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Abstract

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Keywords

Collaboration, Supply, Chain, Multi, Agent, Approach

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Collaboration in supply chain: a multi-agent approach

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Abstract:

Supply chain collaboration has become a critical success factor for supply chain management. Supply chain collaboration builds on information sharing, collaborative planning and execution. Many information systems have been developed for supply chain management. However, these systems do not sufficiently support collaborative supply chain. Recently, intelligent agent technology has received a great potential in supporting transparency in information flows and modeling the dynamic supply chain for collaborative supply chain. This paper explores the similarities between multi-agent system and supply chain to investigate the appropriateness of multi-agent based technology to model supply chain system and support collaborative supply chain planning and execution. In addition, the framework of the multi-agent-based collaborative supplychain management system will be presented.

Keywords

Supply Chain Management, Supply Chain Collaboration, Information System, Agent Technology and Multi-Agent System

1 INTRODUCTION

Supply chain management (SCM) represents a critical competency in today's fast-paced, global business environment. The collaboration of supply chain has become a critical factor for the SCM and effectively improved the performance of organizations in various industries. It is generally believed that the collaborative planning and execution within and between different firms in the supply chain can enhance customers' satisfaction, reduce cost, improve efficiency and minimize overall risk, thus maximizing profitability. Collaboration and coordination of the activities among supply chain participants is one of the critical challenges in the management of the supply chain, which consists of autonomous and semi-autonomous entities with different and even conflicting organizational objectives. The successful implementation of supply chain collaboration requires effective support of advanced information technology and information system. Many information systems have been developed for the SCM from electronic data interchange (EDI) and enterprise resource planning system (ERP) into the newly developed advanced planning and scheduling system (APS) and e-business solution. However, the capability of these systems to support supply chain collaboration is limited due to the complexity and dynamics of the supply chain. Recently, agent-based system and technology have been applied as a new paradigm for conceptualizing, designing and implementing the software system, which offers the potential to overcome many limitations of current information systems for the SCM. The aim of this paper is to investigate the appropriateness of multi-agent based technology to support collaborative supply chain planning and execution. The remainder of this paper is organized as follows. First, supply chain and supply chain collaboration will be discussed in section two. Then, the roles and limitation of current information systems in the SCM will be discussed in section three. In section four, the characteristics of agent technology will be elucidated and the similarities between supply chain system and multi-agent system will be analyzed. Finally, the framework of multi-agent-based supply chain collaboration will be presented.

2 SUPPLY CHAIN AND SUPPLY CHAIN COLLABORATION

A supply chain can be referred as a network consisting of autonomous or semi-autonomous entities such as suppliers, warehouses, manufacturers, wholesalers, and retailers. It involves constant flow of information,

materials and funds across multiple functional areas both within and between supply chain participants (Chorpa & Meindl 2004). The objective of the SCM is to manufacture and delivery the right products to right segmented customers in the right quantities, to the right locations, at the right time, with minimized overall costs while satisfying service level requirements (Simchi-Levi et al. 2003). Today, the key to genuine business growth is to emphasize the creation of an efficient and responsive supply chain. An efficient supply chain (push style) emphasizes cost reduction by using forecasting technology and economic of scale while a responsive supply chain (pull style) focuses on the ability to match supply chain demand and thus concentrates on service levels (Simchi-Levi & Simchi-Levi 2001). The supply chain strategies have evolved from push to pull strategy, and finally to push-pull strategy. Push-pull supply chain is a strategy that allows the supply chain partners to achieve both objectives of cost reduction and responsiveness. However, the push-pull strategy requires much closer relationship between supply chain participants and it cannot be implemented successfully without the collaboration between and among various supply chain partners.

