An e-commerce system for construction material procurement

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Abstract: This paper presents an e-commerce system that is being used for construction material procurement. The paper identifies the limitations relating to information retrieving, recording and sharing in the traditional material procurement process. E-commerce applications that can improve the efficiency and effectiveness of the material procurement process in construction are then identified and described. Finally, the design and implementation of an e-commerce system for construction material procurement for trading construction materials in China is presented and discussed.

Key words: e-commerce, web, electronic catalog, bidding system, material procurement.

Introduction

The value of materials that are required to be purchased and used for any construction contract make up a large proportion of a project’s total contract sum. Typically materials account for 40–45% of the cost of all construction work (Andrew et al., 1998). Maintaining an efficient and effective material procurement system as well as procuring materials at the right price, quality and time are essential for contractors to remain competitive in today’s environment.

The emergence of internet technology has enabled information to be shared and exchanged through a common global network in an efficient and relatively low cost environment. Many companies are now conducting their business using a web-based e-commerce system. In fact, it has been suggested that e-commerce can provide a win-win situation for both suppliers and buyers, as e-commerce can provide an expanded marketplace within which buyers and suppliers can communicate directly with each other (Cheng et al., 2001). Online construction trading markets are not limited by the physical limitations of store spaces and can carry a much larger variety of products, which can range in style and size. At the same time, buyers can search through a wide range of products with low transaction costs at any time convenient to them. More importantly, direct communication between buyers and suppliers will eliminate the multiple middlemen that often exist between the two. Consequently, products can be purchased at lower prices and delivered quicker to the purchaser (Bakos, 1991).

This paper presents an e-commerce system that is being used for construction material procurement. The paper identifies some problems relating to information retrieval, recording and sharing in the traditional material procurement process. E-commerce applications that can improve the efficiency and effectiveness of the material procurement process in construction are then identified and described. Finally, the design and implementation of an e-commerce system for trading construction materials in China is presented and discussed.

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The traditional construction material procurement process

In a traditional contractual environment, the contractors’ procurement of materials commences at the tender stage when the design of the project is finished. The main concerns of material procurement are the provision of the right materials at the right time, in the right place and to an agreed budget such that progress on site is uninterrupted (Canter, 1993).

Figure 1 depicts the activities and their sequence in a typical material procurement process. After receiving the tender documents, contractors invariably start estimating and send out enquires to their selected suppliers. When quotes are received from suppliers, contractors will select the best quotes and complete the tender documents. If contract is awarded in the later stage, the purchasing function will reconfirm the validity of the supplier’s original quote or negotiate a revised price for materials. Once a suitable supplier has been selected, the next step in the purchasing process is to raise and issue a purchase order to the supplier, which will constitute a legal contract when the supplier accepts or acknowledges receipt of the order. In effect the order becomes a written commitment to accept and pay for goods under an agreed set of terms and conditions. Orders will be tracked until materials are received and checked on site.

Information flow in the material procurement process

From the requisition of quotations at the tender stage to the actual receipt of materials and signing invoices, different paper-based documents are produced, copied, passed and referenced by different groups of participants in the traditional material procurement process. During the tender stage the

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**Figure 1** Typical material purchasing sequence
estimating teams of contractors obtain construction materials information from physical catalogues of suppliers. Based on these catalogues they compare and select suppliers and send enquiries to and receive quotations from the selected suppliers.

Figure 2 shows a typical paper-based document system of a purchasing function during the post-contract stage of a project (Calvert, 1995). In this paper-based document system, the site office prepares two copies for the requisition of materials. One copy is sent to the buying department and one copy is filed. The buying department then prepares four copies of the purchase order. One copy is sent to the selected supplier and the site office, the accounts department and the buying department keep the remaining copies for their records. The site office will receive an advice note and invoice issued by the supplier when materials arrive on site. The invoice will be compared with the purchase order by the buying department and after confirmation, be passed to the accounts department to issue payment.

