INTEGRATING INFORMATION ACROSS CONSTRUCTION SUPPLY CHAIN USING ND MODELLING

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ABSTRACT

Information integration has been recognized as key factors for effective construction supply chain (CSC) management. It acts as an enabler to implement lean production philosophy by facilitating information sharing, joint decision making, process integration and team cooperation. This paper aims to explore an nD modelling based information system to enhance the CSC information integration and sharing. Mixed methodologies including literature review, theory analysis and workshop discuss were employed. The research identified that lack of information integration across the CSC is the main barrier to effective supply chain information management. An nD modelling based two level construction supply chain information system, consisting of operational project supply chain extranet and strategic organizational supply chain extranet, was proposed and illustrated in detail. Application of the system shows it could enable construction information integration and interdisciplinary analysis to facilitate collaborative decision making and process integration, and also provide a solution to match the principle of long term cooperation for supply chain management with the actual unique and transient nature of project based construction.

KEY WORDS:

information integration, construction supply chain (CSC), nD modeling

INTRODUCTION

Information plays a profound role in the construction process whether it is during the preconstruction period or during the project implementation (Titus, 2005). Such information is vital especially when lean construction goals such as just-in-time production, minimum waste and supply chain (process) integration is desired, in which case limited space of construction sites and associated technical requirements always dictate that many works should be done just before or after some work packages. This requires that the construction team has a good information system

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enabling real-time information access at the right time and from right place.

With the growing realization of adoption of supply chain management concept to improve construction performance, there are many research activities related to the strategy, concepts and modelling of CSC networks (O'Brien, 1995; London et al.,1998; Al-Sudairi et al., 1999; Vrijhoef et al., 2001; Love et al.,2002). Many researchers have realized the importance of proper information management during construction process and developed different information management framework or prototype (Tam, 1999; Elliman and Orange, 2000; Deng et al. 2001; Peansupap and Walker,2005). These efforts have led to the development of several technical solutions for the construction supply chain integration. However, according to Alshawi et al. (2002) and Li et al (2007), although there are already some successful specialty software applications, the existed application of IT in construction still suffers from the lack of information and software integration.

This paper started with brief introduction of supply chain management and its application in construction. Information integration was identified as a key factor contributing to CSC integration and management that support lean supply chain. Then characteristics of information and its management in construction was summarized and gaps between requirement of information integration for effective CSC management and current industry practice was discussed. Followed by detailed introduction of nD concept and its application in organization supply chain extranet and project supply chain extranet, acting as an information and knowledge integrator to facilitate information storing, sharing, transference and construction knowledge generation. Brief discussion was developed to facilitate the implementation of nD modelling concept.

CONSTRUCTION SUPPLY CHAIN MANAGEMENT AND INTEGRATION

Supply chain management takes a systems view of the production activities of autonomous production units (subcontractors and suppliers in construction) and seeks global optimization of these activities (O'Brien et al., 2002). Construction supply chain is a concept adapted from retailing and manufacturing industry, and is generally understood as the integration of construction business network from original suppliers to end users that provides materials, products, services, and hence add value for construction clients and other stakeholders (Li, et al., 2007a), figure 1 described the typical supply chain configuration and main process for a specific project under Design-Bid-Build procurement route. It shows that CSC is a typical made to order network providing construction services with many stakeholders.

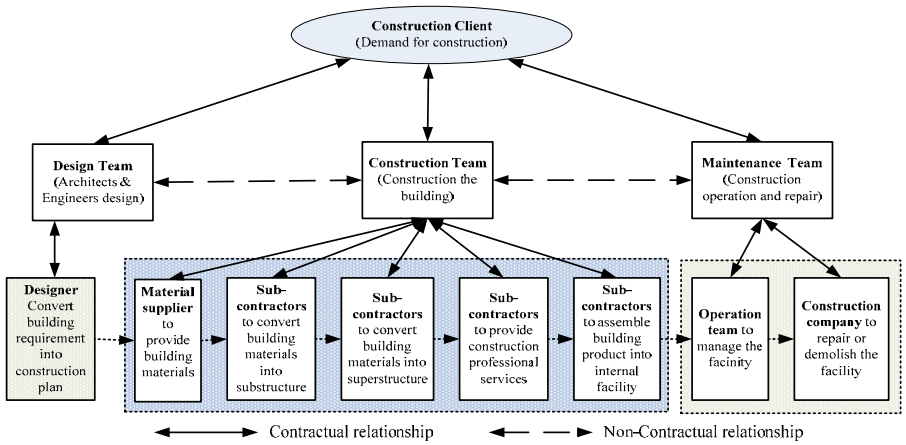

Figure 1: Typical configuration of project supply chain under Design-Bid-Build procurement route

