Critical Success Factors for Implementing Integrated Construction Project Delivery

Journal:	*Engineering, Construction and Architectural Management*
Manuscript ID	ECAM-02-2019-0073.R1
Manuscript Type:	Original Article
Keywords:	Construction Planning, Design Management, International Construction, Management, Organization
Abstract:	

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Abstract

Purpose – Identify the critical success factors (CSFs) to implement integrated project delivery (IPD) systems in the Korean construction industry.

Design/methodology/approach – Categorized potential CSFs and analyzed them using factor analysis and multiple regression analysis to choose the best ones based on responses from Korean construction experts.

Findings – 29 potential factors were selected and categorized into seven CSFs using factor analysis.

Originality/value – Useful as a reference for applying the IPD system in different developing countries and mid-sized construction industries.

~~Due to increasing project complexity, construction projects are carried out both separately and independently using various systems of delivery.~~ For increasing large and complex construction projects to be carried out efficiently, a collaborative execution process needs to be devised to integrate and manage the vast amount of information and production activities. For this to be successful in complex construction projects, an integrated project delivery (IPD) system has been applied, in which all project participants work together as a team from the outset. The aim of this study is to identify the critical success factors (CSFs) to implement IPD systems in the Korean construction industry. To this end, 29 potential factors were selected and categorized into seven CSFs using factor analysis. A multiple regression analysis shows that ~~four of the seven CSFs have significant correlations with the research findings.~~ four factors are essential among seven CSFs to implement IPD systems. They are ‘Reform of contract law and adoption of appropriate IPD agreement form (CSF 1)’, ‘Team building and management for collaborative business process (CSF 2)’, ‘Early involvement and enhanced role of key participants (CSF 3)’, and ‘Improvement and utilization of BIM for collaborative process of

IPD (CSF 4)’. Interestingly, some CSFs with typical features including “government leadership” and “IT technology support” can have a substantial impact on developing the construction sector and other construction-related industries. The outcomes of the study could be useful as a reference for applying the IPD system in Korea reflecting specific characteristic of the construction sector. These CSFs also could be applied in other different developing countries that have similar structures of the construction industry. In addition, identified CSFs also could be analyzed and applied in other mid-sized construction industries by the resetting of the analysis environment in accordance with their specific situation for implementing IPD.

Keywords collaborative working, construction management, construction team, project delivery.

Paper type Research paper

1. Introduction

Due to the trends of large scale and multifunctional project, the construction industry has suffered from various complications, such as cost overruns, schedule delays, quality issues, and limited trust between different project participants (O’Connor, 2009; Lahdenpera, 2012). Almost all participants in construction projects have experienced setbacks caused by inadequate cooperation and poor administration throughout the project. These problems occur due to the competing interests of the project participants, incompatible individual habits, and a lack of substantial real-time information (CURT, 2004). These tendencies have resulted in the need for a new delivery system (Chan *et al*., 2004; Kent and Becerik-Gerber, 2010), and developing a collaborative project delivery system is currently one of the most significant issues in the construction industry (El Asmar *et al*., 2013). However, there are limitations in a conventional procurement system resulting from owners, contractors, architects, and other project participants making contracts separately. Thus, collaborative and integrated project implementation is difficult with a traditional procurement method due to a lack of project continuity and information sharing.

The American Institute of Architects (AIA) launched the integrated project delivery (IPD) technique for construction projects to advance procurement systems using seamless integration and collaboration between project participants (AIA, 2007a). Based on contractual and behavioral principles, IPD emphasizes mutual respect and effective communication for the implementation of a project. Individual accomplishment in this new procurement system is subject to the sharing of information, knowledge, experiences, frameworks, business structures, and practices throughout the life of the project (Lahdenpera, 2012). Unlike traditional delivery systems, the main project participants are involved from the initial pre-design stage, including clients, architects, and contractors, who share their own distinct skills and knowledge to reduce project risk (Kent and Becerik-Gerber, 2010).

However, the IPD system is still not prominent in the global construction industry. Only a small number of case studies have been carried out in the United States (AIA, 2010b). There is limited explicit data on the effectiveness of IPD, it is challenging to encourage emerging construction industries to apply the IPD system in common practice. In addition, IPD is still in the test stage in developing construction sectors such as South Korea, and there is a lack of information on actual plans for applying IPD. Since the IPD was invented assuming the collaboration of the individual construction parts for a single project from early stage as a one team, it is highly likely that it will be successful in an overall fully matured and experienced built environment. For countries including South Korea that still do not have enough competency in soft skill such as contract management or risk management, there is careful research and practical feedback needed. However, there are still not many actual project cases even in a country in which IPD has been developed. Thus, determining the critical success factors (CSFs) is necessary to introduce IPD successfully. It is also necessary to determine the kinds of projects where it is more difficult or impossible to apply IPD.

The aim of this study is to identify the CSFs needed to implement an IPD in a developing construction industry. We categorized potential CSFs and analyzed them using factor analysis and multiple regression analysis to choose the best ones based on responses from Korean construction experts. This study was carried out based on the Korean construction environment for the application of IPD. However, our research findings may also be useful in other emerging construction industries or developing countries that do not yet have a fully mature market environment.

2. LITERATURE REVIEW

2.1 Project delivery in general

Project delivery comprises a series of contractual relationships that coordinate all the components of a project (Cho *et al*., 2010). Conventional project delivery systems (PDS) are based on a transactional contract, and examples include the fixed price lump sum, guaranteed maximum price, and cost-plus-fee systems. Halpin (2006) and El Asmar *et al*. (2013) consider a PDS to be an advancement or association of a framework that is needed to fulfill a project. They considered the establishment of a formal contract and casual connections between project partners to be important. According to Hanna (2010), a PDS is a framework that characterizes the relationship between different parties in an agreement, and it PDS plays a fundamental role in increasing mutual trust and clearly defining relationships between project participants based on a written agreement.

However, in recent years, other academic researchers and industrial experts have argued that there is limited cooperation and advancement when using a conventional PDS in actual construction projects (Middlebrooks, 2008; Swarup *et al*., 2011). Researchers have tried to develop procurement systems to complement PDS for complex and large-scale projects. Forbes and Ahmed (2011) suggest that PDS agreements only reward or punish the performance of individual team members who are bond by a contract without consideration of the effects on the entire team's performance.