Limitations of traditional material procurement process
It is proffered that the traditional material procurement process has the following limitations. First, this process has specific business hours and can only work with suppliers within a defined geographical region. In addition, the traditional process can only collect limited amount of information about the suppliers and their products through the collection of physical catalogues. Physical catalogues are cumbersome to use, and require large storage areas. They also become dated very quickly, and make searching and comparison of prices and quality a nebulous task. These disadvantages make it increasingly difficult for contractors to stay abreast of market conditions and thus select the most suitable materials and suppliers for a given project.
Additionally, the paper-based transaction system that is commonly used within the realm of the traditional process of material procurement is time consuming (and thus non-value adding). As mentioned above, copies of different documents are produced manually and are used by different parties in the material procurement process. The probability of error increases as information is transcribed from one document to another. Although paper documents can be retyped into a computer-based environment, data entry of document information requires multiple transcriptions of the information. Consequently, such process can result in the introduction of additional errors to the system. Furthermore, the paper-based system is also dependent on ensuring that all appropriate departments obtain copies of the documents necessary to do their job. If a small percentage of those documents are lost or misplaced, there can be gaps in the system and orders may go unfulfilled.

E-commerce applications

E-commerce refers to business activities involving consumers, manufacturers, service providers, and intermediaries using computer network. Electronic data interchange (EDI) has been used to forge automated linkages between the buyers and suppliers to transmit orders, receipts, and payments electronically. Studies have shown that using EDI for linking with so-called 'channel partners' can help reduce processing cycle-time, improve accuracy, and create strategic value (Mukhopadhyay, 1998). However, EDI requires the support of private lines or value-adding networks (VANs) and relies on software that can incorporate varying formats, which limits its coverage. Moreover, EDI requires significant investment to facilitate trading among business partners, especially when contractors have to deal with a large number of suppliers, which are invariably different for each project. The costs associated with EDI can be further exacerbated when sources of construction materials are geographically remote.

Web technology can be used to overcome the system incompatibility problem of EDI by encapsulating enterprise systems as object components, made accessible by standardized interfaces, and standardized protocol for transmitting documents between these components through the internet (Gek, 2000). The internet provides a transparent means of communication between the buyers and suppliers. Users only need to know the address of the other party. Even though the internet is a complicated network of switches, communication lines, software and equipment, it is of no concern to users. The key to this simplicity is the separation of the various user organizations into islands with their own internet networks connected to the islands by a common protocol (Andreoli et al., 1997). The standardization of network communication technology has significantly reduced the cost for installing a web site and the unit cost for information transmission also becomes virtually negligible. Web technology thus enables contractors and suppliers to trade construction materials online easily with low transaction cost and to eliminate errors that existed in the paper-based document system.

E-commerce as a proliferated business practice has at least four types on the internet (Wang and Huang, 2000):

- off-line order, off-line delivery;
- on-line order, off-line delivery;
- on-line order, on-line delivery;
- off-line order, on-line delivery.

For the off-line order, off-line delivery type, information is available from the Internet, but both ordering and delivery are executed off-line. The on-line order, off-line delivery type of e-commerce system provides on-line information for products and also allows users to make orders on-line. Once ordered, the product will be delivered off-line. In a on-line order, on-line delivery e-commerce system, information for the products is provided on-line, and users can order the products in the
system. Once ordered, the products or services will be delivered to the customer on-line. The off-line order, on-line delivery type of e-commerce requires customers to make orders in the traditional way, but the products or services is delivered through the internet.

Among these four types of business practice, off-line order, off-line delivery and the on-line order, off-line delivery types are applicable in developing e-commerce systems for construction material exchanges. However, as the off-line order, off-line delivery type only makes available information related to material and suppliers on the Internet, both ordering and delivery are executed off-line. This type of e-commerce cannot overcome all the problems that exist in the traditional material procurement process. It would appear that the on-line order, off-line delivery type, however, is more useful, as this type of e-commerce system makes both product information and ordering through the internet available. Once the user completes the ordering, the ordered products will be delivered off-line to the user. The on-line order, off-line delivery type is selected as the basis for developing our e-commerce system for supporting construction material procurement process, as this type can improve the efficiency of information transfer during the ordering procedure in which all parties can communicate and share information via the internet.

