

Study of Digital Lean Construction Platform for Precast Components

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ABSTRACT

Construction industrialization is the very trend in the construction industry of China. The deeply integration of informatization and industrialization is the inevitable course of transformation and upgrading of the construction industry. Based on this, from the perspective of supply chain optimization management, we developed a software platform system and integrated all the project members of precast components (PC) into this platform. On this unified platform, the companies work collaboratively. Established on the basis of the BIM (Building Information Modeling) model, this platform is a digital lean construction platform to integrate virtual construction technology, internet of things technology, cloud services technology, remote monitoring technology and high-end aided engineering equipment. On the platform, the whole construction project is under the control of the supply chain management and companies can achieve the targets, like “optimal of business process”, “shortest cycle”, “lowest cost”, “minimum inventory”, “faster cash flow”, “enterprise value maximization”. Based on the actual case, the achievements of the prefabricated digital lean build platform based on supply chain were showed, and the developments of the platform for the future were discussed.

INTRODUCTION

On the whole, China construction industry lacks abilities of high technology and knowledge intensive. Value-added level is very low. So, Chinese construction enterprise's competitive strategy should shift from cost advantage to the innovation advantage [Wang Wuren (2008)].

After years of development and application, Supply Chain Management (SCM) [Gunasekaran A (2004)] [Wang Wuren (2008)] and lean construction (LC) [Ballard Glenn (2003)] had been gradually mature, which provided an important theoretical and technical basis for construction innovation. With the particularity of precast component project, we can't simply copy the existing theory. We need to combine with the characteristics of PC and studies related issues systematically. In this paper, through analyzing the characteristics of precast component supply

chain (PCSC), we apply the theory of lean manufacturing to the whole process of design, production, transportation, construction of PC, study the digital lean construction platform, and implement a new construction mode of production.

The characteristics of PCSC. Since Oliver and Michael set up the theoretical of supply chain [Oliver (1982)], great advances of supply chain management theory have been made, from the enterprise internal to the external supply chain and to the dynamic alliance the study. In 1992, Koskela firstly applied the supply chain management theory in the construction industry [Koskela L (1992)], and from then on many domestic and overseas scholars were targeted to focus on the study of construction supply chain (CSC).

The structure of PCSC not only has obvious differences with SC structures, and also has obvious differences in different construction modes (DBB, EPC, DB, EP, BOT, BOOT, TOT and so on). Figure 1 is the typical structure of PCSC in EPC project in China.

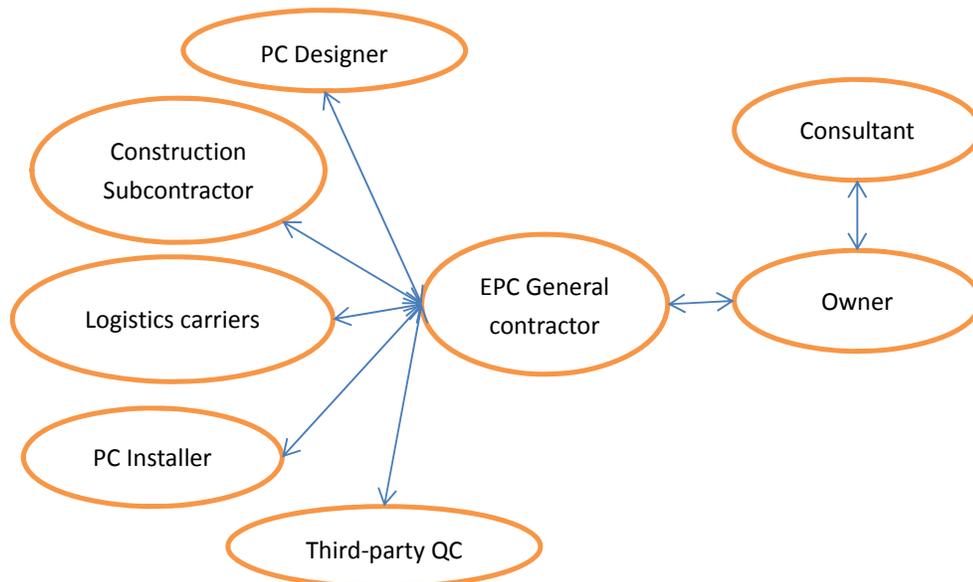


Figure 1. The structure of PCSC in EPC project

By analyzing the structure of PCSC, PCSC has the following characteristics:

(1)PCSC is a demand-based chain. The operation mode of PCSC is “Pull”. PC project has the characteristics of customization, fixed-point production, so the driving force comes from the owner. General contractors, designers, construction subcontractors, installers and so on, all work cooperate around the demand of the owner. So the PCSC is a chain pulled and driven by the owner.