According to the American Institute of Architects (AIA) (2010a), relational contracts are more valuable than transaction contract. They considered that transactional contracts are likely to lead to avoidance of responsibility and to conflict between contracting parties, whereas relational contracts help with cooperation, collaboration, and reliance among the principle project stakeholders. Common difficulties and potential conflicts in transactional contracts can be reduced by multi-party contracts (Thomsen, 2009). Integrated multi-party contracts have been used as a way of complementing PDS in ambiguous or complicated projects, which involve many different project participants and execution systems.

2.2 Integrated project delivery

Integrated project delivery (IPD) is one promising relational contract[1] system that provides a platform for projects. Comparing to the traditional PDSs tightened by strict terms and condition, since relational contract system is structured by the mutual trust rather than contract clauses, it has fewer changes and a tighter schedule than traditional PDSs (AIA, 2007a). The AIA defines IPD as an approach to project delivery that incorporates people, a framework, business structures, and practices into one system. The greatest difference between IPD and traditional PDSs (excluding integrated multi-party contracts) is the capacity to shift work volume from the introductory periods of the design phase to the construction process, by which all essential contributions are supported by different key stakeholders (Ilozor and Kelly, 2012). From the initial project stage, main project players including owners, architects, and contractors share their experience, technology, knowledge, and even foreseeable risks and benefits. With integrated multi-party contracts between project team members, relationships can become more reliable, cooperative, and respectful (AIA *et al*., 2010a; El Asmar *et al*., 2013).

According to the AIA (2007b), the benefits of IPD include collective backup capabilities and problem-area identification by different project members, which increases the effectiveness of project management. Various experts with different technical backgrounds work together within one system, and even minor issues that do not seem critical initially but have a serious impact later on can be managed in advance. This makes the problems to be recognized and controlled in advance.

An absence of responsibilities, poor group collaboration, and unsatisfying interfaces are some of the issues in a traditional procurement project (Volk *et al*., 2014). One approach to these issues is to understand the overall procedure of project improvement. To ensure this, the application of IPD supported by different project management tools is recommended, such as a project management information system (PMIS) or building information modeling (BIM). These management tools are useful for supplementing the issues of collaboration and integration, and they are expected to realize the concept of IPD practically over the entire life of the project. Monteiro et al. (2014) suggest that the goals of IPD can be fully achieved by supporting other project management tools (such as BIM). IPD is recognized as a successful

[1] A relational contract is a contract whose effect is based upon a relationship of trust between the parties to which it pertains.

delivery system that can be most effective when it is used with BIM. BIM can be used to manage rich, object-oriented, intelligent, and parametric digital representation information for construction projects.

To carry out a project successfully, there is a need for all project participants to cooperate as a team, including clients, design teams, quantity surveyors, contractors, and specialists. These individual experts can effectively pool their skills and experiences together in the IPD system, through which they share the benefits and risks of the project. Using different management tools, IPD can integrate different types of information, work processes, and activities into a single project boundary.

3. METHODOLOGY

The research process used in this study is shown in Figure 1. The research steps involve gathering data, maintaining data criteria, and determining the success factors of IPD. The limitations of the existing project delivery system and potential success factors for IPD were first determined, and then semi-structured interviews and questionnaire surveys were carried out to determinate the prerequisites for implementation of IPD that are used as dependent variables in multiple regression analysis and to ensure reliable data collection. Factor analysis and multiple regression analysis were then conducted to identify critical IPD factors that can be used in various developing construction industries.

Insert < Figure 1. Research framework > here

The study began with IPD data and reports published by the AIA, National Association of State Facilities Administrators (NASFA), and Associated General Contractors of America (AGC) (e.g. and AIA, 2007b; AIA, 2007a; AIA *et al.*, 2010a). Different studies were then reviewed to evaluate the reliability of data from previous studies. All relevant factors for the implementation of IPD were obtained from AIA reports including Integrated Project Delivery: Case studies (AIA, 2010b), and other practical factors were included from industrial project case studies and academic literature. Based on the data, several unique factors to Korea were included based on practical conditions in the Korean construction sector.

A total of 60 potential factors were obtained and used to conduct semi-structured interviews with 13 Korean construction experts to develop a questionnaire and ensure clarity and relevance. The interview respondents are in senior managing positions or higher in their organizations and have an average of over 16.5 years of work experience in the construction industry. Using their empirical experience and expertise, they reviewed the different essential prerequisites ~~potential IPD factors to determine the most influential ones.~~ ~~They also~~ and determined three dependent variables that are the least or most critical for a successful application of IPD in the Korean construction industry. These three dependent variables ~~indispensable conditions were analyzed using~~ were collected from different references (Middlebrooks, 2008; Kent and Becerik-Gerber, 2010; Raisbeck, et al., 2010) were discussed and finally chosen by semi-structured interviews. ~~seven factor clusters (FCs) (see Table VI).~~

Pilot surveys were used to gather comments and suggestions for the survey items, item wording, item sequence, and directions. The questionnaires were distributed to different Korean construction experts comprising key personnel in client organizations (such as owners), architects, consulting practices, and construction and engineering firms. All respondents were selected from registered members of the Construction Association of Korea, which is supported by the government and is the largest construction organization in Korea.

The structure of the questionnaire was divided into two main parts. Part 1 included six general questions to acquire general information and determine the overall recognition of IPD in the Korean construction industry. In part 2, the respondents were asked to rate all the potential IPD success factors and to suggest ways in which introducing and implementing IPD could be successful in Korea. We used a five-point Likert scale (ranging from 1 = strongly disagree to 5 = strongly agree). The responses were used to determine how critical individual IPD factors would be in implementation. Statistical analyses were carried out on the results using the Statistical Package for Social Sciences (SPSS).

Factor analysis is an advanced statistical technique that is used to examine the underlying patterns or relationships of a large number of variables and to determine whether the exhaustive list of variables can be condensed or summarized with a smaller set of explainable components (Norusis, 2012). This is useful when representing relationships involving numerous interrelated components. Factor analysis was mainly used to categorize and reduce the initial 60 IPD factors to a more manageable number of CSFs. The factors were extracted and rotated to obtain a minimum quantity of aspects and acquire an accurate understanding of what is represented by the factors.

