., abusive behavior)

improved 〈Table 6〉.

3.2.4 Construction Industry and Social Environment

The regulations mentioned above for the construction industry are heavily influenced by changes in the macro-industrial and social environments. Changes in the macro environment might appear unrelated to individual construction projects; however, they can influence each other either directly or indirectly 〈Table 7〉.

4. Regression Analysis to Identify Failure Factors in Construction Quality Management

4.1 Data Collection

The survey for this study was conducted over nine days, from August 16–24, 2023. During the survey period, responses were collected through an online platform from respondents with relevant experience, such as professionals in design, construction, CM/supervision, specialized construction, and researchers, regarding the extent to which they agreed with the influencing factors of substandard construction and occurrence of substandard construction (poor design, poor construction, inadequate supervision). Responses were provided on a 6-point Likert scale. The total number of respondents was 724, with an average length of experience of approximately 22 years. The response rate by industry type is shown in 〈Table 8〉.

Table 8. Respondent Information

Sectors	Response	Rate
Architectural designer	112	15.5%
Structural designer	109	15.1%
Constructor	201	27.8%
CM/Supervisor	210	29.0%
Specialty construction	42	5.8%
Academia/Research	27	3.7%
etc.	23	3.2%
Total	724	100%

4.2 Descriptive Statistics

4.2.1 Perceived Competence and Attitude of Participating Technicians and Organizations

1) Competence of Skilled and Technical Personnel

As shown in ⟨Fig. 1⟩, the closer to 6 points, the more it is perceived as lacking, indicating an overall acknowledgment of deficiency. Although a slight difference was noted, the lack of technical skills in supervision and architectural design personnel was reported to be greater. Moreover, the lack of technical skills in ordering agencies and supervisory authorities was perceived as the most serious issue.

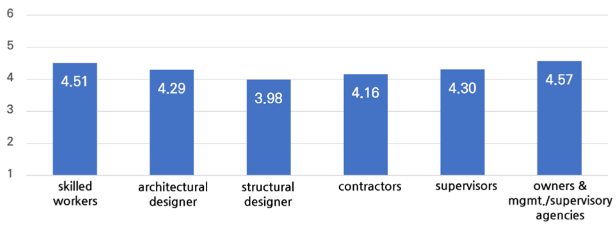

Fig. 1. Awareness of lack of professional competency

2) Professional Attitude and Responsibility of Skilled and Technical Personnel

As shown in ⟨Fig. 2⟩, respondents recognized an overall lack of professional attitude and responsibility in skilled and technical personnel.

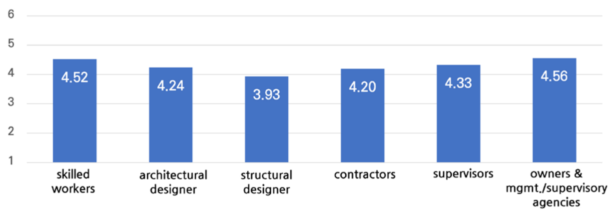

Fig. 2. Awareness of lack of the attitude and accountability

3) Management System within Participating Organizations

Regarding the management system of participating organizations, as shown in ⟨Fig. 3⟩, all were rated above 4 points, indicating a high level of recognition of the absence or inadequacy of management systems within organizations.

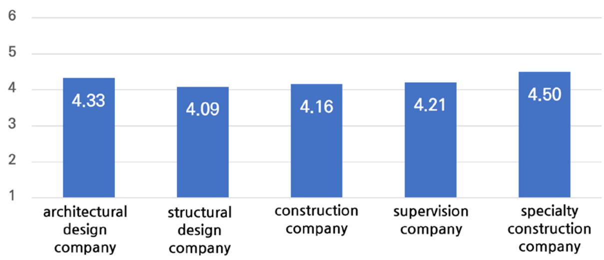

Fig. 3. Awareness of the absence and insufficiency of the management system within the organization

4) Deployment of Qualified and Competent Technical Personnel

Regarding the degree to which participating organizations deploy qualified and competent technical personnel to projects, as shown in ⟨Fig. 4⟩, considering the areas of design, construction, and supervision separately, all were perceived as lacking, with ratings above 4 points.

