Coordination mechanisms for construction supply chain management in the Internet environment

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Abstract

The construction industry in general is characterized with high fragmentation, low productivity, cost and time overruns, and conflicts compared with other manufacturing industries. Supply chain management as an innovative management mode provides a new solution for resolving these problems from systems perspective. Coordination is the core issue to improve construction performance in construction supply chain (CSC). In this paper, the concepts of CSC and CSC management are defined. Furthermore, the inter-organization problems that effect CSC coordination are identified. Considering the Internet fosters the integration of construction processes and provides an efficient platform for CSC coordination, this paper presents two types of Internet-enabled coordination mechanisms: market mechanism, such as auction and contracting, and coordination flow, including information hub and electronic marketplace, for improving construction performance and to accelerate the innovations in the construction industry.

Keywords: Supply chain coordination; Construction supply chain; Internet; Construction industry

1. Introduction

Recent years have seen a growing globalization of markets and the concentration of companies on their core competencies resulting in increasing supply chain coordination in supply chain management (SCM). No industry is left untouched. The construction industry in general is characterized with high fragmentation, low productivity, cost and time overruns, and conflicts and disputes compared with other manufacturing industries. These characteristics also are major causes of performance-related problems facing the industry [1].

These problems in general are supply chain management problems. This urgently requires coordinating construction supply chain (CSC) to improve construction performance in construction supply chain management (CSCM). The barriers that obstruct coordination and integration of CSC are identified as follows [2]:

- Attitude-related issues: such as narrow minded “win-lose” attitudes and short-term focus, arrogant attitudes, exclusion of the subcontractors and suppliers from the early involvement phases, lack of praise for good performance, and lack of understanding of the subcontractors and suppliers problems.
- Quality of information-related issues: such as poor information quality from general contractor and less transparency coupled with inadequate information exchanges and limited communications.
Financial/cost-related issues: These are related to competitive tendering based on price (with inadequate focus on life-cycle costs and ultimate value), which has developed adversarial relationships among clients, general contractors, subcontractors and suppliers that result in serious problems with regards to payments.

Programming/time-related issues: such as false expectations on part of the general contractor, unrealistic program times, and unrealistic and uncertain lead time of materials and equipments.

The Internet fosters the integration of construction business processes across the CSC by facilitating the information flows necessary for coordinating construction business activities [3]. In the traditional CSC, for reasons of information asymmetry and uncertain factors intervened by people, the construction processes frequently cannot be controlled well, easily resulting in inefficient management and poor project performance. However, the rise of the Internet has thoroughly changed the traditional market’s business rules and has brought a revolution in transaction practices. The use of Internet-based technology initiatives makes the exchange of information simple, fast, accessible, and accurate, and brings a new, pivotal opportunity and force to development of the construction industry [4]. The omnipresent Internet provides a rich environment as well as an effective tool for CSC coordination.

This paper presents the concepts of CSC and CSCM and analyzes the inter-organization problems in CSC business activities. An Internet-based framework for CSC coordination is described, which emphasizes on two Internet-enabled coordination mechanisms, i.e. market mechanism and coordination flow. Another purpose of this paper is to suggest a research agenda in CSCM for improving construction performance.

2. CSC and CSCM

2.1. CSC

Construction is a multi-organization process, which involves client/owner, designer, contractor, supplier, consultant, etc. It also is a multi-stage process, which includes conceptual, design, construction, maintenance, replacement, and decommission. From this perspective, CSC can be defined as flowing:

CSC consists of all the construction business processes, from the demands by the client, conceptual, design and construction to maintenance, replacement and eventual decommission of building, and organizations, which are involved in the construction process, such as client/owner, designer, general contractor (GC), subcontractor, supplier, consultant, etc. CSC is not a chain of construction businesses with business-to-business relationships but a network of multiple organizations and relationships, which includes the flow of information the flow of materials, services or products, and the flow funds between client, designer, contractor and supplier, as shown in Fig. 1.

2.2. CSCM

SCM is a concept that originated and flourished in the manufacturing industry. It was developed from innovation such as just-in time (JIT), as a part of the Toyota Production System, and the field of quality control and total quality management (TQM). Now, it has become a buzzword in the field of operation management. Although a number of scholars have provided contributions to understanding of SCM, there is a lack of agreement among educators, consultants and practitioners on the precise definition of SCM. SCM in general can be defined as an integrative philosophy to manage the total flows of the entire business process. Systemic, client-oriented, win-win and cooperative manage-
Construction strategy is the core philosophy of SCM. Based on the understanding of SCM, CSCM can be defined as:

Construction supply chain management is the integration of key construction business processes, from the demands of client, design to construction, and key members of construction supply chain, including client/owner, designer, contractor, subcontractor and supplier. CSCM focuses on how firms utilize their suppliers’ processes, technology and capability to enhance competitive advantage. It is a management philosophy that extends traditional intra-enterprise activities by bringing trading partners together with the common goal of optimization and efficiency. CSCM emphasizes on long-term win-win, cooperative relationships between stakeholders in systemic perspective. Its ultimate goal is to improve construction performance and add client value at less cost.