(2)PCSC is a short and asymmetric chain. To be compared with other SC, the core is the general contractor; there are not much intermediate agencies in SC. So PCSC is a short chain. In addition, with thousands of node enterprises, the downstream node of general contractor is only the owner, and upstream nodes are

numerous enterprises. So the PCSC is a asymmetric chain.

(3)PCSC is a hypotactic network chain. In Figure 1, PCSC is not a single chain, but a network chain made up of multiple nodes. In the PCSC, general contracting enterprises with comprehensive management ability undertake the overall control task for the project, and so they are located in the center of the PCSC positioning and play a leading role. The subcontractor and supplier partners are numerous and have an import impact on construction cost, quality, and progress. This characteristic determines the general contractor has a strong dependence on subcontractors and suppliers.

(4)PCSC is a short-term network chain and based on the individuality of project. Although the principal part of network chain may be the same, the individuality of project determined that different projects have different upstream subcontracts and suppliers and the management pattern also changed [Ma Zhiliang (2011)][Wu Haoxuan (2013)]. Based on project requirements, we need establish an individuation PCSC network chain. Project can be continued for months, even years, but compared to the manufacturing industry SC, PCSC is still a short-term network chain. PCSC was born as the project starts, and fell as the end of the project.

(5)The information sharing and management of PCSC is very difficult. In real engineering project, the owner requirements often change and the design is often developed concurrent with construction activities. And because PCSC is a hypotactic and asymmetric network chain, transmitting modification information accurately from general contractor to the upstream and doing the adjustment accordingly is very difficult. Based on many uncertainty project factors, companies tend to evade a responsibility. When maximizing their interests, enterprises are not willing to consider maximizing the benefit of project [Liu Xuelin (2011)] [Li H (2010)].

The above analysis shows that when introducing the theory of supply chain, the characteristics of PC design, production, transportation and construction should be fully considered, and the application framework and ideas should be established specially.

The main research contents of PCSC. So far, there are so much research results and literature of the general supply chain, and there are also some famous practices. Academics have summarized and reviewed in some ways [Croom S (2000)]. The main content of these documents involved in supply chain design and analysis, supply chain modeling and optimization, relationship between the supply chain members, bullwhip effect, performance evaluation of supply chain, supply chain management, etc. Especially Chen and Paulraj according to the analysis of more than 400 articles [Chen I J (2004)], combined the valuable results and gave a important framework of supply chain management research. The authors draw lessons from this framework and presented a PCSC research framework. See Figure 2.

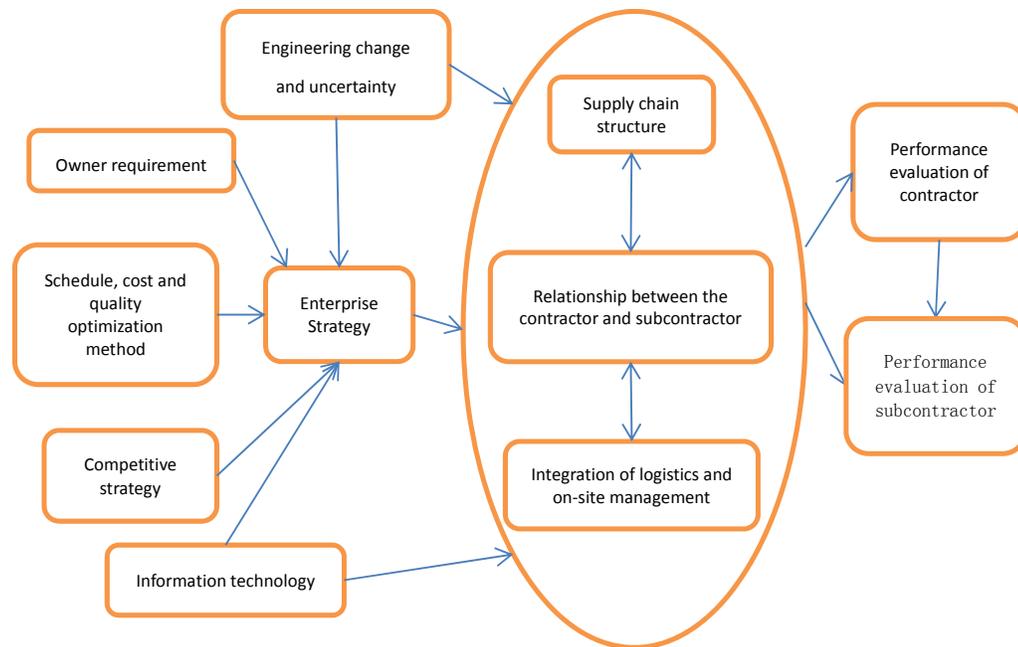


Figure 2. PCSC research framework

(1) Engineering change and uncertainty. Even in simple or complex engineering, the changes and uncertainty are a major problem, which should be considered in the first place in the research work of PCSC. The strategy, structure and performance is the key to the success of PCSC and influence each other. The changes of external environment directly affect the PCSC strategy and structure. So, the main sign of PCSC success is how to cope with change and has a good results.