Based on the results of factor analysis, a multiple regression analysis was performed to test the relationship between ~~on~~ the seven factor clusters (FCs; independent variables) ~~FCs~~ and three prerequisites (dependent variables) for a successful application of IPD. ~~to analyze the contributions of individual factors to IPD introduction.~~ The results show the independent variables (FCs) ~~showed which CSFs are positively related to successful IPD introduction in Korea~~ that have a positive correlation with dependent variables (three prerequisites for IPD) according to the beta coefficient and *t*-test. This study hypothesizes that successful FCs (independent variables) should satisfy the prerequisites (dependent variables). Thus, only FCs that have significant correlation with three prerequisites (dependent variables) will be recognized as CSFs for IPD application. ~~Multiple regression analysis indicated correlations between the seven FCs (independent variables) and three successful application conditions (dependent variables).~~

4. DATA COLLECTION AND ANALYSIS

4.1 Data collection

During data collection, 362 questionnaires were distributed to Korean construction experts by e-mail or in person. A total of 118 valid responses (approximately 32%) were received for data analysis. The responders consisted of 14 clients, 22 architects, 32 general contractors, 13 project managers, 10 construction engineers, 9 manufacturers and suppliers, 6 project inspectors, 9 academic or research institutions, and 3 other engineers, as summarized in Table Ⅰ.

Insert < Table Ⅰ. Information from respondents to a questionnaire survey > here

As shown in Table Ⅱ, the success factors of IPD are ranked in order of agreement according to their mean values. The mean values and standard deviations of each factor were derived from the total sample to determine the level of agreement. Mean values that are greater than the average value of all factors (3.129) are recognized as critical. Finally, 29 factors among the initial 60 items were determined as critical for IPD implementation. The 29 selected IPD factors were categorized into 7 FCs using factor analyses. After multiple regression analyses, four CSFs for IPD were determined among seven IPD FCs, as shown in Figure 2.

Insert < Table Ⅱ. Respondents' ratings of IPD success factor > here

Insert < Figure 2. Analysis procedures to identify CSFs > here

4.2 Factor analysis

Factor analysis is a series of methods for identifying groups of related variables, and it is an ideal technique for reducing numerous items into a more easily understood framework (Norusis, 2012). Factor analysis was applied to explore the data groupings. The 29 selected IPD factors were subjected to factor analysis using SPSS 22.0. For reliable factor analysis, the Bartlett test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were used.

Insert < Table Ⅲ. Results of Bartlett's test and KMO measure > here

As shown in Table Ⅲ, the result of the Bartlett test was 617.036, and the associated significance level was 0.000. All variables had a significant correlation of at least 5%. This implies that no other variables need to be excluded from the analysis. The KMO measure of sampling adequacy is 0.742, and since it is higher than 0.5, the samples meet the fundamental requirement for factor analysis (Norusis, 2012).

~~**Insert < Table Ⅳ. Final statistic of principal component analysis > here**~~

As shown in Table IV, shows the final statistics of the principal component analysis (PCA), in which the seven extracted FCs comprise 58.45% of the variance. The varimax rotation of PCA was used to interpret the FCs. as shown in Table V. Each IPD success factor belongs to one of the seven FCs, and the loading on each factor exceeds 0.60. Only 23 of the 29 IPD factors were clustered into the seven FCs. The varimax rotation result of six factors was less than 0.60. The seven FCs and their relevant features are labeled as follows:

FC 1: Reform of the contract law and adoption of appropriate IPD agreement form.

FC 2: Team building and management for collaborative business process.

FC 3: Intensified planning and management from early project stage.

FC 4: Early involvement and enhanced role of key participants.

FC 5: Mutual respect and trust with government support.

FC 6: Improvement and utilization of BIM for collaborative process of IPD.

FC 7: PMIS for collaborative decision making and a networked sharing system.

Insert < Table IV. V. Component analysis and matrix after varimax rotation > here

4.3 Correlation analysis

Correlation analysis was conducted to investigate the relationships between independent variables (the seven FCs) and dependent variables determined from the interviews, as shown in Table VI. Three dependent variables were recognized as fundamental criteria when deciding whether the seven analyzed FCs are critical for IPD implementation in Korea.

Insert < Table VI. Results of correlation analysis > here

The correlation analysis results show that there is a significant positive correlation between the dependent variables and seven FCs. "Impact of IPD adoption on overall construction industry" was correlated with five independent variables (FC1, FC2, FC4, FC5, and FC7), "Understanding and experience about IPD system" was correlated with four independent

~~variables (FC1, FC2, FC5, and FC7), and "Synergy effect between IPD and BIM" was significantly correlated with five independent variables (FC1, FC2, FC4, FC5, and FC7).~~

~~4.4~~ 4.3 Multiple regression analysis

Stepwise multiple regressions were carried out to test how much correlation between the three dependent variables and seven FCs as independent variables using SPSS 22.0. In accordance with the hypothesis of this study in which only successful independent variables (FCs) will be recognized as the SCFs for implementation of IPD in Korea, 7 FCs were analyzed to see how significant correlation were with three dependent variables using multiple regression analysis. Since the purpose of this study is not to recognize whether a certain independent variable may become the CSF but to recognize what independent variables can be CSFs for IPD implementation, multiple regression analysis was used to find out multiple CSFs. Table Ⅴ ~~Ⅶ~~ shows the standardized regression coefficient (β), standard significance (p), coefficient of determination (R2), adjusted R-square value (Adjusted R^2), and variation in the R-square value (ΔR^2). The size of the sample used in the final outcome is 118. Among the seven independent variables, only four (FCs), were analyzed with a significant correlation showing the differences from 0.000 at $p \leq 0.04$: "Reform of the contract law and adoption of appropriate IPD agreement form" (CF1), "Team building and management for collaborative business process" (CF2), "Early involvement and enhanced role of key participants" (CF4), and "Improvement and utilization of BIM for collaborative process of IPD" (CF7).