Supply chain collaboration is now a cornerstone of high performance in supply chain. According to Quinn (2001), it is believed that whether or not a company can effectively collaborate with the upstream and downstream supply chain participants has become a core business competency. Collaboration builds on three basic paradigms: sharing information, collaborative planning and execution (Simchi-Levi 2001, Gattorna 2000, Bowersox, et al. 2002). Information sharing is the basic level of collaboration in which supply chain partners share information about demand, inventory level, and promotional activities. It is recognized that only sharing information on historical or accurate sale data is not enough. Of greater importance is to share strategic information about future activities to facilitate collaboration. Collaborative planning and execution is the main content of supply chain collaboration.

It is clear that these collaborative activities between firms that integrate processes can provide information visibility across internal functions and organizations, which can reduce the bullwhip effect (Lee et al. 1997, Yu et al. 2001, McCullen & Towill 2002). Also, the collaborative planning can better match supply and demand, reduce inventory risk and increase movement velocity. Furthermore, collaboration can enable corporations to improve mutual trust and interdependence, and to focus on their own core competencies. Based on a survey results it has been shown that an effective collaboration in supply chain can lead to financial and non-financial benefits (see Table 1), which in turn, offers competitive edge over other supply chain (Mentzer et al. 2000). In another study conducted, it has been shown that large manufacturers and retailers can generally benefit significantly from superior collaboration with downstream and upstream supply chain partners (Matchette & Seikel 2004). Table 2 summarizes the benefits that can be gained by the manufacturers and retailers with superior collaboration in the SCM. Therefore, more and more organizations have focused on collaboration and coordination in supply chain management in order to achieve these competitive advantages. However this complex coordination and information sharing between organizations require effective support of information technology and system.

Financial benefits	Reduced inventory; Improved customer satisfaction; Shorted lead-time; Faster speed to market of new products; Improved shareholder value
Non-financial benefits	Increased sharing of information and data; Enhanced public image; Stronger focus on core competencies; Greater trust and interdependence among the supply chain participants

Table 1: The financial and non-financial benefits from effective supply chain collaboration (Mentzer et al. 2000)

Manufacturer:	Reduce Transportation cost	10%
	Reduce Warehousing cost	13%
	Reduce Inventory level	30%
	Shorten lead time	50%
	Enhance customer service	10%
Retailer:	Raise store-shelf stock rates	5-8%
	Reduce inventories by an average of	10%
	Reduce logistics cost	3-4%

Table 2: Superior collaboration can help manufacturers and retailers (Matchette & Seikel 2004)

3 INFORMATION SYSTEMS IN SUPPLY CHAIN MANAGEMENT

Collaborative supply chain management such as information sharing, collaborative planning and execution between organizations require effective support through advanced information technology. Information technology, as an important enabler of effective supply chain management, consists of tools used to collect, organize, access, share and analyze the information, and act on it to improve the performance of the supply chain. Over the last decade, various information systems have been developed to support the SCM from early less sophisticated legacy systems to the ERP systems, then to the more advanced SCM systems such as the APS. However, inter-organizational coordination and collaboration increasingly require more effective information technology support and are usually not covered sufficiently by traditional information systems such as the legacy systems, ERPs and APSs (Yuan et al. 2001, Hillegersberg et al. 2004). More often than not, current information systems that support the components in the supply chain process are developed by different vendors and are generally disconnected. Typically, these systems have evolved over the years based on various local and company-wide requirements and were rarely integrated (Erasala et al. 2003). Disparate IT systems and lack of integration and collaboration make it impossible for many corporations to support the required responsiveness and capability demanded by customers (Puckridge & Woolsey 2003). Although the more recently introduced E-markets and E-hubs also aim to support inter-organizational coordination, their success has been limited. They mainly provide the platform of connectivity, information exchange and support for trading between companies in a network.

Legacy system:

The problem of integrating with legacy systems was viewed as one of the major challenge and inhibitors to new IT development (Erasala et al. 2003). Legacy systems evolved as functional solutions using mainframe or minicomputers. In the past, mainframe-based legacy systems were applied to support transactional processes within one specific function such as order entry, inventory control and accounting. These transactional processing systems were isolated and implemented with incompatible hardware and software. These system lacked integration across functional areas even within a single company (Yuan et al. 2001). Nowadays, in spite of extensive investment in state of the art application software, many firms are still dependent on legacy systems for mission-critical applications (Erasala et al. 2003).

