Electronic Purchasing Agent (EPA): an Electronic-Agent Based System for Material Procurement

B. H. W. Hadikusumo

Email: kusumo@ait.ac.th

Sataporn Petchpong

Email: N/A

Chotchai Charoenngam

Email: chot@ait.ac.th

Construction Engineering and Infrastructure Management, School of Civil Engineering, Asian Institute of Technology

1. Introduction

More than 50 - 60% of total project cost is the cost of materials and equipment (CII, 1987). Hence, effective materials management is one of the most important requirements of this industry. An effective material management can increase a company's profit by reducing unnecessary costs such as those from delays, claims, etc.

Improper methods and substandard purchasing and procurement practices can result in costly delays, loss of profit and possible litigation. Due to the fact that traditional purchasing processes are being done on a paper-based system, there are many associated drawbacks: low accuracy, time consumption, labor consumption, loss of data and high uncertainty (Udeaja and Tah, 2002). In order to solve these problems, the organization has to be proactive and should implement proper information technology practices, which are increasingly being encouraged for the exchange of information and coordination of activities. The problems with paper-based purchasing have now been solved by using electronic purchasing as a means. This electronic purchasing was initiated by EDI technology; and is easily used and adapted by using Internet technology.

An approach to develop a web-based purchasing is to create a centralized database. In this approach, the purchasing human agent has to place the Request for Quotation (RFQ) of needed goods/services on the organization's website database. Thereafter, seller/supplier human agents have to seek information and submit quotations to purchasers' website via the Internet environment.

We, the author of this article, consider that this approach is not effective in construction industry in terms of reliability, consistency and practicability. In term of reliability, If a supplier failed to check the contractor website, the contractor will miss the opportunity to receive a good offer. In terms of consistency, suppliers have to be familiar with different web-based procurement system of different contractors, and this may lead to problems of learning how to use the different systems. In addition, in terms of practicability, a supplier has to input its material data to all contractors' databases for submitting its quotations. In order to reduce this problem, a proactive means of electronic purchasing is proposed where suppliers have to maintain its decentralized database storing data related to materials and the price and the contractor purchasing agents have to visit the suppliers' database for retrieving the information. This decentralized database is similar to the real procurement in 'brick and mortar' business where the supplier is responsible for managing its own data.   The Electronic Purchasing Agent (EPA) is developed based on this rationale. This article discusses the EPA developed in terms of framework, design and implementation.

2. A Review of Material Purchasing

Purchasing is a fundamental function of material procurement that refers to the acquisition of materials, goods, and services and an establishment of mutually acceptable terms and conditions between a seller and a buyer (McConville, 1993). It is an activity that occurs in all phases of a construction project. It is not only related to the construction industries but also applies to the domestic scenario in which an individual does "shopping".

Functions of Material Purchasing

The functions of any purchasing department of an organization may generally involve some of the following tasks (Barrie and Paulson, 1992; Doubler and Burt, 1996): a) Identification or recognition of the need via coordination with user departments, b) Issuance and processing of internal requisition, c) Discussion with sales representatives, d) Identification of potential suppliers, pre-qualification and preparation of Approved Supplier List (ASL), e) The conduct of market studies for important materials, f) Solicitation of bids and price quotations, g) Negotiation with potential suppliers, h) Analysis and evaluation of proposals, i) Select and award suppliers, j) Issuance of Purchase Order (PO), subcontracts or leases, k) Administration of contracts and resolution of related problems, l) Tracking and expediting, m) Delivery and inspection of goods supplied, n) Maintenance of a variety of purchasing records.

Material Purchasing Problems

Based on literature review (Kasturi 1983, CII 1987) and interviews with three medium size contractor firms, problems with material purchasing are identified (see Figure 1). This problems can be grouped into: a) Communication Problems, since the traditional purchasing process makes use of the paper-based system (i.e. handwritten), the information may be unclear (i.e. specification, delivery date and place). Due to unclear or ineligible writing, problems, such as repudiation of RFQ and PO; absence of acknowledgement from suppliers, might occur. All such problems may create misunderstandings between the contractor and the supplier; b) Supplier Selection Problems, supplier selection is carried out in two stages; potential supplier selection and the most appropriate supplier selection. Problems in selection may arise due to a limited source of supplier information (ASL), less competition, preferable supplier selection and unclear selection criteria (i.e. lowest price, payment term, performance score); c) Supplier Evaluation problems, most of the problems encountered here include the omission of the evaluation process by the contractor, the evaluation process not being based on actual

performance of existing suppliers, and the evaluation criteria not covering important aspects; and d) Other Problems, the whole process of purchasing is complex and could lead to problems other than the ones mentioned above. These include time consumption, labor consumption, loss of information, using outdated information. All these problems can lead to an unnecessary increase in cost.