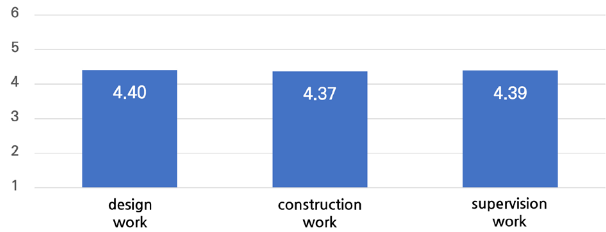

Fig. 4. Awareness of the lack of qualified and competent technical personnel

4.2.2 Perceptions of Project Management System Structure and Operation

Upon examining whether the structure and operation of project management systems are insufficient, as shown in ⟨Fig. 5⟩, negative responses predominated in both aspects of project management system structure and operation. In particular, “reduction in the effectiveness of project management tasks due to redundant/unnecessary tasks” along with “lack of labor/infrastructure/resources for operating the project management system” were perceived as the most serious issues.

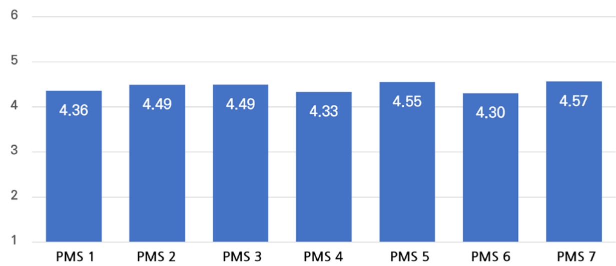

Fig. 5. Awareness of insufficient composition and operation of project management system

4.2.3 Perceptions of the Institutional Environment

Regarding the institutional environment, as shown in ⟨Fig. 6⟩, factors related to reduced construction/service fees and insufficient design and construction periods were ranked as the most important issues that need improvement.

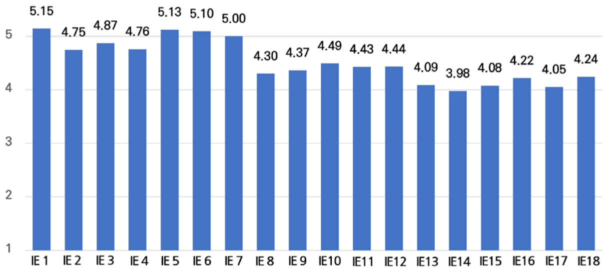

Fig. 6. Awareness of the institutional environment

4.2.4 Perceptions of the Construction Industry and Social Environment

Regarding the construction industry and social environment, as shown in 〈Fig. 7〉, the factor related to skilled labor in construction was identified in the survey as the factor most in need of improvement.

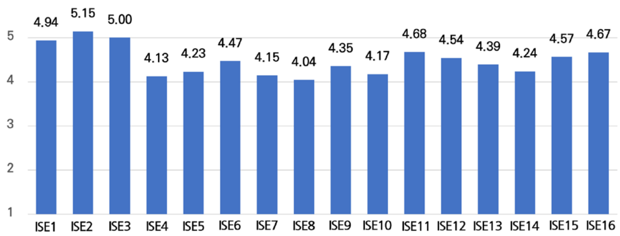

Fig. 7. Awareness of the construction industry environment and social environment

4.3 Hypothesis Testing

The 61 items derived in Chapter 3 were used as independent variables, and the occurrence levels of poor design, poor construction, and inadequate supervision were used as dependent variables to conduct regression analyses. The independent variables comprised factors related to the responsible parties identified in Section 2 (i.e., structural designers, architectural designers, contractors, and supervisors). Therefore, regression analyses were conducted for four hypotheses.

First, an independence test for the residual terms, a basic assumption of the regression model, was conducted. The results showed that all four regression models had Durbin–Watson values converging to 2, thus satisfying the assumption of independence (Belsley et al., 1980). Next, a multicollinearity test was conducted, and all independent variables had tolerance limits exceeding 0.1 and variance inflation factor (VIF) values below 10, indicating no multicollinearity issues in this study (Nunnally, 1978).

4.3.1 Regression Analysis Between Factors Related to Structural Design Organizations and Poor Design

An analysis of the relationship between factors related to structural design organizations and their effects on poor design 〈Table 9〉 revealed that, with an F-value of 9.553 and at a significance level of 0.001, the

Table 9. Regression analysis results between structural design organization-related factors and poor design