Insert < Table Ⅴ ~~Ⅶ~~. Multiple regression result > here

These four independent variables (CSF1, CSF2, CSF3, CSF4) ~~(CSFs)~~ altogether explained 60.7% (R^2=0.607) of the variance of the three dependent variables (Table Ⅴ ~~Ⅶ~~). Among the four CSFs identified, "Reform of the contract law and adoption of appropriate IPD agreement form" is the strongest CSF, which accounted for 31.5% of the total explanation (R^2=0.315, $p \leq 0.001$). This result indicates that IPD can be implemented successfully in Korea if contract law is reformed and an appropriate IPD agreement form is adopted. "Team building and management for collaborative business process" (CSF 2), "Early involvement and enhanced role of key participants" (CSF 3), and "Improvement and utilization of BIM for collaborative process of IPD" (CSF 4) account for 29.6%, 14.3%, and 2.5% of the explanation for the overall implementation success of IPD, respectively.

5. RESEARCH FINDINGS

In this section, the identified CSFs are further described in terms of their practical meaning and usefulness.

5.1 CSF 1: Reform of contract law and adoption of appropriate IPD agreement form (FC 1).

CSF 1 consists of three IPD factors (F01, F04, and F05) and accounts for 31.5% of the total variance explained. CSF 1 accounts for the largest part, which is greater than those of the rest of the three CSFs combined. This means that the most critical factor in applying IPD to the Korean construction industry is law amendments and active commitment by the government, at least for public government projects.

BIM-based projects and public-private partnership (PPP) are now very common in Korea, but they were all initially applied and adapted to the market led by the government. Compared to the construction industries in developed countries such as the UK and US, the Korean construction industry is smaller and simpler, so there are limitations on creating and developing innovative systems in the private sector (Lee and Lee, 2009). Whenever new systems such as BTL, Design-Build, and PPP are launched in Korea, they are first applied in public projects led by the government. Thus, the role of the government is crucial in the Korean construction industry.

National contract law should be amended to implement an IPD system in Korea practically. In addition, there is no practical IPD agreement form in Korea, so the US IPD form created by the AIA (2010) could be adapted to the Korean construction industry's needs. The probability of successful IPD implementation in Korea will increase if the government could set up explicit guidelines to reform Korean law or if it could accept adapted IPD forms from abroad.

5.2 CSF 2: Team building and management for collaborative business process (CF 2).

CSF 2 comprises three IPD factors (F17, F22, and F27), all of which are relevant to appropriate team building and management for a collaborative business process. CSF 2 accounts for 13.3% of the total variance (the second largest). In traditional procurement in Korea, contractors tend to have more responsibility than any other project participant throughout all project stages. This occurs because all participants tend to rely on the contractor's technology, experience, knowledge, equipment, and capital for the sake of efficiency (Sachs *et al*., 2004; Cho and Chung, 2011). Thus, an explicit definition of the work scope and responsibility (F22) can make an IPD project seem more reliable and clear to potential participants (El Asmar, 2012; Zhang *et al*., 2013). By using this definition, contractors can expect the risk they normally bear to be shared, and other project participants can easily access advanced technologies, information, and other benefits through active involvement.

The increasing authority and role of independent project managers (F17) and developing an IPD business process model (F27) can help to manage IPD projects with a collaborative business model in target project performance. In all project stages, particularly in the construction process, each team member such as a supplier or architect has a different purpose and interest in the project according to their economic situation and business area (Asmar *et al*., 2013; Monteiro *et al*., 2014). These differences are likely to make the project more complicated and difficult to manage. However, if a project manager has authorized leadership and a successful reference model, the project can be successful while applying the IPD model in the construction industry within a short period of time.

5.3 CSF 3: Early involvement and enhanced role of key participants (FC 4).

There are two IPD factors (F20, F21) involved in CSF 3, which is responsible for 9.1% of the total variance. IPD is an approach for maximizing a project's value by collaboration, risk and benefit sharing, and mutual respect between project participants from the initial stage (Song *et al*., 2011). The involvement of the contractors in the design process and architects in the construction process (F21) indicate the changing role of all project participants and make the project more flexible. Thus, the construction industry can be changed to a more favorable environment to apply IPD (Lee *et al*., 2012). However, if key project participants including clients and architects do not have enough competence to adapt to the different roles, acceptance of the changing roles may become the biggest constraint on project success and the ability to implement IPD at an early project stage.

5.4 CSF 4: PMIS for collaborative decision-making and networked sharing system (FC 7).

There are three success factors (F47, F49, F60) involved in CSF 4, which is responsible for 7.0% of the total variance. In Korea, contractors usually use their own information management system specified by the PMIS. PMIS can be defined as a web-based database that centralizes information and represents specific data from the project, as well as non-geometric information (Thomsen *et al*., 2010). In IPD systems, knowledge and information sharing is recognized as the most basic and critical factor because without it, the core values of IPD cannot be realized, such as collaboration and integration between participants. Thus, the capacity of IPD team members supported by various technologies is critical, including BIM, PMIS, and other collaboration tools (F49). These IT technologies (BIM or PMIS) can transfer and restore information and knowledge systematically. Fortunately, the Korean construction industry is already a favorable environment for projects based on IT technologies (Kim, 2005; Suh *et al*., 2013). These conditions are favorable for applying IPD systems in Korea.

6. CONCLUSION

An extensive analysis was conducted on IPD systems in the Korean construction sector. We developed an outline of data taken from academic and industrial sectors that highlight key components for successful implementation of IPD. Questionnaires were used to collect local knowledge and personal viewpoints on how an IPD system could be successfully implemented. Among the 60 initial IPD factors, 29 were selected for further investigation through a questionnaire survey. The extracted IPD factors were categorized into seven FCs based on a factor analysis. Finally, using multiple regression analysis, four of the FCs consisting of several IPD factors were identified as CSFs in the implementation of IPD systems.

Our findings could be used as framework of reference to measure the success of IPD projects. They could also provide useful guidelines for project stakeholders who are considering IPD projects. The findings indicate that these CSFs could strongly influence the implementation of IPD systems in Korea. In addition, developing countries are actively accepting the advantages of managing systems such as BIM and PMIS to enhance their competitiveness in the global market. Thus, the CSFs for IPD in Korea could be applied to other developing or mid-sized construction industries without major reform or technical constraints.