Many researches addressed CSC management and integration issues mainly from the process, organization, procurement and strategy perspectives. O'Brien (1999) suggested in many construction projects there is a lack of integration of the construction company and its suppliers. Previous research (Koskela, 2000; Sterzi, 2007) indicated that the Last Planner System® can contribute to the integration of construction companies and their suppliers in the management of project supply chains. Researchers (Alshawi and Faraj, 2002) also found that there have been major efforts to develop the technology for integrated construction environments, evidently, the development of the technology and its effective implementation are among the main contributors to this.

This research identifies that the conflict between the transient nature of project based construction industry and the requirement of long term cooperation for successful supply chain management is the main challenge to the adopting and integration of supply chain in construction. Authors of this paper proposes a two level supply chain arrangement to match the requirement of long term cooperation between supply chain partners with one-off collaborative environment for specific project implementation. The first level is strategic organization supply chain at a company level for long term cooperation through joint goal of continual works awarding, which echoes the principle of long term cooperation for effective supply chain management. It is also consistent with the characteristic of project oriented construction industry since all construction companies try to ensure long term stability in the market despite their specific project tend to be unique and one-off. The second level called project supply chain is at the project and operational level for the implementation of specific projects. The relationship between the two levels is that the partner of project supply chain should normally be chose from the existing company supply chain to ensure continuity of work and ongoing co-operation. In the case of specialist work, there may be no appropriate partner within the existing company supply chain. However, if this situation re-occurs frequently, the strategic company supply chain should

be re-designed to bring the specialist partner within the supply chain.

INFROMATION MANAGEMENT IN CONSTRUCTION SUPPLY CHAIN

Information is a collection of facts or data that has been given meaning by ways of relational connection (Bellinger, 2004), it provide human beings the basic resources and start to develop successful decisions or activities. Construction information often exists in the form of documentation, such as brief, drawings, specifications, contracts and conditions, explanations, clarifications, which are communicated between parties (Edum-Fotwe, 2001). Generally, there are two types of information including production information and process information generated during the lifecycle span of the facility. The construction information types, characteristics and examples are summarized in table 1.

Table 1 CSC information types, characteristics and examples

Information Types		Characteristic	Examples
Production information	Geometry information	Define a building object by using geometric information, space relationship between these objects	3D ccoordinate information, space interaction information, horizontal map and elevation
	Property information	Describe a properties of objects through function, material and criteria information	Materials, appearance, strength character, design standard and construction regulation
Process/supply chain information	Process information	Define the work package according to the construction practice and resources	Who, what time, how and where to finish a specific work package
	Supply and demand information	Provide supply and demand information according to the construction plan or market	Suppliers of materials, machineries and human resources, requirements of demand

There is a general realization that information integration and sharing play a key role in the CSC integration and management (Tam, 1999; Mak, 2001; Edum-Fotwe, 2001; Bellinger, 2004; Li et al., 2007). To some extent, it decides the performance of the CSC since integrated information allows, forbids and directs the physical flows as well as financial flows, and also enables the checking and conforming as well as provides proof and audit trails for transactions. Lack of information integration across the whole CSC is identified as main barrier to effective supply chain information management (Li et al., 2007b). It causes the problem that every end user could struggle to collect various information generated by different partners, which is time consuming and difficult under the current adversarial contractual oriented relationships in construction project. Although many researches have made some contribution in this area (Tam, 1999; Mak, 2001; Nitithamyong and Skibniewski, 2004), many of these endeavours aim to develop a integrated information system to store, transfer and share various information. However, most of the research mainly focused on the transfer of the fragmented information rather than providing integrated information. It is identified this approach is still time

consuming and even difficult when users search for target information in the system after it 'grow' bigger and bigger and more complicated in some large-scale projects.