ERP:

The ERP system facilitates the flow of transactional data in a company relating to manufacturing, logistics, finance, sales and human resources. It mainly focuses on providing the visibility of information within the enterprise and the automation of business processes. It offers the promise of homogeneous, transactional data that can facilitate integration of functional areas within the enterprise at the operational level (Taylor 2004, Simchi-Levi et al. 2003). The ERP mainly focuses on collecting, organizing, accessing, and sharing the information within the enterprises, rather than focusing on analyzing data and information to make decision. Although some ERP vendors have begun to address this issue and add more planning modules, it remains focusing on scheduling individual production facilities and not the entire networks of facilities operating in collaboration. The ERP offers two main benefits that do not exist in non-integrated departmental systems: an enterprise-wide view of business encompasses all functions and departments; and an enterprise-wide

database, in which all business transactions are recorded, processed, accessed, monitored and reported (Umble et al. 2003). Due to the fact that the information processes across functional areas within the enterprise are now integrated, it provides a much better base for inter-enterprise cooperation. However, since the major focuses of ERP are limited to intra-enterprise operation, these systems lack support for inter-enterprise collaboration in the SCM (Yuan et al. 2001).

APS:

Faster and easier access to transactional data does not automatically leads to better decision-making and competitive edge in the SCM (Shaprio 2001). The APS system, such as production scheduling, forecasting, and supply chain network optimization systems, is a powerful tool for effective supply chain planning. It provides analytical applications to optimize the use of supply, manufacturing, distribution, and transportation resources to match the demand. It can be used to tackle strategic, tactical and day-to-day operational problems (Simch-Levi et al. 2003). It uses sophisticated algorithms and relies on inputs of transactional data collected from the legacy or ERP systems (Chopra & Meindl 2001). It is worthwhile pointing out that developing an integrated supply chain information system may requires that all systems to be re-developed into a monolithic integrated system capable of handling all foreseeable scenarios for planning and execution. However this is regarded as not feasible due to the high development and maintenance cost, not to mention the inflexibility of such a system. What is viewed to be more important is to integrate analysis with the ERP system to allow collaboration to be achieved among various partners in the SCM (Yuan et al. 2001).

E-commerce:

E-commerce is promoted by the rapid growth of Internet and web technology, which has provided a great potential for networking and interaction between business and consumer (B2C) and between business partners (B2B). It encompasses the electronic buying and selling transactions between organizations, named as E-procurement (Neef 2001, Swaminathan & Tayur 2003). It can be applied to set up E-marketplaces and E-hubs for online biding and auctions for business competition (Neef 2001, Emiliani 2000, Swaminathan & Tayur 2003). Moreover, E-commerce offers not only the solutions required for inter-company transactions but also the standards that will facilitate connection and communication among corporations (Berger 2003). However, in spite of the fact that E-commerce has improved the supply chain visibility through information sharing and the coordination between buyers and sellers through the Internet, the new technology is still needed to support for high-level knowledge sharing (not just transaction data) and facilitate more robust collaboration (not just simple buy and sell models) (Yuan et al. 2001)

In summary it is clear that inter-organizational coordination and collaboration were not sufficiently achieved by traditional information systems. The successful supply chain collaboration requires more effective information technology supports. Recently, intelligent agent technology and multi-agent systems have shown great promise in supporting collaboration in supply chain management, particularly in supporting transparency in information flows and modeling of the dynamic supply chain for collaborative supply chain planning (Iskanius et al. 2004, Xue et al. 2005). In addition, intelligent agent technology offers the potential to overcome many limitations of current supply chain technologies and offers new means and tools for collaborative supply chain management (Gutpa et al. 2001, Frey et al. 2003).

