https://doi.org/10.1061/(ASCE)CO.1943-7862.0001242

Contractor-Led Critical Design Management Factors in High-Rise Building Projects Involving Multinational Design Teams

Seoung-Wook Whang[1], Roger Flanagan, A.M.ASCE[2], Seungho Kim[3], and Sangyong Kim, A.M.ASCE[3,*]

[1] Ph.D. Research Student, School of Construction Management and Engineering, University of Reading, Whiteknights, PO Box 219, Reading, Berkshire, RG6 6AW, United Kingdom, Tel: +44-798-551-7482, E-mail: zz026014@reading.ac.uk

[2] Professor, School of Construction Management and Engineering, University of Reading, Whiteknights, PO Box 219, Reading, Berkshire, RG6 6AW, United Kingdom, E-mail: r.flanagan@reading.ac.uk

[3] Ph.D Student, School of Architecture, Yeungnam University, 280 Daehak-ro, Gyeongsan-si, Gyeongbuk 712-749, Republic of Korea (corresponding author), Tel: +82-53-810-3971, Fax: +82-53-810-4625, E-mail: seung-ho@ynu.ac.kr

[3,*] Assistant Professor, School of Architecture, Yeungnam University, 280 Daehak-ro, Gyeongsan-si, Gyeongbuk 712-749, Republic of Korea (corresponding author), Tel: +82-53-810-2425, Fax: +82-53-810-4625, E-mail: sangyong@yu.ac.kr
*Corresponding author

Abstract

High-rise building projects (HRPs) are comprised of various complex design elements. The involvement of a multinational design team increases design-related issues for contractors, which must be managed during the construction stage. Thus, contractors need to understand how appropriate design management can positively affect project performance and their profit. Identification of critical design management factors (CDMFs) can provide appropriate decision-making support for contractors, including how limited resources including money, manpower, and equipment can be allocated throughout the construction stage. This study identifies and ranks the CDMFs for HRP designed by multinational design teams. Through a questionnaire survey in South Korea, 21 design management factors were acknowledged among 40 initial factors. Then, using factor analysis, these 21 identified CDMFs were categorized into four groups: interface management, design information, production stage, and risk contribution. Based on results, this study identifies general and regional features of design management. Because these CDMFs are chosen from the contractor's perspective, if they are used to make appropriate decisions, the overall project performance should be increased during the construction phases.

Author keywords: Critical factor, Design management, High-rise building project, Multinational design team

Introduction

The development of high-rise building projects (HRPs) is a global phenomenon (Wardani et al., 2006). A large multifunctional project requires various state-of-the-art technologies and management skills. To undertake the task of iconic architectural design and engineering of an HRP, multinational design teams that consist of international architects and multidisciplinary building specialists are used (Wakisaka et al., 2000). This involves increased project complexity because of the desire for innovative and exciting design solutions that should also be built faster, safer, and greener. The construction of an HRP is a process in which risk, uncertainty, and complexity are integrated. This creates significant unexpected design-related problems during the construction stage. Particularly, a design solution generated by a multinational design team adds another layer of complexity that the contractor must manage, because design and production risks tend to be passed on to the contractor. This problem can seriously affect the contractor's profit in an HRP due to unexpected costs and delays. Thus, this study focused on how design management can help a contractor reduce the design-related risks in the construction stage of an HRP. Even if various project members including international and local architects, engineers, and subcontractors are involved in a single HRP, they have their own interests and objectives. Moreover, in the completion of the production and the handing of it over to the client, the contractor has greater responsibility than other project members. Eventually, the contractor has no choice but to be proactive in managing all project issues, including design issues. Thus, this research focuses on design management from the contractor’s perspective among different project stakeholders.

A report by the National Economic Development Council (NEDC, 1987) indicates that more than 50% of the contractor’s problems on a site are related to poor design management. Due to the involvement of different design elements and technologies in HRPs, design errors and omissions are inevitable. Architects and designers focus on aesthetics, form, function, and structural and environmental integrity, whereas contractors focus on resources, production methods, processes, and sequences (Hegazy et al., 2001). Traditional design management has focused on coordinating the design team members and design information. From the designer’s perspective, design management tries to manage the design process to ensure that the design information is at a sufficient stage for a contractor. However, they fail to manage the complicated and advanced design elements used in HRPs. As a designer, it is difficult to integrate different state-of-the-art building technologies and intricate off-site detailed design into the managing the process (Koskela et al., 2002). On the other hand, even if the subcontractor and supplier are familiar with the practical and detailed technologies of HRP, their design managing is limited and sporadic rather than covering all of the project stages. This poor design management causes unnecessary construction changes, which in turn cause the contractor to face serious production risks on site due to insufficient design information (Vidal and Marle, 2008).

A high-rise building design relies heavily on the integration of different engineering areas such as structures; electrical; heating, ventilation, and air conditioning (HVAC); and the environment. Therefore, important tasks are to organize, manage, and integrate these different high technologies throughout the construction stages (Kim and Kown, 2005). Design management is an important tool for the contractor to use in managing resources effectively during the construction stage. In order to sufficiently use and allocate limited resources including materials and equipment on site, contractors need to establish their own design management tools that are suitable in the practical construction stage, as well as a comprehensive construction plan and technical support. An understanding of the critical design management factors (CDMFs) by a contractor who has in-depth knowledge of construction materials and methods, and empirical experience, could be a key factor in reducing project uncertainty and promoting efficiency in HRPs.

The contribution of this research is related to CDMFs from the contractor's perspective in order to reduce unexpected design-related risks during construction. For empirical research, the Korean construction sector was investigated. In Korea, design management is used very comprehensively and broadly, involving close cooperation with the site engineering team throughout the construction stages.

Importance of CDMFs in Korean HRPs

Korea has over 38 high-rise buildings (over 200 m), which means it ranks fourth in the world behind China, the United States, and the United Arab Emirates (CTBUH, 2011). In addition, diverse super-HRPs (over 100 stories) are being developing. The designs of many of these domestic HRPs are conducted by multinational design teams because domestic architectural and engineering consulting firms do not have either the innovative design approach, or the technological knowledge, to deliver outstanding designs. Thus, Korean clients seek famous international architects with a reputation for exciting and different design solutions (Bea et al., 2006). It makes contractor very difficult for the contractor to recognize the critical design factors affecting the construction stage, investigate appropriate construction methods, and execute the plan according to the design information within a short period of time at the early project stage.

In Korea, contractors have a greater social responsibility as they also have different economic advantages from political supporters. Such political support allows contractors to expand their business model; actually, almost all Korean contractors have their own real estate developing and building maintenance departments to increase and expand their business profit. Hence, the contractor plays different roles throughout the project delivery process, including running the design management team to manage complex design information. For example, when some design omissions or errors occur on site, the contractor should deal promptly with the problems using their own design management team instead of using support from the architect and design team (Song et al., 2009). Even if the architect and engineer are contracted directly with the client, they tend to follow the execution plan of the contractor because the contractor has overall legal and social responsibility throughout the project process in Korea.

Due to the legalization of selling property before the commencement of construction, clients are usually in contact with famous large contractors that have market power, such as Samsung or Hyundai. In addition, these large construction companies often develop a HRP as the client to promote the business of their affiliation companies that are involved in development, manufacturing, heavy equipment, construction materials, architecture, and engineering. A construction company should consider the various business aspects related to the affiliation companies when attempting to develop an HRP (Almeida et al., 2011). Brother companies constantly ask for design or material changes so that they can supply their own material or equipment (Kim and Kown, 2005). Eventually, a contractor's design management team should analyze and manage all design and production issues in order to reduce any unexpected risk from these changes. If complex issues are not managed systematically by the contractor's design management team, a project may suffer from diverse design changes and unnecessary rework (Swickerath and Tillson, 2011). Consequently, contractors must fully understand the CDMFs, particularly in HRPs.