This paper proposes to integrate the information at the building object level instead of at the system level to facilitate convenient information searching, storing and sharing. It could provide construction information through the integrated 'object', which could be a building element or a function entity. All the associated information about a object (e.g. position, material and cost, even possible supplier) will construct a integrated information unit. Once the end user choose a object (e.g. window), all the associated product and process information affiliated to the object will be available for the authorized users. nD modelling based information system, taking IFC as its building information model, not only provides construction product and process information in a integrated manner (both object level and system level), but also provides a collaborative information management platform to do 'what if' analysis for each supply chain partner to take other partners' benefits into account, which is especially useful when supply chain integration is desired.

ND BASED CONSTRUCTION SUPPLY CHAIN INFORMATION SYSTEM

An nD model is an extension of the building information model (BIM), which incorporates multi-aspects of design information required at each stage of the lifecycle of a building facility (Aouad, 2006, Lee et al., 2007, Fu et al., 2007). nD modelling is based upon the BIM, a concept first introduced in the 1970s and the basis of considerable research in construction IT ever since. The BIM is a repository that stores all the data "objects" with each object being described only once. Both, graphical and non-graphical documents, such as drawings and specifications, schedules and other data, respectively, are included (Lee et al., 2005). By handling project documentation in this way, communication problems that slow down projects and increase costs can be greatly reduced (Cyon Research, 2003).

nD modelling enabled construction supply chain information system is constructed based on building 'object' (information unit), which includes associated core information such as 3D geometric information, materials and suppliers, cost, schedule and so on. It also can provide 'what if' analysis of time, cost, buildability, accessibility, sustainability, maintainability, acoustics, lighting and thermal requirements (Lee et al., 2007), which can enhance the supply chain integration since each partner can take other partners' process and benefits into account when they make decision.

As discussed in section 2, the transient nature of project based construction business practice is not consistent with the long term cooperation principle of successful supply chain management. A two level supply chain arrangement is proposed to provide the solution to match long term cooperation requirement with a one-off collaborative environment for specific project implementation. Accordingly, construction supply chain information system is arranged into two levels, see figure 2. One level is a construction organization supply chain extranet for strategic long term

supply chain partners, the other is a construction project supply chain extranet for specific project supply chain partners.

