# Applying Electronic Supply Chain Management Using Multi-Agent System: A Managerial Perspective

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**Abstract** *In the electronic business environment, supply chain management must deal with globalization, proliferating product variety, organizational barriers, and quick information sharing. Consequently, appropriate tools are needed to support supply chain management. We believe that software agents are good candidates to overcome these challenges. In this paper, I propose MASƏSCM, which is a Multi-Agent System (MAS) to support Electronic Supply Chain Management (E-SCM). The proposed model consists of a set of agents that are working together to maintain supplying, manufacturing, inventory and distributing. The main operations of the software agents include: (1) receiving information from customer orders (2) check the inventory (3) make the production schedule (4) issue the order of raw materials from the suppliers (5) receive the raw materials (6) production (7) deliver products to the customer. In addition to the interface agents and communication protocols among agents.*

**Keywords**: *E-business, E-Supply Chain Management, Multi-Agent Systems.*

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## 1. Introduction

Supply-chain management is concerned with planning and coordinating the activities of organizations from raw material procurement to finished goods delivery. In the new economy, effective supply-chain management is vital to the competitiveness of manufacturing enterprises because it directly impacts their ability to meet changing market demands in a timely and cost-effective manner [7]. With annual worldwide supply-chain transactions in the trillions of dollars, the potential impact of performance improvements is tremendous [16]. Although today's supply chains are essentially static, relying on long-term relationships among key trading partners, more flexible and dynamic practices offer the prospect of better matches between suppliers and customers as market conditions change. Adoption of such practices has however proven elusive because of the complexity of many supply-chain relationships and the difficulty in effectively supporting more dynamic trading practices [21].

The Internet and the World Wide Web have dramatically changed the business computing landscape. Now, new opportunities are emerging under the umbrella of E-business -- the execution of business processes with the assistance of Internet technologies [20]. Businesses that successfully embrace E-business will find a pathway to increased supply chain efficiency via intelligent supply chains, reduced cycle time and greater customer loyalty.

Electronic Supply chain Management activities and infrastructure consists of six processes [24]:

- E-Planning: Collaborative planning requires buyers and sellers to develop a single shared forecast of demand and a plan of supply to support this demand, and to update it regularly, based on information shared over the Internet.
- E-Replenishment: Supply chain replenishment encompasses the integrated production and distribution processes. Companies can use replenishment information to reduce inventories, eliminate stocking points, and increase the velocity of replenishment by synchronizing supply and demand information across the extended enterprise.
- E-Procurement: The use of Web-based technology to support the key procurement processes, including requisitioning, sourcing, contracting, ordering, and payment. E-procurement supports the purchase of both direct and indirect materials and employs several Web-based functions such as online catalogs, contracts, purchase orders, and shipping notices.
- E-Collaboration: Collaborative product development involves the use of product design and development techniques across multiple companies to improve product launch success and reduce time to market.
- E-Logistics: E-logistics is the use of Web-based technologies to support the warehouse and transportation processes. E-logistics enables distribution to couple routing optimization with inventory tracking information.
- E-B2B Exchange: The use of B2B exchanges in the e-supplys. Play a critical role in E-SCM, this role in what they call e-supplys. E-supplys

emerge as alternative configurations to the traditional supply chains.

Existing supply chain management systems, such as, Material Requirements Planning (MRP) and Enterprise Resource Planning (ERP) that integrate production, purchasing, and inventory management of interrelated products. Although such systems are useful in many cases, helping drive inventory levels down and streamlining portions of the supply chain, they failed in many cases [11]. One of such cases is the realization that schedule-inventory purchasing operations are closely related to financial and labour resources [8]. This realization resulted in an enhanced MRP methodology called Manufacturing Resource Planning (MRP II), which adds labor requirements and financial planning to MRP.

Enterprise Resource Planning (ERP) integrates the transaction processing and other routine activities of all functional areas in the entire enterprise. ERP initially covered all routine transactions within a company, including internal suppliers and customers, but later it was expanded to incorporate external suppliers and customers in what is known as extended ERP software.

The paper is organized as follows: Sections 1.1. and 1.2. discuss the related works in using agents in supply chain management. Section 2 presents the proposed model. The evaluation of the model is presented in section 3, while section 4 concludes the work and discusses the future work.

