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Identification of Critical Success Factors for Construction Innovation: From the Perspective of Strategic Cooperation

Abstract Nowadays, China is in the period of industrialization, modernization and urbanization. The investment to the infrastructure is increasing which requires the support from construction innovation. Construction innovation is project-based cooperative innovation. The innovation based cooperation not only focuses inside the boundary of project, but also emphasizes the long-term strategic cooperation among the participants of innovation network. Therefore, it is significant to explore the Critical Success Factors (CSFs) of construction innovation based on the viewpoint of strategic cooperation. This paper first presents the definition and characteristics of construction innovation. By tracking the international frontiers, the authors studied a great number of literatures on the influence elements of construction innovation. Combining the effort of literature review and expert interview, this present paper identified 20 CSFs for construction innovation, which is verified and perfected by a case study in the end. The findings of this research will be of great importance for guiding the practice of construction innovation in China.

Keywords: critical success factors, construction innovation, identification, strategic cooperation

Nowadays, China is in the period of industrialization, modernization and urbanization (Wang & Zhang, 2011). The investment to the infrastructure is increasing which requires the support from construction innovation. Construction industry is a complex project based industry. The uniqueness of construction projects leads to the fact that innovation is the key of the success of construction projects (Li, 2008). Construction innovation has gradually been the focus of academic and industrial circles; however, most relevant literatures focus on the study of innovation modes and the driving forces of construction innovation. Research on the construction innovation based on the strategic cooperation is few. In this perspective, this paper first analyses the definition and characteristics of construction innovation. Combining the efforts of tracking and studying the international frontier literatures and expert interview, this paper identifies the Critical Success Factors(CSFs) of construction innovation from the viewpoint of strategic cooperation. A case study is also presented to verify and perfect the CSFs identified.

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1 Construction innovation

1.1 Definition of construction innovation

Innovation, whether technical or not, is complex, dynamic and non-linear (Ozorhon, 2013). OECD (The Organization for Economic Co-operation and Development) (2005) defines innovation as the implementation of a new or significantly improved product (good or service), process, or delivery method, a new marketing method, or a new organizational method in business practices, workplace organization or external relations (Ozorhon, 2013; Ozorhon, Abbott, & Aouad, 2014). The Department of Trade and Industry (DTI) (UK) (2007) regards innovation as the adoption of an idea or behavior, whether a system, policy, program, device, process, product or service, that is new to the adopting organization (Ozorhon, 2013). Slaughter (1998) distinguishes innovation from invention as the "actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change". (Slaughter, 1998; Slaughter, 2000). In construction context, Pinto and Covin (1989) claim that construction projects are composed of two kinds of project, which are business projects and development (innovation) projects. In accordance with Bosch's

(2009) definition, a business project is the project executed by order of a specific client whereas an innovation project aims at innovation and takes place separately from a business project. However, there is still no clear definition of construction innovation given.

Construction is a diverse, project-based industry (Ozorhon, 2013). Thus, construction innovation has its own nature which is different from other industries, such as manufacturing, service. The project-based nature of construction industry makes every project unique (Veshoskey, 1998), thus there is significant opportunity and tendency for innovative behavior (Kulatunga, Amaratunga, & Haigh, 2006, pp.654–662), which, most of the time, tends to happen at the project level (Ozorhon, 2013; Winch, 2003; Widén, Olander, & Atkin, 2013). We think construction innovation is the project-based process to reconstruct the world around us through constructive activities and buildings. Construction innovation, taking the participants of the project as the subject and aiming at fulfillment of the goal of construction project, is the choosing, synthesizing and integration of various elements in terms of technologies, human resources, economy, management, society etc. The process of construction innovation consists of the definition of the issue, the propose and screening of problem solutions, engineering experiment and evaluation, implementation and operation etc.