Literature review

Management of project complexity

The construction industry has had great difficulty in coping with the increasing complexity of large-scale projects. Understanding the complexity is very critical for project management, because throughout the project, decision-making and goal attainment stem from complexity. Complex projects demand an exceptional level of management. The application of traditional management approaches developed for ordinary projects have been found to be inappropriate for complex projects (Baccarini, 1996).

There are different bodies of knowledge on the management of complexity in construction projects. Major authors have focused on systematic approaches (Sinha et al., 2001; Moldoveanu, 2004; Vidal and Marle, 2008) or organizational approaches (Cleland and Ireland, 2002; Williams, 2002; Cooke-Davies et al., 2007). In-depth studies have been conducted on project coordination, interaction, and the interface of project elements. Baccarini (1996) suggested that project complexity is composed of technological and organizational complexity, which he regards as the core elements. Remington and Pollack (2007) categorized complex projects into four dimensions, based on the source of the complexity: structural, technical, directional, and temporal. They emphasize that a proper and balanced integration of the complex sources is the critical factor for the appropriate management of a complex project.

Other authors (Luhman and Boje, 2001; Migliaccio et al., 2008) have investigated external factors in order to understand dynamic changes in a project. Owens et al. (2012) state that current projects are influenced by external state-of-the-art technology rather than by the construction or business aspects. Thus, a project manager needs to manage the interface between traditional project resources (money, labor, and equipment) and innovative building technology. Other reports in the literature indicate that recent large projects are involved with numerous internal and external project elements, and eventually many projects end in failure due to a failure in managing such complex elements. In order to cope with project complexity, a contractor needs to manage all project elements including participants, resources, systems, technology, and information.

Construction-led design management

In the construction management literature, the study of contractor design management began in the 1990s. Gray et al. (1994) described the growing importance of contractor-driven design management in their seminal report (1994) and subsequent book (Gray and Hughes, 2001). Contractor-led design management is the coordination and regulation in the building design process used to deliver high quality buildings (Flanagan and Tate, 1997). It fosters better cooperation between the contractor and other project participants throughout the design and construction process. To obtain maximum performance, contractor's knowledge and experience will be useful, when it can be applied from the early project stages (Jergeas and Put, 2001).

However, the functions of design management are much less well defined, and there has been little empirical research on design management from the contractor's perspective. In addition, researchers (Andersen et al., 2005; Tzortzopoulos and Cooper, 2007) have found that even if specialized design professionals and construction trades have made complex HRPs possible, they have decoupled the design process from the contractor's work scope. This separation has hindered the integration of design and construction knowledge, and has diminished the opportunity for contractors to influence design processes (Song et al., 2009; Mills and Glass, 2009).

Studies on contractor-led design management have been conducted recently. Emmitt (2007) argued that a complex construction process makes a contractor undertake more management responsibility for the entire project. Moreover, Ng and Skitmore (2002) suggested that systematic design management is essential for contractors who undertake particularly large-scale projects. They explained that contractors are in the best position to provide systematic management because they have empirical data that they have collected from previous completed projects. Deane (2008) researched design management from the contractor's point of view. He states that design management is a function that coordinates design information into the production stage to deliver high quality products. In the same context, more practical research has been attempted by Walker and Walker (2012). They argued that because contractors have empirical experiences in on-site design-related problems, the contractors' early involvement could be a key factor in resolving design-related risks before the commencement of building construction. The benefits from the contractor's early involvement include an improved schedule, reduced cost, improved safety, and increased quality performance (Gil et al., 2004; Emmitt, 2010). According to studies of Pulaski and Horman (2005) and Song et al. (2009), contractor can have adequate time for a better construction planning by early involvement of design management or strategy such as constructability and value engineering programs.

In more practical literature, early application of contractors' design management which is cooperating with fabrication and sub-contractors made the contractor achieve a total installed cost for the platform 35% below the owner's original cost estimate in a real case project (Jergeas and Put, 2001). Moreover, Song et al. (2009) analyzed project performance in three application stages of the design management from the initial concept developing stage to detail design stage. According to three steps application of the contractors' design management, performance simulation leaded to a savings from 1.4 to 5.5% on total man hours and a larger savings from 3.4 to 12% on overall project duration. By this, the contractor improves value and reduces wasteful rework during the construction stage.

Critical factors for project success

Due to the increasing scale and complexity of construction projects, numerous project factors should be considered for HRPs. Since the introduction of the concept of project success factors by Rubin and Seeling (1967), there has been a considerable increase in the research on critical factors. Generally, critical success factor (CSF) studies for construction projects can be categorized into three research categories: general project management, specific purpose and procurement, and regional features as seen in Appendix I. Initially, the majority of general project management research has examined the perception of how project implementation factors satisfy the various stakeholders and clients. Since the 2000s however, due to the various characteristics and discrete purposes of construction projects, the research focus on CSFs has diversified (Chua et al., 1999). However, the major parts of CSFs studied were related to the general aspects of the traditional management context. Studies had been focused on general management systems and processes rather than considering of the various aspects of project success.

Recently, CSF studies are being diversified due to different regional project features. They consider the nature and structure of the local construction industry, procurement systems, and local cultural values and norms. Moreover, in accordance with diverse project execution in different countries for hospitals, housing complexes, infrastructure, and high-rise buildings, research on CSFs has been conducted based on multinational projects. Therefore, understanding of the cultural and religious characteristics and differences of counterpart countries has been essential. To implement multinational projects successfully, in-depth and cumulative awareness of regional features are important from technical aspect such as working process, industrial standard, building code to conventional aspects including linguistic gap, life style, social hierarchy, and political situation. Phua (2004) researched a multi-firm project from the multinational perspective, and suggested that international projects need a balance between managing traditional elements such as the budget, timetable, and technical specifications, and the external influences according to regional and cultural features. Toor and Ogunlana (2009) also studied the CSFs for international projects. In order to recognize more suitable CSFs, they analyzed and divided numerous project management factors by comparing the importance and correlation values. In line with the trend of international construction projects, the understanding of CSFs has received attention from the academic field of project management.

Research Methodology

The present research is structured into three methodology parts: the factor identification phase, the data collection phase, and the data analysis phase, as seen in Fig. 1. Available potential CDMFs were obtained from diverse academic studies and industrial data. Apart from various literature reviews, the practical knowledge of the Korean HRP market, contractor-led design management, and multinational design teams were also studied.

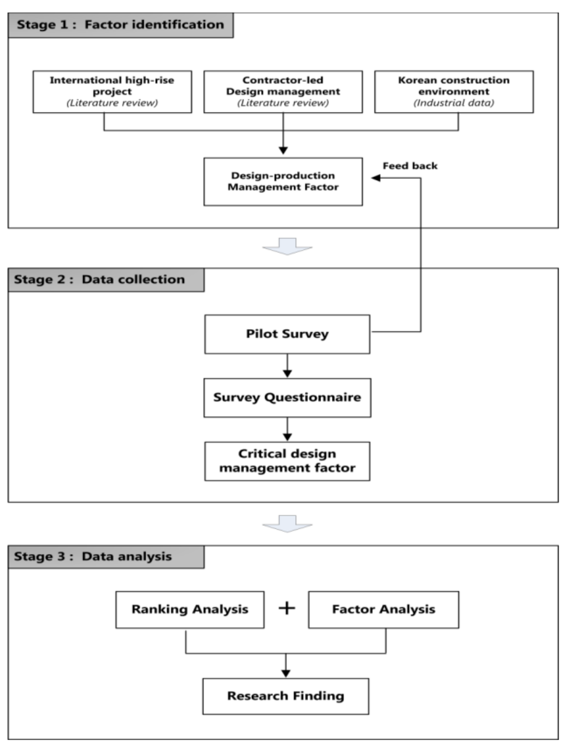

Figure 1. Research flow

Pilot survey

Through an initial factor collecting procedure, a total of 58 potential CDMFs were obtained. These initial factors were adjusted through a pilot survey. The pilot survey was tested on 16 industry professionals before determining the main questionnaire structure to ensure the clarity and relevance of the questionnaire. All participants in the pilot survey were in senior managing positions in their organizations and had an average of over 18.3 years of working experience. As part of the pilot survey, comments and suggestions for the survey items, item wording, item sequence, and directions were also solicited. According to a review of the pilot survey, 40 CDMFs (Appendix II) were determined to be included in the questionnaire survey.