We identify eight key construction business processes that are implemented within the CSC cutting across organizational boundaries. The eight key construction business processes are project management, client service management, supplier relationship management, demand management, order fulfillment, construction flow management, environment management and research and development. Fig. 2 presents a schematic view of CSCM.

3. Inter-organization problems in CSC

Over the last decades, although there have been some changes in construction industry with the development of the technology and culture, much research projects suggest that construction is still ineffective and many problems in CSC can be identified. Analysis has shown that a major of these problems are supply chain problems, which originate at the interfaces of different organization or stages involved in the CSC [5], as shown in Fig. 3.

4. Internet-enabled coordination mechanism for CSCM

4.1. Impacts of the Internet on CSCM

Construction is one of the most information-dependent industries amongst others, with its diversity of forms of information, which include detailed drawings and photos, cost analysis sheets, budget reports, risk analyzes charts, contract documents, planning schedules. Construction information can be group into three categories: general information, organization-specific information, and project-specific information. Two-thirds of the inter-organization problems in CSC were caused inefficient means of communication of project information [1]. Wasting of time and cost in construction projects can be traced back to poor co-ordination caused by inadequate information-insufficient, inappropriate, inaccurate, inconsistent, late or a combination of them all. Timely and accurate information is important for all project participants as it forms the basis on which decisions are made and physical progress is achieved. Thus, communication is always the key factor leading to the success or failure of a construction project. The use of the Internet as the communication platform can help information transfer more effectively during the construction process. Besides its speedy transmission, open, easy to use, it also saves money in communication compared to the traditional information handling methods [6], e.g. electronic data interchange (EDI).

The Internet is causing a paradigm shift in the way CSCM is being performed. It plays an important role in CSCM by providing all participants with visibility and decision support via advanced decision support systems. Internet-enabled CSCM facilitates decision-making, increasing flexibility, responsiveness and speed in operations. This, in turn, enables the project manager to create value for client.

Generally speaking, the Internet results the transformation of old organizations and the creation of new network based enterprises, provides an open collaboration environment and platform and changes the construction business structure and management methods [7].

4.2. Internet-enabled coordination mechanism

The Internet-enabled coordination mechanisms in general can be grouped into: market mechanisms and coordination flows [3]. A market mechanism is used to conduct a business transaction, to purchase something at a given
price. Frequently, market mechanisms are used to foster price competition among potential suppliers. Therefore, market transactions are often one-time transactions because a different supplier can be selected for each transaction. We identified five Internet-enabled market mechanisms: auctions, contracting, purchasing groups, electronic purchasing aids and agents. In contrast with market mechanisms, in coordination flows, purchasing decision has been made and information is shared to coordinate the flow of products. Coordination flows are implemented when managers do not need to search the market and evaluate alternatives for each transaction. Coordination flows usually have a greater impact on the organization that market transactions and, therefore, are suitable for more stable relationships. Coordination flows can be classified into: information hub and electronic marketplaces. Fig. 4 shows the basic components of Internet-enabled CSC coordination mechanisms.

4.2.1. Market mechanisms
(1) Auctions. An auction is a market mechanism in which the buyers and seller agree on the item to be auctioned, and on payment and delivery conditions. Each auction can be regarded as a one-time transaction because the bidding process can output a different winner each time.

There are three participants in an auction: the seller, the buyer, and auctioneer. Usually, no relationship-specific assets between buyer and seller are needed in an on-line auction on the Internet. Additionally, sellers and bidders require little assets that are specific to the relationship with the auctioneer. Online auctions are a good example of how the Internet changed the business environment.
Reverse auctions are popular in business-to-business (B2B). In reverse auction, firms sell a contract for the provision of an item and suppliers bid for the contract. A reverse auction fosters price competition among potential suppliers promising lower unit cost to the buyer.

Since auctions are one-time transactions, the transaction risk associated with the closeness of the relationship is low. The operational performance risk for auctions can be high and might be the highest of all mechanisms reviewed in this paper.

(2) Contracting. Optimal CSC performance requires the execution of a precise set of actions. However, those actions are not always in the best interest of the members in the CSC, which often results in poor performance. Optimal performance can be achieved if the firms coordinate by contracting.

