A Literature Review on Information and Communication Technology (ICT) System to Support Integration Construction Supply Chain Management

Rafikullah Deraman  
(University Malaya, Malaysia, rafikullah73@hotmail.com)

Hafez Salleh  
(University Malaya, Malaysia, hafez@um.edu.my)

Abstract
Previous studies have shown that in today’s construction environment, the use of an appropriate ICT system has the potential to integrate and collaborate among supply chain’s participants successfully. However certain ICT systems may not be capable to integrate with the various distinct participants and support the entire supply chain participants to work collaboratively. This paper aims to review the previous development of ICT systems that have enabled integration and collaboration in construction supply chain. The study is based on the analysis of numerous publications on supply chain management and construction supply chain management from year 2000-2009. The findings will provide further information about limitation and barriers of the system and will give directions for further research.

Keywords
Construction Supply Chain Management, ICT, Integration.

1. Introduction
Nowadays construction industry is moving towards globalisation and innovation of new information. ICT has been recognised as a driver for many construction businesses and operational processes. According to Bennet (2001) information technology can support for better projects, utilization of resources, and profits. Moreover the system could be useful for managers in construction firms to assist in making better decisions and enhancing communication. Previous studies demonstrated that in today’s construction environment the use of an appropriate ICT system has the potential to integrate and collaborate among supply chains participants successfully (Gajendran, Brewer & Chen2005; Gajendran, Brewer, & Chen, 2003; Sun & Aouad, 2000). In line with this, for example, Malaysian construction industry has developed CIMP initiative to promote the development of ICT in construction industry. By streamlining operations and processes using ICT, coupled with integration of all industry players along the supply chain, the construction industry would eventually become effective and efficient.

As stated by Earl (1989), ICT must have the potential to be a strategic weapon on the following ways which are to gain competitive advantages, to improve productivity and performance, to enable new ways of managing and organising and to develop new businesses. Therefore in order to be successful, he suggested that the utilization of ICT in strategic and managerial activities is more important than in operational context.
1.1 Definitions of Construction Supply Chain Management

There are numerous definitions given to construction supply chain management in different perspectives. One of the most significant reference is that a network. For instance, Love, Irani, & Edwards (2004) define it as the network of resources and activities that provide added value to final client/customer, in functions of project design, contract management, provision of materials and services, production and delivery of raw material and management of the installations/resources. The same goes with Muya, Price, & Thorpe’s (1999) definition, which interpret it as a network of multiple organisations and relationships, which includes the flow of information, flow of materials, services or products; and flow of funds between owner, designer, general contractors and suppliers.

On the other hand, there are researchers refer to it as process integration. Li, Li, Wu, & Wang (2007) define it as the integration of construction business network from original suppliers to end users that provide materials, products, services, hence add value for construction clients and other stakeholders. This is also supported by Fisher & Morledge (2002), who refer it as coordination of inter-organisations decision making, integration of key construction business processes and key members involved in construction supply chain management. But some researchers claim it as an operation process and the people involved. For example Saad, Jones, & James (2002) define the construction supply chain management as a construction processes from the initial demands by the client/owner, through design and construction, to maintenance, replacement and eventual demolition projects. It is also involved organisations such as client/owner, designer, general contractor, subcontractor, and suppliers.

From the above listed definitions, it can be summarised that the construction supply chain management can be concluded as process integration for all activities involved in different stages and peoples that provide added values along the supply chain.

1.2 Critical Elements in Construction Supply Chain Management

Construction supply chain management deals with the management of materials, information and financial flows in a network consisting of general contractors, subcontractors, suppliers and distributors (Titus & Brochner, 2004). According to Dainty, Briscoe, & Millet (2001), various participants involved in a construction project, makes project more extremely complex, mainly in a large project. As a result, for an effective supply chain management, coordination and integration of the three resources flow (materials, information, financial) and peoples (owner, designers, contractors, sub-contractors, and suppliers) are very crucial in order to complete a project within a specified time, and required cost and quality. These facts can be illustrated through the Figure 1 below.

![Figure 1: Conceptual view of the construction project supply chain (O’Brien, London, & Vrijhoef, 2002)](image-url)
2. Importance of Managing Supply Chain Management Using ICT

Many believe that the construction industry is fragmented by nature (G. Brewer, 2004; Chiang, 2008; CIDB, 2009; Economy, 2009). In a construction project life cycles, for instance, planning, design, procurement, construction and maintenance are separated by disciplines and executed in different phases, with an adversary environment and small interaction between phases and disciplines. In addition, there are many players involved in the industry. Taking Malaysian construction industry as example, there are 63,977 registered contractors from various categories of Grade, which includes 164 foreign contractors up to December 2008. Furthermore, there are 59,304 engineers, 3,252 architects and 2,081 quantity surveyors registered until August 2009 with professional bodies involving 934,590 construction workers in various categories (CIDB, 2009). With these huge numbers of different parties involved, on top of various phases, disciplines, and dynamic organizational structure, it increases difficulties in communication, integration and collaboration amongst project participants in the industry. Therefore, to overcome this problem, a few initiatives have been attempted with one of those being to integrate the fragmented process using ICT system.