In most construction material trading circumstances, there are three major players: buyers, suppliers and agents (brokers). Buyers are customers who purchase certain materials and products. Suppliers are products and/or services providers. Agents are intermediaries who help the buyers and suppliers to complete a transaction. The buyer and supplier must exist in any trading, while the agent exists only in certain trading situations. A good e-commerce system should support various trade situations. In the next section of the paper, some major trading situations are discussed, which is followed by a description of an e-commerce system designed for construction material trading.

Trading situations

By discussing with professionals involved in construction material procurement, the authors have identified the following four trading situations frequently encountered in construction material trading. The four trading situations are bargaining, bidding, auction and contract.

Bargaining

Bargaining is a trading situation in which the buyer negotiates with the supplier until an acceptable deal is reached. Usually, the buyer finds a supplier, examines product price and other terms, and negotiates in order to obtain a better deal. If the deal fails, the buyer finds another supplier to bargain again until the buyer is satisfied with the deal.

Bidding

Bidding is a trading situation that involves a buyer and many potential suppliers. The buyer compares the received bids and chooses the best one. A typical bidding process includes the following steps: the buyer firstly calls for bidding after determining the specification amount and base price; bidders then submit their bids; the buyer chooses the best bid; at last the buyer pays for and the winner delivers the products and/or services.

Auction

Auction is a trilateral trading situation that involves a supplier, many potential buyers and an agent who handles the auction. The buyers bid sequentially to compete for the object to be sold. A typical auction process includes:
• the supplier determining the bottom price of the object to be sold;
• the agent announcing the object and calling for an auction;
• the potential buyers assessing the value and bidding for the object sequentially;
• the agent choosing the buyer who offers the highest price which is also higher than the bottom price;
• the winner paying and the supplier delivering the object. Commission fees are paid to the agent.

Contract
Contract is a trading situation in which both buyers and suppliers are constrained by a set of mutually agreed rules. If there is no contract, then both sides need to negotiate for an agreement. If a contract already exists, then ensuring accurate implementation of individual orders under the regulation of the contract becomes the primary concern. A typical trading process under contract often includes:
• the buyer informing the supplier to deliver certain products or services;
• the supplier confirming the request;
• the buyer paying and the supplier delivering the products and services according to the contract terms.

System design
An e-commerce system for assisting product procurement creates electronic links between suppliers, buyers and agents (Sirinivasan, 1994; Wang and Seidmann, 1995; Choudhury and Konsynski, 1998).
These links can be organized in different ways. As shown in Figure 3, buyers and suppliers can either form direct connections without any intermediary (Figure 3a), with intermediaries (Figure 3b), or acquire the products through electronic markets (Figure 3c) (Strader and Shaw, 1997). These three types of connections allow product information of suppliers and the request for product by buyers to be accessed through a network, which provides a platform for buying and selling of products electronically.

From Figure 3, it can be seen that type (a) provides direct linkage between suppliers and buyers, which supports bargaining and bidding trading situations, but it is difficult to support other trading situations. Type (b) allows buyers to search and compare more products from the intermediary’s platform and facilitates trading situations such as auctions and contracts based trading, but the intermediary becomes an unavoidable part of the supply chain which makes it inconvenient to have direct communications between buyers and suppliers. Therefore, type (b) cannot support bargaining and bidding trading situations. The electronic market in type (c) provides a platform for the suppliers to put their product information online. Buyers can easily search and compare products of a pool of suppliers, and to contact suppliers directly. If necessary, buyers can also invite the agents to undertake certain tasks required in order to complete a transaction. Thus, type (c) has the most flexibility and functionality to support all the four trading situations encountered in construction material trading. The e-commerce business model presented in this paper is therefore based on the type (c). To facilitate the four trading situations, the e-commerce system presented has the following modules: E-catalogs, bidding, requisition quotation, and order, as shown in Figure 4. Each of the module functions within the e-commerce system are discussed below.

