KSCE Journal of Civil Engineering (2011) 15(3):439-445
DOI 10.1007/s12205-011-1064-5

www.springer.com/12205

Factor Analysis of Construction Practices for Infrastructure Projects in Korea

Hee-Sung Park* and Soonwook Kwon**

Received November 30, 2009/Accepted July 5, 2010

Abstract

Although extensive research has been undertaken on practices influencing the success of construction projects, very little of this research contains information relevant to the critical success factors of Korean infrastructure projects. The object of this paper is to gain an understanding of the practices influencing infrastructure construction in Korea. This was achieved through a study conducted by 136 Korean construction professionals. A questionnaire survey was conducted to gather opinions from experts in the construction industry. The initial analysis of the 28 practices considered in this study proposed 22 best practices based upon the mean value of each practice. Analysis of variance revealed that the opinions of the experts are not significantly different regardless of their organization, designation, and experience. Further analysis, based on a factor analysis, shows that the practices could be grouped into six critical success factors-selection of a competitive contractor, pre-project planning, contract strategy, engineering enforcement, contract guarantee, and lessons learned feedback. The critical success factors presented in this paper can be used as a check list to prepare and implement public infrastructure projects in Korea. Furthermore, it will also provide information on general concepts involved in the preparations of international construction projects.

Keywords: *project management, infrastructure, best practices, statistical analysis*

1. Introduction

The construction industry plays a very important role in the Korean economy. For the past 5 years, Korea's construction investment has accounted for 17.7% of the total GDP, and the size of the construction industry would increase further if related industries such as the wood, steel, machinery and equipment industries were included. In addition, new infrastructure constructions are underway in developing countries, including Korea, in addition to constructions for the expansion, repair, and maintenance of existing infrastructure. As shown in Table 1, over 30% of the total construction contracts in Korea were in the public sector, namely in infrastructure construction.

In order to succeed in infrastructure construction, wherein a gargantuan amount of funds is invested each year, there is a need to improve the capability of quantifying and assessing the performance of the construction business. Establishment of best practices for improving construction performance is also critical issue. However, most construction companies in Korea have not yet outgrown the passive project management style, wherein a given budget is met, and it acts as an obstacle when companies try to secure a competitive edge through the improvement of the efficiency of construction processes.

In order to efficiently implement a construction project, political support for the development and settlement of best practices is urgently needed. This paper investigates the conventionally used practices in infrastructure construction in Korea and classifies the critical success factors using the factor analysis technique. This study will enable construction participants to better understand these best practices.

This research focused on primarily on Korean infrastructure construction projects and related best practices. Therefore, the results of the paper are most applicable to infrastructure projects in Korea. The basic ideas and approaches, however, may be applied to private construction projects and to other countries. While there are numerous practices that affect the process and

Table 1. Total Contract Amounts by Year (billion US $)

Sector	Year 1997	Year 1998	Year 1999	Year 2000	Year 2001	Year 2002	Year 2003	Year 2004	Year 2005
Public	35.6	29.5	24.4	24.6	29.9	30.9	32.2	33.8	31.8
Private	44.3	18.4	26.7	35.5	37.9	52.3	70.2	60.8	67.6
Total	79.9	47.9	51.1	60.1	67.8	83.2	102.4	94.6	99.4

*Member, Associate Professor, Dept. of Civil Engineering, Hanbat National University, Daejeon 305-719, Korea (E-mail: jackdaniel@hanbat.ac.kr)
**Member, Associate Professor, Dept. of Civil, Architectural and Environmental System Engineering, Sungkyunkwan University, Suwon 440-746, Korea (Corresponding Author, E-mail: swkwon@skku.edu)

performance of infrastructure construction, this paper focused on 28 practices suggested by previous research (KICT 1999). A survey was conducted to consolidate similar practices into small numbers of critical factors. It may help owners and contractors to manage infrastructure construction projects in that they focus on implementing important best practices.