Contracting has been used as a means to coordinating buyers and suppliers in the supply chain to achieve higher system efficiency. There are two types contracting: classical and relational contracting. The identities and personal attributes of parties are irrelevant in classical contracting, which do not attach significance to coordination and fall short in considering aspects such as needs for continuing relationships, collaborative and cooperative management or risks and uncertainties. In contrast, in relational contracting, the identities and personal attributes of parties are crucial and written documentation is treated as a record of what has been agreed, which can promote the coordination between the parties in CSC. Furthermore, contractual completeness level has a great impact on CSC coordination. Unfortunately, the drafting of complete contracts could only be possible for very simple procurement exercises. Under most situations, construction contracts are incomplete in nature. Fig. 5 depicts a matrix of coordinating potentialities in different levels of relational contracting and contractual completeness [8].

(3) Purchasing groups. The buyers in purchasing groups can agree on pooling their individual purchasing volumes and let the group management negotiate on their behalf. However, buyers need to accept the rules of the purchasing group. Additionally, the members have to standardize their purchasing needs and batch their requirements. Standardizing and batching requirements might cause disruptions to some organizations; however, many have already done this to leverage their purchasing volume internally.

In purchasing groups, complexity of product description needs to be medium to low. No specific assets are needed for joining a purchasing group. Transaction risk is low because using a purchasing group is similar to a one-time transaction and no barrier restricts a firm’s management from purchasing independently from the group.

Since the group management may decide to change supplier without notice, operational performance risk is as high as conducting a one-time transaction in purchasing groups. Additionally, because high frequency of purchase indicates that a closer relationship with some suppliers is needed, low to medium frequency is appropriate for using a purchasing group.

(4) Electronic purchasing aids. Electronic purchasing aids are some kinds of software, such as price search engines, recommendation agents and comparison matrices, that help buyers to find the right product at the best price available. Price search engines are extensively used in business-to-consumer e-commerce for products such as books, music and computer components. Using price search engine can find the lowest price of products that fit with the input description. Recommendation agents use self-reported information of the user to recommend the product that fits the buyer’s needs. Comparison matrices are used to compare the product features side-by-side on a single page.

(5) Agents. An agent in computer field usually is a software entity, which is characterized with environment awareness, ongoing execution, autonomy, adaptiveness, intelligence, mobility, anthropomorphism and reproduces. Agents can monitor and retrieve useful information, and do transactions on behalf of their owners or analyze data in the global markets. It can also try to find the best deal for the customer with less cost, quicker response, and less user effort, make rational decisions for humans, and negotiate the price of the trade with peer agents strategically, and manage the supply chain network of a company at a low cost [9].

Agents are semi-autonomous pieces of software that are constantly searching for business opportunities based on a set of rules. They can be used to automate time-consuming stages of the purchasing process reducing the transaction cost for buyers and sellers. For example, buying agents can automatically collect information on vendors and products that may fit the need of the company evaluate the various offerings, make a decision on which merchants

<table>
<thead>
<tr>
<th>Contractual completeness level</th>
<th>High</th>
<th>Lesser conflicts and claims; lower transaction costs; disputes/claims could be settled by arbitration; enhanced harmony; improved product quality; and overall best value in win-win atmosphere</th>
</tr>
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<tbody>
<tr>
<td>Relational contracting level</td>
<td>High</td>
<td>Higher trust to enhance contractual relationships; conflicts and contractual non-commitments settled through local adjustments and/or renegotiations; disputes/claims could be settled by mediation</td>
</tr>
<tr>
<td>Low</td>
<td>Higher potentials for conflicts, claims and disputes; higher transaction costs; compensation/penalties are normally decided by the law and litigation</td>
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<tr>
<td>Low</td>
<td>Lesser conflicts and claims; lower transaction costs; disputes/claims could be settled by mediation</td>
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Fig. 5. Coordinating potentiality in different levels of relational contracting and contractual completeness.
and products to investigate, negotiate the terms of transactions with these merchants, and finally place orders and make automated payments. An agent-based framework for CSC coordination is shown as Fig. 6 [10].

In this framework, the domain agents include both ‘service’ agents i.e. coordinator agent, monitor agent, and name server agent and ‘specialty’ agents i.e. owner agent, design agent, GC (General Contractor) agent, subcontractor agents, and supplier agents. All agents communicate and cooperate through the Internet.

The specialty agents are designed to delegate corresponding behaviors of CSC participants. The GC agent stands for GC to perform its responsibilities including cost control, schedule, quality, safety, and environment performance of the project through coordination with subcontractors, suppliers, owner, and designers. The subcontractor agents simulate the decision-making process of subcontractors to negotiate with GC and their suppliers. The owner agent tracks the real schedule, cost, quality of the project and duly send the information of design changes (new demands) to the designer agents and the GC agent. The designer agents will respond to the demands and send information and design change drawings to the owner and the GC. The GC agent re-schedules the project, makes new decisions, and sends the information to subcontractor agents, supplier agents and owner agent. In the framework, all coordination processes are based on multi-attribute negotiation (“M-Negotiation” as shown in Fig. 5 between specialty agents. According to Andreas [11] agent-based automated negotiation provides an effective mechanism to coordinate the decision-making activities in supply chain.