According to Gajendran, Brewer & Chen (2003), the industry has lack of efforts to improve practices and productivity, and as a result, the industry continues to be fragmented. Cox & Ireland (2002) found that among the solutions intended to address the issue is by increasing the effectiveness of project delivery using ICT. However, studies by Bulmer & Brewer (2000) show that the full potential of ICT to integrate operation along the supply chains is not widely spread. Until now, many ICT systems have been developed to support the needs of supply chains in construction. Nevertheless, there is a great challenge to identify which ICT package is capable of addressing such issues in order to deliver various tasks within context (Egan, 1998). In addition, Yang, Wu, & Tsai (2007) revealed that certain company which introduced the ICT system to manage supply chains in construction were unsuccessful.

This paper aims to review the previous development of the ICT system that enables integration and collaboration in the construction supply chain and barriers during the implementation of the system.

3. The Recent Use of ICT System in Construction Supply Chain Management

The roles of the ICT system’s solution in supply chain are to support the business process which involved transaction processing, coordination, collaboration among partners and eventually as tools for support in decision making. Therefore, in this review, the ICT system which is being used in managing supply chain management in construction may not include the systems which applied for functional oriented (isolated application) but gives priorities on the system that enables it to integrate with various disciplines and functions on the entire project life-cycles. From the analysis of literature reviewed, the ICT systems recently being used in construction are as followings. The barriers of each system’s implementation are shown in Table 1.

3.1 Enterprise Resource Planning (ERP) System

The purpose of using ERP is to integrate all departments and functional information flows across a company onto a single computer system that can provide all the enterprise needs. Latest development of ERP has extended features which are known as extended ERP software that incorporate external suppliers and customers. According to Gattiker, Huang, & Schwarz (2006) research findings, it proves that ERP promises benefits ranging from increased efficiency to improved quality, productivity and profitability. A studies from Voordijk, Leuven, & Laan (2003) found that, a construction firms having more than 1,000 employees in Netherlands have implemented an ERP system.
3.2 Radio Frequency Identification (FRID) System.

Radio frequency identification system allows the information flow in real time from various sources. By using this technology, it can provide automatic data captures and avoiding manual data entry in the information systems. In the retail industry, for example, RFID technology has been successfully applied where the RFID tags are used to identify and track products along the retail supply chain (Konstantinos Domdouzisa, 2007). This technology has a potential to be used for applications in the construction industry.

3.3 E-Business

According to Elliman & Orange (2000), e-business encompasses business activity that embraces relationships with clients, contractors, suppliers, installers, designers and other partners. In addition to that, it includes service infrastructure, multiparty and multidisciplinary (business-to-business) transactions as well.

Lee & Wong (2001) argued that the benefits of embracing ICT in developing e-business solutions to support supply chain activities are clearly apparent, for example to reduce transaction costs and improve communications. Furthermore, as many researchers agree, in an e-business setting, the supply chain parties can establish a relationship with a number of suppliers for managing its supply chain (B.A.Wagner, Fillis, & Johansson, 2003; C.W.Kong & P.E.D.Love, 2001). Hence, members in the supply chain can take full advantage of the e-business process that can facilitate work along the project cycle. The types of e-business can be used to improve the performance of members in the supply chain in terms of quality, time and cost such as business-to-business (B2B), business-to-administrator (B2A), consumer-to-administrator (C2A) and others. Among of the e-business system that has been used widely is e-procurement and e-tendering.

3.3.1 E-Procurement

Dolmetsch, Fleisch, & Osterle (2000) refer to e-procurement as management of supply chains in the procurement of indirect goods that is based on internet information systems and also e-market. Numerous research emphasize the potential benefit of using e-procurement in supply chain and among them was conducted by Puschmann & Alt (2005). E-procurement enables companies to decentralize operational procurement processes and centralize strategic procurement processes. As a consequence, the e-procurement system makes supply chains visible.

3.3.2 E-Tendering

Electronic tendering integrates every process and component of the entire construction tendering supply chains onto an electronic medium. According to Booty (2004), e-tendering is reduces bid costs and bureaucracy and at the same time offers opportunities for greater clarification of information.

The National e-Procurement Project highlights the approximate savings of £8 million per annum within local authorities by using e-tendering (Robert, 2004). Besides, Booty (2004) also shows that the saving of an organisation at £1500 per tender in paper and administration costs, time reduction and overall spending against the budget was reduced by 20%. Therefore, e-tendering has been assumed to be more cost effective than the traditional method, in addition to time-saving offered by the process.