## 1.1. Related work

Using agent-based systems in managing supply chain is a promising task. The supply-chain activities are distributed to the agents. Researches in coordination of using multi-agent system in electronic supply chains can be categorized into five common areas: function-oriented, application, process-oriented, decision-making, simulation.

As a function-oriented, [9] developed a framework, with machine learning, for automated supply chain configuration, which used to be mostly a one-shot problem. Once a supply chain was configured, researchers and practitioners were more interested in means to improve performance given that initial configuration over time to take advantage of better configurations. They model each actor in the supply chain as an agent who makes independent decisions based on information gathered from the next level upstream, they show performance improvements of the proposed adaptive supply chain configuration framework over static configurations.

As an application, [2] presented an approach of an agent-based information and trading network (ITN) called CASA for dynamic production and sales of timber. The integrated services for logistics and e-commerce are efficiently coordinated by appropriate types of holonic structured intelligent agents of the network, they introduce the agent-based architecture and describe how the agents build their plans and optimize them afterwards.

As a process-oriented, [23] focus on the supply chain as a multi-agent system and propose a new coordination technique to reduce the -bullwhip effect- fluctuations of orders placed by each company to its suppliers and amplification of the demand variability in such a supply chain, they propose a technique based on tokens to achieve a decentralization that manages effects on company inventory due to variations of the demand.

As a decision-making, [2] put forth the viewpoint of applying agent technology to automate the coordination and decision-making tasks in a typical home PC industry supply chain. As for Simulation, [13] discussed the strengths and weaknesses of system dynamics for supply chain and discrete agent-based modelling. They presented an approach for integration of the two modelling methodologies. They discussed Issues concerning the practical coupling of software environments and a simple, prototypical supply chain model. They described Experiments for which the integrated simulation solution is applied. Insights in emergent structures in supply chains are derived from these simulation analyses.

The main features of the proposed approach, which differentiate it from other approaches, are the following: (1) In our prototype, the coordination agents have both cooperation and competition patterns; (2) It use JADE (Java Agent Development Framework) as the agent development environment to realize efficient and reusable agent software; (3) It produced some innovative models for the business processes and issues faced by parties in the supply chain. A prototype and the overall process flow is also described.

## 1.2. Multi-Agents in Managing a Supply Chain

Multi-agents can be introduced as a generic and reusable software components and interfaces, [5]. Using these components, developers can build on a high-level infrastructure, whose abstractions provide a conceptual framework that helps in designing and understanding agent systems.

Figure 1 shows such a conceptual framework. At the outermost layer, communication services allow agents to exchange messages composed from domain-independent communicative acts and domain-dependent content specifications. The next coordination level provides a full design of a coordination language (COOL) based on the conversation metaphor. Conversations can model peer-to-peer interaction in which autonomous agents make requests, volunteer

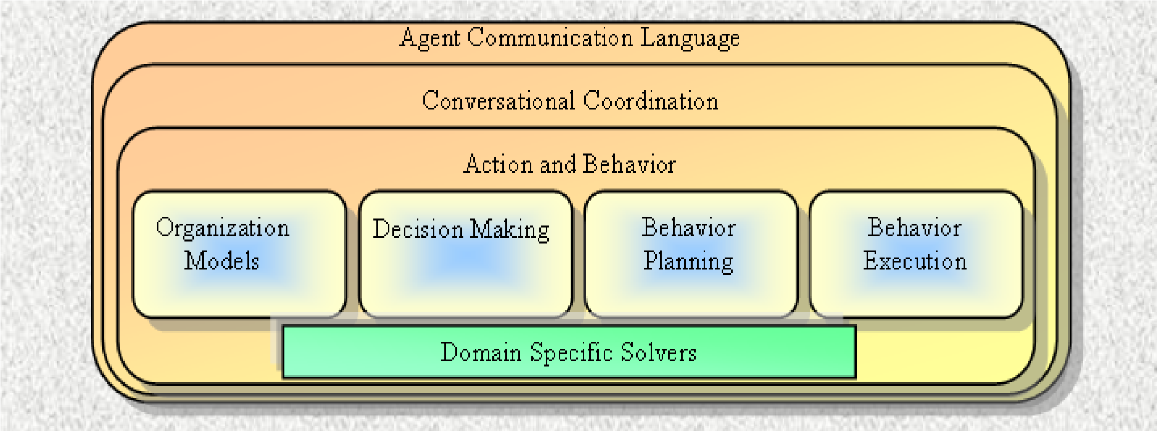


Figure 1. The conceptual framework

information, react to events, update their state, and so on [31]. Conversations express the shared conventions that stand at the basis of coordination and are used as the basic abstraction for capturing the coordination knowledge and social know-how.