7. Acknowledgements

This work was supported by the 2017 Yeungnam University Research Grant.

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Figure Caption List

Figure 1. Research framework

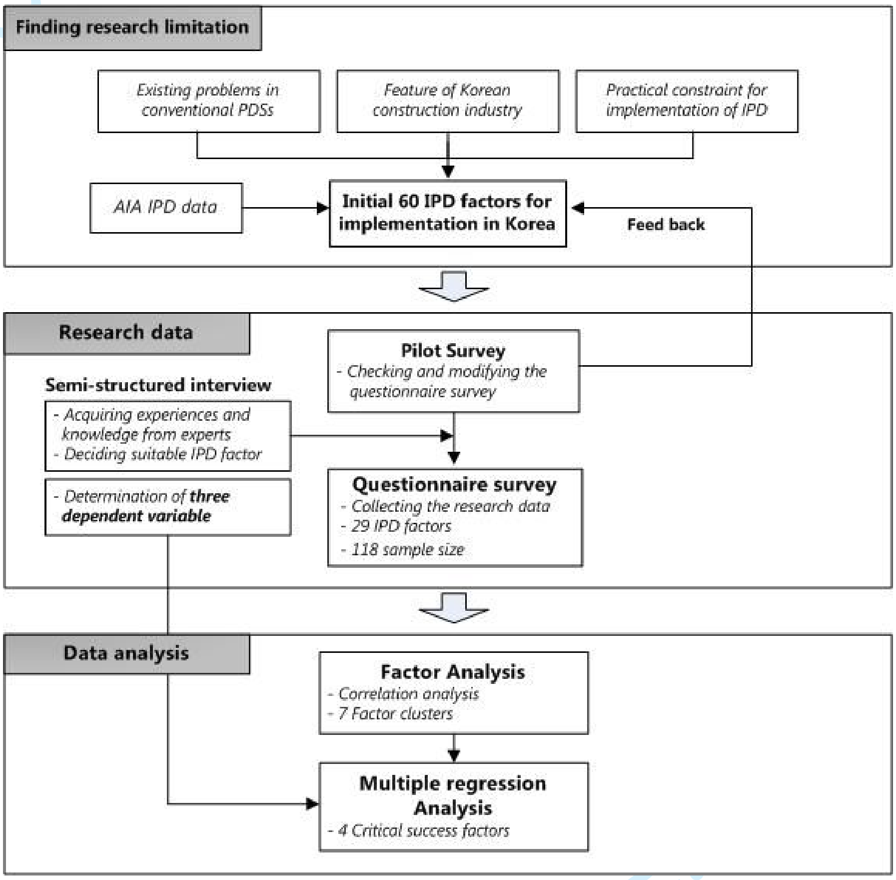

Figure 2. Analysis procedures to identify CSFs

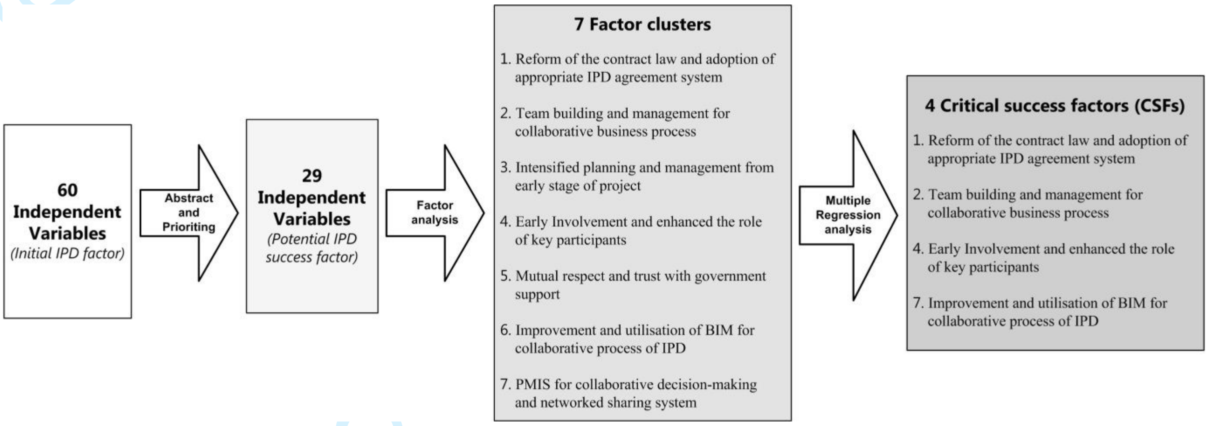

Table Caption List

Table 1. Information from respondents to a questionnaire survey

Respondents	Contents	Frequency	Percentage (%)
Occupation	Owner (client)	14	11.86
	Architect	22	18.64
	General contractor	32	27.12
	Project manager	13	11.02
	Construction engineer	10	8.47
	Manufacturer/supplier	9	7.63
	Project inspector	6	5.08
	Working in academic or research institutions	9	7.63
	Others	3	2.55
	Total	**118**	**100.00**
Present career experience	Less than 3 years	20	16.95
	3 to 5 years	27	22.88
	6 to 10 years	44	37.29
	11 to 15 years	16	13.56
	More than 15 years	11	9.32
	Total	**118**	**100.00**

Table 2. Respondents' ratings of IPD success factor

Success factor of IPD		Mean	Standard deviation	Ranking
F57	Developing customized IPD business process involving BIM technology.	3.706	1.108	1
F05	Introducing multi-party agreement.	3.701	0.958	2
F21	Direct involvement of contractors and engineers in the design phase.	3.688	0.921	3
F39	Introducing IPD system to public projects with IT vitalization policy by the government.	3.657	0.933	4
F11	Establishing risk sharing system between team members.	3.611	1.218	5
F22	Defining work scope and responsibility between team members.	3.609	1.112	6
F47	Developing decision making system for the participation of all team members to contribute their expertise.	3.590	0.984	7
F04	Establishing standard IPD contract form considering Korean construction environment.	3.558	1.191	8
F60	Developing and operating project management information system (PMIS) based on business process of IPD.	3.547	1.103	9
F27	Developing IPD business process model for collaborative work between team members.	3.524	1.020	10
F49	Capacity of IPD team members to fully utilize IPD supporting IT such as BIM or PMIS.	3.523	1.003	11
F37	Reforming relationships from the vertical to horizontal among key project participants.	3.513	0.981	12
F45	Establishing expected project benefit through the implementation of IPD project in	3.511	0.958	13