General Construction Materials Purchasing process

Processes   **Problems**

Site prepare Schedule of Materials — Improper schedule of materials

Materials need to be approved from owner — Type of Contract and specifications

Request sample of materials for approval —
Time consuming
Very specific specifications
Cannot find the sample of materials for approval
Use the equivalent specification materials

Owner Approved —
Owner do not approve materials
Owner change specifications

Issuance Purchase Requisition (PR) —
PR lost while sending to Purchase dept.
Communication problems.
Unclear specification, date, time, place, etc. in PR
Unclear writing PR because it is written by handwriting and sent by facsimile.

ASL Yellow pages etc.

Select the potential suppliers —
Select improper supplier
Source of vendor is narrowly
Less competition
Select only preferable supplier
Information not up to date

Request for Quotation (RFQ) —
Communication problems.
Repudiation QFR from supplier
Late for receiving and submitting RFQ
Unclear RFQ because it is sent by facsimile.

Negotiation and Evaluation RFQ. —
Unclear selection criteria
Base on lowest price
Select improper supplier
Select only preferable supplier

Manager approved —
Rejection of RQF
Negotiation or bargain the price and other aspects
Change suppliers
Making another bidding

Cost of materials > authorized — Personal Authorization

Director of Purchasing Dept. Approved —
Rejection of RQF
Negotiation or bargain the price and other aspects
Change suppliers
Making another bidding

Authorization processes are uniqueness   1/2

1

Issuance Purchase Order (PO) and send copy to the involvements —
PO missing while sending to supplier.
Repudiation PO. from suppliers
Communication problems.
Unclear specification, date, time, place, etc. in PO
Unclear writing PO because it is written by handwriting and sent by facsimile.

Receive the acknowledgement from suplier —
Suppliers do not acknowledge to purchaser
Repudiation PO. From suppliers

Receive invoice from supplier and deliver materials to site work —
Incorrect invoice
Not deliver on time, place
Wrong specification
Materials defect while deliver

Site work Approved materials —
Materials are rejected
Wasting time
Bad relationship with suppliers

send Inspection report to purchasing office —
Time consuming
Lost information

Director of Purchasing Dept. Approved

Send Invoice and inspection report to account dept. —
Time consuming
Lost information

Make payment to supplier

Evaluate supplier —
Omission of evaluation process
Evaluation process not base on PO
Evaluation result not up to date
Lost some information for evaluate
Criteria for evaluation may not cover all performance

Send evaluation result to suppliers and keep it into ASL database —
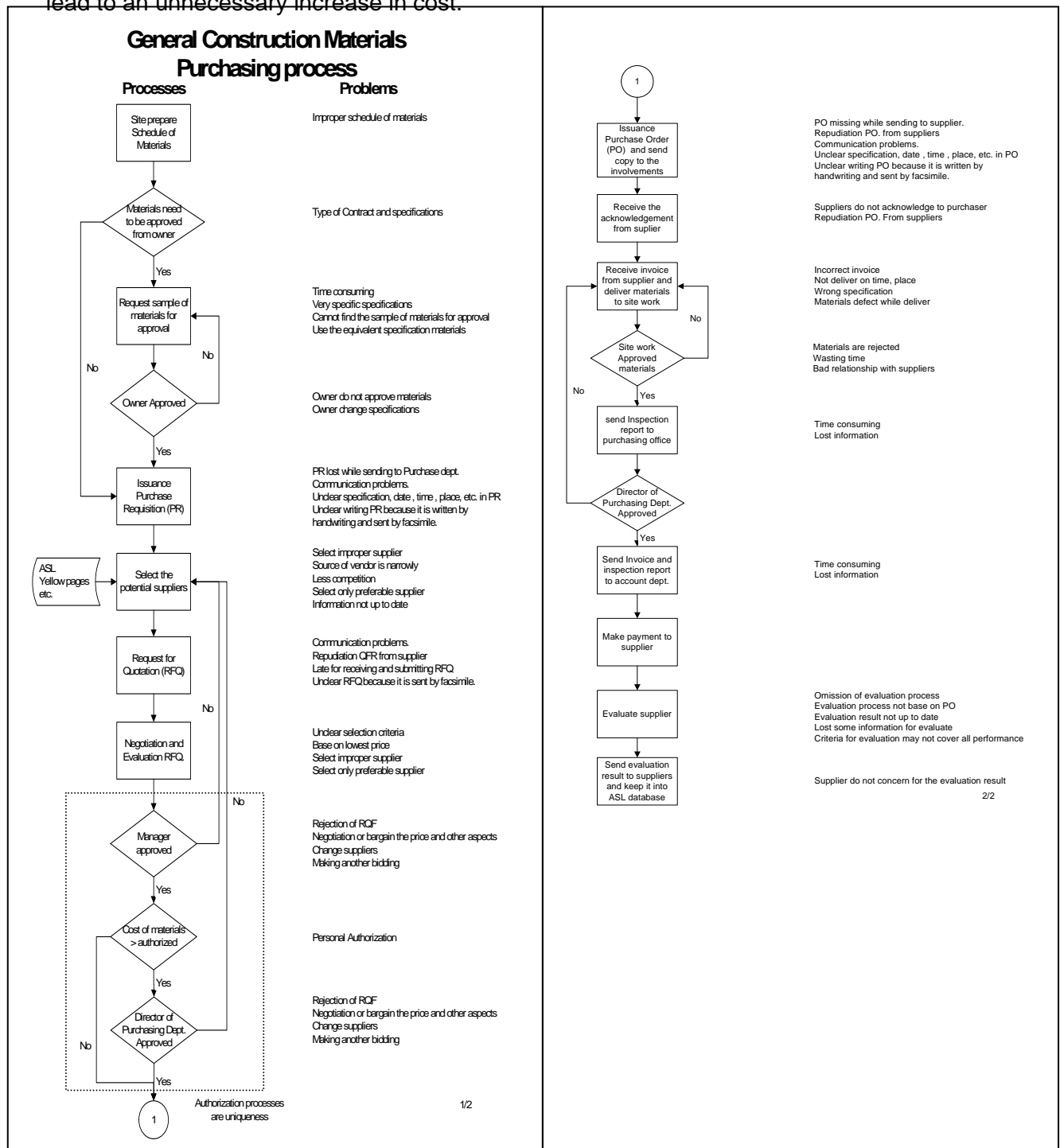Supplier do not concern for the evaluation result