4 SUPPORTING SUPPLY CHAIN COLLABORATION BY USING AGENT TECHNOLOGY

There is no universally accepted definition of the term of agent. According to Wooldridge and Jennings (1995), an agent is a self-contained software program capable of controlling its own decision making and acting based on its perception of its environment, in order to gain one or more goals. The agent has the following main behavior attributes autonomous, cooperative (social), reactive, proactive, and learning (Wooldridge & Jennings 1995). Being autonomous means that agent can act without intervention by other entities (humans or computer systems), and exercising control over one's own action/algorithms. Agents can interact with other agents (or possibly humans) via some kind of agent communication language (social). To be reactive means that agents can perceive the environment around itself and are able to respond in a timely fashion to changes in the environment (reactive). In addition, agents do not simply act in response to the environment but are parts of a more complex goal-oriented behavior (proactive). Also, agents can change their behavior based on their previous experience (learning).

A multi-agent system is one that consists of a number of agents that take specific roles and interact with one-another to solve problems that are beyond the capabilities or knowledge of any individual agent (Wooldridge 2002). These interactions can vary from simple information interchanges, to request for particular actions, and on to cooperation, coordination and negotiation in order to manage interdependent activities (Jennings 2000). The interaction and coordination are the core process of a multi-agent system (Lee et al. 2004). According to Jennings & Wooldridge (2002), agent technology and multi-agent system can be used to develop highly complex systems. Paranak et al. (1998, P.24) claimed, "...agent-based modelling is most appropriate for domains characterized by a high degree of localization and distribution and dominated by discrete decision..." Supply chain system is a large-scale complex system. Decentralisation, collaboration and intelligence are its essential characteristics. The greater details of the similarities of the nature of these two systems are shown as follows:

Firstly, individual agent has incomplete information, knowledge or capabilities to solve the problem and thus has a limited viewpoint. Data, information and knowledge are in distributed agents (Jennings et al. 1998). In addition, different agents also have the different core functionalities that play the different roles in the multi-agent systems. MAS can solve problems that are beyond the capabilities or knowledge of any individual agent (Wooldridge 2002). The supply chain network has the same characteristic. A supply chain consists of multiple autonomous participants that play the specific roles along the supply chain (Chopra & Meindl 2004). Each supply chain participant has its own resource, expertise, capabilities and capacities. It performs certain tasks and roles in making the products that conform to customer requirements (Simchi-Levi 2003). Different supply chain participants have different core competency. An individual supply chain participant cannot solve all the tasks in the supply chain.

Secondly, there is no system global control in a multi-agent system. A multi-agent system consists of different autonomous agents can play different roles and functions in the system (Jennings & Wooldridge 2002). Each agent responds on its own to monitor changing environment, proactive to take self-initiated action, and behave socially to interact and communicate with other agents. In most cases there is no single authority in the supply chain. Usually, the different functions belong to different companies in a supply chain. A single company cannot govern or control the whole supply chain performance. The supply chain participants are autonomous. They have the authority to implement different supply chain strategies and take certain actions in response to the changing markets.

The third similar characteristic is collaboration and coordination. In fact coordination is the core process of the multi-agent system (Lee et al. 2004). In a multi-agent system, each agent attempts to maximize its own utility while cooperating with other agents through negation and cooperation to achieve their overall goal (Jennings 2000). In a supply chain, dfferent supply chain participants may have different and conflicting objectives (Chopra & Meindl 2004, Simchi-Levi et al. 2003). To optimize performance and achieve the whole system optimization, the supply chain participants must work in a coordinated and collaborative manner (Lau et al. 2004). In the collaborative supply chain, decision-making is through multi-party negotiation and coordination in order to minimize the total cost and maximize the total supply chain profitability while meeting the customers' needs.