3.4 Web Portal

Manthou (2004) argued that companies increasingly take advantages of the Internet and information technology to create a virtual e-chain to communicate and collaborate with supply chain participants. Therefore, the web services model has emerged as a promising approach to connect and aggregate distributed web applications and information sources (Cheng & Law, 2008). Through web portal
system, it provides the supply chain members a single point of access to information and applications regardless of location or storage mechanism.

One example of web portal usage was developed by Cheng & Law (2008) which is known as SC Collaborator System. The researchers have demonstrated that web portal supports supply chain collaboration among project participants and achieves interoperability among organisation in the networks. The system also supports communication channel among participants.

### 3.5 Web-Based Document Management System

By using the web-based document management system it can provide a centralised, accessible and reliable means of transmitting and storing information along the supply chain life cycles. Nitithamayong & Skibniewski (2004) mentioned by modifying documents to a series of total web-based system, it has shown to have tremendous potential for adding value not only to the internal performance of an organisation but also to the entire supply chain, which can be appreciated on studies by Forcada, Casals, Roca, & Gangoles (2007) which can be found on [www.constructiondms.up.ec](http://www.constructiondms.up.ec).

### 3.6 Mobile Wireless Technology – On Construction Logistics

In the construction supply chain, logistics is a vital component. Therefore, managing logistics in the construction industry is very critical. Effective logistics system can ensure delivery of the right products and services to the right players at the right time at minimum cost. Bassi R. & Parand F. (2002) argued that by having advancement of ICT and wireless technologies in the global market, most construction companies are driven to deploy supply chain management strategies to seek better output. As a result, there are potential usages of these emerging wireless technologies to represent the ICT application to construction logistics management.

### 3.7 Virtual Reality (VR)

VR is being used by professional project teams and supply chains to visualize and manage engineering and design data. Studies by Whyte (2003) found that major business drives for the usage of VR are on :-

- Simulating dynamic operation
- Coordination of detail design
- Scheduling construction
- Supported interactions with supply chain members
- Demonstrating technical competence by visualization of previous works and design review.
<table>
<thead>
<tr>
<th>Types of IT/IS</th>
<th>Researcher</th>
<th>Issues Derived To Development</th>
<th>Barriers During Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ERP System</strong></td>
<td>Voordijijk, Leuven, &amp; Laan, (2003)</td>
<td>-Non integrated information systems in various functions in organization</td>
<td>-Require high intra-organizational IT maturity</td>
</tr>
<tr>
<td>Metacom6 (ERP system)</td>
<td></td>
<td></td>
<td>-Temporary &amp; multiple nature of organisational structure (result on cost strategy)</td>
</tr>
<tr>
<td>Ban ERP system (commercial package)</td>
<td></td>
<td></td>
<td>-Stability networks and centralised coordination.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-SAP or other ERP systems are not project oriented and enables to support project management functions</td>
<td>-Knowledge capabilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Level of automation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Interaction between human and system on decision making.</td>
</tr>
<tr>
<td><strong>RFID Technology / Wireless Technology</strong></td>
<td>Chiang (2008)</td>
<td>Communication and transferring of information between supply chains participants effectively.</td>
<td>Not reported</td>
</tr>
<tr>
<td>Automatic digitalized rebar design system (GS BAS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource Management in Civil Construction Using RFID Technologies</td>
<td>Changyoon Kim, Yeonjong Ju, Kim, &amp; Kim (2009)</td>
<td>Managing resources effectively in scattered locations and in a real-time manner</td>
<td>IT infrastructure (internet connectivity)</td>
</tr>
<tr>
<td>Mobile Construction Supply Management (using PDA and Bar Codes)</td>
<td>Angeles (2005)</td>
<td>Enables process freedom and real-time visibility</td>
<td>-IT infrastructure (false reading and system capabilities)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E-Business</strong></td>
<td>Tserng &amp; Dzeng (2005)</td>
<td>-Managing the information between office and site</td>
<td>-Appropriate information sharing needed by all players involved in construction site</td>
</tr>
<tr>
<td>E-Commerce (system for construction material procurement, COME)</td>
<td>C.W.Kong &amp; P.E.D.Love (2001)</td>
<td>-Managing information in traditional material procurement process</td>
<td>-Hardware capabilities</td>
</tr>
<tr>
<td>E-Procurement (electronic purchasing agent (EPA) for material procurement)</td>
<td>Hadikusomo, Petchpong, &amp; Charoenngam (2003)</td>
<td>Improper methods and substandard purchasing procurement practices</td>
<td>-Cost of investment onto system (suppliers unable to cover additional costs for systems)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-User friendly interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project/Service</td>
<td>Authors/Publications/Ref. (Year)</td>
<td>Problems/Benefits</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| E-Tendering National E-Tendering Imperative (NeTI), Malaysia                  | CIDB, Malaysia                                                                                 | -Problem of national construction tenders, contractors and tender authorities administrators on traditional tendering system.  
-Reduce people-based error in existing tendering system process.               |
| eTender System Queensland Department of Public Works/Services                  | Kajewski (2001)                                                                                | -Traditional paper-based tender processes  
-To achieve efficient and effective business process for all parties involved   |
| WEB PORTAL/ WEB-BASED                                                          |                                                                                               | -System security  
-Network issue  
-People issue  
-Legal and contractual issues |
| Online Remote Construction Management System (ORCM) (Queensland Department of Main Roads) | Thorpe (2003)                                                                                 | -Project information not collected in one central area.  
-Each party has it own project management system but experiences difficulty in communicating with each other.  
-Traditional communication process the project easy to lost information.      |
| Malaysian Construction Industry Portal (www.ciportal.com.cccmy)               | CIDB and E-Construct Service                                                                    | -One stop centre for knowledge sharing for industry players  
-Improve collaboration and discussion amongst players                           |
-Needs a platform for individual and organization to collaborate and share information visibly.  
-System inter-operability in construction organization.  
-System facilitates integration, collaboration, accessible, scalable and established relationship among participants. |
|                                                                              |                                                                                               | -Security and access control capability for user                                   |
| Web Databases for Document Management System (Prototype DMS) | Forcada et al. (2007) | -Integration and inter-operability of document management system  
-Adding value for information exchange through life cycle project | -Lack of process of standardized document  
-Redesign process to facilitate data exchange  
-Immaturity of IT knowledge and training |
| --- | --- | --- | --- |
| E-logistics | Tiago, Jose, & Maria Sameir (2007) | -Exchange of information  
-Improve communication | Not reported |
| Intelligent Wireless Web (IWW Service logistic supply chain) | Omar & Ballal (2009) | -Poor logistics services  
-Changes in business strategy | -Reluctant to change work culture (technological conservatism in construction organizations)  
-Knowledgeable worker & training  
-Top management commitment  
-Government initiative |
| VIRTUAL REALITIES  
Virtual Prototype For Design and Construction | H. Li et al. (2008) | -Lack of capability to capture and reuse knowledge generated in design and construction  
-Lack of ability to ‘try before build’  
-Design and planning of information incomplete and contain mistake | -Adoption of VR amongst contractor  
-Misunderstanding of VR and argued VR technology are only for animation tools. |
4. Discussion