Questionnaire development

Questionnaire surveys have been widely adopted by previous researchers for deriving CSFs in different contexts (Li et al., 2005; Lu et al., 2008). In this research, the questionnaire was divided into two parts. Part 1 included 5 questions designed to acquire personal and general information. In part 2, the respondents were asked to rate the importance of the factors from the contractors' perspective using a Likert five-point scale. Values of 1 to 5 were assigned to the responses for the "importance" of contractor-led design management factors, with 1 as "negligible," 2 as "unimportant," 3 as "neutral," 4 as "important," and 5 as "extremely important."

All questions were translated into Korean and issued to Korean construction professionals who have engaged in internationally-based HRPs as a project manager, site manager, project engineer, or design manager. All respondents were selected from Grade 1 contracting and engineering firms that were registered with the Construction Association of Korea International Contractors Association of Korea or Korea Construction Engineers Association. To ensure a better understanding of the questions, a brief description of CDMFs was provided with a cover letter. The confidentiality and anonymity of all questionnaire responses were ensured at every stage of the research process.

Questionnaire distribution

The questionnaires were distributed by e-mail and personal delivery to increase the rate of response. A total of 284 questionnaires were distributed and 127 valid responses were received, representing a response rate of 44%. Table 1 shows that among the 127 responses, 21 respondents (16.5%) were project managers, 51 (40.1%) were site managers, 22 (17.3%) were project engineers, and 33 (26.1%) were design managers. As seen in Table 2, the majority of the respondents (86%) had working experience of more than 5 years with their organizations. They were professionally positioned at the middle or higher management level, which implies that a high level of accuracy and credibility of the data was achieved.

Group	Project Manager	Site Manager	Project Engineer	Design Manager	Total Responses
LSP	10	22	7	7	46
JVP	7	13	5	11	36
IBP	4	16	10	15	45
Total	21	51	22	33	127

Note. LSP: Large-scale project, JVP: Joint venture project, IBP: International-based project

Table 1. Project types and positions held by respondents

Experience(Years)	Project Managing	Site Managing	Project Engineering	Design Managing	Total Responses
Under 5	-	4	6	7	17
5-10	2	12	6	9	29
11-15	6	17	5	6	34
16-20	8	11	4	5	28
21-30	3	6	-	3	12
Over 30	2	1	1	3	7

Total	21	51	22	33	127

Table 2. Working period of respondents

Data analysis

In order to identify the CDMFs that affect the performance of an HRP, ranking analysis and factor analysis were used. Ranking analysis was used to find the critical factors which were considered a priority among various design management factors; whereas, factor analysis was used to identify the underlying dimensions. For balanced data analysis, it is preferred that both analysis methods are used at the same time (Wang and Yuan, 2011). If only ranking analysis is used, it is difficult to investigate common elements and correlation between factors which are recognized as critical. In addition, if only factor analysis is used and not ranking analysis it is difficult to apply these factors directly to a project, because the importance value of these factors cannot be recognized easily.

Statistical analysis of this study was facilitated by the Statistical Package for the Social Sciences (SPSS V21.0, IBM, Chicago). Cronbach's alpha coefficient was particularly used for determining the reliability of the questionnaire by measuring the internal consistency among the factors (Norusis, 2005). The result of the test was 0.836, which is greater than the 0.5 significant level, indicating that the five-point scale measurement was reliable.

Ranking analysis

The CDMFs were ranked in order of importance according to their mean values. The mean and standard deviation of each factor were derived from the total sample to determine the level of importance. If two or more factors had the same mean value, the factor with the lower standard deviation was considered to be more important. Design management factors with mean values greater than the average value of all factors, 2.942, were classified as CDMFs that affected a contractor's project performance. Finally, 21 factors were identified as CDMFs and the ranking results of these factors are shown in Table 3.

No.	Critical design management factors	Rank	Mean	Standard deviation
F29	Management of the design interface between international design firms (Interior/landscape architect/lighting designer)	1	3.602	0.947
F08	Organization of the integrated design management team on-site (ranked with TFT and CM)	2	3.574	0.928
F04	Proposal of value engineering	3	3.541	1.059
F11	Standardization of different types of drawings and documents (for international partner contractors and sub-contractors)	4	3.513	0.979
F01	Project documents review (cost statement, B.O.Q, drawing, specification)	5	3.482	0.914
F10	Application of BIM connected with the PMIS	6	3.463	0.974
F27	Coordination of working drawing by changed design (material change, changed items, constructability, delivery schedule)	7	3.293	1.023
F07	Establishment of a project management information system (PMIS)	8	3.265	1.116
F02	Review of the adequacy of the design level compared to the project budget	9	3.217	1.125
F18	Documents management by the application of Fast-Track (drawing distribution/instruction)	10	3.214	1.022
F26	Instruction of a construction manual and guidelines for off-site material	11	3.145	1.191
F20	Study of adequacy of structural grid planning (over design, omission)	12	3.120	1.098
F14	Establishment of a design checklist on-site	13	3.056	1.021
F22	Standardisation of the pre-assembly and modularization process	14	3.048	0.909
F40	Support for an environmental building certification	15	3.012	0.958
F25	Approval working drawing and sample product	16	2.976	1.168
F35	Discussion with property selling department (concept of interior design, computer graphics, interior finishing simulation)	17	2.963	0.961
F28	Interface management between Korea standard and global standard	18	2.960	1.145
F38	Management of whole documents for inspection of building completion	19	2.954	1.230
F24	Regular detailed design meetings with international subcontractors and suppliers	20	2.954	0.948

F34	Discussion the pre-requirement of major tenants or buyers	21	2.946	1.107

Note: TFT (Task force team), CM (Construction management), BOQ (Bill of quantity),
Fast-Track (Starting construction before the design is complete)

Table 3. Respondents' rating perception of CDMFs

Among the CDMFs, the "Project management information system (PMIS) (F07)," "Off-site construction manual and guideline (F26)," and "Making criteria for pre-assembly process on site (F22)" factors have general feature of design management. Even if they are not highly ranked; 8th, 11th, 14th respectively, due to their applicability into diverse project, they are always recognized as important to contractors. To some extent these factors are more closely related to the production stage than design process. However, because these factors are strongly influence by the integrity of design information, frequently they are identified as part of the design manager's role in the construction sector (Kim and Kown, 2005). There are also no obvious defined roles of both information management and delivery management for contractors. Thus, a portion of information and delivery issues are handled by the design management team. Other factors such as "Discussion with property selling department (F35)" and "Prior discussion on major buyer's requirements (F34)" have regional features of design management. Because a contractor can sell a property on behalf of a client before the start of construction, the contractor should manage the interior finishing or material changes based on the requirements of major tenants or buyers during the construction stage. As a unique factor used only in the Korean construction industry, it is not considered an important factor in other country.

The factors F29, F08, F04, F11, F01, and F10 were the top six critical factors, each of which had a mean value above 3.40. Among the 21 critical factors, only 6 factors indicated a remarkably high mean value as well as a relatively low standard deviation. This means that regardless of their work position and experience, almost all respondents recognized these 6 factors as being quite significant.