2. Literature Review

Best practices for successful construction projects have attracted the interest of many members of academia and industry. However, very few researches have proposed best practices for civil infrastructure projects in Korea. Jawaharnesan and Price (1997) provided best practices for owner's representatives. They identified 12 important tasks and related best practices. These include 1) preparing and organizing, 2) developing project definition, 3) procurement, 4) organizing a joint management team, 5) design management, 6) safety management, 7) measuring and reviewing performance, 8) communications, 9) motivation, 10) coordination, 11) documentation, and 12) project postmortem. Proverbs and Holt (2000) identified contractors' construction practices for achieving early project completion. Bommer *et al.* (2002) proposed the skunkworks approach to deliver a project on time and within budget. Skunkworks encompasses 1) adhering to a clear focus on the mission, 2) extensive up-front planning efforts, 3) critically analyzing customer needs, 4) leveraging project overlaps, 5) early supplier involvement, 6) empowering the team, and 7) breaking rules. In the design phase, the frequency of design team meetings and the frequency of design progress reports have an impact on the design-phase cost performance (Kuprenas, 2003).

KICT (1999) presented 28 practices to promote public funded construction projects. As shown in table 4, 28 practices are grouped in 5 categories such planning and engineering, project budget, bid and contract, construction, and post-construction. Those practices are developed by several workshops and survey for construction experts including public owners, engineers, general contractors, and academia. Construction related regulations are amended by this research results and construction practitioners have applied those practices during engineering and construction.

3. Research Methodology

A survey was conducted among experts engaged in a variety of construction fields such as public-owned organizations, academia, research institutes, general contractors and engineering companies. The questionnaire consisted of basic personal information and their perception, utilization, efficiency, and satisfaction with each practice. The questionnaire was designed to automatically treat the low responses of the respondents in the perception column as a missing value. Subsequently, the system elicits answers from the respondents only to those questions in which they have a certain level of perception. This was done to ensure the reliability of the survey. This study aimed to deduce the critical success factors for 28 practices that are currently adopted for infrastructure construction in Korea. Therefore only the data related to the efficiency of the best practices in the survey was used. These 28 practices were identified by previous research funded by the Korean government (KICT, 1999).

A total of 136 experts from construction and construction-related fields answered the survey. The results dataset was classified according to the respondents' organizations, designations, and experience, as shown in Table 2 and Table 3.

As shown in Table 2, half of all the respondents are engaged with a general contractor or an engineering company, and 33% of all the respondents are members of academia. Although the number of respondents from public-owned organizations were relatively few, this study does not aim to determine differences between groups, and therefore this factor is considered irrelevant.

Table 3 shows the respondents classified by their organizations and the roles they are engaged in. Sixty-six of the respondents were from the field of research and education, accounting for half of the total respondents, followed by 34 respondents from engineering, 19 respondents from construction, 16 respondents from management and planning, and one respondent from marketing. The respondents selected for the survey were experts from a variety of fields; this was done to prevent data distortion caused by the imbalances in respondent groups. The average experience of the respondents is 19 years, and it is considered that the respondents could reliably answer the questions based on their sufficient experience in construction.

4. Practices in Korean Infrastructure Projects

This study was initiated based on the practices in public construction projects suggested by the Korea Institute of Construction Technology (1999). Twenty-eight practices suggested by the preceding studies were deduced through the survey question-

Table 2. Organization Types of the Respondents

Grouping	Number	Percentage
Contractor	63	46.3%
Public-owned organization	9	6.6%
Research institute	19	14.0%
Academia	45	33.1%
Total	136	100%

Table 3. Designations of the Respondents

Grouping	Contractor	Public-owned organization	Research institute	Acedemia	Total
Engineering	34	0	0	0	34
Construction	16	1	2	0	19
Management	9	6	1	0	16
Research/Education	3	2	16	45	66
Marketing	1	0	0	0	1
Total	63	9	19	45	136

Table 4. Practices in Korean Infrastructure Projects

Project Phase	Practices
Planning and engineering	Effective project process
	Pre-feasibility study
	Feasibility study
	Engineering process
	Engineering Value Engineering (VE)
	Life Cycle Cost (LCC) review
Project budget	Project selection process
	Budget plan
	Right-of-way construction
	Right-of-way process
Bid and contract	Previous experience evaluation
	Contractor selection criteria
	Open bid
	Performance bond
	Design-Build implementation
	Fast-Track
	Reimbursement of engineering cost
	Alternative engineering plan
	Multi prime contract package
	Fair contract
Construction	Information classification system
	Earned Value Management System (EVMS)
	Construction management implementation
	Web-based permit system
	Project standardization
	Research & development incentives
Post-construction	Project participants
	Post evaluation

naire or interviews of 130 experts from construction and construction-related fields. These 28 practices have been implemented in public construction projects in Korea since 1999. The practices were divided into five project phases, as shown in Table 4.

