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Multiagent Framework for Distributed and Global Purchasing*

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I. Introduction

For the sharing of business information, maintaining business relationships, and conducting business transactions by means of telecommunications networks, e-commerce is adopted. It includes not only buying and selling goods, but also various processes within individual organizations that support that goal. Thus, it involves using network communications technology to engage in a wide range of activities up and down the value-added chain both within and outside the organization. It can be classified as customer-to-business, business-to-business, and intraorganizational (Riggins and Rhee, 1998). As the increase of the internet-based business and e-commerce (Zwass, 1996], agent has been adopted to perform tedious and routine tasks instead of the user or principal. We mean agent as a software program which performs a given function automatically or semi-automatically by communicating with other computer agent, program or human agent (O'Leary et. al., 1997). Agents are programs that act on behalf of their human users to perform

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laborious tasks such as information locating, accessing, filtering, integrating, adapting and resolving inconsistencies. The external communication protocol takes HTML format, internal message handling requires SGML for document exchange. Agent has the capability to acquire information, to optimize the utilization of resources, to perform a difficult task by reacting independently and promptly for the changing environment.

With the growing number of information sources available all around the world, the problem of how to combine distributed, heterogeneous information sources become more important. The available information sources include knowledge bases, human expert's knowledge, databases, internet-based data, programs, etc. The concept of cooperative problem solving as the cooperative solution of problems by a decentralized, loosely coupled information sources, is described. Information sources cooperate in the sense that no one of them has sufficient knowledge to solve the whole problem. Decentralized means that both data and resources are logically and geographically distributed. The whole process can be divided into four phases: problem decomposition, sub-problem distribution, sub-problem solution, and synthesis of solution. A major motivation of the cooperative problem solving lies in the potential it offers for making available more problems solving power through a collection of distributed knowledge and information.

One problem is that when there are more than one active agent in the system, there is the possibility that their actions are in some fashion mutually interfering rather than mutually supportive. The conflict can happen in many ways. We may have conflict over resources, one agent may unknowingly undo the results of another, and the same actions may be carried out redundantly. Thus, the collection of agents may somehow fail to act as a well-coordinated, purposeful team. This problem is due to difficulty of obtaining coordinated behavior when each agent has only limited, and local knowledge. For these reasons, any distribution of problem solving effort appears to imply incomplete, local knowledge. It is not obvious how we can guarantee overall coordination from aggregations of actions based on local views with incomplete information.

The central element in a cooperative problem solving is the concept of negotiation. Negotiation means a discussion in which the interested parties exchange information and come to an agreement. The process is as follows: first there is a two-way exchange of information. Second, each party evaluates the information from their point of view. Third, the contractor submits a proposal and finally both sides agree with the condition and final decision is drawn. The negotiation process between a buyer and suppliers is shown in Figure 1. A familiar metaphor for a problem solver through a software agent is a group of human experts trying to complete a large task. The way how human experts solve a complicated problem is: (a) they interact to solve the overall problem, (b) the manner in which the task is distributed among them, and (c) how to synthesize the results. Thus, any one expert can not solve or control the whole problem.

Multiagent systems are the best alternative to characterize or design distributed problem solving. Agents communicate in order to achieve better goals. Communication can enable the agents to coordinate their actions and behaviors, resulting in systems that are more coherent. Coordination is a property of a system of agents performing some activities in a shared environment. Cooperation is coordination among friendly agents, while negotiation is coordination among competitive or simply self-interested agents. The issue in a multiagent system is how it can maintain global coherence (Huhns and Stephens, 1999). The agents must be able to determine goals they share with other agents, determine common tasks, avoid unnecessary conflicts, and pool knowledge and evidence.

This study proposes a multiagent-based framework for the order and supply management to be implemented in the global purchasing and manufacturing environment. Section 2 suggests a framework for agent-based purchasing mechanism and methodology. Section 3 discusses the multiagent system based on the distributed object. Section 4 shows a prototype of the system to be applied in a shoe making company. Section 5 discusses conclusions.