Based on the general design management factors (F29, F11, F01, F10), the distinctive factors (F08, F04) were added to these 6. Even if F08 and F04 are applied in other construction industry, because in Korea, they are used dominantly by contractor in large-scale and complex, they can be perceived to have distinctive Korean (regional) features.

Remarkably, the factor “Integrated design management team on-site (F08),” ranked in second place, is unique but common in the Korean construction sector. In terms of HRPs particularly designed by a multinational design team, almost all Korean contractors launch an on-site design management team, which manages all design information as well as the foreign architects. Because an international design-based project in which the design changes or errors need more time and consensus to process, the on-site design management team, which can settle the problems through discussions with either the foreign architects or local design partners, can be a CDMF for the contractor.

The “Proposal of value engineering (F04)” factor was ranked as the third critical factor. In a Korean construction project, the proposal of value engineering is very common. Sometimes it is requested from the client. In many Korean HRPs, contractors conduct value engineering not only from the contractor’s perspective, but also from the client’s perspective. Typically, value engineering has been recognized by Korean contactors as the last opportunity to change the design and construction methods in a way that could reduce project costs and duration. Value engineering is used as a way to change the original design created by an international architect to be constructed easily and at low cost (Cheah and Ting, 2005). It is conducted mainly by the contractor’s design management team through the support of the local design partners.

The factors “Off-site construction manual and guideline (F26)” and “Making criteria for pre-assembly process on site (F22)” were ranked eleventh and fourteenth, respectively. These factors are related to off-site construction. Although their rankings were not relatively high, they indicate the changed role of design management in a construction project. Due to the development of building materials and increased building complexity, products can be produced in off-site factories (Blismas et al. 2006). According to Eastman and Sack (2008), the market value of an off-site product in the United States has grown by 74% over the last 10 years. Since these off-site productions are produced based on different building codes and standards, interface management between off-site and in situ production is recognized as a critical factor.

As a factor related to the environment, “Support for an environment-friendly building certification (F40)” was ranked fifteenth. The Korean government has enforced environment-friendly building methods, and provides incentives (such as a tax relief for environment-friendly buildings) that have caused clients and contractors to try to achieve an environmental certification, such as the Green Building Certification Criteria (GBCC) (Whang and Kim, 2014). Particularly, most HRPs must be developed based on the governmental sustainable guideline in Korea. However, it is quite complicated and difficult to maintain a sustainable level of project from the design stage to the construction stage, because of empirical barriers including delivery problems or increasing material costs. Different interface managements are needed between environmental consultants, contractors, designers, and even project authorities.

Factor analysis

Factor analysis is a series of methods for identifying groups of related variables, and is an ideal technique for reducing numerous items into a more easily understood framework (Norusis, 2005). It was used in this study to explore the groupings that might exist among the CDMFs.

Comp-onent	**Initial eigenvalues**	**Extraction sums of squared loadings**	**Rotation sums of squared loadings**

	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)
01	6.132	31.638	34.638	6.132	31.638	34.638	4.526	23.352
02	3.283	16.938	48.576	3.283	16.938	48.576	3.467	17.888
03	1.715	8.848	57.424	1.715	8.848	57.424	2.393	12.347
04	1.277	6.589	64.013	1.277	6.589	64.103	2.021	10.427
05	.938	4.840	68.853					
06	.815	4.205	73.057					
07	.682	3.519	76.576					
08	.639	3.297	79.873					
09	.526	2.714	82.587					
10	.470	2.425	85.012					
11	.429	2.213	87.225					
12	.403	2.079	89.305					
13	.365	1.883	91.188					
14	.327	1.687	92.875					
15	.298	1.538	94.412					
16	.251	1.295	95.707					
17	.226	1.166	96.873					
18	.186	0.960	97.833					
19	.167	0.862	98.695					
20	.134	0.691	99.386					
21	.119	0.614	100.000					

Extraction method : Principal component analysis.

Table 4. Total rotated factor variance explained for CDMFs

In this study, the survey data of the 21 factors was fed into the SPSS 22.0 system for principal component analysis, which is a common method in factor analysis. The Bartlett test of sphericity analyzed by SPSS is 643.192 and the associated significance level is 0.000, indicating that the population correlation matrix was not an identity matrix. The value of the Kaiser–Mayer–Olkin (KMO) measure of sampling adequacy was 0.738, higher than 0.5, indicating that the sample meets the fundamental requirements for factor analysis (Norusis, 2000). The lower limit of the eigenvalue was set to 1.00, as suggested by the scree plot obtained during analysis. Principal component analysis produced a four factor solution with an eigenvalue greater than 1.00, explaining 64.01% of the variance, as seen in Table 4. The remaining factors together accounted for 35.99% of the variance.

	Critical success factors	**Component (factor groupings)**			
		Group 1	Group 2	Group 3	Group 4
F11	Standardization of different types of drawings and documents	0.912			
F29	Management of the design interface between international design firms	0.868			
F22	Standardisation of the pre-assembly and modularization process	0.735			
F27	Coordination of working drawing by changed design	0.712			
F18	Documents management by the application of Fast-Track	0.709			
F35	Discussion with property selling department	0.693			
F24	Regular detailed design meetings with international subcontractors and suppliers	0.636			
F28	Interface management between Korean standard and global standard	0.617			
F34	Discussion the pre-requirement of major tenants or buyers	0.613			
F01	Project documents review (cost statement, B.O.Q, drawing, specification)		0.833		
F07	Establishment of a project management information system (PMIS)		0.752		
F14	Establishment of a design checklist on-site		0.716		
F10	Application of BIM connected with the PMIS		0.676		
F38	Management of whole documents for inspection of building completion		0.637		
F08	Organization of the integrated design management team on-site				
F26	Instruction of a construction manual and guidelines for off-site material			0.772	
F04	Proposal of value engineering			0.729	
F40	Support for an environmental building certification			0.703	
F25	Approval working drawing and sample product			0.684	
F02	Review of the adequacy of the design level compared to the project budget			0.651	0.860
F20	Study of adequacy of structural grid planning (over design, omission)				0.775

Extraction method: Principal component analysis.
Rotation method: Varimax with Kaiser normalization.
Rotation converged in seven iterations.

Table 5. Component matrix after varimax rotation

The factor groupings, based on a varimax rotation, are shown in Table 5. Each factor belongs to one of the four groups generated by the factor analysis, with the loading on each factor exceeding 0.60. The four factor groupings and their related factors are labeled as follows:

Factor grouping 1: Interface management

Factor grouping 2: Design information

Factor grouping 3: Production stage

Factor grouping 4: Risk contribution

Research Findings (Interpretation of grouping factors)

Interface management

The eight extracted CDMFs for factor grouping 1 are all related to interface management or integration management. In international HRPs, the importance of interface management between diverse design information sets and the construction processes that connect them has increased. In accordance with the development of high technology, fundamental changes have forced contractors to control and manage different interfaces between design and construction processes (Lee et al., 2005) as well as on-site and off-site products. Accordingly, the factors "Standardization of different types of drawings and documents (F11)" and "Management of design interface between international design firms (F29)" have high loadings, 0.912 and 0.868, respectively, as shown in Table 5. Some other factors (F27, F18, F24, F28) are detailed interface management factors that can be used for on-site contractors.

Unlike the above factors that mainly deal with design and engineering interface management, the factors "Discussion with property selling department (F35)" and "Prior discussion on major buyer's requirements (F34)" are related to property selling, which is a unique feature of the Korean construction environment. Although there are different requests and arguments between the selling department and potential customers, eventually, contractors should manage the interfaces between clients, property customers, contractors, and designers.

Design information

Efficient information management becomes one of the most critical factors in an HRP. A large quantity of complicated information is generated by the designers, suppliers, and engineers throughout a project (Flanagan et al., 2007). All design information is interconnected between them. In a contemporary HRP, design management begins with an appropriate understanding and classification of information (Stewart et al. 2004).