5. Data Analysis and Results

The data were analyzed using the Statistical Package for the Social Sciences (SPSS). As part of the analyses, reliability analysis was performed and Cronbach alpha reliability was produced. The Cronbach alpha reliability measures or tests the reliability of the five-point Likert scale used in this study (Norusis, 1992). Cronbach's coefficient alpha was 0.871, indicating strong internal consistency among 28 practices. It implies that the 5-point Likert scale used for measuring the effectiveness of practices adopted in Korean infrastructure projects is reliable. Further, Analysis of Variance (ANOVA) was performed to test the difference of the respondents' opinions of according to their organization, designation, and experience. The first ANOVA was based on the respondents' organization type(contractor, public-owned organization, research institute, and academia). The p values of four practices were below 0.05, suggesting a difference of opinion between groups. The second ANOVA was performed based on the respondents' roles (engineering, construction, research, education, and sales). In this case, opinions regarding only one practice differed across groups. The third ANOVA was performed based on the respondents' experience; in this case, the p values of all practices ranged from 0.057 to 0.97, which is higher than 0.05. Although the opinions of the respondents regarding a few practices differed across groups, the ANOVA tests generally suggested that the respondents' opinions were similar regardless of their organizations, roles, and experiences. Therefore, the collected sample could be treated as a whole. Next, two statistical analyses were undertaken-scale ranking and factor analysis. The results of these analyses are explained in detail in the subsequent sections.

5.1 Ranking of Practices

The first analysis involved the ranking of the 28 practices based on the mean values of the responses. In cases wherein multiple practices had the same mean value, a lower standard deviation was assigned a higher ranking (Shen and Liu, 2003).

Table 5. Ranking of Practices for Infrastructure Project in Korea

Practices	Mean	Std. Dev.	Ranking
Design-Build implementation (P1)	3.90	0.92	1
Reimbursement of engineering cost (P2)	3.80	0.84	2
Post evaluation (P3)	3.76	0.77	3
Project participants (P4)	3.75	0.75	4
R&D incentives (P5)	3.74	0.76	5
Alternative engineering plan (P6)	3.73	0.73	6
Pre-feasibility study (P7)	3.72	0.70	7
Performance bond (P8)	3.71	0.58	8
Engineering VE (P9)	3.70	0.78	9
Fast-Track (P10)	3.69	0.82	10
Right-of-way construction (P11)	3.68	0.70	11
Contractor selection criteria (P12)	3.65	0.59	12
Web-based permit system (P13)	3.63	0.69	13
LCC review (P14)	3.60	0.82	14
Engineering process (P15)	3.59	0.69	15
Information classification system (P16)	3.59	0.70	16
Fair contract (P17)	3.59	0.84	17
Right-of-way process (P18)	3.58	0.59	18
EVMS (P19)	3.56	0.64	19
Budget plan (P20)	3.53	0.54	20
Effective project process (P21)	3.50	0.63	21
Feasibility study (P22)	3.50	0.69	22

The practices with means exceeding or equal to 3.50 were recognized as the best practices - 22 practices were identified as the best practices that could lead to the successful completion of infrastructure projects. Table 5 lists the rankings of the best practices according to the value of their means.

5.2 Factor Analysis

To capture any multivariate relationship existing between the practices, the factor analysis technique was used to investigate the cluster of the relationship (Akintoye, 2000). This analysis technique helps to detect clusters of related variables and reduce the number of variables (Norusis, 2000). In this study, factor analysis was used to explore the underlying constructs in the identified practices for infrastructure projects in Korea.