1.2 The characteristics of construction innovation

(1) Construction innovation is project-based cooperative innovation. This cooperation reflects at two levels, project level and strategic level. First, in construction settings, much of the innovation is co-developed with other project participants, such as clients, contractors, sub-contractors, suppliers, consultants, and designers, each part of which has a different role in the innovation process (Ozorhon, 2013). Second, the innovation based cooperation in construction field should not only focus inside the boundary of the project, but also focus on the long term strategic cooperation with all of the participants of the innovation network. This expectation of long term strategic cooperation will make the construction innovation network face more challenges, nevertheless, at the same time, will be of great importance in strengthening the competitiveness of the players in the innovation network.

(2) Construction innovation is integrative innovation. Construction innovation is first the integration of technological elements. Moreover, construction innovation requires the integration of technological, economic, society, management elements, etc. (Li, 2008; Li, 2010).

(3) Construction innovation is a kind of open innovation. Construction project consists of different phases, which most of the time are completed by different organizations with various professional backgrounds. This means that the innovative activities in the different phases of construction are different. The sources of construction innovation are numerous; any participant of the project can be the source of innovation (Wang & Zhang, 2011). Besides, the organizations in the supply chain or even outside the construction industry can sometime contribute to the construction innovation. Therefore, the construction innovation is a kind of open innovation with various innovation sources.

(4) Construction innovation needs the presence of integration champion. The collaboration and integration of technological innovation and management innovation is necessary to the success of construction innovation, which needs the presence of integration champion. In order to collaborate and integrate all kinds of resources, the integration champion should not only own certain technological capabilities, but also be capable of innovation management.

(5) Construction innovation, which is complex, dynamic, and nonlinear, includes not only the radical innovation but also the incremental innovation (Li, 2010). The uniqueness of construction projects results in that there are no two buildings the same. In other words, innovation is the nature of construction. According to previous research, the incremental innovation occurs at a relatively higher frequency in construction.

2 Literature study

2.1 The importance of strategic cooperation for construction innovation

Innovation has a context sensitive nature (Ozorhon, 2013), success or failure of innovation is influenced by a whole range of factors which often vary from one organization to another, from one industry to another, and even from one country to another (Jones & Saad, 2003). Literature exploring the process of construction innovation once considered innovation is the responsibility of individual firms (Gann & Salter, 2000; Ozorhon et al., 2014). However, in the recent era, researchers increasingly emphasize the importance of interfirm cooperation relationships and networks in innovation projects (Holmen, Pedersen, & Torvatn, 2005; Rothwell, 1992; Slaughter, 1998).

Among which, cooperation is taken as the key aspect of construction innovation. Blayse and Manley (2004) claim that tighter "couplings" among firms and individuals involved in construction projects are likely to be more supportive of innovation. This idea is further researched by Miozzo and Dwick (2004) who call for stronger inter-organizational cooperation as a way of enhancing construction innovation. Rutten, Dorée, and Halman (2009) presented a literature synthesis on the role of cooperation as an enabler of construction innovation. As regards to how to ensure the sustainable and stable cooperation among all of the participants, Nam and Tatum (1992) emphasize the importance of non-contractual relationship (owner's leadership, long-term relationship, employing integration champions and the professionalism of project participants) in construction innovation. Bossink (2004) distinguishes the main drivers of innovation in construction networks including environmental pressure,

technological capability, knowledge exchange and boundary spanning. Nam and Tatum (1997) found out that to foster innovation, there must be implicit vertical integration. Ozorhon et al. (2014) also conclude that integration and leadership are two important enablers of innovation in construction.

Construction innovation is project-based cooperative innovation. In fact, construction innovation not only depends on the cooperation inside the boundary of project, it also spends an effort on strategic cooperation. The innovation based strategic innovation can play an important role in strengthening the competitiveness of the member of innovation network as well as accelerate the innovation pace of construction. Nevertheless, this kind of long term strategic cooperation will lead to even stronger challenge to the management of construction innovation. Therefore, to this end, it is necessary to explore the CSFs for construction innovation based on the viewpoint of the strategic cooperation, which is also the main subject of this research.