Research hypothesis		Unstandardized Coefficients		β	t	p-value
		B	SE			
Poor design	(Constant)	1.272	0.261		4.870	0.000
	CA3	-0.137	0.067	-0.138	-2.039*	0.042
	CA9	0.186	0.063	0.190	2.934**	0.003
	CA14	0.062	0.053	0.060	1.153	0.250
	CA18	0.195	0.047	0.180	4.101***	0.000
	PMS1	0.147	0.061	0.131	2.407*	0.016
	PMS2	-0.003	0.061	-0.003	-0.049	0.961
	PMS3	0.196	0.061	0.175	3.217**	0.001
	PMS4	-0.006	0.058	-0.006	-0.112	0.911
	PMS5	-0.050	0.053	-0.047	-0.934	0.350
	PMS6	0.035	0.060	0.031	0.574	0.566
	PMS7	0.001	0.056	0.001	0.012	0.990
	IE1	-0.032	0.052	-0.028	-0.607	0.544
	IE2	0.013	0.043	0.014	0.307	0.759
	IE3	-0.030	0.049	-0.031	-0.623	0.533
	IE4	0.058	0.051	0.060	1.147	0.252
	IE5	0.066	0.058	0.059	1.139	0.255
	IE6	-0.118	0.060	-0.101	-1.985*	0.048
	IE7	0.018	0.054	0.016	0.342	0.733
	IE13	0.015	0.033	0.017	0.458	0.647
	IE18	0.090	0.041	0.094	2.173*	0.030
	ISE4	0.018	0.039	0.020	0.460	0.645
	ISE5	-0.040	0.041	-0.044	-0.986	0.324
	ISE9	0.066	0.036	0.076	1.847+	0.065
	ISE11	-0.113	0.043	-0.109	-2.605**	0.009
	ISE12	-0.070	0.047	-0.071	-1.486	0.138
	ISE13	0.117	0.049	0.127	2.364*	0.018
	ISE14	-0.063	0.044	-0.069	-1.443	0.149
	ISE15	0.018	0.055	0.017	0.325	0.745
	ISE16	0.018	0.052	0.017	0.355	0.723

D-W=2.057, R^2 =0.285, F=9.553 p.=0.000
***〈0.001, **〈0.01, *〈0.05, + 〈0.1

estimated regression model was statistically significant. The R-squared value was 0.285, indicating that these influencing factors explained approximately 28.5% of the poor design.

4.3.2 Regression Analysis Between Factors Related to Architectural Design Organizations and Poor Design

An analysis of the relationships between factors related to architectural design organizations and their impact on poor design 〈Table 10〉 showed that, with an F-value of 11.046 and at a significance level of 0.001, the estimated regression model was statistically significant. The R-squared value of 0.316 indicated that these influencing factors explained approximately 31.6% of the poor design.

"Absent or inadequate internal design management system in architectural design companies (CA13)" was the most significant factor affecting poor design, followed by "backward practices such as solicitation, favoritism, and collusion (ISE13);" "unclear or unreasonable role-responsibility-authority sharing system among participating entities (PMS3);" and "absent or inadequate project management system in ordering organizations and supervisory authorities (PMS1)."

Table 10. Regression analysis results between architectural design organization-related factors and poor design

Research hypothesis		Unstandardized Coefficients		β	t	p-value
		B	SE			
Poor design	(Constant)	1.161	0.255		4.554	0.000
	CA2	0.061	0.064	0.059	0.951	0.342
	CA8	0.079	0.064	0.078	1.248	0.213
	CA13	0.231	0.053	0.221	4.388***	0.000
	CA18	0.020	0.054	0.018	0.367	0.713
	PMS1	0.104	0.060	0.093	1.733+	0.084
	PMS2	0.048	0.059	0.043	0.807	0.420
	PMS3	0.154	0.060	0.138	2.577*	0.010
	PMS4	-0.029	0.057	-0.026	-0.511	0.610
	PMS5	-0.021	0.051	-0.020	-0.402	0.688
	PMS6	0.029	0.059	0.026	0.489	0.625
	PMS7	0.021	0.055	0.019	0.388	0.698
	IE1	-0.033	0.051	-0.029	-0.634	0.526
	IE2	0.023	0.042	0.024	0.546	0.586
	IE3	-0.043	0.048	-0.043	-0.893	0.372
	IE4	0.049	0.050	0.050	0.976	0.329
	IE5	0.045	0.057	0.040	0.785	0.433
	IE6	-0.115	0.059	-0.098	-1.957+	0.051
	IE7	0.014	0.052	0.012	0.269	0.788
	IE13	0.019	0.032	0.022	0.598	0.550
	IE18	0.066	0.041	0.069	1.629	0.104
	ISE4	0.021	0.038	0.023	0.547	0.584
	ISE5	-0.023	0.039	-0.026	-0.596	0.551
	ISE9	0.049	0.035	0.056	1.387	0.166
	ISE11	-0.105	0.042	-0.101	-2.493*	0.013
	ISE12	-0.073	0.046	-0.075	-1.589	0.113
	ISE13	0.130	0.048	0.140	2.673**	0.008
	ISE14	-0.082	0.042	-0.090	-1.938+	0.053
	ISE15	0.038	0.053	0.035	0.708	0.479
	ISE16	0.003	0.051	0.003	0.058	0.954