The general discussion concluded that the previous developments of ICT systems in construction supply chain management are primarily developed intentionally for integration and collaboration of all supply chain participants. This integration and collaboration could be on the following dimensions:

- Flows of resources
- Processes and activities
- Technologies and systems
- Structure and organisations.

For example, RFID Technology in construction supply chain management can integrate the flow of resources in scattered location and in real-time visibility. This technology also facilitates of communication and transferring information between designer, manufacturer, logistics providers and end-users. By using the system, the organisation can reduce production loss, construction duration, unnecessary relocation and movement, including material inventory (Chiang, 2008). On the other hand, application of e-business, the manufacturers of materials can readily access contractors and even clients (Elliman & Orange, 2000). Therefore as a consequence, it improves accessibility and connectivity among players in the construction supply chain.

The level of ICT system used in the construction supply chain management can be divided into two categories which are at the stage of inter-organisational system (refer to FRID Technology, e-business and web-based system) and functional management information system including enterprise system (refer to ERP system and VR). Both of the ICT systems developed in this stage are capable of managerial and operational activities which are the core of the activities in construction supply chain management.

However, such ICT systems need to be improved and should be able to overcome the barriers faced during implementation. From the analysis of literature review, the researcher found that there are several barriers of the system which can be categorized into IT infrastructure, management process, people issues, work environment and capital investment. These identified barriers should be addressed to ensure efficiency and effectiveness of the system to end-users is obtained.

5. Conclusion and Future Work

ICT systems have been perceived as a driver for many processes in construction particularly on supporting construction supply chains. This paper discussed about literature review on ICT systems to support the integrated construction supply chain management which focus on the current state of the ICT system in construction supply chain management.

As a result of the literature reviewed, we can see that ICT systems has a tremendous development from academia and practitioners who are interested in achieving improvement in the construction supply chain, during the implementation there are several obstacles in the system which need to be resolved before it can be fully utilized.

Despite the acknowledgement of the existence of the ICT system in the construction supply chain and identification of the limitation and barriers of such system, there is still needs for further empirical studies to see how the system integration can help improve project performance. This future work is very important in order to justify that the recent ICT system is truly beneficial and enable to enhance efficiency and effectiveness of project performance.
References