2.2 The key influence elements of construction innovation

This present study followed two tracks, literature review and expert interviews, to arrive at the CSFs (Sagheer, Yadav, & Deshmukh, 2009). The target papers for literature review mainly come from the leading international journals in the construction field, which are indexed by the SCI-E (Science Citation Index-Expanded) and EI (Engineering Index) database, such as *Journal of Management in Engineering*, *Journal of Construction Engineering and Management*, *Automation in Construction*, *Journal of Civil Engineering and Management*. Besides, some excellent relative books and internet materials, such as *Managing Innovation in Construction*, were also fully studied to gain a comprehensive understanding of the CSFs for construction innovation. "Construction Innovation", "Cooperative Innovation", and "Collaborative Innovation" were taken as the keywords to search for the relative academic articles. After collecting and studying the found literature, a compilation of selected literature focusing on exploring the influence factors of construction innovation is shown in Table 1.

According to Table 1, we can find that construction innovation can become successful by constructing long-term stable cooperation relationships with proper partners, developing a favorable context and using appropriate management skills (Cheng et al., 2000). In a complex systems industry such as construction, firms must rely on the capabilities of other firms to produce innovations. In that point of view, the selection of proper partners and the relationship with other partners is of great significance for initiating innovation in construction projects (Blayse & Manley, 2004). Contextual characteristics of the project networks may strengthen or hamper the innovation; the successful implementation of innovation may require major contextual changes (e.g., culture, business strategies) from participants involved, which most of the time is difficult. On the other hand, since innovation, no matter technical-or non-technical, is non-linear, dynamic and complex, critical management skills are prerequisite to effectively manage the collaborative working relationship (Cheng et al., 2000).

3 Experts interview

Triangulation is a typical strategy for qualitative researchers to check and establish validity and reliability in their studies (Guion, Diehl, & McDonald, 2011, p.2). To assure validity and reliability, triangulation was used (Azevedo, Carvalho, & Cruz-Machado, 2013). Triangulation may involve combining multiple data sources (data triangulation), using multiple investigators to work on the same task (investigator triangulation), applying multiple qualitative and/or quantitative research methods to analyze the same problem (methodological triangulation), using different locations, settings or other key factors related to the environment in which the study took place (environmental triangulation), or using multiple theories to support the research result (theory triangulation) (Azevedo et al., 2013; Guion et al., 2011).

The target survey respondents include industrial practitioners who have extensive hands-on experience in executing innovation management in construction projects; and academies that have rich experience in doing research about technological innovation in the construction field. To this end, 10 experts, 5 from industry and 5 from academia, were consulted. All of the experts involved in this research hold senior management positions in their respective companies or institutions, and have significant experience about innovation projects of over 10 years. Thus, data triangulation was used in this research since the CSFs of construction innovation were established depending on the contributions of experts from both academia and the construction industry (Azevedo et al., 2013).

To attain the CSFs of construction innovation, semi-structured interview and Delphi technique were adopted. During the semi-structured interview, the 10 experts were first shown the background and objective of this study, then they were invited to openly discuss on the definition and characteristics of construction innovation and list as many ideas as possible about the CSFs. Opinions about the management of construction innovation are also welcomed. In light of the result of the first round semi-structured interview and literature review, a checklist consists of 26 critical factors was constructed.

Delphi technique was applied to further identification of CSFs for construction innovation. The checklist attached with the explanation of each factor was provided to the experts to obtain their opinions (agree, disagree, detailed modification advice—add, delete or combine factors, etc.) on the factors identified. During the first round, there were three pairs of factors getting combined, for example, the efficient allocation of risks and the reasonable distribution of interests were combined into the reasonable allocation of risks and interests; and there were two factors getting deleted such