The "Project documents review (F01)" factor is conducted at a very early project stage. Through this factor, all project information can be reviewed and recognized before commencement of practical construction. Particularly, different forms of design information such as drawings, documents, and images are re-classified and transferred to the next information processing system (Soibelman et al. 2003).

The "Project management information system (PMIS) (F07)" and "Application of BIM (F10)" factors are related to information processing systems. A variety of information is stored, improved, and transferred by these factors. These factors are not decisive factors that can change the whole status of a project; thus, they do not have high loadings, which are 0.752 and 0.676, respectively. However, from the contractor's perspective, they are very critical factors that can be the backbone for project implementation. From project inception via the construction stage to production hand-over, all project elements are strongly related to both BIM and PMIS systems. Subsequently, all design information processed within BIM and PMIS systems make the "Establishment of design integrity checklist (F14)" and "Document management for inspection of building completion (F38)" factors more effective during the construction stage.

Production stage

The five extracted CDMFs for Group 3 influence the performance of the production stage directly because these factors, which relate to the management of the drawings, engineering methods, and materials, are implemented completely from the contractor's perspective. The importance of the "Off-site construction manual and guideline (F26)" factor has increased with the development of building material technologies. Particularly, in a contemporary HRP in which different building functions are integrated within a single project, many off-site materials are used. A design management team should manage not only the quality of the off-site materials, but also the assembly interface between off-site and on-site products.

In the Korean construction sector, the "Proposal of value engineering (F04)" factor is predominant and essential. Almost all contractors propose value engineering during the production stage. They perceive that value engineering is the last opportunity to change the design and production method to reduce the cost and duration. Through value engineering, the detailed design becomes more explicit and can be erected more easily, and production performance can also be improved by applying effective engineering methods with which the contractor has experience and competence (Cheah and Ting, 2005).

Risk contribution

The risk contribution grouping consists of two CDMFs, "Review of the design level compared to budget (F02)" and "Structural grid planning review (F20)," which have relatively high loadings of 0.860 and 0.775, respectively. This means that despite the small number of design risk managing factors, the importance of each factor is quite high.

Architects and designers tend to focus on aesthetics, form, function, and structural and environmental integrity. With more subordinately depiction, international architects consider the overall balance between ideal and practical design, whereas local architects concentrate on the realization of the practical design more easily according to regional features. However, contractors focus on resources, production methods, processes, and sequences (Fang et al. 2004). Thus, a detailed and comprehensive design review by a contractor is quite critical for risk management, particularly during the initial stage. Due to the limited time for project commencement, a contractor normally cannot check for latent detailed design issues. If incomplete design is revealed earlier, the contractor can prepare alternatives to reduce production risks (Walker and Walker, 2012). Thus, design-related production risks such as omissions or overdesign should be controlled by the application of appropriate CDMFs.

Conclusion

In Korean HRPs, design processes and construction methods are becoming more complex. Additionally, design-related risk for contractors is increasing. This study identifies and ranks the CDMFs for HRPs designed by multinational design teams. Through a questionnaire survey, 40 initial design management factors were ranked according to their mean values. Among them, only 21 factors were acknowledged as CDMFs. The "Management of design interface between international design firms (F29)," "Integrated design management team on-site (F08)," and "Proposal of value engineering (F04)" factors were recognized as the top three critical factors for Korean construction professionals. Using the factor analysis technique, the 21 identified CDMFs were categorized into four groups: (1) interface management, (2) design information, (3) production stage, and (4) risk contribution.

Until now, in terms of design, the contractor has responded only passive and belated reactions, even if they can make serious reworks and delay during production stage. The findings of this research can offer decision-making support for contractors by providing a comprehensive understanding of how CDMFs influence production processes on-site. By using these, the contractor can control all project processes, not only construction activities, but also design elements through project life cycle. Moreover, if the contractor recognizes these findings in an early construction stage, they may be able to predict practical production risk and prepare appropriate responses in advance.

Although this study was conducted based on Korean HRPs, its findings can be applied to other places by adjustment of some factors according to the industrial or regional features. If a contractor or project manager wants to achieve further improvement, additional study should focus on a segmented production process

Appendix I. Classification of critical success factor in construction project

This appendix indicates the research trend flow of critical success factor in recent construction project. According to project procurement or development way, critical factors have been shifted. In the past, dominant critical factors had general and basic management aspects. Nowadays, due to different project procurements or location and increasing building technologies and functions, critical factor are getting diverse. In Table 6, classification of literature reviews is presented to show the expanded concept of critical factor in construction project.

Categories of Critical factor	Description of Critical factor	Relevant literature
General & traditional Project management	Construction industry	Abraham (2003), Arslan and Kivrak (2008)
	Specific project management	Caralli et al. (2004), Dobbins (2002), Shen and Liu (2003), Pollalis and Frieze (1993)
	Tendering risk	Chan and Au (2009)
	Human resource	Belout and Gauvreau (2004)
	Success factor analysis	Yu et al. (2005), Belassi and Tukel (1996), Selin and Selin (1994)
	General project management	Savindo et al. (1992), Morris and Hough (1987), Pinto and Slevin (1987), Cash and Fox (1992), Ashley et al. (1987)
	Contractor competitiveness	Lu et al. (2008)
	Innovative project management	Boynton and Zmud (1984), Jang and Lee (1998), Fortune and White (2006), Westerveld (2003)
	Project implementation	Chua et al. (1999), Baker et al. (1983), Clarke (1999)
Variety of project purpose &	Project life-style	Park (2009), Khang and Moe (2008), Pinto and Slevin (1987)

procurement		
	Design-Build	Chan et al. (2001), Songer and Molenaar (1997)
	Joint venture	Gale and Luo (2004), Phua (2004-A), Phua (2004-B)
	BOT / BOOT	Jefferies et al. (2002), Tiong (1996)
	PPP	Li et al. (2005), Zhang (2005), Jacobson et al. (2008)
	International development	Kwak (2002), Ika et al. (2012), Ahadzie et al. (2008)
	Partnering	Black et al. (2000), Cheng et al. (2000), Cheng and Li (2002)
	Project information system	McGolpin and Ward (1997), Nandhakumar (1996), Yeo (2002)
	Large-scale project	Tan (1996), Toor and Ogunlana (2005)
Variety of project region	UK	Shash (1993)
	Russia	Khoo and Tan (2002)
	Norway	Torp et al. (2004)
	Thailand	Toor and Ogunlana (2008)
	Vietnam	Nguyen et al. (2004)
	Malaysia	Denni-Fiberesima and Rani (2011)
	China	Lu et al. (2008), Wang et al. (2010), Qiao et al. (2001), Ika et al. (2012), Wang and Yuan (2011)
	Taiwan	Chen and Chen (2007),
	Korea	Yu and Kwon (2011)
	Pakistan	Muhammad et al. (2008)
	Indonesia	Kaming et al. (1997)
	Hong Kong	Ng and Mo (1997)
	Nigeria	Denni-Fiberesima and Rani (2011)

Note: BOT (Build-operate-transfer), BOOT (Build-own-operate-transfer), PPP (Public-private partnership)

Table 6. Classification of critical success factor study in construction project

Appendix II. Potential critical design management factors

By factor collecting procedure, initially 53 design management factors are achieved from diverse academic literature reviews, industrial reports, and actual project case-studies. All selected potential factors are suitable and applicable to high-rise project in Korea. For more objective and substantial survey, initial 53 factors were adjusted through a pilot survey by Korean construction experts. By this, some fewer related and ambiguous factors were excluded, while omitted factors were included. Table 7 shows the 40 potential critical factors determined by pilot survey. Among these, 21 factors were selected as CDMFs by ranking analysis and factor analysis.