II. A Framework for Agent-Based Purchasing System

As mentioned in the previous section, the purchasing mechanism is reviewed as the process of solving a complex problem in a distributed environment. Purchasing is well positioned to help firms reduce cost and add more competition against their competitors. Global sourcing or worldwide sourcing is commonly used for improvement in cost and quality, gaining exposure to worldwide product and process technology, increasing the number of available sources, satisfying offset requirements and establishing a presence in foreign markets (Fawcett and Scully, 1998). In other point of view, the above mentioned problem is named as supply chain. The supply chain is defined as a world-wide network of suppliers, factories, warehouses, distribution centers and retailers through which raw materials are acquired, transformed into products, delivered to customers, serviced and enhanced. It should work in a tightly coordinated manner. However in real world, market situation works differently. Customers change or cancel orders, materials are delayed, machine breaks, production plan changes, or other situation changes. These events can not be handled locally meaning a single supply chain agent can not solve all the problems, rather requiring several related agents to coordinate and cooperate to cope with the complex problems. The purchasing and manufacturing activities follow a similar pattern with the manufacturing resource planning system. Production plan is related to the bill of material, and the material requirement planning. It generates an order and a procurement plan.

The main elements that guarantee competitiveness in the global sourcing are know-how, method, operating capability to control a series of supply chain. The needs for global sourcing are recognized as: (a) information technology to support part information and data for the global environment. (b) continuous cost reduction and reduction of product cycle due to the new product from competitors. (c) emphasis on the material cost as a managerial factor. (d) development of high quality part suitable for the quality management situation. (e) higher need for the national industry standard and the forming of economic block. (f) need for technology information for the multi item with small quantity (Bae et. al., 1998). The task required for the procurement stage in the global situations is summarized as Table 1.

Recently, most commercial internet applications focus on using the web to direct a company's marketing message to end customers. More companies have started implementing internet technology that might dramatically change relationships with their business partners. The business-to-business applications of internet technology are called extranets. This implies that intranet data are shared with those outside the organization, mainly suppliers, subcontractors or interested groups. A global purchasing system is composed of internet, intranet and extranet environment. In the intranet environment, all data and information is shared among the group members through the common database. Purchasing agent announces the list and specification of the items to be ordered through the internet to the global market. This information is shared among the employees in the company through intranet. Potential suppliers can receive the order schedule and prepare for the proposal using internet. The supplier agent can automate this process. Extranet is constructed between buyer and suppliers for regular business works. They send and receive data and information for the previous order. The characteristics among intranet, extranet and internet are compared in Table 2.

As an interaction protocol for cooperative problem solving among agents, the contract net protocol is most widely applied (Davis and Smith, 1983). It is modeled on the contracting mechanism used by businesses to govern the exchange of goods and services. The contract net provides a solution for the so-called connection problem: finding an appropriate agent to work on a given task. The system is composed of a manager and potential contractors. The roles of the manager agent are: to announce a task that needs to be performed; to receive and evaluate bids from potential contractors; to award a contract to a suitable contractor; to receive and synthesize results. The roles of contractors are: to receive task announcements; to respond with a decline or a bid; to perform the task if my bid is accepted; to report my results. The roles of agents are not specified in advance. Any agent can act either as a manager agent or a contractor agent.

The multiagent framework proposed in this research follows the basic ideas of contract net. The communication protocol enables agents to exchange and understand messages. The knowledge query and manipulation language (KQML) is a protocol for exchanging information and knowledge (Finin and Weber, 1993). The message protocol to interchange messages among agents is composed of three layers. The top level is the agent communication language layer, which specifies the basic parameters and format for the KQML. The middle is the message layer, which identifies the message protocol. The bottom layer is the content or product specification layer. The detail specification of the product and other conditions are described in this layer. There are both binary and n-ary communication protocols. A binary protocol involves a single sender and a single receiver, whereas n-ary protocol involves a single sender and multiple receivers. A protocol is specified by a data structure with five fields: 1) sender, 2) receiver(s), 3) language in the protocol, 4) encoding and decoding functions, 5) action to be taken by the receiver(s).

The term performative is used to identify the illocutionary force of the utterance. Illocution implies the intended meaning of the utterance by the speaker in the speech act. Examples of performative verb include *promise, report, convince, insist, tell, request,* and *demand.* The structure of KQML basic protocol and its application to the blocks-world ontology which implies block A is on top of block B could be represented as the Figure 2. The knowledge interchange format (KIF) is a formal syntax for representing knowledge. KQML messages can be nested in that the content of a KQML message may be another KQML message, which is self contained. Likewise, in the content layer, the details can be represented describing the tasks of receiving agents. An example of KQML protocol representing order performative from the purchasing agent to the supplier agent for the order of outsole in shoes is given in Figure 3.