The framework provides a full conversational ontology [15], containing conversation plans, conversation rules, and actual conversations, in terms of which complex interactions are described. An important extension deals with using decision-theoretic planning to make conversation more adaptive. Programming tools supporting conversational interaction also are provided, the most important being a tool for dynamic, on-line acquisition of conversation plans. The next layer of the framework deals with generic models of action and behaviour, the representation of obligations and interdictions derived from the authority of agents in the organization, the use of obligations in negotiation, and the ways in which agents plan their behaviour and execute the planned activities.

## 2. The Proposed Model

Multi-agent systems can be used as a very natural and powerful tool to model supply chain management. This proposed model uses multi-agent system to form a supply chain in a task dependency network. Agents have specialized capabilities and can perform only certain combinations of tasks or produce certain resources. In order to complete a complex task, an agent may delegate subtasks to other agents, which may in turn delegate further subtasks. Resource contention is used to constrain the set of feasible supply chain allocations and the optimal allocation is one of the feasible allocations that maximize the value of the supply chain such as the sum of total consumer value minus the total supplier cost. Agents negotiate through simultaneous, ascending auctions for each good or task to form a supply chain in the task dependency network. However, due to the computational complexity and the nature of distributed decision-making, the solution generated through agent negotiation may not necessarily be optimal.

The framework of this model has functional agents that are used to represent companies with their own interests and may join in, stay, or leave the system according to their own judgment. When an order arrives, a virtual supply chain may emerge from the system through automated or semi-automated negotiation processes between agents.

Technical speaking, I suggest using both Knowledge Interchange Format (KIF), and Knowledge Query Manipulation Language (KQML) as a message format and a message-handling protocol to support run-time knowledge sharing among agents [10]. I use KQML as a language for an application program to interact with an intelligent system while I use KIF as a computer-oriented language for the interchange of knowledge among heterogynous programs.

The agents are grouped according to their tasks, which uses ontology. For example, e-market ontology are used in search criteria such as clarity, coherence, extendibility, minimal encoding bias, and minimal ontological commitment this will give significant advantages of reducing the scope of the ontology.

The proposed model is intended to adapt to the changes in the environment. Agent descriptions provide an ability to specify both static and dynamic characteristics of various supply chain entities. The manager agent can be assigned to model a facility and relationships can be defined as links to connect these agents together, which could show the supply chain as a network of facilities.

The relationships among facilities pertain to how materials "flow" from suppliers to the plants, undergo transformation or assembly, transported to field warehouses or distribution centers, and finally reach the hands of customers. These relations can be represented in quantities of materials or products, in cost or scheduling of deliveries, etc.

As a result, I have a finite set of variables, each is associated with a finite domain, and a set of constraints that restrict the values of the variables can simultaneously take. Today's business environment engineers, so the analogy can be extended to distribute constraint optimization [27].