In this study, 22 practices were subjected to factor analysis using principal components analysis and varimax rotation. The principal component analysis produced a six-factor solution with eigenvalues greater than 1, explaining 90.00% of the variance. Then, the varimax orthogonal rotation of principal component analysis was used to interpret these factors. An unrotated principal component analysis factor matrix explains only the relationship between individual factors and practices. It is difficult to interpret the structure of the practices. However, rotation techniques such as the varimax method ease the task of interpretation (Akitoye, 2000). The factor grouping based on varimax rotation is shown in Table 6. Each variable weighs heavily on only one of the factors. The factors and associated practices are shown in Table 7. Factor 1 is the selection of a competitive contractor, factor 2 is pre-project planning, factor 3 is contract strategy, factor 4 is engineering enforcement, factor 5 is contract guarantee, and factor 6 is lessons learned feedback.

Table 6. Rotated Component Matrix

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
P02	.859					
P05	.864					
P06	.864					
P12	.833					
P07		.881				
P20		.687				
P21		.836				
P22		.817				
P11			.536			
P16			.873			
P17			.736			
P18			.873			
P09				.817		
P10				.659		
P13				.807		
P14				.605		
P15				.894		
P08					.911	
P19					.906	
P01						.432
P03						.791
P04						.824

6. Discussion of Factor Analysis Results

6.1 Factor 1: Selection of a Competitive Contractor

For a successful construction project, it is essential to select a competitive engineering company and a general contractor. Various researches on selection criteria and selection methods have been actively conducted (Chinyio *et al.*, 1998; Hatush and Skitmore 1998; Holt *et al.*, 1994; Lo *et al.*, 1998; Samuelson and Levitt 1982). In other words, selecting a contractor that can successfully execute the project implies selecting a contractor that has the least possibility of failure.

The first factor involves four practices related to the selection of a contractor. The contractor selection criteria involves adjusting each item to be estimated and each weight for each item after taking the construction type and characteristics into consideration when the pre and post-qualification are applied. Further, setting a higher cut-off helps in selecting a highly capable contractor.

Reimbursement of engineering costs refers to providing engineering planning compensations to the rest of the bidders, except for the contractor selected in the design-build and alternative bidding. Up to 1.5% of the construction budget is used to reimburse unsuccessful bidders according to their ranking. This

Table 7. Six Cluster Groups

Cluster 1	Selection of competitive contractor - Contractor selection criteria - Reimbursement of engineering cost - Alternative engineering plan - R&D incentives
Cluster 2	Pre-project planning - Effective project process - Pre-feasibility study - Feasibility study - Budget plan
Cluster 3	Contract strategy - Right-of-way construction - Right-of-way process - Fair contract - Information classification system
Cluster 4	Engineering enforcement - Engineering process - Engineering VE - LCC review - Fast-Track - Web-based permit system
Cluster 5	Contract guarantee - Performance bond - EVMS
Cluster 6	Lessons learned feedback - Design-Build implementation - Project participants - Post evaluation

system has contributed an increase in number of bids from companies with advanced technologies by giving more bidding opportunities to small- and medium-sized companies that could not afford the bidding expenses due to the financial burdens involved in engineering.

Alternative bidding refers to a bidding system that suggests alternatives with new construction technologies or methods to shorten the construction period more than that originally suggested by the bidders. This proposal system aims to facilitate the efficiency of construction by employing the creativity and new technologies of contractors. As a result of the active introduction of this system in large-scale infrastructure construction, contractors could receive incentives for reduced construction expenses and shortened construction periods.

Similar to the Value Engineering Change Proposal (VECP) in the United States, R&D incentives refer to a system where incentives are granted to the contractor when the engineering plan is modified based on the condition that the construction expenses will be reduced through the adoption of new technologies, construction methods, or innovative materials suggested by the contractor. A certain portion of the saved expenses is provided to the contractor as incentives. The aforementioned four practices are recommended as selection criteria for companies that have the capability to conduct construction projects and contractors that are the most qualified and suitable for the successful completion of the relevant infrastructure project by compensating them for expenses on engineering planning and encouraging suggestions for alternative engineering plans.

6.2 Factor 2: Pre-Project Planning

The interrelation between pre-project planning with a feasibility study and the success of the construction project has been proven in a preceding study (Cho, 2000). The results of previous studies indicate that the success of a construction project depends on the extent of project planning prior to its commencement. Thus, it is inevitable that pre-project planning has the second-highest priority among these factors.