	Korean construction sector.			
F33	Improving motivation and teamwork between IPD team members from initial project stage.	3.509	0.968	14
F01	Reforming national contract law and amending IPD agreement form.	3.448	1.132	15
F54	Developing integrated real-time information and document sharing system with cloud system.	3.411	1.017	16
F06	Reforming unfair contract structure and practice (especially, design contract).	3.396	1.106	17
F42	Vitalizing the construction management (CM/PM) to support client who suffers from increasing workload and lack expert knowledge in IPD system.	3.351	0.991	18
F17	Increasing authority and role of independent project manager to organize and coordinate IPD team.	3.340	0.983	19
F30	Training experts to support IPD project from the early project stage.	3.336	1.013	20
F26	Determining the design changes and disputable factors from early project stage.	3.327	0.915	21
F56	Establishing work process and data transfer system between IPD team and IT system (BIM or PMIS).	3.321	1.128	22
F55	Improving communication and collaboration between team members through the 3 D/4D visualization and modeling technology.	3.294	0.908	23
F23	Enhancing supply chain management plan among key participants from design phase.	3.226	1.164	24
F20	Changing the role of owner (government) in public construction projects.	3.203	0.999	25
F28	Fully trust and mutually respect other industry team members as one team.	3.177	1.104	26
F41	Developing official guideline on the implementation of IPD by a government initiative.	3.172	0.980	27
F35	Quick organization of IPD team at the early project stage.	3.150	1.207	28

F32	Establishing horizontal decision-making and information exchange system between team members.	3.141	0.943	29

Table 3. Results of Bartlett's test and KMO measure

Bartlett's test of sphericity	Approx. χ^2	617.036
	Sig	.000
	Df	110
KMO measure of sampling adequacy		.742

Table 4. Component analysis and matrix

	IPD Success factors	Component (factor cluster) 1	2	3	4	5	6	7	Eigenvalues	Percentage of variance	Cumulative percentage of variance
	1. Reform of the contract law and adoption of appropriate IPD agreement form								**6.492**	**23.417**	**23.417**
F01	Reforming national contract law and amending IPD agreement form.	0.863									
F04	Establishing standard IPD contract form considering Korean construction environment.	0.742									
F05	Introducing multi-party agreement.	0.608									
	2. Team building and management for collaborative business process								**2.108**	**7.604**	**31.021**
F17	Increasing authority and role of independent project manager to organize and coordinate IPD team.		0.776								
F22	Defining work scope and responsibility between team members.		0.738								
F27	Developing IPD business process model for collaborative work between team members.		0.715								
	3. Intensified planning and management from early project stage								**1.884**	**6.796**	**37.817**
F23	Enhancing supply chain management plan among key participants from design phase.			0.831							
F26	Determining the design changes and disputable factors from early project stage.			0.664							
	4. Early involvement and enhanced role of key participants								**1.671**	**6.027**	**43.844**
F20	Changing the role of owner (government) in public construction projects.				0.780						
F21	Direct involvement of contractors and engineers in the design phase.				0.747						
	5. Mutual respect and trust with government support								**1.598**	**5.764**	**49.609**

F28	Fully trust and mutual respect other industry team members as one team.	0.862					
F33	Improving motivation and teamwork between IPD team members from initial project stage.	0.813					
F35	Quick organization of the IPD team at the early project stage	0.766					
F37	Reforming relationships from the vertical to horizontal among key project participants.	0.712					
F41	Developing official guideline on the implementation of IPD by a government initiative	0.648					
F42	Vitalizing the construction management (CM/PM) to support client who suffers from increasing workload and lack expert knowledge in IPD system.	0.615					
6. Improvement and utilization of BIM for collaborative process of IPD					**1.332**	**4.805**	**54.413**
F54	Developing integrated real-time information and document sharing system with cloud system.		0.795				
F55	Improving communication and collaboration between team members through the 3D/4D visualization and modeling technology.		0.761				
F56	Establishing work process and data transfer system between IPD team and IT system (BIM or PMIS).		0.740				
F57	Developing customized IPD business process involving BIM technology.		0.661				
7. PMIS for collaborative decision-making and networked sharing system					**1.120**	**4.040**	**58.453**
F47	Developing decision making system for the participation of all of team members to contribute their expertise.			0.807			
F49	Capacity of IPD team members to fully utilize IPD supporting IT such as BIM or PMIS.			0.715			
F60	Developing and operating project management information system (PMIS) based on business process of IPD.			0.683			

Extraction method: Principal component analysis.

Rotation method: Varimax with Kaiser normalization.

Rotation converged in seven iterations.

Table 5. Multiple regression result

Independent Variables (FCs) \ Dependent Variables		Impact of IPD adoption on overall construction industry	Understanding and experience about IPD system	Synergy effect between IPD and BIM	β	p value	R^2	Adjusted R^2	$\triangle R^2$
CSF 1	Reform of the contract law and adoption of appropriate IPD agreement form (F01, F04, F05).	**.455****	**.332****	**.489****	**.527**	**.000**	**.315**	**.294**	**.315**
CSF 2	Team building and management for collaborative business process (F17, F22, F27).	**.329****	**.473****	**.389****	**.421**	**.000**	**.448**	**.411**	**.296**
	Intensified planning and management from early project stage (F23, F26).	.163	-.092	-.024					
CSF 3	Early involvement and enhanced role of key participants (F20, F21).	**.415****	.139	**.239***	**.380**	**.001**	**.539**	**.497**	**.143**
	Mutual respect and trust with government support (F28, F33, F35, F37, F41, F42).	**.394****	**.274***	**.328****					
CSF 4	Improvement and utilization of BIM for collaborative process of IPD (F54, F55, F56, F57).	.077	.054	.188	**.294**	**.002**	**.607**	**.581**	**.025**
	PMIS for collaborative decision-making and networked sharing system (F47, F49, F60).	**.323****	**.447****	**.333****					

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (1-tailed).