No.	Critical design management factors
F01	Project documents review (cost statement, B.O.Q, drawing, specification)
F02	Review of the adequacy of the design level compared to the project budget
F03	Terms and agreement review
F04	Proposal of value engineering
F05	Legal factors review (domestic and international)
F06	Similar projects case study (design, construction method and cost, duration, advanced technologies)
F07	Establishment of a project management information system (PMIS)
F08	Organization of the integrated design management team on-site (ranked with TFT and CM)
F09	Establishment of delivery control plan for international supply chain (long lead/distance item)
F10	Application of BIM connected with the PMIS
F11	Standardization of different types of drawings and documents (for international partner contractors and sub-contractors)
F12	Analysis of impact on the surrounding buildings (view, insolation, privacy, vibration, dust)
F13	Establishment of shop drawing master schedule by subcons and suppliers
F14	Establishment of a design checklist on site
F15	Interface management between domestic building code and international code
F16	Feedback the site situation to PMIS
F17	Analysis of site conditions (site topography/ground condition/groundwater level)
F18	Documents management by the application of Fast-Track (drawing distribution/instruction)
F19	BIM simulation for Top-Down method
F20	Study of adequacy of structural grid planning (over design, omission)
F21	Building frame work master schedule (milestone schedule management and control)
F22	Standardisation of the pre-assembly and modularization process
F23	Work cooperation with project supervisors and authorities
F24	Regular detailed design meetings among international subcontractors and suppliers
F25	Approval working drawing and sample product
F26	Instruction of a construction manual and guidelines for off-site material
F27	Coordination of working drawing by changed design (material change, changed items, constructability, delivery schedule)
F28	Interface management between Korea standard and international standard
F29	Management of the design interface between international design firms (Interior/landscape architect/lighting designer)
F30	Discussion with interior design team for detailed interior design
F31	BIM simulation for interference with other work packages (Interference check with structural work)
F32	Simulation of life-cycle cost (maintenance cost)
F33	Establishment of mechanical and electrical facilities up-grade plan (ranked with PMIS, BIM)

F34	Discussion the pre-requirement of major tenants or buyers
F35	Discussion with property selling department (concept of interior design, computer graphics, interior finishing simulation)
F36	Supporting the making of interior mock-up test
F37	Discussion of extra requirements from client and licensors before project closing
F38	Management of whole documents for inspection of building completion
F39	Support of facility management system (FMS) establishment
F40	Support for an environmental building certification

Note: TFT (Task force team), CM (Construction management), BOQ (Bill of quantity),
Fast-Track (Starting construction before the design is complete)

Table 7. Initial 40 design management factors

Acknowledgements

This work was supported by the 2015 Yeungnam University Research Grant.

References

Abraham, G. L. (2003). "Critical success factors for the construction industry." *Proc., Construction Research Congress in Construction-Wind of Change: Integration and Innovation* (CD-ROM), Construction Institute-Construction Research Council, ASCE, Univ. of Colorado at Boulder, Boulder, Colo.

Ahadzie, D. K., Proverbs, D. G., and Olomolaiye, P. O. (2008). "Critical success criteria for mass house building projects in developing countries." *Int. J. Project Manage*., 26(6), 675-687.

Almeida, H., Park, S. Y., Subrahmanyam, M. G., and Wolfenzon, D. (2011). "The structure and formation of business groups: Evidence from Korean chaebols." *J. Financ. Econ*., 99(2), 447-475.

Andersen, J., Nycyk, M., Jolly, L., and Radcliffe, D. (2005). "Design management in construction company." in Radcliffe, D and Humphries, J. (eds), *Proc., ASEE/AaeE 4th Global. Colloquium Engineering Education,* Australasian Association for Engineering Education, Sydney, Australia.

Arslan, G., and Kivrak, S. (2008). "Critical Factors to Company Success in the Construction Industry." *Int. J. Soc. Behav. Educ. Econ. Bus. Ind. Eng*., 2(9), 997-1000.

Ashley, D. B., Laurie, C. S., and Jaselskis, E. J. (1987) "Determinants of construction Project success." *Proj. Manage. J*., 18(2), 69-79.

Baccarini, D. (1996) "The concept of project complexity a review." *Int. J. Project Manage.*, 14(4), 201-204.

Cleland D. I., and King W. R. (1983). *Project management handbook*. Van Nostrand Reinhold, New York.

Baker, B. N., Murphy, D. C., and Fisher, D. (1983). "Factors affecting project success," in *Project Management Handbook,* Cleland, D. I. and King W.R., Eds. New York: Van Nostrand.

Bea, J. I., Shin J. W., and Kwon, O. K. (2006) “A suggestion for design process improvement to develop a design management model.” *Korea Inst. Constr. Eng. Manage*., 7(6), 90-98 (in Korean).

Belassi, W., and Tukel, O. L. (1996). “A news framework for determining critical success/ failure factors in projects.” *Int. J. Project Manage*., 14(3), 141-151.

Belout, A., and Gauvreau, C. (2004). “Factors influencing project success: the impact of human resource management.” *Int. J. Project Manage*., 22(1), 1-11.

Black, C., Akintoye, A., and Fitzgerald, E. (2000). “An analysis of success factors and benefits of partnering in construction.” *Int. J. Project Manage*., 18(6), 423-434.

Blismas, N., Pasquire, C., and Gibb, A. (2006). “Benefit evaluation for off-site production in construction.” *Constr. Manage. Econ*., 24(2), 121-130.

Boynton, A. C., and Zmud, W. (1984). “An assessment of critical success factors.” *Sloan Manage. Rev*., 25(4), 17-27.

Carali, R. A., Stevens, J. F., Wilke, B. J., and Wilson, W. R. (2004). “The critical success factor method: Establishing a foundation for enterprise security management.” *Carnegie Mellon University Press*. Pittsburgh.

Cash, C., and Fox, R. (1992). “Elements of successful project management.” *J. Syst. Manage*., 43(9), 10-12.

Chan, A. P. C., Ho D. C. K., and Tam, C. M. (2001) “Design and build project success factors: multivariate analysis.” *J. Constr. Eng. Manage*., 10.1061/(ASCE)0733-9364(2001)127:2(93), 93-100.

Chan, E. H. W., and Au, M. C. Y. (2009). “Factors Influencing Building Contractors’ Pricing For Time-Related Risks in Tenders.” *J. Constr. Eng. Manage*., 10.1061/(ASCE)0733-

9364(2009)135:3(135), 135-145.

Cheah, C. Y. J., and Ting, S. K. (2005). "Appraisal of value engineering in construction in Southeast Asia." *Int. J. Project Manage.*, 23(2), 151-158.

Chen, W. T., and Chen, T. T. (2007). "Critical success factors for construction partnering in Taiwan." *Int. J. Project Manage.*, 25(5), 475-484.

Cheng, E. W. L., Li, H., and Love, P. E. D. (2000). "Establishment of Critical Success Factors for Construction Partnering." *J. Manage. Eng.*, 10.1061/(ASCE)0742-597X(2000)16:2(84), 84-92.

Cheng, E. W. L., and Li, H. (2002). "Construction Partnering Process and Associated Critical Success Factors: Quantitative Investigation." *J. Manage. Eng.*, 10.1061/(ASCE)0742-597X(2002)18:4(194), 194-202.

Chua, D. K., Kog, Y. C., Loh, P. K. (1999). "Critical success factors for different project objectives." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(1999)125:3(142), 142-150.

Clarke, A. (1999). "A practical use of key success factors to improve the effectiveness of project management." *Int. J. Project Manage.*, 17(3), 139-145.

Cleland, D., and Ireland, L. (2002). *Project management: Strategic design and implementation*, McGraw-Hill, New York.