Finally, the structure of the multi-agent system is re-configurable. It supports handling of dynamics and is capable of making a quick response to the changing environment (Persson & Davidsson 2005). Multi-agent system is flexible. Agents in the multi-agent system can be organized according to different control and connection structure and agents can be created or discarded. In addition agents can delegate its task to other agents and coordinate other agents to form a higher-level system (Jennings 2001). The supply chain is a dynamic system and the relationship among different participates can evolve over time (Simchi-Levi et al. 2003). The supply chain participants may join or quit the supply chain. Therefore, the structure of the supply chain is flexible and is responsive to the changing environment. The structure of the supply chain can be organized differently when implementing different strategies according to different environment and business goals. Also, tasks in supply chain can be decomposed into subtasks, or multiple tasks can be composed to form a large task.

Therefore, it can be seen that supply chain system has many similarities with the characteristics of Multi-agent system. Thus it is reasonable to apply the multi-agent system to model the supply chain network and process, and to implement supply chain management applications. In fact, multi-agent systems involving

multiple agents with distributed knowledge and information are well suited for analysing coordination problems in supply chain management (Bond & Gasser 1988).

5 FRAMEWORK OF AGENT-BASED SUPPLY CHAIN COORDINATION

In this section, we will present a framework of agent-based supply chain coordination and collaboration management system. The collaborative supply chain is analysed in the context of a typical multi-national corporation scenario. The proposed framework focuses on the coordination of manufacturing and distribution functions. The supply chain network consists of several manufacturers, distributors, suppliers and logistics service providers (see Figure 1).

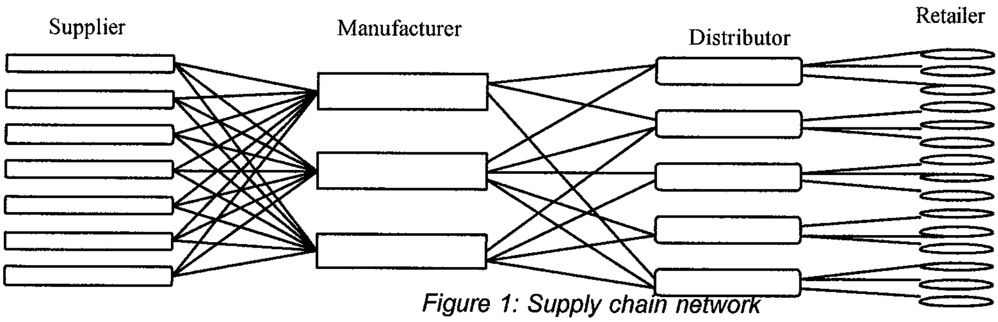

Figure 1: Supply chain network

In the framework of a multi-agent based supply chain coordination system, there are several agents involved: function agent, coordination agents, communication agent, and monitoring agent (Showed in figure 2). Coordination agents, communication agent and monitoring agent are designed to accomplish the manufacturing and distributing tasks in the multi-national enterprise together with existing planning and execution software (function agent). We will discuss the roles and functions of each of these agents in the proposed supply chain coordination system.