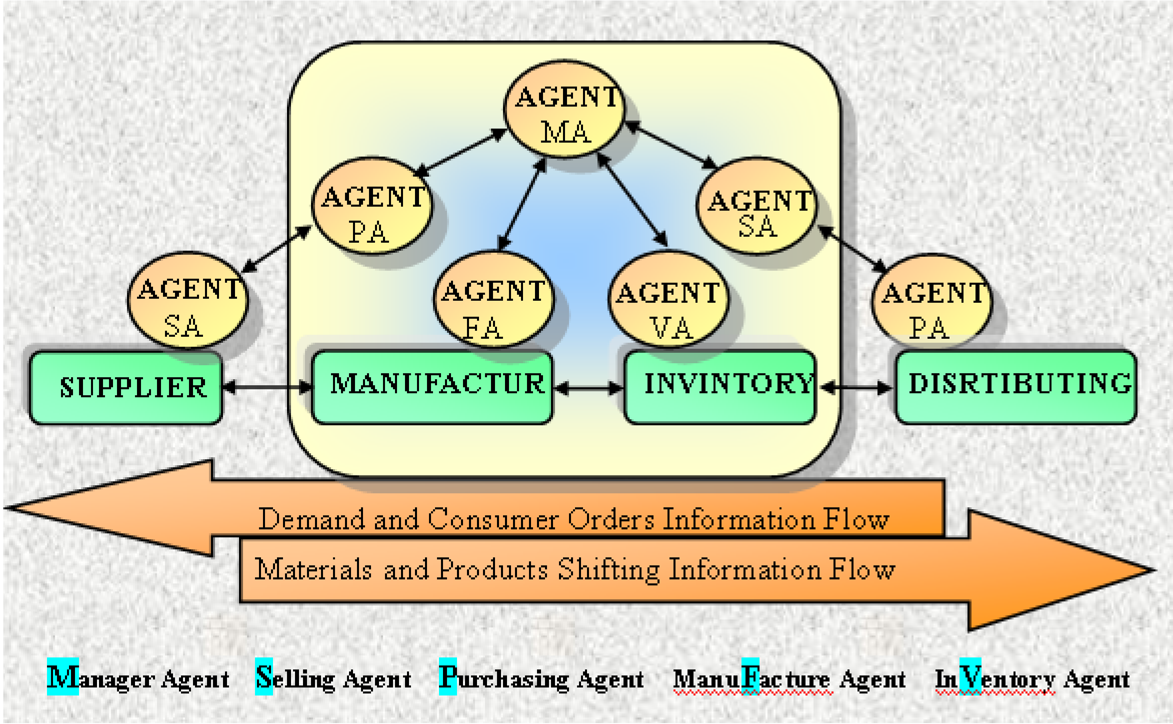


Figure 2. Framwork for E-SCM Model using MAS

When we zoom into each facility, a process can be decomposed into a set of sub-processes and each sub-process can be modelled by an agent. It is impossible to use one agent to model a large process, but a group, or a society, of agents can be a solution [18].

### 2.1. MAS-SCM Framework

Figure 2 shows the framework of MAS-SCM, which consists of various types of agents that implement some functionality of the supply chain management, called functional agents. All agents have some understanding of system ontology and use a certain Agent Communication Language (ACL) i.e., KQML to make conversation. The system ontology includes knowledge about the goods that the system is dealing with and interaction rules, e.g. the negotiation protocol used in the system.

In this framework, a number of information agents are predefined, which are in charge of providing different system information, a major task of an agent is to assign a value to each variable that satisfies all the constraints according to their own rules or orders from their owners. In addition to finding solutions for the constraint network, agents can be an interface between the manager agent and other agents. Therefore, each functional agent handles a specific problem.

Functional agents can be divided into five types: Selling Agent:(SA), Purchasing Agent (PA), Manufacturing Agent (FA), Inventory Agent (VA), Manager Agent (MA) and the role of these agents is as following:

- *Selling Agent (SA):* This agent contacts and interacts with many outside purchasing agents owned by distributors, retailers, customers, which contains the constraints for supply and maintain quote. In addition to receive orders and deliver products to customers.
- *Purchasing Agent (PA):* This agent contacts and interacts with many outside selling agents owned by suppliers, which contains the constraints for order management, fill orders and deliver materials to the manufacturer.
- *Manufacturing Agent (FA):* The agent controls the manufacturing process, which contains the constraints for monitoring the operation, production scheduling, and monitoring the quantity of raw materials.
- *Inventory Agent (VA):* The agent controls the inventory levels, which contains the constraints for monitoring inventory flow, acquire information from manager agent to calculate needed materials based on historical data for optimal reorder quantities, also determines inventory replenishment policy; generate delivery plan, and safety stock.
- *Manager Agent (MA):* The agent manages and controls all the above-mentioned agents. In the same time these agents are designed for providing system information. Manager agent use local Database that stores all related information.