2/2

Figure 1. Material Purchasing Process and Problems

3. Electronic Agent System

Nwana (1996) defined an agent, only an agent and not specify whether it is intelligent or not, as a component of software and/or hardware, which is capable of acting exactily in order to accomplish tasks on behalf of its user. Nwana also defined an intelligent agent in terms of three primary behavioural attributes, any two of which must be possessed by a software agent. According to Nwana, these are a) Autonomy: If the agents are autonomous, it means that they can act on their own without the need for human guidance. Hence agents have individual internal states and goals, and acts in such a manner as to meet its goals on behalf of its user; b) Cooperation: In MAS, it is important that such agent has to cooperate each other. In order to cooperate, agents need to possess a social ability, i.e. the ability to interact with other agents and possibly humans via some communication language; and c) Learning: For agent to be considered truly smart, they would have to learn as they react and/or interact with their external environment.

In the EPA proposed, the agent is considered as a non-intelligent agent system since the role of electronic agent in the EPA is to identify other parties' agents and to establish an electronic connection between two parties. This non-intelligent agent system can still perform its role for material purchasing since some parts of purchasing activities, such as selecting attractive offers by different suppliers and negotiating the payment terms, are still conducted by human. These issues can be addressed for further researches. The purpose of this article is to show that a simple agent in decentralized databases can be used to create EPA that can significantly reduce human tasks and errors in identifying suppliers, and selecting suppliers.

4. Electronic Purchasing Agent (EPA)

The main purpose of the proposed system, EPA, is to eliminate the existing problems of the traditional purchasing process that are discussed in section 2. The objectives of proposed system are explained: a) In order to eliminate the communication problems, the system is created with a communication pattern among the involved groups. For example, the system has a standard for inputting the specification of each required material, otherwise the suppliers agent may not understand the needs of the customer agent; b) The traditional process of selection of suppliers is normally based on the lowest bidder. However, in some cases, the lowest bidder is not selected because of the problem of the 'preferable supplier'. Therefore, the proposed system should provide a transparent selection process showing all the important aspects for selection such as specification, the supplier's past performance score, quoted price, payment terms, additional conditions and so on; and c) The past performance evaluation process is one of the vital processes for any business transaction. However, most of the customers and suppliers do not pay much attention to this process. Therefore, the EPA offers an easy method for customers to evaluate the supplier's performance based on each transaction (PO).