(2) Owner requirement. Because PCSC is running around the owner requirements, throughout the full life cycle of project the owner requirements have a continuous effect on PCSC. And the owner requirements are constantly changing, Need PCSC needs to be a consultation body to identify "efficient" requirements, and make adjustments to changing requirements.

(3) Schedule, cost and quality optimization method. In the past, the optimization is limited within the enterprise; the scope of optimization is very small. Only from the whole value and efficiency of the supply chain, there can be a breakthrough. The essence of PCSC is the combination of construction enterprise, which will integrate the single enterprise's competitive advantage, achieve "sum of the parts are greater than the whole". Because the supply chain essentially is a Time-Based Competition (TBC) production management method, the impact on schedule is great. More in-depth study of PCSC effect on schedule optimization should be made.

(4) Competitive strategy. Chinese construction industry is a fully competitive industry, and even excessive competition in some areas and regions. "Low cost", "small profit", these competitive strategies are not only bad to promote technological progress, but also let the enterprise itself on the verge of the

difficulty. With the aid of the overall advantages of PCSC, developing the enterprise core competence is the correct choice of construction enterprise.

(5) Information technology (IT). Recently, application of IT in construction industry is in the ascendant, especially the BIM technology. The essence of PCSC is the enterprise alliance and cooperation; information sharing is the foundation of PCSC operation and the guarantee of success. BIM technology is important means to improve the quality of the construction industry information exchange. On the other hand, PCSC will be the effective carrier of BIM technology. Currently, the application of BIM technology in the construction industry is gradually thorough, but slowly. One reason is that the technology application of the threshold is too high, but more reasons are that the benefit of the value-added application is difficult to measure, and incentives of profit distribution are inadequate. The author thinks that PCSC and BIM are two technical methods and ideas which will be complementary to each other, in the future there will be a large space for development.

(6) Enterprise Strategy. PCSC management approach is different from the traditional management mode, often means that corporate strategy needs to be adjustment, so the risks and opportunities coexist. When developing business strategies, according to the characteristics of the PCSC some strategies must be considered, such as “Emphasis on long-term strategic cooperation with partners to achieve win-win situation”, “Focus on all of the enterprises’ benefit in the supply chain”, “Immediate payment to minimize the cost of capital”, “Improve the information sharing to reduce uncertainty”, “Allocate the resources on the whole supply chain”, “Apply flexible management styles” and so on.

(7) Supply chain structure, Relationship between the contractor and subcontractor, Integration of logistics and on-site management. The three parts are not only independent subjects, but also closely linked as a whole. In the construction industry, there are some different construction modes adapted to the different conditions. The supply chain structure and the relationship between the contractor and subcontractor are different, the same to the logistics and on-site management. How to construct an agile, flexible supply chain structure, how to deal with the relationship between the contractor and subcontractor, how to get building materials timely, all these problems are the key research areas.

(8) Performance evaluation of contractor and subcontractor. The literature on supply chain performance evaluation is very much, the evaluation methods are different [Gunasekaran A (2004)][Brewer P C (2000)][Naim M(2002)]. Based on two important roles in PCSC, "contractor" and "subcontractor ", there should be different performance evaluation method. At present, there is little research literature about supply chain diagnosis methods; we can referent the enterprise diagnosis model to study the PCSC diagnosis methods.

Application Case. Based on the study of PCSC, we developed a digital lean construction platform for PC, and the structure of platform is showed in Figure 3. On this unified platform, the companies in PCSC work collaboratively.

Established on the basis of the BIM model, this platform is a digital lean construction platform to integrate virtual construction technology, internet of things technology, cloud services technology, remote monitoring technology and high-end aided engineering equipment. On the platform, the whole construction project is under the control of the supply chain management and companies can achieve the targets, like “optimal of business process”, “shortest cycle”, “lowest cost”, “minimum inventory”, “faster cash flow”, “enterprise value maximization”. This platform is applied to the laboratory building project of China State Construction Engineering Corporation (CSCEC).