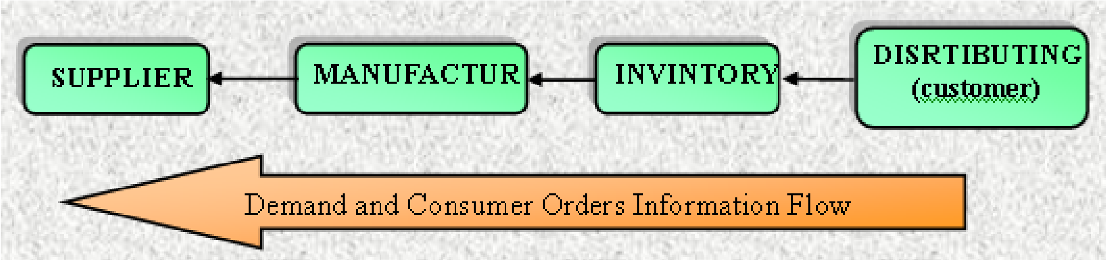


Figure 3. Forward information flow

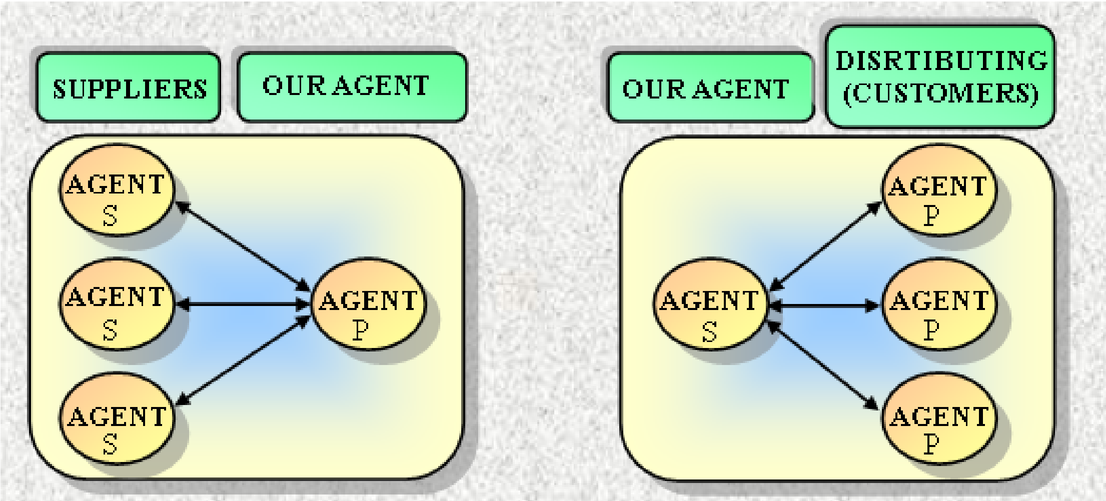


Figure 4. Communication between internal & external Agents

## 2.2. A Scenario

In this Model the flow of the information is bi-directional; forward and backward. Figure 3 shows the forward direction that starts at the customer, which could be a consumer, retailer or distributor.
The scenario, suggested here, takes the following steps:

- A number of customers, who exactly need the same products that our firm produces, start searching the web to find our Purchasing Agent (PA).
- Negotiation will occur between our Selling Agent (SA) and many Purchasing Agents (PA) until one deal takes place, and a certain customer decides to buy from our firm. Figure 4 illustrates how SA communicates with PA.
- The Selling Agent (SA) receives an order from Purchasing Agent (PA).
- Selling Agent (SA) passes the order information to the Manager Agent (MA).
- Manager Agent (MA) passes the order information to both the Manufacturing Agent (FA) and the Inventory Agent (VA).
- Manufacturing Agent (FA) checks the ability to accomplish the order, decide the production plan, make the scheduling, and inform the Manager Agent (MA).
- Inventory Agent (VA) checks the requirements of raw materials and inform Manager Agent (MA).
- Manager Agent (MA) decides to purchase our needs of raw materials, and pass the information to our Purchasing Agent (PA).
- Negotiation will occur between the Purchasing Agent (PA) and many suppliers' Selling Agents (SA) until one deal takes place. The Purchasing Agent (PA) decides to buy from a specific supplier. Figure 4 illustrates how the PA communicates with multi suppliers' SA.
- Purchasing Agent (PA) sends the specific suppliers' Selling Agents (SA) the required order.

The other direction, which is backward direction, starts at the supplier. The supplier accomplishes our order and sends it back to our firm as illustrated in figure 5.
The scenario, suggested here, takes the following steps:

- Supplier's Selling Agents (SA) accomplishes our order and confirms the order to the Purchasing Agent (PA) with the date and place of delivery of the raw materials.
- The Purchasing Agent (PA) passes the order delivery information to the Manager Agent (MA).
- Manager Agent (MA) passes the order delivery information to both the Manufacturing Agent (FA) and the Inventory Agent (VA).
- Manufacturing Agent (FA) decides the production schedule to accomplish the order and decides the production plan. The Manager Agent (MA) will be informed about these activates.