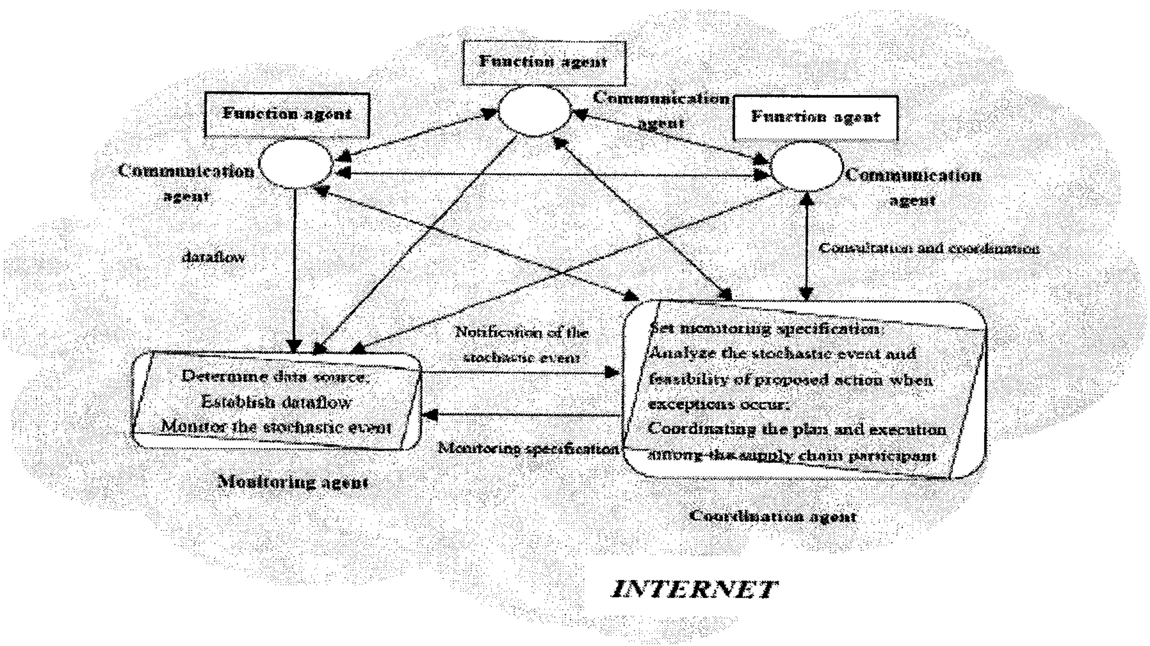

Figure 2: Framework of a multi-agent based supply chain coordination system

1) Function agent: Function agent is a set of existing and separate application software that are used by the distributors, manufacturers as well as by the logistics service providers. These application software

are utilized in different part of planning, scheduling, and execution processes such as capacity analysis software, ERP, manufacturing execution system forecast software and so on.

2) Coordination agent: Coordination agent is designed with specified expertise, knowledge and coordination mechanism to coordinate the activities among agents in order to minimize enterprise-wide cost or maximize profitability of the whole supply chain system. Coordination agent may link to the communication agent, monitoring agent and function agent to get the necessary information. The coordination agent is further classified into distribution coordination agent, manufacturer coordination agent and transporter coordination agent (showed in figure 3).

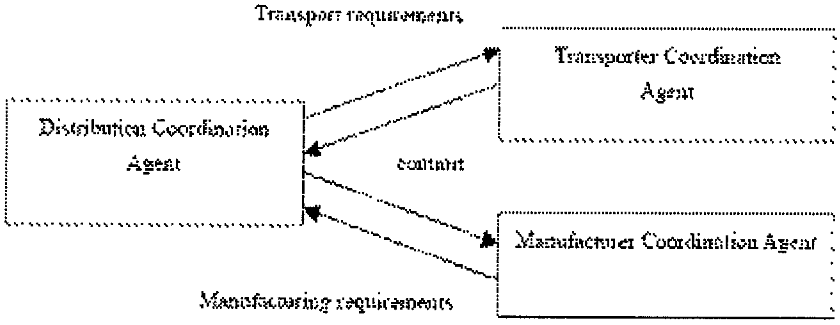

Figure 3: Supply chain coordination agents

a) *Distribution coordination agent:* Distribution coordination agent aggregates data and information from the distributors in different areas and perform distribution requirements computation. Then the distribution requirement plan can be established. It consists of four parameters, namely type, quantity, price and due date. The "type" parameter is the various kinds of products for manufacturing and transportation. The "price" parameter is the summation of all the prices of various products ordered by retailers. The "due date" parameter refers to the final date when the different distributors can receive the products and the "quantity" parameter is the desired quantity of each type of products. In addition, the distribution coordination agent can determine which "type" of products can be produced by the specific manufacturer, or by several manufacturers according to historical data and knowledge. Then, the distribution coordination agent transfers the "due date" of the "type" of the products into total "lead time" ("lead time" for manufacturers and "lead time" for transporters). Furthermore, the distribution coordination agent will coordinate with the transporter coordination agent and the manufacturer coordination agent to reach a feasible and optimized global supply chain solution. Figure 4 shows the functions of the distribution coordination agent.