Cooke-Davies, T. J., Cicmil, S. J. K., Crawford, L. Y., and Richardson, K. (2007). "We're not in Kansas anymore, Toto: Mapping the strange landscape of complexity theory, and its relationship to project management." *Proj. Manage. J.*, 38(2), 50-61.

CTBUH (Council on Tall Buildings and Urban Habitat). (2011). "Tall Building Database." (http://buildingdb.ctbuh.org/) (Apr. 7, 2015).

Deane, M. (2008) "The builder's role in developing sustainable tall buildings." *Struct. Des. Tall*

Spec. Buil., 17(5), 869-880.

Denni-Fiberesima, D., and Rani, N. S. A. (2011). "An evaluation of critical success factors in oil and gas project portfolio in Nigeria." *Afr. J. Bus. Manage.*, 5(6), 2378-2395.

Dobbins, J. (2002). "Critical success factor (CSF) analysis for DoD risk management." *Program manager,* 31(3), 40-45.

Eastman, C. M., and Sacks, R. (2008). "Relative Productivity in the AEC Industries in the United States for On-Site and Off-Site Activities." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2008)134:7(517), 517-526.

El Wardani, M., Messner, J., and Horman, M. (2006), "Comparing Procurement Methods for Design-Build Projects." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2006)132:3(230), 230-238.

Emmitt, S. (2007). *Design Management for Architects*, Blackwell Publishing, Oxford, U.K.

Emmitt, S. (2010). "Design Management in Architecture, Engineering and Construction: Origin and Trends." *Gestão & Tecnologia de Projetos*, 5(3), 28-37.

Fang, D. P., Li, M., Fong, P. S., and Shen, L. Y. (2004). "Risks in Chinese construction Market-contractors' perspective." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2004)130:6(853), 853-861.

Flanagan, R., Lu, W., Shen, L., and Jewell, C. (2007). "Competitiveness in construction: a critical review of research." *Constr. Manage. Econ.*, 25(9), 989-1000.

Flanagan, R., and Tate, B. (1997). *Cost control in building design*, Blackwell Science Ltd, Oxford, U.K.

Fortune, J., and White, D. (2006). "Framing of project critical success factors by a systems

Model." *Int. J. Project Manage*., 24(1), 53-65.

Gale, A., and Luo, J. (2004). "Factors affecting construction joint ventures in China." *Int. J. Proj. Manage*., 22(1), 33-42.

Gil, N., Tommelein, I. D., and Ballard, G. (2004). "Theoretical comparison of alternative delivery systems for projects in unpredictable environments." *Constr. Manage. Econ.,* 22(5), 495–508.

Gray, C., Hughes, W., and Bennett, J. (1994). *The Successful Management of Design*. Centre for Strategic Studies in Construction, University of Reading, Reading, U.K.

Gray, C., and Hughes, W. (2001). *Building Design Management*, Butterworth-Heinemann, Boston, MA.

Hegazy, T., Zaneldin, E., and Grierson, D. (2001). "Improving Design Coordination for Building Projects. I: Information Model." *J. Constr. Eng, Manage*., 10.1061/(ASCE)0733-9364(2001)127:4(322), 322-329.

Ika, L. A., Diallo, A., and Thuillier, D. (2012). "Critical success factors for World Bank projects: An empirical investigation." *Int. J. Project Manage*., 30(1), 105–116.

Jacobson, C., and Choi, S. O. (2008). "Success factors: public works and public-private partnerships." *Int. J. Pub. Sector Manage*., 21(6), 637-657.

Jang, Y., and Lee, J. (1998). "Factors influencing the success of managing consulting projects." *Int. J. Project Manage*., 16(2), 67-72.

Jefferies, M., Gameson, R., and Rowlinson, S. (2002). "Critical success factors of the BOOT procurement system: reflections from the Stadium Australia case study." *Eng. Constr. Archit. Manage*., 9(4), 352-361.

Jergeas, G., and Put, J. V. D. (2001). "Benefits of constructability on construction projects." *J. Constr. Eng. Manage*., 10.1061/(ASCE)0733-9364(2001)127:4(281), 281-290.

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., and Harris, F. C. (1997). "Factors influencing construction time and cost overruns on high rise projects in Indonesia," *Constr. Manage. Econ.*, 15(1), 83–94.

Khang, D. B., and Moe, T. L. (2008). "Success criteria and factors for international development projects: A lifecycle-based framework." *Project Manage. J.*, 39(1), 72-84.

Khoo, H. H., and Tan, K. C. (2002). "Critical success factors for quality management implementation in Russia." *Ind. Commer. Training*, 34(7), 263-268.

Kim, A. H., and Kown, J. W. (2005) "A study on the design collaborative work with foreign architects for the high-rise buildings in Korea." *J. Archit. Inst. Korea*, 21(10), 13-20 (In Korean).

Koskela, L., Houvila, L. P., and Leionen, J. (2002). "Design management in building construction: From theory to practice." *J. Constr. Res.*, 3(1), 1-16.

Kwak, Y. H. (2002). *Critical success factors in international development project management*. Paper presented at CIB 10th Int. Sym. Constr. Innov. Global Competitiveness. Cincinnati, Ohio.

Lee, S., Pena-Mora, F., and Park, M. (2005). "Quality and change management model for large scale concurrent design and construction project." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)00733-9364(2005)131:8(890), 890-902.

Li, B., Akintoye, A., Edwards, P. J., and Hardcastle, C. (2005). "Critical success factor for PPP/PFI projects in the UK construction industry." *Constr. Manage. Econ.*, 23(5), 459-471.

Luhman, J. T. and Boje, D. M. (2001). "What is complexity science? A possible answer from narrative research." *Emergence*, 3(1), 158-168.

Lu, W., Shen, L., and Yam, M. (2008). "Critical success factors for competitiveness of contractors: China study." *J. Constr. Eng, Manage.*, 10.1061/(ASCE)0733-

9364(2008)134:12(972), 972-982.

McGolpin, P., and Ward, J. (1997). *Factors influencing the success of strategic information systems. In: Mingers, J., and Stowell, F., editors. Information systems: an emerging discipline*, McGraw-Hill, London.

Migliaccio, G. C., Gibson, G. E. Jr., and O'Connor, J. T. (2008). "Changing project Delivery strategy: An implementation framework." *Pub. Works Manage. Policy*, 12(3), 483-502.

Mills, F. T., and Glass, J. (2009). "The construction design manager's role in delivering sustainable buildings." *Archit. Eng. Des. Manage*., 5, 75-90.

Moldoveanu, M., (2004). "An intersubjective measure of organisational complexity: A new approach to the study of complexity in organizations." *Emergence: Complexity and Organization*, 6(3), 9-16.

Morris, P.W., and Hough, G. H. (1987). *The Anatomy of Major Projects*, John Wiley and Sons, New York.

Muhammad, S., Farooqui, R. U., Lodi, S. H. (2008). "Assessment of Critical Success Factors For Construction Projects in Pakistan." Paper presented at the *Proc. 1st Int. Conf. Construction in Developing Countries* (ICCIDC–I): Advancing and Integrating Construction Education, Research & Practice, 392-404, Karachi, Pakistan.

Nandhakumar, J. (1996). "Design for success?: critical success factors in executive information systems development." *Eur. J. Inform. Syst*., 5(1), 62-72.

NEDC (National Economic Development Council). (1987). *Achieving Quality on Building Sites*, National Economic Development Office (NEDO), London, U.K.

Ng, L. Y., and Mo, J. K. W. (1997). "Hospital procurement by design and build: A case study in

Hong Kong." Paper presented at the *Proc., CIB W92 Procurement-A Key to Innovation, Procurement Sys. Symp.*, 545–553.

Ng, S. T., and Skitmore, R. M. (2002). "Contractors' risk in design, novation and construct contract." *Int. J. project manage*., 20(2), 119-126.