D-W=2.066, R^2 =0.316, F=11.046, p.=0.000
***<0.001, **<0.01, *<0.05, + <0.1

4.3.3 Regression Analysis Between Construction Organization-related Factors and Poor Construction

An analysis of the relationship between construction

Table 11. Regression analysis results between construction organization-related factors and poor construction

Research hypothesis		Unstandardized Coefficients		β	t	p-value
		B	SE			
Poor construction	(Constant)	1.449	0.251		5.779	0.000
	CA1	-0.022	0.054	-0.021	-0.403	0.687
	CA7	0.087	0.054	0.083	1.614	0.107
	CA4	-0.062	0.059	-0.063	-1.046	0.296
	CA10	0.263	0.062	0.265	4.268***	0.000
	CA15	0.069	0.051	0.068	1.365	0.173
	CA19	0.034	0.046	0.033	0.725	0.469
	PMS1	0.012	0.057	0.011	0.219	0.827
	PMS2	0.056	0.056	0.052	0.992	0.322
	PMS3	0.039	0.055	0.036	0.709	0.478
	PMS4	0.024	0.052	0.021	0.455	0.649
	PMS5	-0.046	0.048	-0.045	-0.951	0.342
	PMS6	0.159	0.054	0.149	2.956**	0.003
	PMS7	0.072	0.051	0.064	1.410	0.159
	IE1	0.010	0.048	0.009	0.201	0.840
	IE2	0.076	0.040	0.080	1.892+	0.059
	IE3	-0.033	0.045	-0.034	-0.739	0.460
	IE4	0.066	0.046	0.070	1.425	0.154
	IE5	-0.004	0.053	-0.003	-0.071	0.944
	IE6	-0.027	0.054	-0.024	-0.505	0.614
	IE7	-0.054	0.052	-0.047	-1.043	0.297
	IE8	0.052	0.036	0.060	1.468	0.143
	IE9	0.060	0.041	0.067	1.471	0.142
	IE10	-0.037	0.044	-0.038	-0.833	0.405
	IE11	-0.089	0.037	-0.097	-2.406*	0.016
	IE12	-0.105	0.040	-0.108	-2.619**	0.009
	IE13	0.115	0.033	0.136	3.523***	0.000
	IE14	-0.088	0.047	-0.097	-1.872+	0.062
	IE15	-0.019	0.043	-0.021	-0.433	0.665
	IE16	0.041	0.055	0.043	0.742	0.458
	IE17	0.054	0.055	0.056	0.973	0.331
	ISE1	-0.095	0.053	-0.083	-1.803+	0.072
	ISE2	0.009	0.064	0.007	0.146	0.884
	ISE3	0.001	0.043	0.001	0.027	0.979
	ISE10	-0.003	0.034	-0.003	-0.085	0.932
	ISE11	-0.112	0.041	-0.111	-2.754**	0.006
	ISE12	0.006	0.043	0.006	0.143	0.886
	ISE13	0.090	0.045	0.100	1.982*	0.048
	ISE14	-0.053	0.040	-0.060	-1.341	0.180
	ISE15	0.056	0.049	0.054	1.140	0.255
	ISE16	0.018	0.048	0.018	0.386	0.699

D-W=1.944, R^2 =0.403, F=11.543, p.=0.000
***<0.001, **<0.01, *<0.05, + <0.1

organization-related factors and their effects on poor construction 〈Table 11〉 revealed that the regression model was statistically significant, with an F-value of 11.543 at a significance level of 0.001. The R-squared value of 0.403 indicated that these factors explained approximately 40.3% of the poor construction.

"Lack of professional attitude and responsibility in construction company personnel (CA10)" was the most significant factor affecting poor construction, followed by "insufficient punishment for contract breach or poor design/poor construction/inadequate supervision (IE13)," and "poor or formalistic project management system operation (PMS6)." Other significant factors included "backward practices such as solicitation, favoritism, and collusion (ISE13)," and "reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting (IE2)."

4.3.4 Regression Analysis Between Supervisory Organization-related Factors and Inadequate Supervision

An analysis of the relationship between supervisory organization-related factors and their effects on inadequate supervision 〈Table 12〉 showed that the regression model was statistically significant, with an F-value of 19.767 at a significance level of 0.001, and the R-squared value of 0.523 indicated that these factors explained approximately 52.3% of the inadequate supervision.