The purchasing agent proposed in this study is composed of an user interface agent, a problem solver, a message controller, an address manager, a message gate and supplier agents. According to the production plan, a new purchasing order is processed through the user interface agent to the problem solver. The problem solver creates new message and finds solutions for the proposed problem. After creating new messages by interfacing with external database and knowledge, it communicates with the message controller. The message controller validates the correctness of the message based on KQML performative, revises and communicates with the address manager. The address manager finds and responds to the address of uniform resource locator from the suppliers database. In the message gate, the message is transformed into communication protocol, then transferred into supplier agent. The supplier agent replies information that satisfies the requirement to the message gate. The retrieved information is evaluated in the message controller and the process is repeated until no more incoming information is available. The whole process is shown in Figure 4.

III. Multiagent System based on Distributed Objects

In order to communicate between distributed objects, the corresponding node should be unique and the implementation object within the node should be identified. Thus, the existing agent system requires fixed internet protocol address or on-line network. In reality, as the small-to-medium sized companies do not possess their own internet protocol address, its not easy to transfer the message in the server into the client side. This problem can be solved using naming service which supports combined name and object reference from CORBA. CORBA specifies a way in which developers achieve seamless integration and interoperability of distributed objects. CORBA is composed of client, object implementation, and ORB (Object Request Broker) which is the core engine of the system. The client is the entity that wishes to perform an operation on the object and the object implementation is the code and data that actually implements the object. The ORB is responsible for all of the mechanisms required to find the object implementation for the request, to prepare the object implementation to receive the request, and to communicate the data making up the request.

Among the CORBA services, the naming service is adopted which collects object references in a single position in order to get object references easily. This corresponds to the telephone directory. The server can register objects name in the naming service in order to help the client find the distributed object with object name. The client acquires the object reference using registered name by accessing naming server. The naming service controls the registered object as a hierarchical tree-like structure which is called a naming graph. Figure 5-(a) shows an example of a naming graph for the human resource management in a company. The task of human resource is composed of staff and engineering department, where the latter contains support department. Each person in the naming graph has its unique compound name. For example, a person A in the department of staff has a compound name like company.staff.A. The naming service controls both the compound name and the object reference. The object reference is composed of ID number, IIOP (Internet Inter-ORB Protocol) version, IP address, port number, and object key. The relationship between compound name and object reference is shown in Figure 5-(b). While the naming service returns object reference to the client who wants to know the location of the objects by their name, the client communicates with the server using the returned object reference.

The OLE automation server is utilized to transfer the internet protocol data into the server side agent. The OLE automation server transmits necessary information to the server side just after the invocation from the client system. Server side agent communicates with the client system based on the information from the OLE automation server replacing the naming service of CORBA. In addition, the OLE automation server motivates the client agent automatically if needed.

In the proposed system, the client system (the OLE automation server) transfers message to the server component. The received message is stored in the database which overcome the instability of the network. Figure 6 shows the mulltiagent architecture using OLE server and ORB. Six agents are defined with the following functions. OLE automation server connects client and server agent by transmitting internet protocol address into the server and replies the status of the server. It receives messages from the server and notifies client users. Storage agent stores client data in the database. Monitor agent checks a meaningful change in the system, then transmit the message to the OLE automation server. Selection agent chooses suppliers. Negotiation agent controls and negotiates conditions when proposal is not satisfied. User agent helps the user to communicate with the other agent through the user interface. Figure 6 depicts the architecture of multiagent system using OLE server and ORB.

IV. Implementation Using A Prototype

The proposed system is implemented using a real world problem in a shoe making industry. The business process model for agent-based procurement in the company is described as: (a) the company designs and makes prototype for a new season item based on the sample request from the potential buyers. (b) the company gets purchasing orders from overseas buyers for the satisfied sample. (c) the bill of material is generated for each product. (d) the part procurement plan is generated. (e) the procurement list is generated, then it is posted in the internet. (f) potential suppliers review the procurement list, then submit proposal. (g) the purchasing agent evaluates the proposals based on the given condition. (h) supplier is selected and the result is posted through the internet. The process following the above mentioned procedure is shown in Figure 7. KQML is used as a software vehicle. For the database manipulation to read files from the server computer, Active Server Page (ASP) is adopted as a server side script.