4.1. Framework of EPA

The systematic framework of EPA contains of two main electronic agents (i.e. contractor agent and supplier agent) and information flow (i.e. specifications, quantity, delivery, price, etc) (see Figure 2).
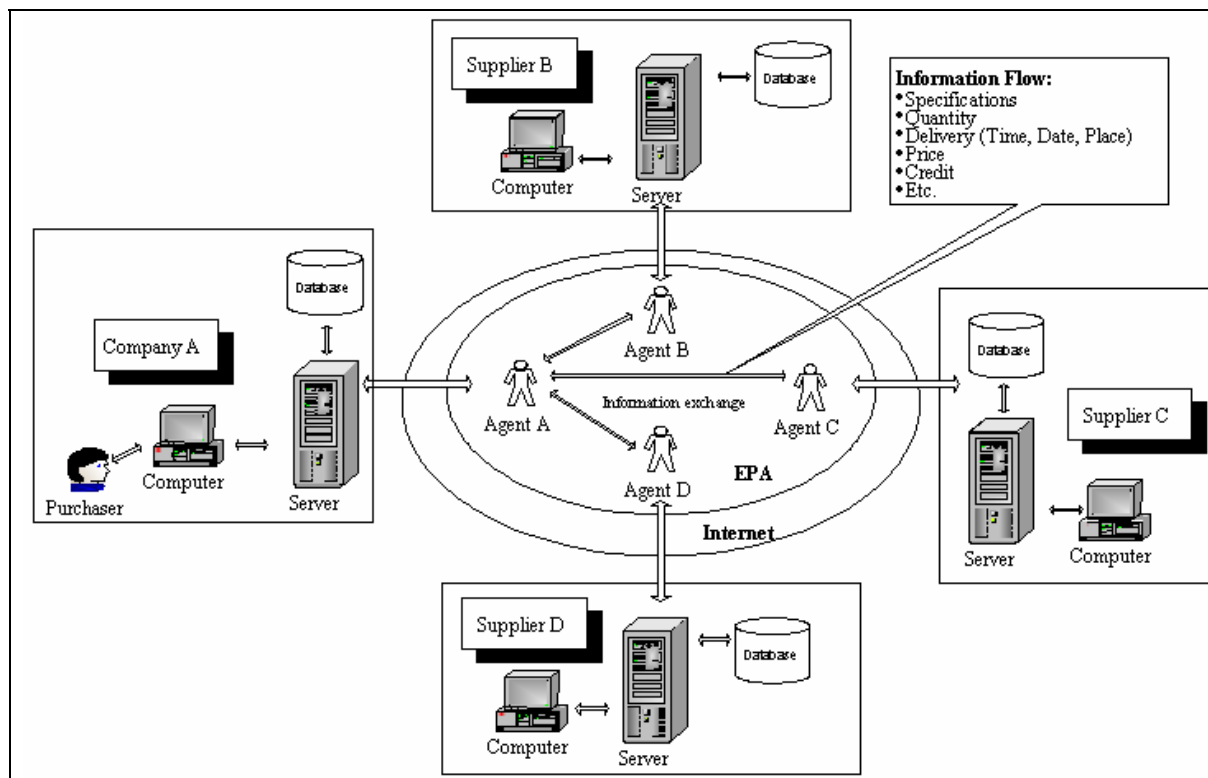
Figure 2. Systematic Framework of Electronic Purchasing Agent System on Internet Environment

The contractor agent communicates with supplier agents using a protocol called TCP/IP (Transmission Control Protocol/ Internet Protocol). The communication scheme starts with the customer agent, which communicates individually with each supplier agent according to the qualified supplier list that is kept in customer agent's database. The communication content is the information of required materials (i.e. specification, quantities).
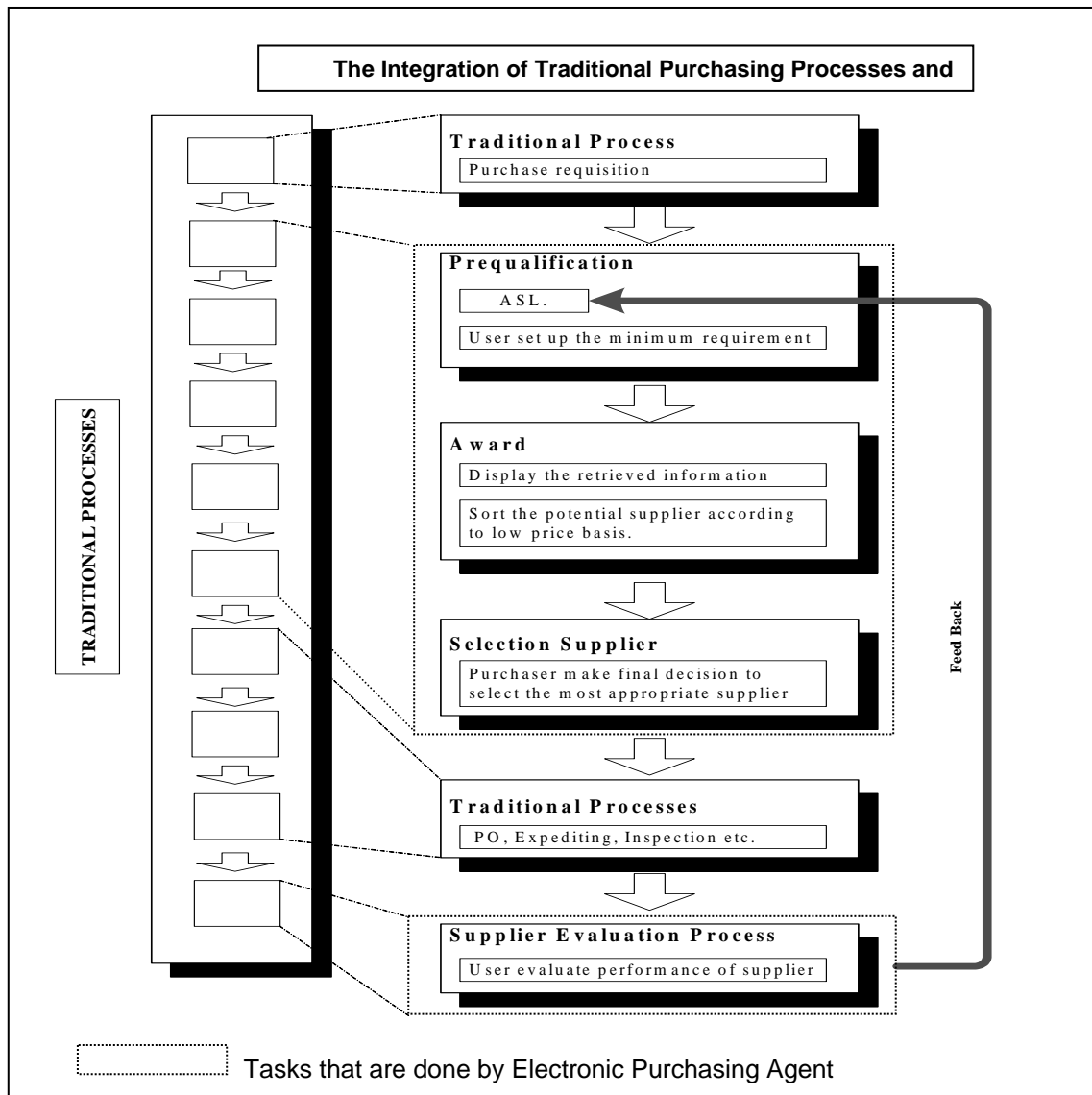
Figure 3. Framework of EPA for Purchasing Construction Materials