"Absent or inadequate internal supervision management system in supervisory companies (CA16)" was the most significant factor affecting inadequate supervision, followed by "insufficient punishment for contract breach or poor design/poor construction/inadequate supervision (IE13)," "lack of professional attitude and responsibility in supervisory company personnel (CA11)," "shortage of labor/infrastructure/resources for operating the project management system (PMS7)," "reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting (IE2)," "poor or formalistic project management system operation (PMS6)," "lack of professional attitude and responsibility in structural design company personnel (CA9)," "unequal contract structures (IE4)," and "formalistic operation in the review of engineering areas such as building permits or project plan approvals (IE18)."

Table 12. Regression analysis results between supervision organization-related factors and Inadequate supervision

Research hypothesis		Unstandardized Coefficients		β	t	p-value
		B	SE			
Inadequate supervision	(Constant)	0.862	0.227		3.796	0.000
	CA5	0.141	0.058	0.139	2.457*	0.014
	CA11	0.179	0.059	0.173	3.007**	0.003
	CA16	0.236	0.052	0.218	4.537***	0.000
	CA20	-0.007	0.048	-0.006	-0.140	0.889
	PMS1	-0.022	0.054	-0.019	-0.415	0.678
	PMS2	0.021	0.054	0.018	0.399	0.690
	PMS3	0.085	0.054	0.073	1.585	0.113
	PMS4	-0.049	0.050	-0.042	-0.995	0.320
	PMS5	-0.019	0.046	-0.017	-0.411	0.681
	PMS6	0.134	0.052	0.116	2.569*	0.010
	PMS7	0.145	0.049	0.121	2.972**	0.003
	IE1	0.030	0.046	0.025	0.651	0.515
	IE2	0.098	0.038	0.096	2.596*	0.010
	IE3	-0.104	0.043	-0.100	-2.422*	0.016
	IE4	0.093	0.044	0.090	2.086*	0.037
	IE5	-0.039	0.051	-0.033	-0.769	0.442
	IE6	-0.008	0.052	-0.007	-0.154	0.877
	IE7	-0.006	0.049	-0.005	-0.134	0.893
	IE8	0.010	0.035	0.011	0.302	0.763
	IE9	0.008	0.040	0.009	0.210	0.834
	IE10	-0.006	0.043	-0.006	-0.135	0.893
	IE11	-0.074	0.036	-0.075	-2.093*	0.037
	IE12	-0.126	0.038	-0.121	-3.286**	0.001
	IE13	0.114	0.032	0.125	3.575***	0.000
	IE14	0.001	0.046	0.001	0.020	0.984
	IE15	-0.002	0.042	-0.002	-0.049	0.961
	IE16	-0.085	0.053	-0.082	-1.624	0.105
	IE17	0.027	0.053	0.026	0.506	0.613
	IE18	0.065	0.037	0.065	1.763+	0.078
	ISE6	-0.020	0.029	-0.023	-0.716	0.474
	ISE7	-0.026	0.042	-0.027	-0.617	0.538
	ISE8	-0.031	0.042	-0.032	-0.728	0.467
	ISE11	-0.096	0.038	-0.088	-2.544*	0.011
	ISE12	-0.007	0.041	-0.006	-0.158	0.874
	ISE13	0.070	0.044	0.072	1.608	0.108
	ISE14	-0.004	0.038	-0.004	-0.105	0.916
	ISE15	0.004	0.048	0.004	0.090	0.928
	ISE16	0.027	0.046	0.024	0.587	0.558

D-W=1.885, R^2 =0.523, F=19.767, p.=0.000
***<0.001, **<0.01, *<0.05, + <0.1

4.4 Implications

From the descriptive statistics analysis results 〈Fig. 1~7〉, all construction project quality management failure factors defined in this study scored above 3.5 points (out of 6), confirming their role as influencing factors of substandard construction. Moreover, regression analysis