The developed prototype is implemented for the global purchasing system in a shoe company. As the system is similar to the supply chain that acquires parts from the global open market, the interested parties need to register in advance. A description for a specific item to order is provided in separate format. All information required for supply is provided including due date, payment method, and decision criteria. When the information for potential suppliers are acquired through supplier agent, the result is updated automatically showing the number of registered companies for the given order number. Based on the decision criteria such as tolerance, supply price, quality standard, and failure rate, a company with highest total score is chosen finally. This procedure is similar with the multiple criteria decision making process.

The implementation test has been performed for selecting suppliers for the selected item in the following stage.

Stage 1. When the company plans a new production schedule, it transmits messages to the vendors using OLE automation server. The vendors receive specific conditions such as due date, suggested price, specification via user interface (UI) agent. This process is shown in Figure 8.

Stage 2. The outside suppliers or vendors considers whether they will attend the bidding. When decided for bidding, the items in the Figure 9 are filled and returned to the server.

Stage 3. When a specific company is not selected, the negotiation agent is activated. Then, negotiation is activated by modifying the given condition. Figure 10 shows the UI agent which is applied to the negotiation process.

Stage 4. After a company with the best condition is selected, production order is transmitted to the company. When the part is produced, the result is transferred to the database through ORB. In order to reduce errors in the database, the business rule is attached between storage agent and database. The production order agent is given in Figure 11.

V. Conclusions

A multiagent framework for an order and supply management is proposed in the global purchasing and manufacturing environment. The order and supply

process include a series of activity which occurs during the whole business process starting from purchasing a raw material to a finished product. The proposed system is implemented using ASP, KQML and CORBA for a shoe making company which is focused on global purchasing and overseas manufacturing. The test result shows a potential of cooperating agents that can be applied to the real-world supply chain management process. The expected benefits will be: reduced cost of real-time information exchange, realization of global manufacturing environment, the maximum utilization of internet for the enterprise data exchange, and the possibility of real world utilization of intelligent agent.

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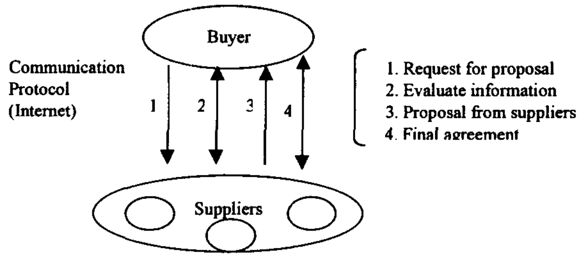
<Table 1> Main task for each procurement stage

Procurement stage	Main task
Suppliers sourcing	● Database sharing of part suppliers between headquarters, international purchasing agent, and manufacturers ● Promptness of sourcing information ● Selection and control of suppliers
Request for quotation	● Procurement cost control between suppliers ● Control of request proposal ● Control of proposed price
Negotiation	● Combined procurement ● Reduction of processing cycle ● Bargain power
Ordering	● Reduction of lead time ● Reduction of of paper work ● Productivity improvement
Delivery	● Delivery route ● Freight charge ● Delivery time

<Table 2> Comparison among intranet, extranet and internet

	Intranet	Extranet	Internet
Network	LAN	VAN, LAN + WAN	WAN
Users	Group members	Members and outside	Any
Information	Not public, Local	Partial open, Local	Open, Global
Purposes	Internal productivity Cost reduction	Customer service Cooperation	Market extension New project
Firewall	Required	Required	Optional
Agent	Groupware	Optional	Required



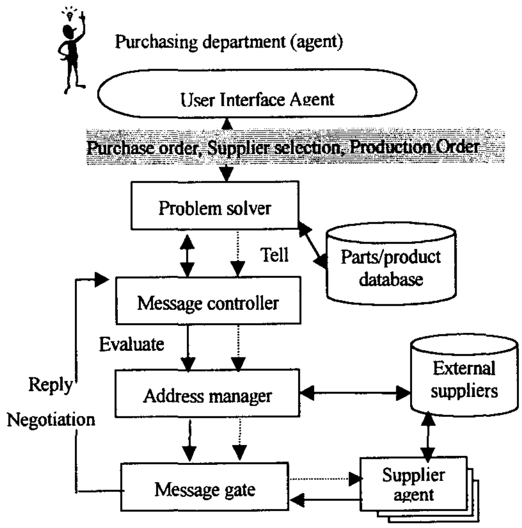
<Figure 1> Negotiation process between a buyer and suppliers

```
(tell
        :sender   Agent1
        :receiver Agent2
        :language         KIF
        :ontology Blocks-World
        :content  (AND (Block A) (Block B) (On A B))
```