Electronic Agents' Role

In EPA, the electronic customer agent (i.e. the contractor purchasing agent) is designed to perform searching and systematically displaying the results of available materials and appropriate suppliers as well as the prompt display of suppliers' performance rating score. This agent can also automatically generate the purchase order (PO) and provide a mechanism for evaluating performance of suppliers for future pre-qualification process. The other tasks (i.e. negotiation and award, purchase order issuance, expediting, inspection) (see Figure 3) have to be done manually by the purchaser following the traditional purchasing processes. Followings are detailed discussion of the role of the contractor agent.

➢ Secure the system. Since the proposed system should be accurate and reliable, it must have a secure security system. The security system is divided into two levels: the system level and user level. The system level aims to secure the network connection between the customer and the supplier. The security process starts from customer

agent (client) who sends a request to make a connection to the supplier agent (server). On the receipt of the request, the server will send a keyword for making a connection back to the client. After that, a username and an encrypted password will be sent to the server. The authentication process is done by the supplier and a connection is created only when the username and encrypted password is entered correctly. Conversely, the main purpose of the user level is to secure the system from unauthenticated users. In this level, authenticated users have to input their user name and password before accessing the system.

➢ Search for the required materials. This role is the most important function of the system. It is designed to assist the customer agent in searching for the required materials from the potential supplier. The system should offer the easiest utility and tool to search for the required information.

➢ Update supplier information. The major function of this role is to allow a user to add new qualified suppliers and remove unqualified suppliers from the database. After the removal, the customer agent is unable to contact the removed supplier.

➢ Assist the user on the supplier selection process. Generally, the supplier selection process is based on the lowest bidder. However, there are other important aspects that can be used as selection criteria (i.e. past performance score, payment term). The system should be able to provide such information to the user in order to assist him in the selection process.

➢ Assist the user on supplier's performance evaluation process. The supplier evaluation process monitors the performance of the supplier and is a pertinent aspect of the system. This system should be able to assist the user in the evaluation process by presenting a user-friendly interface for ease of use. The main criteria is separated into six groups namely, attitude, capability, delivery, price, quality and service. A score of 1-5 is given (1 is very bad and 5 is very good) for each sub-criterion. It will then be accumulated and added into each main-criterion and the raw score is saved into the system database. Finally, by using the results of the raw score and the defined weights, the performance of the supplier is calculated. The final result is graded on a scale of 1-10 (1 is very bad and 10 is very good). Moreover, it allows the user to define the weight of each main criterion. Therefore, the supplier's performance score will always be changed according to the defined weight.

➢ Create a Purchase Order. The final role of this system is to create a purchase order (PO). In order to reduce human error when creating the PO form, the form is automatically generated using the information in the database i.e. selected materials and selected suppliers.

The main functions of the supplier agent are securing the system and updating information of customers and materials (i.e. specification, unit price, stock quantities, and terms of payment for each customer) as follows:

➢ Secure the system. As discussed in the previous section, the security system consists of the system and the user level. The details of both levels are clearly explained under the functions of the customer agent.

➢ Update materials and customer information. This is the most important function of the supplier agent. The user is allowed to update the information of customers and materials. The most important aspect needed to update customer information is an authentic username and password. Similarly, for that of updating materials are quantities, unit price, payment term and additional condition.

Product and Specification Coding

Since the most important task is information retrieval, EPA must have a standard coding for specifying materials offered by suppliers. In EPA, the material coding is mainly identified by Product ID and Specification. The product ID has four digits (see Table 1). The first two digits (e.g. 20xx) represent type of product (e.g. Brick and Masonry), and the last two digits represent product details (e.g. 2001 represents Concrete Block). While the specification coding is identified by four codes. A product can be specified by using maximum of four identifications. For example, Product ID 2005 (Brick) can be specified as "Type=Masonry Size=7x16x3.5". This specification coding is important for information searching purposes.   Therefore, all suppliers have to follow this product ID and specification ID, otherwise the contractor agent cannot understand. For new products, this specification code can be determined later by the suppliers and contractor.