Table 13. Significant influencing factors by stage

Divisions		Significant influencing factors	
Poor design	Structural designer	CA9	Lack of professional attitude and accountability of structural designer
		CA18	Lack of input of qualified and competent technical personnel in design work
		PMS1	Absence or lack of project management system for owners and management/supervisory agencies
		PMS3	Unclear or unreasonable role-responsibility-authority sharing system for each participant
		IE18	Formal operation of review of engineering fields in building permit or business plan approval (such as structural etc.)
		ISE9	Excessive dependence on outsourcing in design stage specialized fields (structural/civil engineering/ equipment/ landscaping/estimate/construction, etc.)
		ISE13	Regressive practices such as asking for favors, looking after things, and sharing food.
	Archi. designer	CA13	Absence or insufficiency of the architectural design company's own design management system
		PMS1	Absence or lack of project management system for owners and management/supervisory agencies
		PMS3	Unclear or unreasonable role-responsibility-authority sharing system for each participant
		ISE13	Regressive practices such as requesting, caring, and sharing
Poor construction		CA10	Lack of professional attitude and accountability of contractors
		PMS6	Poor or formal operation of the project management system
		IE2	Decreased actual construction and service costs due to illegal subcontracting and subcontracting
		IE13	Insufficient punishment for non-compliance with contract or poor design/poor construction/ inadequate supervision
		ISE13	Regressive practices such as requesting, caring, and sharing
Inadequate supervision		CA5	Lack of technical competency of technical personnel of supervisor
		CA11	Lack of professional attitude and accountability of supervisor
		CA16	Absence or insufficiency of the supervision company's own supervision management system
		PMS6	Poor or formal operation of the project management system
		PMS7	Lack of manpower/infrastructure/financial resources to operate the project management system
		IE2	Decreased actual construction and service costs due to illegal subcontracting and subcontracting
		IE4	Unequal contract structure
		IE13	Insufficient punishment for non-compliance with contract or poor design/construction/supervision
		IE18	Formal operation of review of engineering fields in building permit or business plan approval (such as structural etc.)

was conducted to identify significant factors for each occurrence level of poor design, poor construction, and inadequate supervision, showing slight differences. The comprehensive results of the regression analysis are discussed below 〈Table 13〉.

First, the cause of poor structural design was found to be due not so much to a lack of competency within the organization's technical personnel but to a lack of professional attitude and responsibility and insufficient deployment of technical personnel. Externally, the formalistic operation of engineering area reviews in building permits or project plan approvals and excessive reliance on outsourcing in specialized design phase areas were identified as problems. In architectural design, the architectural design company either lacks its own design management system or has one that is inadequate is considered a cause of poor design. Common issues considered causes of poor design also include an absent or inadequate project management system in ordering organizations and supervisory authorities; an unclear or unreasonable role-responsibility-authority sharing system among participating entities; and backward practices such as solicitation, favoritism, and collusion.

Second, for poor construction, similar to structural design, the lack of professional attitude and responsibility of technical personnel rather than competency was a significant internal factor. Regarding the project management system, issues were perceived more in the operation aspect, such as being either poorly or formally operated, rather than in its composition. Externally, reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting, as well as insufficient punishment for poor design, construction, or supervision, were significant factors. Similar to poor design, backward practices such as solicitation, favoritism, and collusion were a reported cause. Notably, reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting was the highest-rated response, indicating that this is the most severe cause of poor construction.

Third, regarding inadequate supervision, within supervisory organizations, a lack of professional competency, attitude, and responsibility and having either no management system or an inadequate one were