First of all, thanks for the comments from the Editor and particular a very supportive from all reviewers. Please find our responses to the rest of the comments that are useful for improving the quality of the manuscript.

• Reviewer #1

Review comment	Description of review comment	In the text the authors added to the paper in response
Very well written paper with good discussion on findings.		

• Reviewer #2

Review comment	Description of review comment	Revised parts in the manuscript according to reviewer's comment
Abstract should be more comprehensive..you have 2 types of analysis, factor and regression. The most significant finding should be from regression analysis. Abstract should reveal the significant findings and implication of study.	As reviewer's comment, we elaborate the significant finding from the regression analysis and their implications of study in abstract.	(Line 15-17) ~~Due to increasing project complexity, construction projects are carried out both separately and independently using various systems of delivery~~. For increasing large and complex construction projects to be carried out efficiently, a collaborative execution process needs to be…. (Line 23-36) A multiple regression analysis shows that ~~four of the seven CSFs have significant correlations with the research findings~~. four factors are essential among seven CSFs to implement IPD systems. They are 'Reform of contract law and adoption of appropriate IPD agreement form (CSF 1)',

		'Team building and management for collaborative business process (CSF 2)', 'Early involvement and enhanced role of key participants (CSF 3)', and 'Improvement and utilization of BIM for collaborative process of IPD (CSF 4)'. ~~Interestingly, some CSFs with typical features including "government leadership" and "IT technology support" can have a substantial impact on developing the construction sector and other construction-related industries.~~ The outcomes of the study could be useful as a reference for applying the IPD system in Korea reflecting specific characteristic of the construction sector. These CSFs also could be applied in other ~~different~~ developing countries that have similar structures of the construction industry. In addition, identified CSFs also could be analyzed and applied in other mid-sized construction industries by the resetting of the analysis environment in accordance with their specific situation for implementing IPD.
The first paragraph is not relevant-suggest to delete	As reviewer's comment, we remove the first paragraph from the manuscript.	(Line 41-56) 1. Introduction ~~Due to the trends of large scale and multifunctional project, the construction industry has suffered from various complications, such as cost overruns, schedule delays, quality issues, and limited trust between different project participants (O'Connor, 2009; Lahdenpera, 2012). Almost all participants in construction projects have experienced setbacks caused by inadequate cooperation and poor administration throughout the project. These problems occur due to the competing interests of the project participants, incompatible individual habits, and a lack of substantial real-time information (CURT, 2004). These tendencies have resulted in the need for a new delivery system (Chan et al., 2004; Kent and Becerik-Gerber, 2010), and developing a collaborative project delivery system is currently one of the most significant issues in the construction industry (El-Asmar et al., 2013). However, there are limitations in a conventional procurement system resulting from owners, contractors, architects, and other project participants making contracts separately. Thus, collaborative and integrated project implementation is difficult with a traditional~~

		procurement method due to a lack of project continuity and information sharing. The American Institute of Architects (AIA) launched the integrated project delivery (IPD)… (Line 427-429) Chan, A. P., Chan, D. W., Chiang, Y. H., Tang, B. S., Chan, E. H. and Ho, K. S. (2004), "Exploring critical success factors for partnering in construction projects", Journal of Construction Engineering and Management, Vol. 130 No. 2, pp. 188-198. (Line 434-437) Construction Users Roundtable (CURT) (2004), Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation, Architectural/ Engineering Productivity Committee of The Construction Users Roundtable (CURT), Cincinnati, OH.
Page 3, line 62: 'In addition, IPD is still in the test stage in developing construction sectors such as South Korea'-this sentence need more explanation.	As reviewer's comment, we elaborated why IPD is still in the test stage in developing construction sector including South Korea.	(Line 69-79) In addition, IPD is still in the test stage in developing construction sectors such as South Korea, and there is a lack of information on actual plans for applying IPD. Since the IPD was invented assuming the collaboration of the individual construction parts for a single project from early stage as a one team, it is highly likely that it will be successful in an overall fully matured and experienced built environment. For countries including South Korea that still do not have enough competency in soft skill such as contract management or risk management, there is careful research and practical feedback needed. However, there are still not many actual project cases even in a country in which IPD has been developed. Thus, determining the critical success factors (CSFs) is necessary to introduce IPD successfully. It is also necessary to determine the kinds of projects where it is more difficult or impossible to apply IPD.
Page 4, line 93.. what is relational contracts?	As reviewer's comment, we elaborate the meaning to relational contract and annotate at the end of page 5 in order to avoid unnecessary confusion of reader.	(Line 117-120) Integrated project delivery (IPD) is one promising relational contract system that provides a platform for projects. Comparing to the traditional PDSs tightened by strict terms

		and condition, since relational contract system is structured by the mutual trust rather than contract clauses, it has fewer changes and a tighter schedule than traditional PDSs (AIA, 2007a). (End of page 5. Annotation) A relational contract is a contract whose effect is based upon a relationship of trust between the parties to which it pertains.
It was not clear how the author develop DV?. Need to explain further on the development of DV in the literature review	As reviewer's comment, we elaborate how the dependent variables are developed.	(Line 159-161) … first determined, and then semi-structured interviews and questionnaire surveys were carried out to determinate the prerequisites for implementation of IPD that are used as dependent variables in multiple regression analysis and to ensure reliable data collection. Factor analysis…. (Line 179-185) Using their empirical experience and expertise, they reviewed the different essential prerequisites ~~potential IPD factors to determine the most influential ones. They also~~ and determined three dependent variables that are the least or most critical for a successful application of IPD in the Korean construction industry. These three dependent variables ~~indispensable conditions were analyzed using~~ were collected from different references (Middlebrooks, 2008; Kent and Becerik-Gerber, 2010; Raisbeck, et al., 2010) were discussed and finally chosen by semi-structured interviews. ~~seven factor clusters (FCs) (see Table VI).~~
Since this study is testing the relationship between IV and DV, the author should include a framework and hypothesis.	As reviewer's comment, we elaborate the framework and hypothesis of research analysis and method.	(Line 208-219) Based on the results of factor analysis, a multiple regression analysis was performed to test the relationship between ~~on~~ the seven factor clusters (FCs; independent variables) ~~FCs~~ and three prerequisites (dependent variables) for a successful application of IPD. ~~to analyze the contributions of individual factors to IPD introduction~~. The results show the independent variables (FCs) ~~showed which CSFs are positively related to successful IPD introduction in Korea~~ that have a positive correlation with dependent