Table 1. Product ID Coding

Product ID	Product Name	Unit
1000	Cast in situ	
1001	Ready mixed concrete strength at 28 days (ksc)	m3
1999	Other cast in situ	
2000	Brick and Masonry	
2001	Concrete block	piece
2002	Light Weight concrete block	m2
2005	Brick	piece
…	…	…

4.2. System Design and Implementation

The system design and implementation covers database, interface, and connection. The database and interface are designed and implemented in Microsoft Access 2000 and Visual Basic, and the connection is implemented using Winsock technology.

4.2.1. EPA Database

The EPA consists of two major parts, the customer and the supplier, and it employs the concept of client-server computing. Therefore, the database has to be designed in such a way that it would suit both a client (the contractor) and a server (the supplier).

Customer's (Contractor) Database

There are eleven database entities (tables) created in this database which include 1) user authentications table, this table is used to store the password of authorized users. In order to make the system reliable, the system will verify the username and password before allowing the user to access it. 2) Project description, this table (project) is used to store the description of the project. 3) Available products in the market, this table (product) stores the names of construction materials that are available in the market. This table (product) stores the names of construction materials that are available in the market. 4) Specification definition, this table contains the data of specification format. The main aim

of this table is to assist the user in selecting the specifications of the items. 5) Request for quotation, this table contains the information required for issuing the quotation. 6) Unfinished search item, this table is used to store information of the required materials that are yet to be found in the search process. 7) Supplier information, this table is used to store the profiles of the supplier: supplier id, company name, address, contact person, phone number, fax number, website, e-mail address, server IP address, login name, password and performance score. 8) Store retrieved information, the main purpose of this table is to store the search results that are received from suppliers. 9) The selected items, after receiving information from the suppliers, the next step is selecting the appropriate materials from the suitable supplier. This table is used to store the data of the selected items. 10) Defined weight of the main criteria for the evaluation process, this table is used to store the weight of the main criteria for the evaluation process. The supplier's performance score depends on the weight of the main criteria. In order to monitor the updated performance of suppliers, the system allows the user to assign weight scores for each main criterion prior to searching for the required materials. There are six main criteria for the evaluation process namely; delivery, quality, price, service and credit, capability and attitude. 11) Purchase order, Due to the supplier's performance evaluation process being based on the purchase order, the main purpose of this table is to store the evaluation score of a supplier. The relationships among the entities and entities' attributes (fields) of contractor database can be seen in Figure 4.
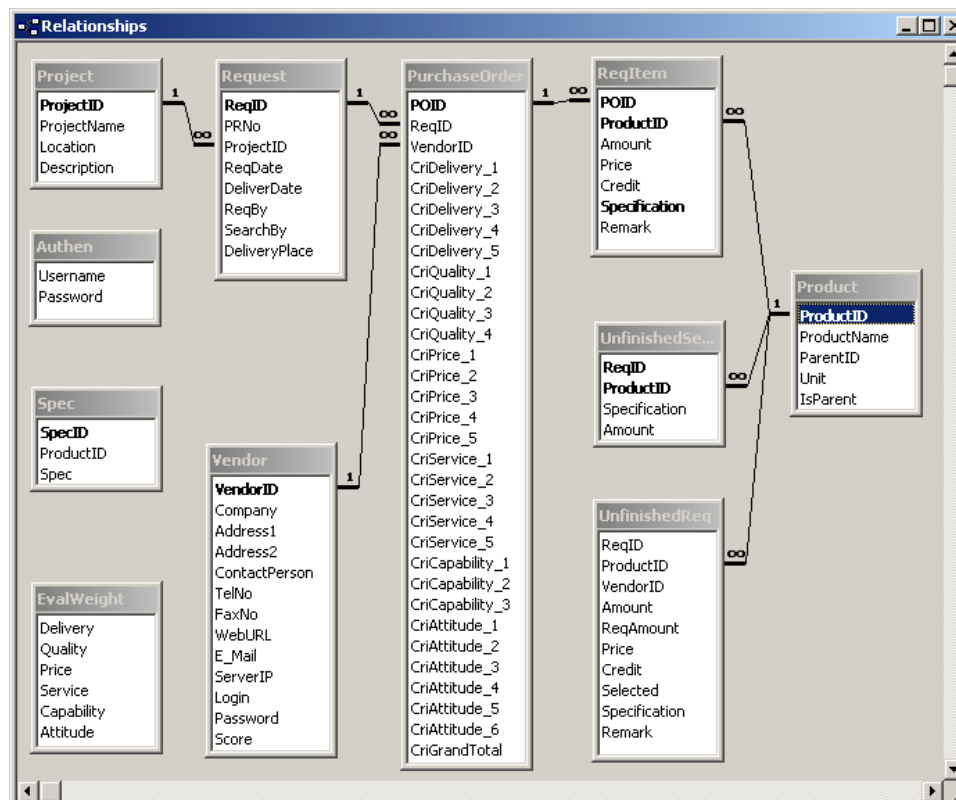
Figure 4. Entity-Relationship Diagram of EPA-Purchaser