Effective project process refers to a system that establishes standard processes for infrastructure construction projects in which public budgets are invested. Thus, the construction project proceeds based on the suggested standard processes. This is designed to facilitate the rational execution of public budgets by standardizing and legislating the entire process of infrastructure projects from the conceptual planning stage, construction, through post-evaluation.

Prior to the formulation of a feasibility study by the government that places an order for the relevant infrastructure construction project, the Ministry of Planning and Budget, which is in charge of budget management, analyzes the plan in the light of balanced regional development and economic efficiency. This is called the pre-feasibility study. Only projects that pass the pre-feasibility study can progress to the feasibility study so that budget wastage from reckless project promotions can be prevented. The feasibility study is a measure for ensuring the objectiveness and reliability of the research results by standardizing detailed research items, evaluation standards, and procedures. On the other hand, the pre-feasibility study focuses on economic efficiency and regional development. The feasibility study is more about the technological feasibility of the infrastructure construction project.

Finally, budget planning refers to accurately calculating the expected total budget required for the construction project and securing the same accordingly. In most infrastructure construction contracts in Korea, a long-term-based continuous contract system is adopted, wherein the government owners make the contracts each year with the budget secured for the relevant year, instead of a continuous expenditure system wherein the contract is concluded to cover the entire expenses expected for the completion of the project. The long-term-based continuous contract system currently in operation fails to encourage the contractor to try and reduce the construction period and expenses, and also makes it rather difficult to introduce new technologies.

6.3 Factor 3: Contract Strategy

The third factor is related to right-of-way compensation prior to the commencement of the construction. In general, when the construction commences while the right-of-way compensation is not yet sufficiently provided(right-of-way compensations are often delayed), it results in increased project costs and prolonged construction periods. A research was recently conducted on the right-of-way compensation in 24 construction projects led by six government owned institutions of the Ministry of Construction & Transportation of Korea. As seen in Table 8, the results show that construction projects with more than 50% of pre-compensations experience a delay in the construction period by an average of one year and three months and an increase in costs by 109.1 million US dollars per project, which accounts for only 12.4% of the initial project cost set in the contract.

However, for construction projects with pre-compensations of lower than 50%, the average construction period was extended by four years and 11 months with the construction cost up by 535.8 million US dollars per project. This is an increase of 99.9 million US dollars (116.7% up from the initial budget) per project

Table 8. Influence of Right-of-Way Pre-compensation on Construction Periods, Project Cost, and Compensations

Compensatory rate in one year from the agreed time	Expansion of average construction period	Incases of average construction expenses (million US $, %)		Increase of average compensation (million US $, %)	
		Increased amount	Increased rate	Increased amount	Increased rate
More than 50%	14.8 months	109.1	12.4	-3.2	-20.4
Less than 50%	58.6 months	535.8	145.2	99.9	116.7

in terms of compensation costs. This indicates that delayed compensations exert a significant impact on project costs and construction periods.

Therefore, in order to prevent such problems, the right-of-way compensation has been placed in operation, wherein construction commences only after a certain amount of the compensation. However, the lack of objective standards in the existing land compensation system has caused many problems. It is in this context that the right-of-way process was introduced in an effort to reform the irrational compensation standards and to simplify the compensation processes while not infringing upon people's property rights.

Many parties engaged in a construction project establish their relationships based on the contracts. Thus, the successful completion of a project is only possible when the contracts are made in a fair manner between the concerned parties. Equality should be guaranteed between the owner and the contractor and between the general contractor and the subcontractor in contract completions and implementations.

Lastly, an information classification system should be developed for construction projects. In order to introduce scientific construction management methods, a Work Breakdown Structure (WBS) for infrastructure projects should be developed to ensure the effective planning and management of every single sub-unit of the projects.

6.4 Factor 4: Engineering Enforcement

The fourth factor is related to the engineering process, Value Engineering (VE) in design phase, Life Cycle Cost (LCC) review, and fast-track and web-based permit system. Construction projects with insufficient engineering planning budgets and time often result in the wastage of their budgets due to excessive or improper construction works, or increased construction expenses and prolonged construction periods due to frequent changes in their engineering plans. Thus, it is rather common knowledge in the construction industry that perfect engineering is critical for ensuring the safety of the structures to be built and the success of construction projects. In this context, owners should allocate an adequate amount of engineering planning budget and time to prevent poor planning.