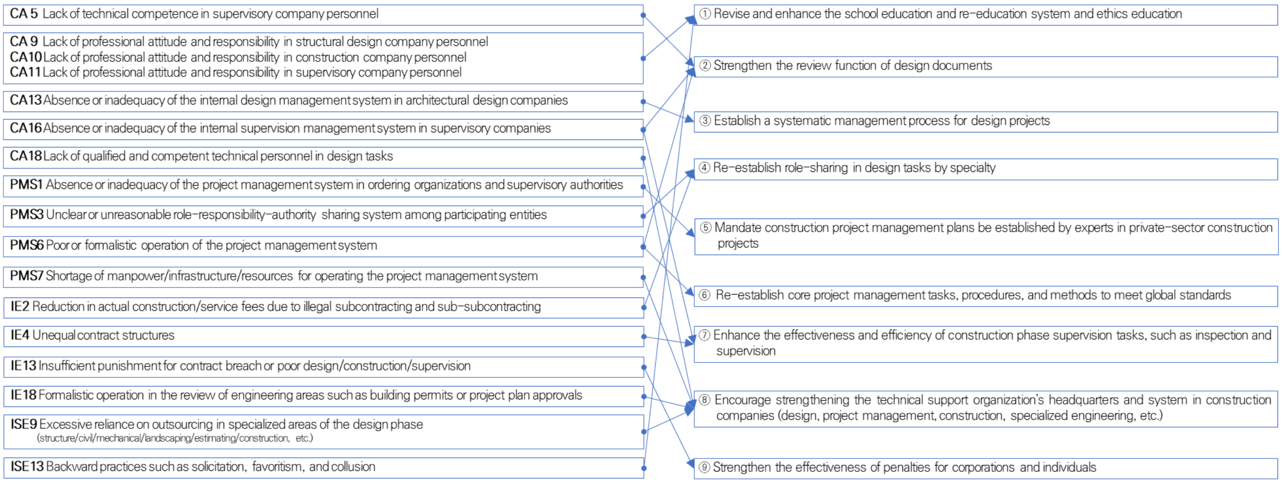

Fig. 8. Suggestions for preventing substandard construction

recognized as issues. For project management systems, the problem was not so much the lack of a necessary management system, but the poor or formalistic operation of existing systems and a lack of labor, infrastructure, and resources for system operation. Institutionally, similar to poor construction, reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting, unequal contract structures between construction and supervisory organizations, failure to act on errors due to such contract structures, and insufficient punishment for contract non-compliance, poor design, construction, or supervision were seen as originating from a lack of serious consideration for these issues. Finally, formalistic operation in engineering reviews for building permits or project plan approvals was a significant factor, linked to the lack of supervisory competency. This issue arises when problem detection has gaps owing to formalistic reviews by expert organizations that already lack competency.

Based on the significant factors identified in this study, recommendations for preventing failures in construction project quality management are described below 〈Fig. 8〉.

1) Revise and Enhance the School Education/ Re-education System and Ethics Education

In collaboration with academic societies and associations, the effectiveness of school education and re-education needs to be holistically re-evaluated to establish a long-term plan for systematic reorganization. Ethics education is especially needed to improve professional attitudes and responsibility and reduce unsafe practices in the industry.

2) Strengthen the Review Function of Design Documents

Without increasing the effectiveness of the existing review function, adding new review functions would be meaningless. ways to enhance the effectiveness of existing review functions need to be devised, such as permitting, structural reviews, and housing project approvals. To increase the possibility of utilizing construction expertise, proactive adoption and implementation of methods such as pre-construction services and integrated project delivery (IPD) are needed at the design phase, along with the development and use of checklists for design reviews and requiring reviewers to sign off on plans.

3) Establish a Systematic Management Process for Design Projects

Although regulations on the preparation, review, and verification of design documents exist under the "Construction Technology Promotion Act," a more detailed establishment of a standard management system for each type of design project is necessary. Furthermore, developing and distributing a design process management platform to provide systematic management of design documents is advisable.

4) Re-establish Role-sharing in Design Tasks by Specialty

For clear role-sharing in design tasks by specialty, engineers in specialized fields are advised to draft their plans, calculations, specifications, and drawings, while architects should coordinate and integrate various design outcomes, prepare comprehensive final design documents, manage the quality of all design documents, and oversee the design schedule. Instead of contracting with architects who then subcontract with engineers in specialized fields, ordering clients should directly contract with design consortia (architects + engineers in specialized fields) as a standard practice for design service contracts. Establishing and encouraging the use of standard consortium agreements, followed by the joint signing of the final design documents by engineers in specialized fields and architects after review, is recommended.

5) Mandate Construction Project Management Plans Be Established by Experts in Private Sector Projects

Article 39-2 of the "Construction Technology Promotion Act" mandates that construction project management plans be established during the construction phase for projects of specified types or sizes. Private-sector clients also need to establish construction project management plans and include them in the content of permits.

6) Re-establish Core Project Management Tasks, Procedures, and Methods to Meet Global Standards

It is essential to establish systematic construction project management manuals for each construction phase and participant by defining terminology and concepts related to construction project management that classify and modularize tasks and redefine participants' roles. This should be the basis for creating a digital project management work environment. To ensure work and measurement standards are understood even in situations where language barriers make regular communication impossible, detailed guidelines for creating construction detail drawings should be established and communication functions strengthened through 3D-rendering/digitalization. If necessary, artificial intelligence technologies linked with BIM should be adopted to improve accuracy and efficiency when creating construction detail drawings.

7) Enhance the Effectiveness and Efficiency of Construction-phase Supervision Tasks

Process re-engineering of construction phase supervision tasks, boldly adjusting lower-priority paperwork, and clearly defining work priorities and related task performance capabilities are necessary endeavors. Additionally, distinguishing between delegated and inherent supervisory tasks (quality and safety management activities such as inspections) and separately defining personnel input for such tasks to ensure the minimum essential staff for inspections and similar tasks should be secured. Establishing the institutional basis necessary for operating inspection specialists, such as required competencies, verification methods for qualifications, and appropriate staffing standards according to project characteristics/scale, is also required.