Supplier's Database
     There are five major aspects in the design of the supplier's database: 1) Authentication, the function of this table is similar to the User Authentication table in the customer's database. This table stores the username and password which will be used to

verify the input username and password. 2) Customer's information, this table is used to store the details of a customer: customer id, company name, address, contact person, phone number, fax number, website, e-mail address, customer login name and password. Most of the field details in this table are similar and have been discussed in the customer's database section, unless Customer ID, the Customer ID is the ID that is used to identify the customer; Login name (login) and Password that are used used to store the pre-determined username and password of a contractor to connect the server (supplier). 3) List of available products, this contains two important data –Product ID and Specification Coding- that must be standardized by a contractor and suppliers. This entity is similar to the product on customer database. 4) Stock of materials, due to the facts that stock of materials always changes, EPA allows the user to update the stock information. The function of this table is to store the information of the materials such as unit price, quantities, and specification. 5) Payment terms (credit), one important factor in selecting a supplier is the payment terms of the supplier, such as cash and credit basis. Thus, it is important for the supplier to provide the payment terms (credit) to the customer. The relationships among the entities and entities' attributes (fields) of supplier database can be seen in Figure 5.
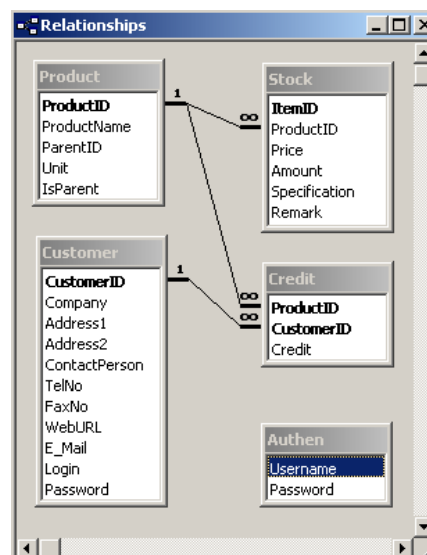
Figure 5. Relationships among Tables of EPA Supplier

4.2.2. EPA Interface and Connection

There are two kinds of interface that are developed: customer interface and supplier interface. Both interfaces are developed using Microsoft Visual Basic by utilizing its add-on components: Microsoft Flex Grid Control 6.0 (SP3), Microsoft Tabbed Dialog Control 6.0 (SP5), Microsoft Windows Common Controls 6.0 (SP4), Microsoft Windows Common Controls-2 6.0 (SP4) and Microsoft Winsock Controls 6.0 (SP5). The last component is the key component in establishing a client-server connection.

Customer Interface

There is a main customer interface that contains other eight interfaces. The user has to key in User ID and password to log-on to the system and to enable the eight interfaces. When the user is log-on to the system, EPA of the contractor searches all of the EPA of suppliers.

The eight customer interfaces developed are: 1) New search, the main function of this form is to search for the required materials, display the results that are received from the supplier and create the purchase order report; 2) Add/edit/remove supplier, this interface is to help the user in updating the supplier's information by updating, editing and removing supplier data, such as company name, address, contact person, etc.; 3) Check supplier status, this interface shows the status of the supplier, that is on the ASL, whether they are online or offline; 4) Supplier Performance Evaluation (see Figure 6), by using this interface a user can give an evaluation to a supplier based on how the supplier perform a PO. There are five categories of elements to be evaluated: Attitude, Capability, Delivery, Price, Quality, and Service; 5) Define weight of main criteria for evaluation (see Figure 7.a), this interface can be used to adjust the weight of evaluation elements; 6) Load purchasing order (see Figure 7.b), this interface is to load a completed PO when the user needs to see past completed POs; 7) Load unfinished search (see Figure 7.c), the purpose of this interface is to load the unfinished material searching. This function comes in handy when the user, after receiving the results from the suppliers, is not able to select the suitable supplier at that time and would like to continue the process later; and 8) Change password.

Figure 6. Supplier Performance Evaluation
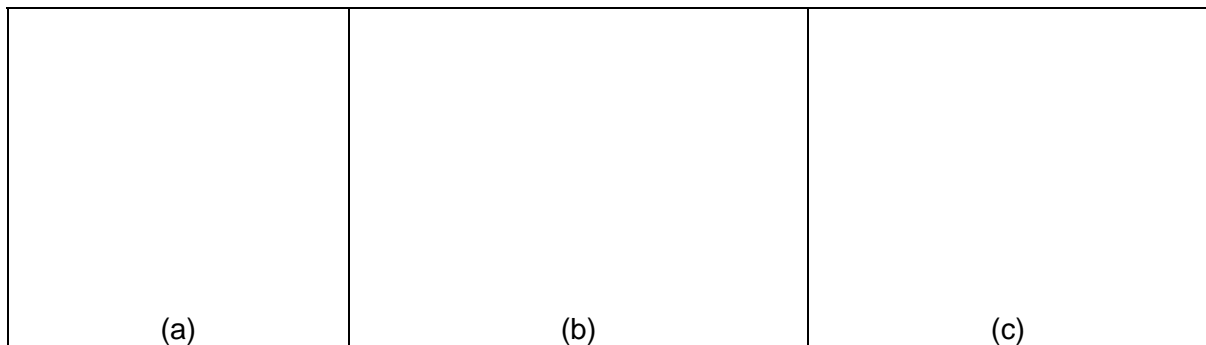
(a)	(b)	(c)