**E-catalogue module**
The e-catalogue module provides an interface for suppliers to advertise their product information into a classified material catalogue. The product information includes the price, units, photos, brand names, quality standard and other relevant details so as to allow the buyers to make judgments on the suitability of the products. Information on suppliers such as the company name, address, telephone, email and service details should also be provided. The searching function of the e-catalog allows buyers to specify searching criteria such as a price range, categories and key words so that the desired materials and products can be found quickly. Also, retrieved results will be presented in a way that enables comparisons to be made.

**Bidding module**
The bidding module allows buyers to specify materials they want to buy when they cannot find suitable materials from the e-catalog. Suppliers can view buyers’ requests for materials on-line and bid
for the order. Messages are sent to the buyers instantly to inform them of the responses from suppliers. A buyer can accept a bid on-line and this will constitute an order from the buyer to a supplier. The buyer and supplier can then use the order module to follow up the order.

Requisition module
The requisition module allows buyers to send requisitions to suppliers after suitable materials have been identified from the e-catalog. Although the unit price of each material is stated in the system, suppliers may give discounts to buyers according to the amount of purchases, payment methods and their relationships with buyers. Supplier can view the requisition on-line and then use the quotation module to reply to the buyer.

Quotation module
The quotation module allows suppliers to send quotations to buyers after receiving requisitions. Buyers will receive notice of the quotations and be able to view the quotation details on-line. They can then use the order module to raise orders.

Order module
The order module allows buyers to send orders to suppliers. The buyer can use the order module in three cases:

1) once suitable materials are identified from the E-catalog the buyer wants to make a direct order;
2) the buyer receives a quotation from the supplier;
3) the buyer accepts a bid from the supplier.

Both the buyer and the supplier can use the order module to proceed with the transaction.

The above modules are the main modules of an e-commerce system developed to facilitate construction materials trading. The e-commerce system has been implemented using ASP as the web programming language and Oracle as the database for storing data and information on a server. The implementation of the e-commerce system is described in the following section.

Implementation of the e-commerce system
The web address of the e-commerce system is http://bsnt42.bre.polyu.edu.hk. The e-commerce system is called COME, which is the abbreviation of ‘COnstruction Materials Exchange’. The COME system adopts an on-line order, off-line delivery model of operation. It is a trading model that is based on the type (c) of the buyer–supplier communication structure, as illustrated in Figure 3. The COME system has five main modules, as indicated in Figure 4, which enable buyers and suppliers to execute the four trading situations previously described. To cope with unexpected trading situations, the system also provides additional services such as building up user profiles, tracking the trading process, and learning the trading experiences. In order to explore the usefulness of the system, the research team worked closely with a commercial firm by which a professional version of the COME system has been developed and is located at http://www.VHcome.com.

Business Model of COME
In designing and implementing the COME system, it is assumed that most suppliers would be from China, whereas buyers can be from anywhere in the world. The reasons for making such an assumption is that over 90% of the construction materials used in Hong Kong are from China and contrac-
tors in Hong Kong have expressed the need of an e-commerce system to expedite the trading process. Secondly, most material producers and suppliers in China have no proper channel to contact buyers from outside of China. The e-commerce system developed is therefore intended to provide a platform for suppliers in China to advertise their products so that trading activities with buyers from anywhere in the world can be conducted on-line.