Table 1 *Literature Review of Construction Innovation*

References	Influence factors
Pinto and Covin (1989)	Mission; top management support; project schedule/plans; client consultation; personnel; technical tasks; client acceptant; monitoring and feedback; communication; trouble-shooting; characteristics of the project team leader; power and politics; environmental effects; urgency
Nam and Tatum (1992)	Owner's leadership; the long-term relationship; employing integration champions; the professionalism of project participants
Freeman and Soete (1997)	Strong in-house professional r&d as well as performance of basic research; readiness to take risks; identification of a clear need and market research; effective internal and external communication
Cheng Li, and Love (2000)	Adequate resources; management support; mutual trust; long-term commitment; coordination; creativity; effective communication; conflict resolution; perceived satisfaction of partners' expectation; compatible goals
Kamara, Anumba, and Carrillo (2002)	Organizational culture for knowledge sharing and learning
Cooper (2003)	Close relationships between partners
Jones and Saad (2003)	Identification of a clear need for change; responsiveness to internal and external change; the achievement of good linkage within and between organizations leading to more collaborative relationships; treating innovation as a corporate-wide task; adopting a strategic approach in the management of innovation; developing and sustaining a supporting organizational culture for innovation; top management commitment and acceptance of risk; presence of certain key individuals or champions; effective and on-going learning process; systematic approach to developing; implementing, monitoring and sustaining innovation; external support
Van der Panne, Van Beers, and Kleinknecht (2003)	Strength of competition; r &d intensity; the degree to which a project is "innovative" or "technologically advanced"; top management support; firm culture; experience with innovation; the multidisciplinary character of the r&d team
Bossink (2004)	Environmental pressure; technological capability; knowledge exchange; boundary spanning
Chan et al.(2004)	Establishment and communication of conflict resolution strategy; commitment to win-win attitude; regular monitoring of partnering process; clear definition of responsibilities; mutual trust; willingness to eliminate nonvalue added activities; willingness to share resources among project participants; ability to generate innovative ideas
Holmen et al.(2005)	Resource ties; actor bonds; activity links
Wan, Ong, and Lee(2005)	Decentralized structure; presence of organizational resources; belief that innovation is important; willingness to take risks; willingness to exchange ideas
Blindenbath-Driessen and Van den Ende (2006)	Planning and effective execution; contingent approach; senior management involvement; expertise; heavyweight project leader; product champion; external communication; customer involvement; supplier involvement; pre-development; market research and testing; launch
Chen [W. T.] and Chen [T. T.] (2007)	Mutual trust; effective communication; commitment from senior management; clear understanding; consistent with objectives; dedicated team; flexibility to change; commitment to quality; commitment to continuous improvement; long-term perspective; total cost perspective; partnership formation at design stage; good cultural fit; company wide acceptance; technical expertise; financial security; questioning attitudes; availability of resources; equal power
Bosch and Postman (2009)	Partner firm's intentions; partner firm's competencies; partner firm's experience in cooperation and innovation; collaborative attitude between partner firms; the support of higher management of the participant firms; strategic importance of innovation project; strategy of transferring knowledge of partner firm's capabilities or new knowledge of the innovation project to business project; promoting knowledge sharing over project boundaries by boundary spanners
Kim et al.(2009)	Systematic methodologies to carefully and accurately monitor research innovation performance; strict incentive system
Forcada, Fuertes, Gangolells, Casals, and Macarulla (2013)	Organizational culture for knowledge sharing and learning
Ozorhon et al. (2014)	Owner's leadership; integration
Skibniewski and Zavadskas (2013)	Mutual trust; culture change for effective and on-going learning and innovation

as the cooperation intention of partners. Besides, associated modifications in the presentations of some of the factors were made according to the experts' advice. The different opinions of experts were made into a chart for comparison. The chart and the modified checklist were sent to the expert again to invite all of the experts to recompose their judgments. In the second round of Delphi technique, all of the experts reach a consensus. To the end, 20 CSFs of construction innovation were identified, which are shown in Table 2. For each CSF identified the frequency at which it was mentioned among the sampled literature was recorded to show its relative state of being aware of.