Figure 7. (a) Evaluation Weight Interface, (b) Load PO Interface, and (c) Load Unfinished Request Interface

Supplier Interface

In the EPA for supplier, there is a main menu that contains three interfaces: add/edit/remove customer, update stock information and change user password. Similar to the main menu of contractor EPA, the supplier has to log-on to the system to establish a connection with the contractor EPA and to enable to the three interfaces. The 'add/edit/remove customer' and 'change user password' interfaces have similar functions to those of contractor's. The 'update stock information' interface (see Figure 8) is used to update material data, such as unit price, quantities in stock, and additional conditions (e.g. payment condition).

Client – Server Interface

In this EPA, an electronic agent, e.g. contractor agent, has to connect and retrieve data from a remote database, e.g. supplier agent. This connection is enabled by setting up a client – server connection. A WinSock control allows for a connection to a remote machine and data exchange using Transmission Control Protocol (TCP). This protocol can be used to create client and server applications. The steps of using the WinSock to

create the connection first start from selecting and setting the protocol as 'sckTCPProtocol' and then, the determination of remote computer name (server) or static IP address for the client side to connect to the server side and finally, creating the coding for both sides.

4.3. System Demonstration

In this section, the main functions of EPA, which are to search materials and print PO to be handed to the selected supplier, are discussed. In order to search materials from the supplier database, the contractor EPA has to use the "New Search" interface (see Figure 9). In this interface, the contractor has to input data, such as Project Information, Purchase Information and Material data (see Figure 9.a). When the contractor EPA has retrieved data from suppliers' database, offers from suppliers are listed (see Figure 9.b). In the 'Search Result' interface, contractor can select attractive offers. Finally, the contractor can directly contact the suppliers who gave attractive offers for further negotiations. The final result of the negotiation can then be updated at the 'Summary' interface (see Figure 9.c) for creating hardcopy of the PO which then be sent to the selected supplier.

5. Conclusions

Nowadays, centralized database at the contractor side has been introduced for managing material purchasing. This, however, has some limitations such as the contractor might miss an attractive offer by a reliable supplier, if the supplier did not visit the contractor database; and a supplier has to learn different centralized database owned by different contractors which cause unnecessary cost for the supplier to learn each database system. In order to solve this problem, we proposed Electronic Purchasing Agent (EPA).

The EPA is a decentralized database system supported with an electronic agent. The electronic agent is used for establishing a communication between the electronic contractor agent and the electronic supplier agent. This electronic agent is also considered as a means of securing the system from outsiders. The decentralized database is built using available technology such as Microsoft Access 2000 database, Visual Basic and Winsock. In this decentralized system, the supplier can manage its own database by updating materials data, such as product type, product specification, price, available quantity, payment method etc. This is similar to the 'brick and mortar' practice where a vendor has to manage its own store and let the buyer browses the store. Once the EPA system is established, suppliers will have to manage their own database, and all electronic contractor agents can retrieve the suppliers' products.

For further research, some issues can be addressed for further developments: a) the database can be represented in XML file so that data can be defined to ease data transactions among different contractors and suppliers, b) the security issues, and c) at present the system is developed for one contractor and multi suppliers, this must be further investigated to support multi contractors and multi suppliers environment.

References
Barrie, D. S., and Paulson, B. (1992). Professional construction management, McGraw-Hill, Singapore.
CII, (1987). Project Materials Management Handbook, Construction Industry Institute, USA.
Dobler, D. W., and Burt, D. N. (1996). Purchasing and Supply Management: text and case, McGraw-Hill.

Kasturi, R. K. (1983). Design and development of purchasing information system, Research Studies Project Report, No. IE-83-6, Asian Institute of Technology

McConville, J. G. (1993). Managing Construction Purchasing: Contract Buyout, QA/QC Methods and Negotiation Strategies, R. S Means Company Incorporated.

Nwana, H. (1996). Software Agent: An overview, Knowledge Engineering Review Journal, Vol 11, 3, November.

Udeaja, C., and Tah, J. (2002). Intelligent Virtual Construction Material Supply Chain Environment, First International Conference on Construction in the 21st Century (CIT2002) Miami, Florida, USA, 25-26 April, 2002.

(a) Inputting Data in 'New Search' Interface

(b) Searching Result from Different Suppliers

(c) Filtering Attractive Offers by Supplier

1. Input purchase information

2. Select item information

3. Select

4. Results from different suppliers are promptly displayed with performance score, credit and additional condition

5. Select attractive offers from supplier

6. Summarized the selected materials according to supplier

7. Last update information for Printing PO

Figure 9. EPA Demonstration: Searching Material For Purchasing