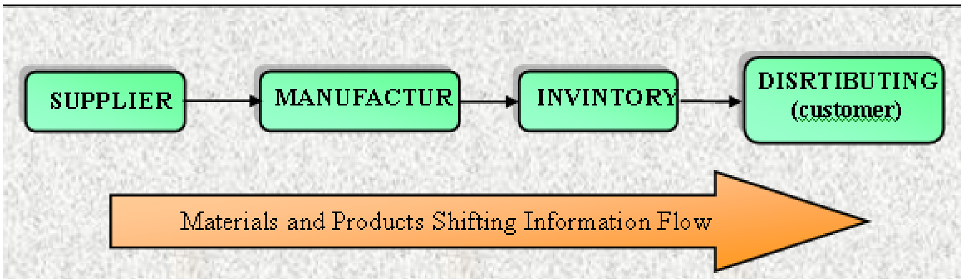


Figure 5. Backward information flow

- Inventory Agent (VA) checks the ability to deliver the raw materials from the supplier and the time that the finished products of the customer order will be ready to deliver and inform Manager Agent (MA).
- Manager Agent (MA) decides the time and the shipping address to deliver the customer's complete order and then pass the information to our Selling Agents (SA).
- The Selling Agents (SA) passes the information of the time and the shipping address to deliver the order to the customer's Purchasing Agent (PA).

## 3. Evaluating MAS-SCM:

In this section, I evaluate MASƏSCM. I assume that our firm produces one product, one warehouse located in the firm, and the firm deals with one tire distributing and production equation, i.e., 1:1 relationship. This means that every one finished product requires one raw material. This uses the following variables (listed in table 1):

The initial value of all variables will be zero, and during the process all the received values will instantly stored in the local database. After each transaction, an update will take place automatically. Figure 6 shows how agents are communicating with each other to accomplish the firm mission of selling and buying. I assumed random values to the following variables (Pf, Pr, Qfx, Qrx, and Tx). Also, I assume the negotiation between SA agent and many potential customers PA agents signed a value to the following variables as shown in table 2 (Qfy=25, Ty=35, Py=9), which means that the customer wants to buy 25 items from our products with price no more than 9/every one item and to delivered no more than 35 days.

These values will be submitted to the MA agent, then communicate with FA and VA agents to calculate the value of (Q=10) & (T=30). This is the quantity of raw material and time required to accomplish the potential customer order, which means that we have 5 finished products in our inventory and need 20 raw materials, 10 of them already in our inventory and the other 10 will be purchased from the suppliers.

Table 1. Variables used in MAS-SCM

| Variable | Description and constraints and formulas | Unit |
|---|---|---|
| **P**<br>**Pr**<br>**Pf**<br>**Py**<br>**Pz** | **Price**<br>**Our deadline price for buying raw materials from suppliers.**<br>**Our deadline price for selling finished products to customers.**<br>**Customer desire price for our finished products.**<br>**Supplier price for raw materials, which we need to buy.** | **$** |
| **Q**<br>**Qf**<br>**Qr**<br>**Q**<br>**Qrx**<br>**Qfx**<br>**Qfy**<br>**Qrz** | **Quantity.**<br>**Qf=Qrx-Qr**<br>**Qr= Qf*S**<br>**Q=Qfx-Qfy**<br>**Our inventory level of raw materials.**<br>**Our inventory level of finished products.**<br>**Customer need of our finished products.**<br>**Supplier available for raw materials, which we need to buy** | **Piece** |
| **T**<br>**T**<br>**Tx**<br>**Ty**<br>**Tz** | **Delivery Time estimated.**<br>**T=Tx+Tz**<br>**Our estimated time to manufacture the finished products.**<br>**Customer desire time need his order to be delivered.**<br>**Supplier available time for deliver raw materials.** | **Day** |
| **S**<br>**1:1** | **Production equation, we assume it in our model(1:1)**<br>**Mean that every one finished product require one raw material.** | **Percent** |
| **D** | **Decision If T=<Ty & Q=<Qrz & Pf=<Py & Pr=>Pz then D=Yes, else D=No**<br>**Yes: (execute) accept the customer order, send order to supplier.**<br>**No: (denied) cancel the operation.** | **Boolean** |