4 Case study

SH Group Company (SHGC in short) emphasizes strategic cooperative innovation and has mastered the core technol-

Table 2 *CSFs for Construction Innovation*

CSFs \ References	Pinto et al. 1989	Nam et al. 1992	Freeman et al. 1996	Cheng et al. 2000	Kamara et al. 2002	Cooper 2003	Jones et al. 2003	Van der Panne et al.2003	Bossink et al. 2004	Chan et al. 2004
Partners' relationship										
F1. Professionalism of partners		○	○					○		
F2. High credibility of partners										
F3. Harmonious long-term working relationships		○		○	○	○			○	
F4. Partners have rich experience in cooperation and innovation								○		
Organizational environment										
F5. Mutual trust				○						○
F6. Owner's involvement and leadership	○	○							○	
F7. Top management commitment	○			○			○	○		○
F8. Strategic importance of the innovation project							○	○		○
F9. Presence of integration champions	○	○					○		○	
F10. External support	○						○		○	
F11. Organizational culture for effective and on-going learning and innovation					○		○	○		
Synergy management										
F12. Effective and open internal and external communication and cooperation	○			○					○	
F13. Appropriate allocation of risks and interests									○	
F14. Clear definition of responsibilities										
F15. Systematic methodologies to carefully monitor the innovation process	○						○			
F16. Establishment and communication of conflict resolving strategies	○			○						
F17. Clear identification of user's needs	○		○				○			
F18. Responsiveness to internal and external changes							○			
F19. Formulating strategies to transfer knowledge of the innovation project to the business project										○
F20. Building a strict incentive system										

CSFs \ References	Holmen et al. 2005	Wan 2005	Blindenbach-Driessen et al. 2006	Chen et al. 2007	Bosch et al. 2009	Kim et al. 2009	Forcada et al. 2013	Ozorhon et al. 2013	Skibniewski et al. 2013	Total number of hits of a certain CSF
Partners' relationship										
F1. Professionalism of partners			○	○	○					6
F2. High credibility of partners	○			○	○					3
F3. Harmonious long-term working relationships	○			○						7
F4. Partners have rich experience in cooperation and innovation	○				○					3
Organizational environment										
F5. Mutual trust	○			○					○	5

cont.

CSFs \ References	Holmen et al. 2005	Wan 2005	Blindenbach-Driessen et al. 2006	Chen et al. 2007	Bosch et al. 2009	Kim et al. 2009	Forcada et al. 2013	Ozorhon et al. 2013	Skibniewski et al. 2013	Total number of hits of a certain CSF
F6. Owner's involvement and leadership			○					○		5
F7. Top management commitment	○		○	○	○					9
F8. Strategic importance of the innovation project		○			○					5
F9. Presence of integration champions			○	○				○		7
F10. External support										3
F11. Organizational culture for effective and on-going learning and innovation				○	○		○		○	7
Synergy management										
F12. Effective and open internal and external communication and cooperation	○	○	○	○	○					8
F13. Appropriate allocation of risks and interests	○	○		○						4
F14. Clear definition of responsibilities	○			○						2
F15. Systematic methodologies to carefully monitor the innovation process						○				3
F16. Establishment and communication of conflict resolving strategies										2
F17. Clear identification of user's needs			○							4
F18. Responsiveness to internal and external changes				○						2
F19. Formulating strategies to transfer knowledge of the innovation project to the business project			○		○					3
F20. Building a strict incentive system						○				1

ogy of heavy haul railway, which has achieved outstanding social and economic benefits. Based on the real engineering requirement, it focuses on the development and research of the whole set of technologies for heavy haul railway. Till now, SHGC has established its own effective strategic cooperation based innovation mode.

The innovation experience in this case study project was investigated for a sufficiently long period of time (one year) accompanied with several semi-structured interviews with the key stakeholders involved. Other sources of evidence, such as the project documents, were also analyzed to gain insights into how to successfully implement construction innovation. Through analysis, the successful experience of construction innovation for SH heavy haul railway (SHHHR in short) can be mainly concluded in three aspects, i.e. the construction of strategic cooperation relationship, the establishment of innovation-pro organizational environment, and the adoption of critical management skills, which matches the CSFs identified in this paper. The successful experience of construction innovation for SHHHR is as follows.