All specialty agents advertise their abilities, knowledge, and preferences in the acquaintance database maintained by of the coordinator agent, and their addresses in the address book maintained by the name server agent. The specialty agents use the coordinator agent to identify agents with the required abilities, knowledge, and preferences. They also use the name server agent to determine the addresses of the identified agents.

The coordinator agent has a mailbox and message handler for receiving and responding to queries from agents about the abilities and preferences of other agents, and an acquaintance database for storing the abilities and preferences of the agents. It functions by periodically querying all the agents in the society about their abilities and preferences, and storing the returned information in its acquaintance database. The monitor agent is used to view, analyse societies of agents. It functions by querying other agents about its states and processes, and then collating and interpreting the replies to create an up-to-date model of the agents’ collective behaviour. This model can be viewed from different perspectives through visualisation tools. The name server agent provides a look-up service for agents’ addresses and has a mailbox and message handler, the component needed for receiving and responding to agents’ requests for the addresses of other agents [9].

4.2.2. Coordination flow

(1) Information hub (IH). IH is an information system. The members on supply chain use it to share business data. It presents a single information communication point enabling data sharing and facilitating coordination in supply chain. Fig. 7 shows the different communication transferring efficiency (CFE) between using IH and not using IH in CSC. However, the following four challenges that exist for those wanting to use IH should be overcome:

- Information asymmetries can lead to exploitation.
- Sharing information with a supplier that is also a competitor can jeopardize confidentiality.
- Many managers are not ready to share information with other supply chain members.
- Management has not achieved internal integration of information systems and business processes in many firms.
Electronic marketplaces (EMs). A marketplace is a governance mechanism. An EM, also called Internet-driven or Internet-based EM [12] is an information system driven by Internet that allows buyers and sellers to exchange information about product offerings and prices bid and asked. EM also is an Internet-based solution that links businesses interested in buying and selling related goods or services from one another [13]. The main objective of an EM is to facilitate trade: buying and selling. Furthermore, EMs can create value by aggregation and matching mechanism. EMs bring together a large number of buyers and sellers under one virtual roof through using the aggregation mechanism. They reduce transaction costs by providing one-stop shopping. The aggregation mechanism is static in nature because prices are pre-negotiated. The matching mechanism that can work in the form of auctions brings buyers and sellers together to negotiate prices on a dynamic and real-time basis. Matching is a more powerful business model than aggregation. However, the matching mechanism is far more complex as well [14].

EM in general can be grouped into four types: vertical and horizontal marketplaces; a more stakeholder-focused way divides markets into buy-side, sell-side, and neutral; an economic and price-focused classification divides markets into markets with fixed or variable pricing mechanism (fix or variable); and open and closed markets [12].

5. Conclusion

The world of business is being changed to an e-economy by new forces global competition, increased information availability, changing relationships, rapid innovations, and increasingly complex products. No industry is left untouched. Coordination has become the key issue in SCM and enterprise strategy, especially in CSCM to improve construction performance.

Construction industry has been characterized with fragmentation and poor coordination among project participants in long time, and there are many inter-organization problems, such as inaccurate information transfer and wrong deliveries in CSC, which result in the dissatisfied performance. Internet provides a rich environment and platform for the coordination in CSC. It has the potential to enable the integration of construction business processes across the CSC.

Of course, CSC coordination is a systemic construction business strategy which involving all the stakeholders in construction process. It requires the partners set up common business goal. Thus, managers need to choose suitable coordination mechanisms that can promote the effective coordination in CSC. Market mechanism, which incorporates auctions, contracting, purchasing groups, electronic purchasing aids and electronic agents, and coordination flow including IH and Ems in general are two foundational Internet-enabled coordination mechanisms.

CSC coordination is a valuable research opportunity for scholars. This paper only presents a general framework for CSC coordination. There is a lot of significant work, such as how to measure the coordination performance, how to calculate the coordination cost, etc, that waiting for us to do for effectively implementing this framework in practice.

Acknowledgements

The work described in this paper was funded by the Tenth Five-year Plan Key S&T Project of China (2004BA209B03) and the Research Grants Council of the Hong Kong Special Administrative Region, China (PolyU 5114/03E). This research was also supported by the National Center for Technology, Policy and Management, Harbin Institute of Technology, China.

References