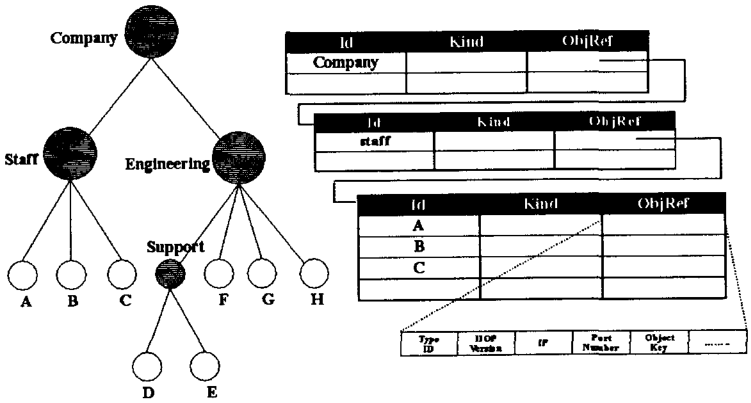
<Figure 2> KQML protocol representing block A is on top of block B

```
(order
        :sender   purchasing agent
        :receiver supplier agent
        :language         KIF
        :ontology outsole_order
        :content  (prod_num        BU0901CRCT1
                   due_date        99-11-20
                   price    5000W
                   delivery Haksan
                   carriage ground ))
```

<Figure 3> An example of KQML protocol representing order performative from the purchasing agent to the supplier agent for the order of outsole.