Engineering VE and LCC review are the two factors essential in ensuring technically perfect engineering planning and economic efficiency in engineering planning. Engineering VE with optimal combinations, where the quality, function and cost of the infrastructure are all sufficiently taken into consideration, induces active suggestions of alternative engineering plans for economic efficiency, improvement in infrastructure functions, and cost reductions. In addition, the LCC review, wherein the cost for the entire life-cycle of the infrastructure is taken into account, is also adopted; this enables the consideration of the operational costs from the planning stage onwards. In design-build constructions, engineering design and construction proceed simultaneously to facilitate fast-tracking, thereby shortening the construction period.

In the course of a construction project, construction work is often delayed due to problems concerning government permits. In order to ensure efficiency in project implementation, a web-based permit system and e-formats for the necessary permits have been developed and are currently in operation.

6.5 Factor 5: Contract Guarantee

From the owner's point of view, a project is deemed successful when the infrastructure is completed within the projected construction period and satisfies the expected quality, while not exceeding the cost stated in the contract. As a safety device, the contractor is asked to submit a performance bond. A performance bond that replaces the existing joint liability on a guarantee system extends opportunities for contractors to participate in the projects. This is expected to lead to successful construction performances.

For the efficient management of construction expenses and periods, the introduction of an Earned Value Management System (EVMS) is being encouraged. EVMS is designed to ascertain factors that cause construction delays, increase in construction expenses, and faults in workmanship in the early stages so that the standards for countermeasures can be recommended in a prompt manner.

6.6 Factor 6: Lessons Learned Feedback

Since infrastructures projects are often one-time construction projects, learned lessons from previous construction experiences are not managed efficiently, and therefore, do not benefit similar future projects. In order to solve this problem, a design-build style is adopted in many construction projects in a bid to select contractors with both abundant experience in similar projects and verified technologies.

Additionally, in an effort to inspire the commitment of the project participants and to motivate them, a real-name system has been adopted for the participants. The project participants' name will be included in the post project report. Lastly, post-evaluation is conducted after the construction is completed. Project performance and effects are thoroughly studied and analyzed in order to provide useful feedbacks for the betterment of future constructions of a similar nature. These lessons learned from the previous cases are actively employed in succeeding projects to contribute to the success of these projects.

7. Conclusions

The focal point of this analysis was the Critical Success Factors (CSFs) and related best practices considered in Korean infrastructure projects. An investigation of these CSFs was performed through an interrelationship between practices using the factor analysis technique.

As mentioned above, factor analysis performed on the 22 practices identified six factors that exhibit a significant impact on infrastructure projects in Korea. The most significant factor is the *selection of a competitive contractor*. The involvement of a competitive contractor is thus crucial to the success of infrastructure construction in Korea. In addition to a competitive contractor, *pre-project planning* also plays an important role. The *pre-project planning* highlights the importance of planning of infrastructure before the commencement of construction. This factor emphasizes the importance of a feasibility study and an effective project process. *Contract strategy* ranked third among the significant factors. Right-of-way process and fair contract culture should be included in the contract strategy for the success of infrastructure projects. *Engineering enforcement* ranked fourth. The inclusion of engineering VE and LCC issues may impact infrastructure success. *Contract guarantee* using performance bond and utilization of EVMS is included in the fifth factor. *Lessons learned* is the last and the sixth factor that influences the success of Korean infrastructure projects.

This paper provides the process and framework for Korean public construction. It also presents the essential points that need to be considered in the implementation of construction in Korea. The critical success factors presented in this paper can be used as a check list to prepare and implement public infrastructure projects in Korea. Since the research results are based on the opinions of experienced construction experts', it will provide valuable information for owners and contractors from Korea as well as other countries on the Korean construction process. Also, practical implementation processes for listed best practices can be researched by academia based on this research result. Government can use this result for revising and establishing construction policies. Furthermore, it will also provide information on general concepts involved in the preparations of international construction projects.

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