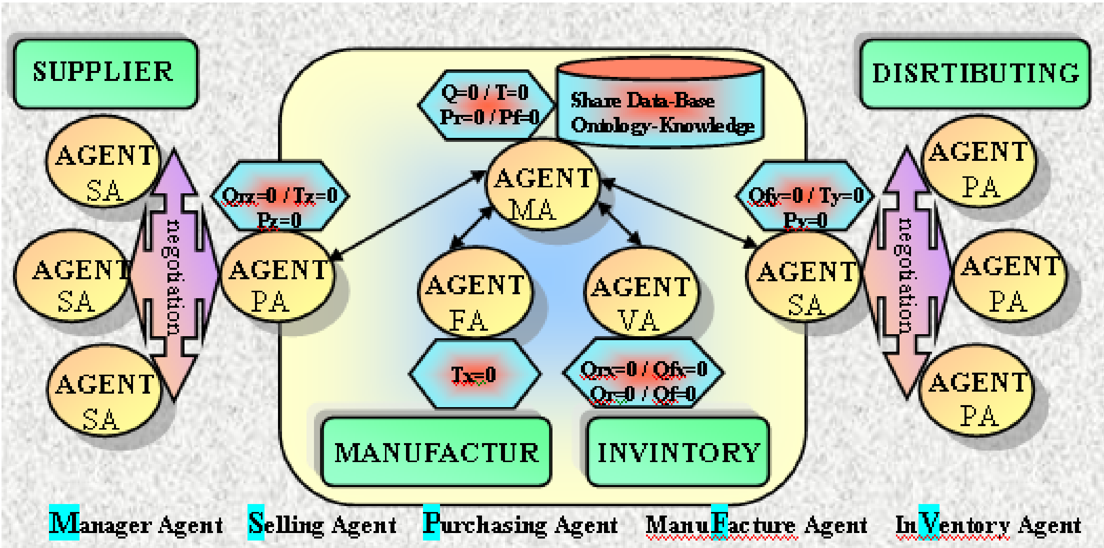


Figure 6. Framwork of example E-SCM Model using MAS

Table 2. Results from processing the model

| Process | S | P | | | | Q | | | | | | | T | | | | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pf | Pr | Py | Pz | Qfy | Qfx | Qrx | Qf | Qr | Q | Qrz | Ty | Tz | Tx | T | |
| 1 | 1:1 | 9 | 5 | 9 | 6 | 25 | 5 | 10 | 30 | 20 | 10 | 10 | 35 | 10 | 20 | 30 | N |
| 2 | 1:1 | 9 | 5 | 12 | 4 | 35 | 5 | 10 | 30 | 30 | 20 | 20 | 35 | 20 | 20 | 40 | N |
| 3 | 1:1 | 9 | 5 | 10 | 5 | 25 | 5 | 10 | 25 | 20 | 10 | 10 | 35 | 10 | 20 | 30 | Y |

The MA agent tells the PA agent to start negotiation with many suppliers available looking for buying Q items in T time. This will be converged until the assumed value from supplier (Qrz=10, Tz=10, Pz=6) is achieved and passed to the MA agent.

The MA agent uses the formulas that compare values (e.g., either Y or N) then passes the decision to the SA agent. In this example, the decision of first process is NO, since one of the conditions (the price) has not been satisfied. (No supplier agreed to provide us the product with price =<5). Eventually, the SA agent makes action by canceling the operation with potential customer. In case of process (3) all conditions when compared were fit with our values, then the decision was YES which mean execute the consumer order.

## 4. Conclusion and Future work

Most researches on Multi-Agent Systems for Electronic Supply Chain Management are still in the early stage of theoretical framework or demonstrative prototyping.

In this paper, I have reviewed the recent trends of supply chain management in the electronic commerce core including the using of multi-agent system technology. I have suggested MASəSCM, which is a multi-agent technology that can be used to support the collaboration and coordination required to apply electronic supply chain through using. MASƏSCM consists of a set of functional single agents that support supplying, manufacturing, inventory and distributing. Functional agents and interface agents were developed to coordinate the operation.

There are some directions for future research. First, determining the tasks of each functional agent. Second developing a standard ontology designed for multi-agent system. Third, developing a standard agent-based language that could be applied within common internet-based protocols.

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