Nguyen, L. D., Ogunlana, S. O., and Lan, D. T. (2004). "A study on project success factors on large construction projects in Vietnam." *Eng. Constr. Archit. Manage*., 11(6), 404-413.

Norusis, M. J. (2000). *SPSS 10.0 guide to data analysis*, Prentice Hall, Chicago, USA.

Norusis, M. J. (2005). *SPSS 13.0 Guide to Data Analysis*, Prentice Hall, Upper Saddle River, N.J, USA

Owens, J., Ahn, J., Shane, J. S., Strong, K. C., and Gransberg, D. D. (2012). "Defining complex project management of large U.S. transportation projects: A comparative case study analysis." *Pub. Works Manage. Policy*, 17 (2), 170-188.

Park, S. H. (2009). "Whole Life Performance Assessment: Critical Success Factors." *J. Constr. Eng. Manage*., 10.1061/(ASCE)CO.1943-7862.0000090, 1146-1161.

Phua, F. T. T. (2004). "Modeling the determinants of multi-firm project success: a Grounded exploration of different participant perspectives." *Constr. Manage. Econ*., 22(5), 451-459.

Phua, F. T. T., and Rowlinson, S. (2004). "How important is cooperation to construction project success? A grounded empirical quantification", *Eng. Constr. Archit. Manage*., 11(1), 45-54.

Pinto, J. K., and Slevin, D. P. (1987). "Critical factors in successful project implementation." *IEEE Trans. Eng. Manage*., EM-34(1), 22-27.

Pollalis, Y. A., and Frieze, I. H. (1993). "A new look at the critical success factors in information technology." *Inf. Strategy*, 10(1), 24-34.

Pulaski, M. H., and Horman, M. J. (2005). “Continuous value enhancement process.” *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2005)131:12(1274), 12745-1282.

Qiao, L., Wang, S. Q., Ting, R. L. K., and Chan, T. S. (2001). “Framework for Critical Success Factors of BOT Projects in China.” *J. Struct. Financ.*, 7(1), 53-61.

Remington, K., and Pollack, J. (2007). *Tools for Complex Projects*, Gower Publishing Limited, Surrey, U.K.

Rubin, I. M., and Seeling, W. (1967) “Experience as a factor in the selection and performance of project managers.” *IEEE Trans. Eng. Manage.*, EM-14(3), 131-135.

Savindo, V., Grobler, F., Parfitt, K., Guvenis, M., and Coyle, M. (1992). “Critical success factors for construction projects.” *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(1992)118:1(94), 94-111.

Selin, G., and Selin, M. (1994). “Reasons for project management success and failure in multiproject environment.” Paper presented at the *Proc., 12th lnt. World Congr. Protect Manage.*, . International Project Management Association (IPMA), Oslo, Norway, 513-519.

Shash, A. (1993). “Factors considered in tendering decisions by top UK contractors.” *Constr. Manage. Econ.*, 11(2), 111-118.

Shen, Q., and Liu, G. (2003). “Critical Success Factors for Value Management Studies in Construction.” *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2003)129:5(485), 485-491.

Sinha, S., Thomson, A. I., and Kumar, B. (2001). “A complexity index for the design process.” *Proc., Int. Conf. Eng. Des, ICED’01*, Professional Engineering Publishing, Glasgow, 157-163.

Soibelman, L., Liu, L. Y., Kirby, J. G., East, E. W., Caldas, C. H., and Lin, K. Y. (2003). “Design Review Checking System with Corporate Lessons Learned.” *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2003)129:5(475), 475-484.

Song, L., Mohamed, Y., and Abourizk, S. M. (2009). "Early Contractor Involvement in Design and Its Impact on Construction Schedule Performance." *J. Manage. Eng*., 10.1061/(ASCE)0742-597X(2009)25:1(12), 12-20.

Songer, A. D., and Molenaar, K. R. (1997). "Project characteristics for successful public-sector design-build." *J. Constr. Eng. Manage*., 10.1061/(ASCE)0733-9364(1997)123:1(34), 34-40.

Stewart, R. A., Mohamed, S., and Marosszeky, M. (2004). "An empirical investigation into the link between information technology implementation barriers and coping strategies in the Australian construction industry." Constr. Innov. Inf. Process Manage., 4(3), 155–171.

Swickerath, C., and Tillson, P. (2011). "Technical paper; Heaundae I'Park, Busan." <http://global.ctbuh.org/resources/papers/download/23-case-study-haeundae-ipark-busan.pdf> (July. 12, 2015).

Tan, R. (1996). "Success criteria and success factors for external technology transfer projects." *Project Manage. J*., 27(2), 45-56.

Tiong, R. L. K. (1996). "CSFs in competitive tendering and negotiation model for BOT projects." *J. Constr. Eng. Manage*., 10.1061/(ASCE)0733-9364(1996)122:3(205), 205-211.

Toor, S. R., and Ogunlana, S. O. (2005). "What is crucial for success: investigating the critical success factors and key performance indicators on mega construction projects." Paper presented at the Proc., *Inst. Annu. Symp,* Project Management Institute Singapore, Singapore.

Toor, S. R., and Ogunlana, S. O. (2008). "Critical COMs of success in large-scale construction projects: evidence from Thailand construction industry." *Int. J. Project Manage*., 26(4), 420-430.

Torp, O., Austeng, K., and Mengesha, W. J. (2004). "Critical success factors for project performance; a study from front-end assessments of large public projects in Norway." Paper presented at the *Proc., Nordnet 2004 Conf.,* Concepts Reports, Norway, 1-5.

Tzortzopoulos, P., and Cooper, R. (2007). "Design Management from a Contractor's Perspective: The Need for Clarity." *Archit. Eng. Des. Manage*., 3(1), 17-28.

Vidal, L.A., and Marle, F. (2008). "Understanding project complexity: implications on project Management." *Kybernetes*, 37(8), 1094-1110.

Wakisaka, T., Furuya, N., Inoue, Y., and Shiokawa, T. (2000). "Automated construction system for high-rise reinforced concrete buildings." *Autom. Constr*, 9(3), 229-250.

Walker, D. H. T., and Walker, B. L. (2012). "Understanding Early Contractor Involvement (ECI) procurement forms." Paper presented at the *Procs., 28th Ann. ARCOM Conf*., Edinburgh, UK, 877-887.

Wang, J. and Yuan, H. (2011), "Factor affecting contractor's risk attitudes in construction projects: Case study from China," *Int. J. Project Manage*., 29(2), 209-219.

Wang, J. Y., Yuan, H. P., Kang, X. P., and Lu, W. S. (2010). "Critical success factors for on-site sorting of construction waste: A china study." *Resour. Conserv. Recycling*., 54(11), 931-936.

Westerveld, E. (2003). "The project excellence model: linking success criteria and critical success factors." *Int. J. Project Manage*., 21(6), 411-418.

Whang, S-W., and Kim, S. (2014). "Determining sustainable design management using passive designelements for a zero emission house during the schematic design." *Energ. Build*., 77, 304-312.

Williams, T. (2002). *Modelling Complex Projects*. John Wiley & Sons, Ltd, West Sussex.

Yeo, K. T. (2002). "Critical failure factors in information system projects." *Int. J. Project Manage*., 20(3), 241-246.

Yu, A. T. W., Shen, Q., Kelly, J., and Hunter, K. (2005). “Investigation of critical success factors in construction project briefing by way of content analysis.” *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2006)132:11(1178), 1178-1186.

Yu, J. H., and Kwon, H. R. (2011). “Critical success factors for urban regeneration projects in Korea.” *Int. J. Project Manage.*, 29(7), 889-899.

Zhang, X. (2005). “Critical success factors for public-private partnerships in infrastructure development.” *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2005)131:1(3), 3-14.