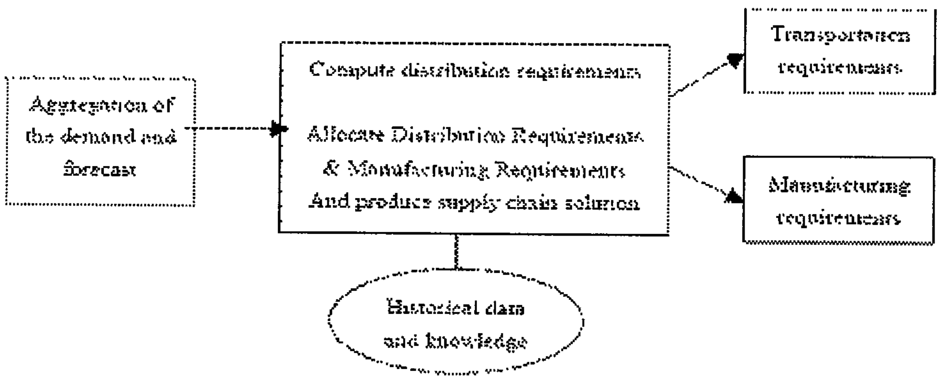

Figure 4: Distribution coordination agent

b) *Transporter coordination agent:* Transporters offer pickup and delivery service from different manufacturers to destination terminals or distributors. The operation decisions facing a transporter coordination agent are: to select the right mode or modes of transportation based on costs and lead-time and to consolidate consignment for economic of scale. The transporter agent receives the transportation requirement and performs local optimization using its data on routes, schedule and consignment to conduct candidate transportation commitments.

c) Manufacturer coordination agent: The manufacturer coordination agent receives manufacturing requirements from the distribution coordination agent and performs local optimization to find feasible manufacturing solutions (specified with type, quantity, lead time and price) based on capacity, inventory, suppliers' capacity and process time. It provides solutions to the distribution coordination agent for selection. The main function of the manufacturer coordination agent is to produce the required type and quantity within the required lead-time with minimized cost. The minimizing of the total cost is subject to a set of constraints, such as quantity constraints, capacity constraints, suppliers' capacity, customer service level and lead-time.

2) Communication agent: Cooperation and coordination of agents in a multi-agent system requires agents to be able to understand each other and to communicate with each other effectively. Communication agent can enable the monitoring agent, function agent and coordination agent to communicate with each other. The infrastructure that supports agent cooperation in a multi-agent system includes the following key components: a common agent communication language (ACL) and protocol, a common format for content of communication, and a shared ontology.

3) Monitoring agent: As a monitoring agent, it receives from other agents (such as the function agent) the monitoring criteria for disturbance events concerning processing rates and notifies the coordination agents when such events occur. The function and process of the monitoring agent is shown in Figure 2. The coordination agent decides what constitutes an exception (stochastic event). The coordination agent evaluates how much the occurrence of one stochastic event in the specific supply chain process will influence the other supply chain processes and the whole supply chain process. Then the coordination agent will identify the monitoring specification of the stochastic events in the different supply chain process. Different plan execution may have different monitoring specification. The monitoring agent determines what data is to be monitored to detect such exceptions according to the monitoring specification identified by the coordination agent and conducts actual monitoring of the data and information flow. When notified by the monitoring agent of the occurrence of the stochastic event (an exception), the coordination agent analyzes the severity of the events, coordinate with other agents to reschedule, reallocate and make appropriate decision in consultation with the function agent. Human decision-maker may be involved during the decision-making process.