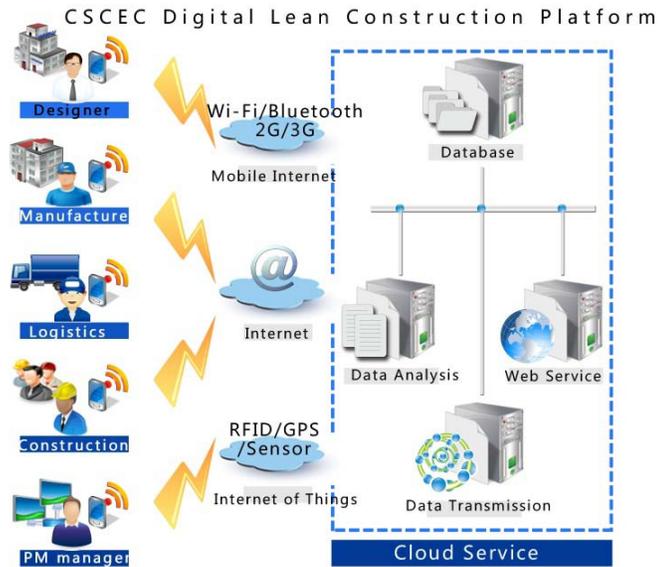


Figure 3. The structure of platform

- (1) Through the RFID technology, all the PCs in this project were recognized in the process of production, logistics, construction and operations. The selection of RFID chip, embedding position and facing are the key problems.
- (2) The system is divided into handheld terminal program and server program, see Figure 4 and Figure 5. Workers used the handheld terminals to collect data through the mobile Internet and WIFI network to connect to the server, and managers used the server to realize the data sharing through web service.
- (3) We use Autodesk Revit to model PCs (see Figure 6) and determine the component installation location and joint position [He G P (2011)]. Through the



Figure 4. Handheld terminal program



Figure 5. Server program

BIM software, directly generated the detailed design drawings and components manufacturing drawing, used to guide the production, construction.

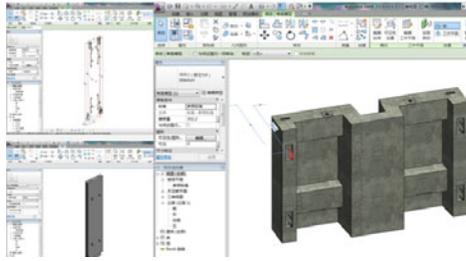


Figure 6. BIM modeling of PCs

(4) In the production, quickly and accurately obtain component the information, such as size, location, number, type, quantity. Automatically output various quantities statistics for cost control and production schedule. Make the pre-production reduced from 30% ~ 40% to 5%.

(5) In the construction, through the platform subcontractor shared the component production and transportation information in time, made and adjustment the construction plan. Through 3D scanning, we completed the wall flatness (see Figure 7) and color difference analysis (see Figure 8).

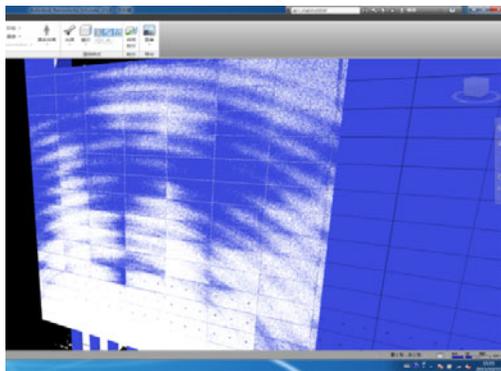


Figure 7. Flatness analysis

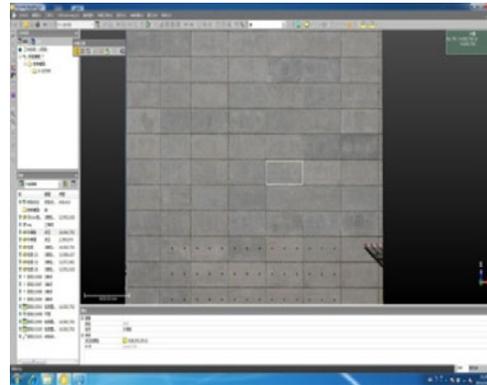


Figure 8. Color difference analysis

CONCLUSION

Through analyzing the demand of Chinese construction industry and the characteristics of PCSC, this paper designed a research framework and analyzed the main problems. Through an application case, we introduced a digital lean construction platform for PC. In the future, we will study the following questions:

- (1) BIM-based PCSC information sharing.
- (2) PCSC partner selection.
- (3) Interest distribution of PCSC cooperation.
- (4) Performance evaluation and problem fast diagnosis of PCSC cooperation.

The competitive strategy of Chinese construction industry has been transforming from cost advantage into innovation advantage. The development trends of domestic construction industry are internationalization and service oriented.

Construction enterprises must go beyond its boundaries and seek development opportunities and competitive advantages on the whole construction supply chain.

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