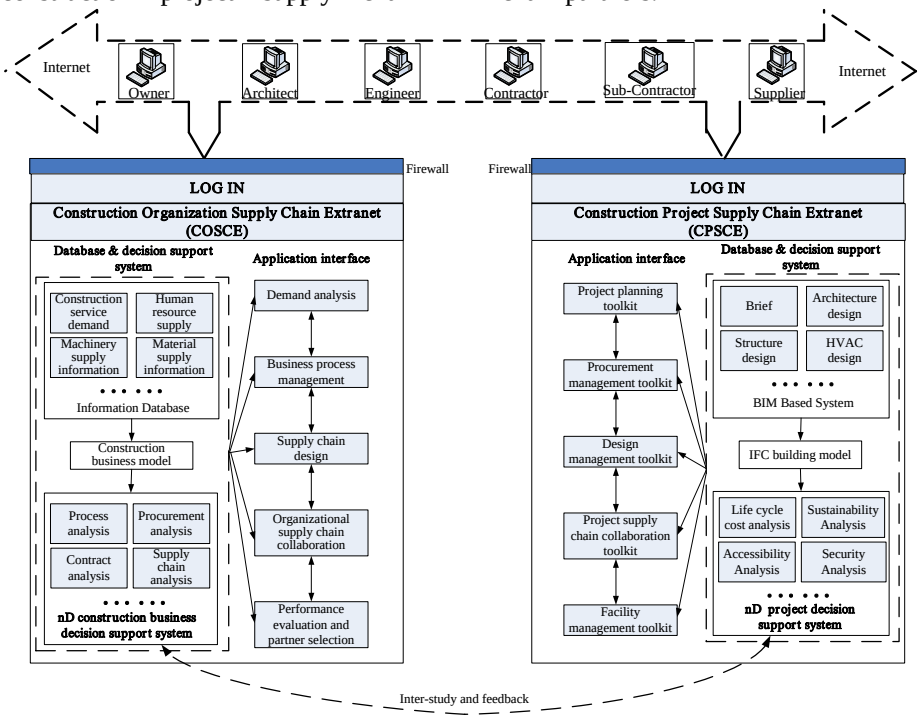

Figure 2 nD modelling enabled construction supply chain information system

Construction organization supply chain extranet consists of four modules: information database, construction business model, nD construction business decision support system and application interface. It starts from the information database, which will initially store the latest business information about projects and construction market. This database provides both the demand information such as the biding/tendering information, project name, scope, investment, start and handover date, equipment requirement, etc, and the supply information such as amount of general consultants, designers, contractors, subcontractors, materials, suppliers and their dominance. The abundant demand and supply information will ease the procurement decision process of construction clients, general contractors as well as other partners across the chain who wants to procure or outsource some products or works. The second module of construction business module is mainly to aggregate and match the supply and demand information for various specific projects and pack up all the information for one specific project into a standard intelligent 'object'. The object will include the information of the project name, location, budget, initial schedule, possible contractors, designers and suppliers, etc. All the standardized information will be link into the module of nD construction business decision support system. Various

interdisciplinary analyses will be completed based on the information. These analyses would include demand analysis, procurement route assessment, process optimization and project supply chain design. The end user can get the project information and business advices from the fourth module of application interface. They also can change some parameters of the project such as initial schedule to do a new round of analysis since some project parameters are usually negotiable.

Similar system structure of project supply chain extranet is designed to provide integrated information for all the partners of a specific ongoing project, which has been partly implemented in the £1.25M construction of a new school building. Users' evaluation results show the concept to be relatively clear and the usability easy (Lee et al., 2005). The whole nD enabled project supply chain extranet also consists of four modules, including BIM based system, IFC building model, nD project decision support system and application interface. Initially, multidisciplinary design information is generated by various design teams using different BIM-based CAD systems, then IFC building model will provide users with an interactive environment to browse an IFC model file and visualize the result of assessment on different IFC model through integrated interface (Fu et al., 2007). Multi-criterion analysis techniques is adopted in the third module of nD project decision support system to provide combined assessment of qualitative criteria (e.g. design criteria and construction regulation) and quantitative criteria (e.g. lifecycle cost and energy efficiency). Integrated stage-oriented information management services is provided through the application module, which provide users a traceable information management route to reuse or reconsider the project information, and make right collaborative decisions to improve supply chain integration.

DISCUSSION AND CONCLUSION

Information makes the difference in the accuracy of supply-chain decisions. The social and technical processes of supply chain information integration can be modelled in ways that improve our understanding of information system development and of supply chain collaboration, and therefore capture some of the "learning", which is generated from the integration effort itself (Pardo and Tayi, 2007). Information integration could facilitate the implementation of lean concepts and techniques in construction by developing information technology methodologies, tools, and systems that support the main lean construction goals and concepts (Soibelman, 2007), but their successful implementation is still hindered by barriers, for the most part non-technical (Nitithamyong and Skibniewski, 2004). Most of the failed endeavours in this area ignore that technology push is not the only critical success factor for effective implementation of a new technology, such as nD modelling in CSC, which are simply involved in many information stakeholders and very much concerned with the integration and exchange of information across the project life cycle. To successfully employ nD modelling in CSC information integration and management, many factors such as technology, process, people, procurement, legal issues, and

knowledge management must be considered equally.

This paper explores the application of nD modelling as an integrator to facilitate the effective information management in construction supply chain, hence support the realisation of the lean construction concepts and goals to reduce unnecessary wait, dispute and waste. It was identified that lack of information integration across the CSC is the main barrier to effective supply chain information management. In the construction industry, information management gets more complicated since there are simply too many information providers/users engage in a project. The lack of integrated standard information model or specification makes the problem worse. nD modelling enabled collaborative construction environment taking IFC as its information specification can provide users integrated construction information and multi-criterion analysis to facilitate effective CSC information management, thus, improve the CSC performance. nD modelling enabled project supply chain extranet and organization supply chain extranet were proposed and described in this paper, which provides a information integrating infrastructure and management platform for both specific project implementation and long term organization cooperation through continual works awarding. Factors including technology, process, people, procurement, legal issues, and knowledge management were suggested to be considered equally to effectively integrate and management information across the CSC using nD modelling, which jointly supports the implementation of lean concepts and techniques to improve the construction productivity and performance.

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