4.1 The construction of strategic cooperation relationship

The success of innovation in construction projects is based first on the selection of cooperation partners and the relationship with partners (Radziszewska-Zielina, 2010). Construction projects are characterized as being filled with adversarial relationships, so the first concern during the selection of partners is the partner firm's professionalism and credibility. The partner companies should not only intend to cooperate at the project level, but also own the long term strategic cooperation expectations. Moreover, convincingly, firms with little experience in performing innovation projects in collaboration and coordination with other counterparts have difficulty executing successful innovation projects. Thus, it is important for the partners of innovation networks, to possess a history of cooperation and a conventional harmonious partnering working relationship. SHGC as the owner of the project holds a harmonious long-term relationship with a great number of design companies, research institutes, consultation companies and universities alike. All of the part-

ners have good reputation, most of them have rich collaborative working experience before, and have sound working relationships with their former partners, which pave the way for successful innovation in the project.

4.2 The establishment of innovation-pro organizational environment

The construction of SH Railway (SHR) involves a wide range of regions; it has a huge economic and environmental effect on the local areas, so the project received substantial support from both regional and national governments. Significant difference can be made by owner's involvement and leadership. The more "demanding" and experienced the client, the more likely it is to stimulate innovation in projects it commissions. The owner of the project acted as the main financial founder, decision maker and beneficiary of the innovation achievements in the innovation project. This organization mode helped streamline the information, knowledge sharing, and communication. This mode's application effectively reduced the risks and conflicts that occurred during the process of the project. Just as one designer of the project said, "It is a small business, so the owner's satisfaction is the most important concern." Innovation was given strategic importance in this project, which dramatically facilitated the process of the innovation project. The commitment of top management of owner and contractor ensures the construction innovation with sufficient resource and authority. Under the unit organization and management of the project's owner, the construction innovation network of SHHHR establishes learn and innovation-pro culture. In this context, the participants of the network can efficiently communicate and share information by opening their organizational boundaries, which can also leads to mutual trust.

4.3 The adoption of critical management skills

The innovation network in construction projects is a complex system. Due to the technical and logistical interdependences, individuals or organizations in the network have to deal with complicated interfaces, which may make corresponding organizational or cultural change occur. Considering the fact that the technological innovation network is a virtual organization, the partners change frequently in light of the variable work. Therefore, contractual relationships addressing the allocation of risks as well as interests and the assignment of responsibilities among the stakeholders are of great importance to maintaining the effective operation of the technological innovation network. SHHHR has applied a whole set of complete governance measures to insure the success of the project. For instance, all of the participants of the innovation project sign a detailed contract which can fairly and clearly allocate the risks, interests and responsibilities. Because the contract template about the cooperative innovation is not perfect, the draft, discussion and amendment of contract text for SHHHR have been through a long time. The owner of this project organizes several discussions among all of the participants of the innovation network to reach the consensus on the cooperative innovation contract. Moreover, strict incentive mechanism, which is shown important for the management of construction innovation, is given emphasize from the inception phase of this project. As SHGC underlines that the construction innovation should tightly consider the instant and long term engineering requirements, strategies to ensure the engineered innovation are important.

5 Conclusions

Construction innovation is completed in a collaborative manner at the project level. Actually, the innovation based cooperation focuses not only on things inside the boundary of the project, but also on the long term strategic cooperation among all of the participants of the innovation network. This kind of long term strategic cooperation raises higher requirements for the innovation network; in the meanwhile, it is also of great importance for the competiveness of the players of the network. Therefore, identifying the CSFs of construction innovation from the view point of strategic cooperation is necessary.

Based on the perspective of strategic cooperation, this paper analyses 20 CSFs for construction innovation from three aspects, i.e. the construction of strategic cooperation relationship, the establishment of innovation-pro organizational environment, and the adoption of critical management skills, which can give some guidance for the practice of China's construction innovation. Further research should take advantage of proper method to study on the mechanism under which the CSFs influence on the performance goals of construction innovation considering the relevancy between the performance goals and CSFs of construction innovation.

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