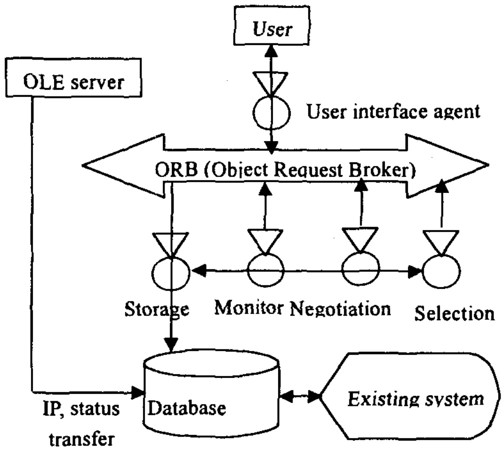


<Figure 4> The Structure of purchasing agent

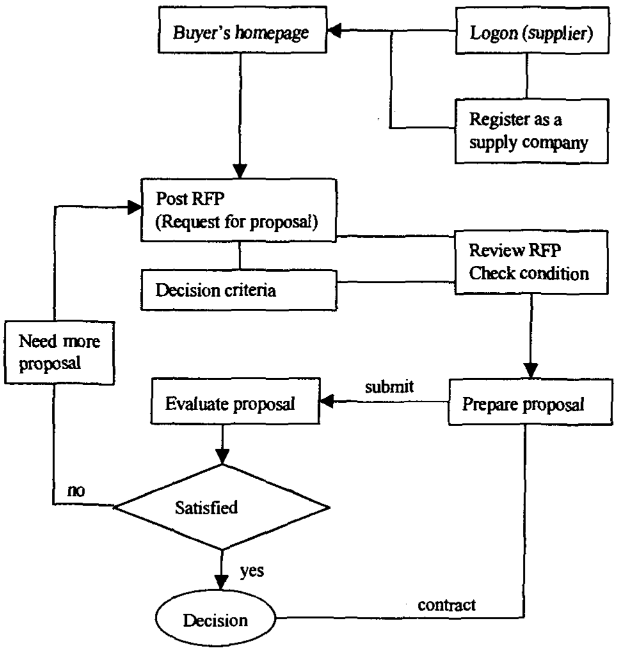


(a) Naming graph (b) Compound name and object reference

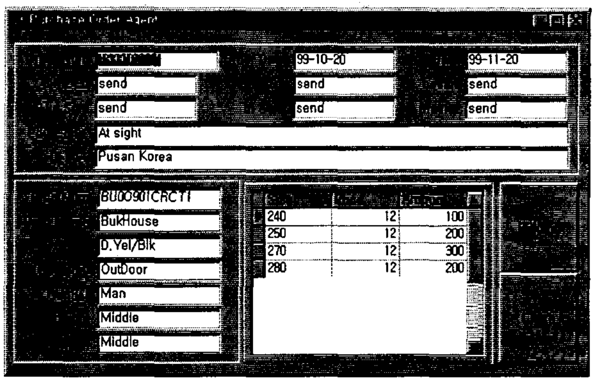
<Figure 5> Naming graph and object reference



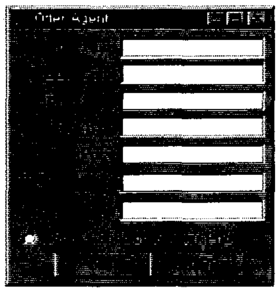
<Figure 6> Architecture of multiagent system using OLE server and ORB



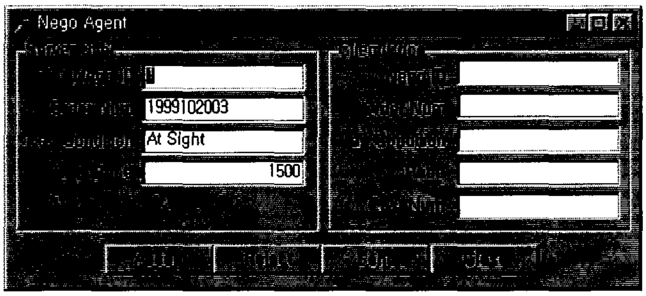
<Figure 7> Internet-based framework for the procurement activity



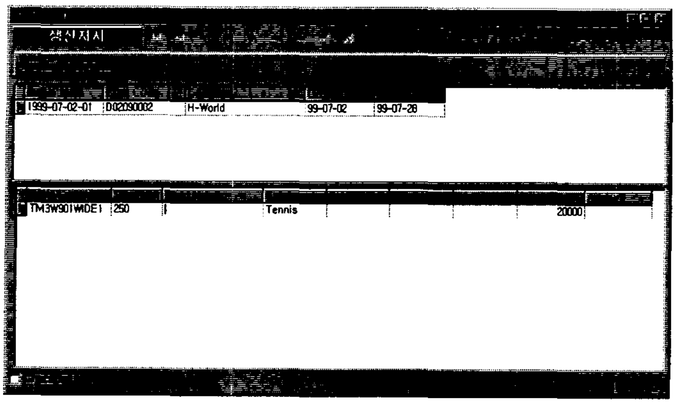
<Figure 8> UI agent showing purchase order



<Figure 9> UI agent showing the conditions of the bidding companies



<Figure 10> Negotiation agent used for negotiate with the suppliers to rediscuss the condition when the bidding was not satisfactory.



<Figure 11> Agent used for production order

<초록>

분산 및 글로벌 구매를 위한 멀티에이전트 설계

김 태 운 · 고 창 성 · 김 원 경

본 연구는 글로벌하고 분산된 환경하에서 다중 에이전트에 기반한 공급업자선정과 이를 통한 글로벌 제조를 위한 프레임웍을 구축하고자 하였다. 에이전트 시스템을 위해서는 KQML에 기반을 둔 메시지 전달 시스템에 근거하여 에이전트 통신 계층, 메시지 계층 및 내용서술계층으로 구분하였다. 또한 분산된 객체간에 클라이언트간의 통신을 위해서는 고정된 인터넷 프로토콜의 주소를 없어도 통신이 가능하도록 OLE automation 서버와 ORB 를 이용하여 시스템을 구축하였다. 시스템 구현을 위해서는 스포츠용 신발을 주로 수출하는 중소기업의 업무를 대상으로 하여 정해진 생산계획에 대하여 관련 부품을 생산 납품할 수 있는 외부 공급자를 선정하는 업무에 대하여 프로토타입을 만들어서 시험하였다. 네트웍 시설이 열악한 동남아 등지에 협력업체를 많이 보유하고 있는 한국의 섬유분야나 신발산업 같은 분야에 있어서 본 시스템의 활용 가능성이 기대된다.