8) Encourage Strengthening the Technical Support Organization Headquarters and System in Construction Companies (e.g., Design, Project Management, Construction, and Specialized Engineering)

Construction companies should be encouraged to have the capability to provide technical support from their headquarters, not only in terms of on-site technical personnel and site operation and construction execution but also for evaluating the technical support capabilities at headquarters. In project management, evaluating the appropriate level (competency and number of personnel) of non-resident supervision (technical support construction project management personnel) is necessary. For design, the status of specialized engineers in each field should be included as an evaluation factor.

9) Strengthen the Effectiveness of Penalties for Corporations and Individuals

Systematically compare and review scattered penalty provisions in various laws to clarify participants' responsibilities and authority according to their roles in the construction project, including clients, designers, supervisors (construction project managers), constructors, and specialized engineers, and secure rational penalties.

Additionally, reviewing the fairness of current penalty provisions and systematizing penalty levels according to the penalty's purpose is necessary.

5. Conclusions

Structural collapses due to substandard construction not only create social and economic problems but identifying the root causes of substandard construction and establishing a prevention plan accordingly is crucial. However, efforts have historically focused more on finding and punishing those responsible rather than identifying the root causes after incidents of structural collapse due to substandard construction.

Therefore, this study aimed to identify the root causes of substandard construction due to failures in construction project quality management by defining substandard construction and its influencing factors through a literature review and case analysis and conducting regression analyses based on survey responses from construction project participants.

The research findings are summarized below.

First, this study measured the influencing factors of substandard construction and the extent to which they occur among 724 practitioners in design, construction, CM/supervision, specialized construction, and academia/research, and confirmed that all are influencing factors of substandard construction. The significant factors identified for each group are as follows.

1) Participating Technicians and Organizations
- Lack of technical competence in supervisory company personnel
- Lack of professional attitude and responsibility in structural design company personnel
- Lack of professional attitude and responsibility in construction company personnel
- Lack of professional attitude and responsibility in supervisory company personnel
- Absent or inadequate internal design management system in architectural design companies
- Absent or inadequate internal supervision management system in supervisory companies
- Lack of qualified and competent technical personnel in design tasks

2) Project Management System Operation
- Absent or inadequate project management system in ordering organizations and supervisory authorities
- Unclear or unreasonable role-responsibility-authority sharing system among participating entities
- Poor or formalistic operation of the project management system
- Shortage of labor/infrastructure/resources for operating the project management system

3) Institutional Environment
- Reduced actual construction/service fees due to illegal subcontracting and sub-subcontracting
- Unequal contract structures
- Insufficient punishment for contract breach or poor design/poor construction/inadequate supervision
- Formalistic operation in the review of engineering areas such as building permits or project plan approvals

4) Social and Industrial Environment
- Excessive reliance on outsourcing in specialized areas of the design phase (e.g., structure/civil/mechanical/landscaping/estimating/construction)
- Backward practices such as solicitation, favoritism, and collusion

Second, based on the significant influencing factors identified through regression analysis, the recommendations for preventing substandard construction are as follows:
- Revise and enhance the school education and re-education system and ethics education
- Strengthen the review function of design documents
- Establish a systematic management process for design projects
- Re-establish role-sharing in design tasks by specialty
- Mandate construction project management plans be established by experts in private-sector construction projects
- Re-establish core project management tasks,

procedures, and methods to meet global standards
- Enhance the effectiveness and efficiency of construction phase supervision tasks, such as inspection and supervision
- Encourage strengthening the technical support organization's headquarters and system in construction companies.
- Strengthen the effectiveness of penalties for corporations and individuals

This study is expected to provide a basis for identifying the causes of substandard construction and establishing measures to prevent these problems. Although the explanatory power of the research hypothesis was limited, this study utilized regression analysis to identify factors that influence the extent to which substandard construction occurs, emphasizing the importance of confirming significant levels over explanatory power.

The limitations and future research directions of this study are as follows.

First, the factors considered as independent variables in this study were those mentioned in existing literature and cases as causes of poor design, construction, and inadequate supervision. However, some factors showed significant negative t-values in the regression analysis results, opposite to the research hypothesis, mostly concerning institutional, construction industry, and social environments. Rather than interpreting this as an inverse relationship, it could be due to differences in perceptions among respondent groups, suggesting the need for future research to analyze responses by group.

Second, although this study did not analyze the causal relationship between the proposed quality management failure factors and measures to prevent failure, future research should define and validate models with higher explanatory power through sophisticated research designs to better understand the mechanisms through which the identified factors influence substandard construction to develop specific policies and programs.

Third, this research focused on construction project quality management failures in South Korea, which may limit its applicability in other countries or cultural contexts. Future studies should explore the applicability of the findings across various countries and cultural backgrounds through factor analysis to broaden the potential for application.

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