In the current legal and business environment, exporting goods and products out of China involves preparing considerable amounts of paperwork required by various governmental bodies, buyers who do not have sufficient knowledge of the statutory regulations and business culture in China will have difficulties in fulfilling the paperwork. To solve this problem, the e-commerce system has not only the buyers and suppliers as two major user groups, but also the agents who can be the brokers in negotiations and auctions, and also carry out all other duties required by the buyers and the suppliers. These duties include the search of suppliers’ information, the preparation of all paperwork required in executing the trading transaction and shipping the products and materials to the buyers. This is because the agents are familiar with the business environment and regulations in China. Without them, it is very difficult if not impossible to sort out all the paperwork involved in exporting commodities from China. The agents can therefore be very helpful to these buyers. The business model of COME is illustrated in Figure 5. This figure summarizes the roles and functions of the three major parties in the COME system: buyers, suppliers and agents.

The e-catalog in the COME system contains over two thousand categories of construction materials classified into seventeen trees with a maximum of four levels of information. With this structure, the search for product information commences at a general level. If more specific information is required, then the searching process will lead to the next level of information. A geographic information system (GIS) is provided to assist the search of material information in specific geographic
regions of China. By using the GIS system, the buyers can define the searching areas by selecting the cities on the map or by specifying a circular area with a given central point and its radius. The system will then find all suitable material information within the area together with the associated costs for transporting the material and/or products from the suppliers to the buyers.

Functions provided for buyers also include sending requests for materials and accepting bids from suppliers, selecting agents to complete orders and purchasing contact information of suppliers. Readers should note that the buyers do not know who the supplier is when they find materials from the e-catalogue. Buyers have to choose to purchase the contact information of suppliers so that they can contact the suppliers directly, or to select an agent to complete the order for them.

The suppliers can use the COME system for the following purposes: adding and maintaining materials and company information in the e-catalogue, reviewing the current market situation in terms of material prices and buyers’ requests, and bidding for buyers’ requests. Functions provided for the agents include managing buyers’ order, and bidding for buyers’ request. Some screen captures of the COME system interfaces are shown in Figure 6.

Figure 6 Interfaces of COME system
Current Status of COME
Currently the professional version of the e-commerce system has over 2000 buyers, 29,000 suppliers and 1000 agents registered in the COME system. Experiments are being conducted to compare the time and costs required to procure construction materials in the traditional way and through the e-commerce system. Users’ opinions about the effectiveness of the COME system will also be collected and analysed.

The next stage of development will incorporate features such as intelligent agents and data mining techniques into the e-commerce environment. Intelligent agents are software entities that possess internal knowledge to perform certain tasks intelligently. The use of intelligent agents in an e-commerce system can support the users at three different levels (Liang and Huang, 2000): market level, transaction level and activity level.

At the market level, intelligent agents can assist the users (buyers and suppliers) to select a proper trade type for their business deal. Intelligent agents at the transaction level ensure that the selected trading type is executed properly. At the activity level, intelligent agents can perform a specific task in the users’ decision making process. Data mining techniques are used to distill knowledge from raw data. The application of data mining techniques will enable us to generalize useful knowledge and information such as the profiles of the users, the most frequently used searching patterns, and the general patterns in delivery, payment and other issues. These types of information will be extremely useful not only to the users, but also to the system administrator responsible for maintaining the operation of the e-commerce system.

Summary
This paper identified the limitations of the traditional construction material procurement method and identifies those areas of e-commerce applications that may help to solve the problems. Models of trading situations, as well as the typical types of communication structures used in e-commerce development are discussed. A design and implementation of an e-commerce application for construction material procurement is presented. The e-commerce system has been upgraded to a professional version, which is now used by suppliers in China and buyers in Hong Kong. As the next stage of the research project, useful features such as the intelligent agents and data mining techniques will be incorporated into the e-commerce system to further enhance its capacity.

The contribution of this research lies at the identification of the trading situations and types involved in construction material procurement process. These trading situations and types provide essential guidelines for developing a business model for an e-commerce system. The design and implementation of the e-commerce system serve as an initial step towards evaluating the practicality and usefulness of the application of e-commerce in supporting construction material procurement.

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References