		variables (three prerequisites for IPD) according to the beta coefficient and t-test. This study hypothesizes that successful FCs (independent variables) should satisfy the prerequisites (dependent variables). Thus, only FCs that have significant correlation with three prerequisites (dependent variables) will be recognized as CSFs for IPD application. ~~Multiple regression analysis indicated correlations between the seven FCs (independent variables) and three successful application conditions (dependent variables).~~ (Line 293-300) Stepwise multiple regressions were carried out to test how much correlation between the three dependent variables and seven FCs as independent variables using SPSS 22.0. In accordance with the hypothesis of this study in which only successful independent variables (FCs) will be recognized as the SCFs for implementation of IPD in Korea, 7 FCs were analyzed to see how significant correlation were with three dependent variables using multiple regression analysis. Since the purpose of this study is not to recognize whether a certain independent variable may become the CSF but to recognize what independent variables can be CSFs for IPD implementation, multiple regression analysis was used to find out multiple CSFs.
Page 7, line 193- 'Multiple regression analysis indicated correlations between the seven FCs (independent variables) and three successful application conditions (dependent variables)'- Determination on the relationship between IV and DV is based on multiple regression result.Would like to suggest the author to exclude the correlation result.	As reviewer's comment, we remove the "4.3 Correlation analysis" section in order to avoid confusion of reader.	(Line 277-290) ~~4.3 Correlation analysis~~ ~~Correlation analysis was conducted to investigate the relationships between independent variables (the seven FCs) and dependent variables determined from the interviews, as shown in Table VI. Three dependent variables were recognized as fundamental criteria when deciding whether the seven analyzed FCs are critical for IPD implementation in Korea.~~ ~~Insert < Table VI. Results of correlation analysis > here~~ ~~The correlation analysis results show that there is a~~

		~~significant positive correlation between the dependent variables and seven FCs. "Impact of IPD adoption on overall construction industry" was correlated with five independent variables (FC1, FC2, FC4, FC5, and FC7), "Understanding and experience about IPD system" was correlated with four independent variables (FC1, FC2, FC5, and FC7), and "Synergy effect between IPD and BIM" was significantly correlated with five independent variables (FC1, FC2, FC4, FC5, and FC7).~~
The multiple regression analysis should be run to test the relationship between 7 IVs to 3 DVs.	As reviewer's comment, we elaborate the relationship between 7 independent variables and 3 dependent variables in line with the research hypothesis and framework.	(Line 208-219) Based on the results of factor analysis, a multiple regression analysis was performed to test the relationship between ~~on~~ the seven factor clusters (FCs; independent variables) ~~FCs~~ and three prerequisites (dependent variables) for a successful application of IPD. ~~to analyze the contributions of individual factors to IPD introduction~~. The results show the independent variables (FCs) ~~showed which CSFs are positively related to successful IPD introduction in Korea~~ that have a positive correlation with dependent variables (three prerequisites for IPD) according to the beta coefficient and t-test. This study hypothesizes that successful FCs (independent variables) should satisfy the prerequisites (dependent variables). Thus, only FCs that have significant correlation with three prerequisites (dependent variables) will be recognized as CSFs for IPD application. ~~Multiple regression analysis indicated correlations between the seven FCs (independent variables) and three successful application conditions (dependent variables).~~ (Line 293-313) Stepwise multiple regressions were carried out to test how much correlation between the three dependent variables and seven FCs as independent variables using SPSS 22.0. In accordance with the hypothesis of this study in which only successful independent variables (FCs) will be recognized as the SCFs for implementation of IPD in Korea, 7 FCs were analyzed to see how significant correlation were with three dependent variables using multiple regression analysis.

		Since the purpose of this study is not to recognize whether a certain independent variable may become the CSF but to recognize what independent variables can be CSFs for IPD implementation, multiple regression analysis was used to find out multiple CSFs. Table Ⅴ ~~Ⅶ~~ shows the standardized regression coefficient (β), standard significance (p), coefficient of determination (R2), adjusted R-square value (Adjusted R2), and variation in the R-square value (∆R2). The size of the sample used in the final outcome is 118. Among the seven independent variables, only four (FCs), were analyzed with a significant correlation showing the differences from 0.000 at p ≤ 0.04: “Reform of the contract law and adoption of appropriate IPD agreement form” (CF1), “Team building and management for collaborative business process” (CF2), “Early involvement and enhanced role of key participants” (CF4), and “Improvement and utilization of BIM for collaborative process of IPD” (CF7). Insert < Table Ⅴ ~~Ⅶ~~. Multiple regression result > here These four independent variables (CSF1, CSF2, CSF3, CSF4) ~~(CSFs)~~ altogether explained 60.7% (R2=0.607) of the variance of the three dependent variables (Table Ⅴ ~~Ⅶ~~). Among the….
Table Ⅶ. should be modified-there should be only one model that is one result indicating relationship between 7IVs and 3DVs.	Regression analysis is a set of statistical processes for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. Since this study intended to identify several critical success factors (CSFs) not only one, multiple regression analysis was utilized to recognized multiple independent variables (CSFs) for successful application of IPD in Korea.	
Suggest data in Table Ⅲ.and Table Ⅳ to be combined in Table Ⅴ.	As reviewer’s comment, we combined tables. We combined Table Ⅳ and Ⅴ. However, Table Ⅲ remains separately for	(Line 259-263) ~~Insert < Table Ⅳ. Final statistic of principal component analysis > here~~

	the effective delivery of content.	As shown in Table Ⅳ, ~~shows~~ the final statistics of the principal component analysis (PCA), in which the seven extracted FCs comprise 58.45% of the variance. The varimax rotation of PCA was used to interpret the FCs. ~~as shown in Table Ⅴ.~~ Each IPD success factor belongs to… (Line 269) Insert < Table Ⅳ. ~~Ⅴ~~. Component analysis and matrix ~~after varimax rotation~~ > here