6 CONCLUSIONS

In this paper we have discussed the similarities between supply chain system and multi-agent system and the underlying reasons why agent technology is the appropriate approach to model the supply chain and build the collaborative supply chain management system. Also, a framework of multi-agent based collaborative supply chain management system is presented. With this approach, a set of agents with specialized expertise has been designed. The communication agents, which facilitate the communication among agents, can select necessary information and share the information in the Multi-agent system. In this way, it can facilitate the information sharing among the supply chain participants and improving the visibility of the supply chain network. The proposed framework wrap the current exist systems such as legacy, ERP, and APS, etc into the function agents and connect these function agents with coordination agents through certain coordination mechanism to reach the system optimization. In addition, in the proposed framework, the monitoring agents monitor the real-time supply chain performance and inform related agents and decision makers when an emergence event occurs, then the related agents and the coordination agents will work together to amend the plan and inform the decision maker or automatically execute it. The paper presented here represents only the first step of our effort toward agent-based collaborative supply chain planning and execution. Further research and experiments are needed to extend the current work to address its shortcomings and design the completed model based on proposed framework and a detailed supply chain scenario.

7 REFERENCES

Bond, A.H and Gasser, L (ed.) 1988, *Readings in Distributed Artificial Intelligence*, Morgan Kaufmann.

Bowersox, D. J., Closs D. J. and Cooper, M. B. 2002, *Supply chain logistics management,* McGraw-Hill, Boston.

Berger, A. J. 2003, "e-commerce and supply chains-breaking down the boundaries" In Gattorna, J. L. (eds.) *Handbook of Supply Chain Management*, 5th edition, Gower, England, pp. 429-441

Chopra, S. and Meindl, P. 2004, *Supply chain Management: Strategy, Planning and Operation,* 2nd edition, Upper Saddle River, New Jersey.

Emiliani, M. L. 2000, Business-To-Business Online Auctions: Key Issues for Purchasing process Improvement, *Supply Chain Management*, Vol.5, No. 4, pp. 176-186.

Erasala, N., Yen, D. C. and Rajkumar, T. M. 2003, Enterprise Application Integration in the electronic commerce world, *Computer standards & Interfaces*, vol. 25, pp. 69-82.

Frey, D., Stockheim, T., Woelk, P. and Zimmermann, P. 2003, Integrated multi-agent-based supply chain management, *Proceedings of the Twelfth IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises*.

Gattorna, J. L. 2000, The E-Supply Chain Reaches Asian Shores, *ASCET*, vol. 2, pp. 335-339.

Gupta, A., Whitman, L. and Agarwal, R. K. 2001, Supply chain agent decision aid system (SCADAS), *Proceedings of the 2001 Winter Simulation Conference*, pp. 553-559.

van Hillegersberg, J., Moonen, H., Verduijn and Becker, J. 2004, Agent technology in supply chains and networks: an exploration of high potential future applications, *proceedings of the IEEE/WIC/ACM International Conference on Intelligent Agent Technology*, pp. 267-272.

Iskanius, P., Helaakoski, H., Alaruikka, A. M. and Kipina, J. 2004, Transparent Information Flow in Business Networks by using Agents, *IEEE International Engineering Management Conference 2004*, pp. 1342-1346.

Jennings, N.R., Sycara, K. and Woodridge, M. 1998, A roadmap of agent research and development, *Autonomous Agents and Multi-Agent Systems,* vol. 1, no.1, pp. 7–38.

Jennings, N. R. 2000, On agent-based software engineering, *Artificial Intelligence*, vol. 117, pp. 277-296.

Jennings, N. R. 2001, An Agent-based Approach for Building Complex Software Systems, Communications of the ACM, vol. 44, no. 4, pp. 35-41.

Jennings, N. R. and Wooldidge, M. J. 2002, Applications of Intelligent Agents, In Jennings, N. R. and Wooldidge, M. J. (ed.) *Agent Technology Foundations, Applications, and Markets*, Springer, pp. 3-28.

Lee, H. L., Padmanadhan, V. and Whang, S. 1997, The Bullwhip Effect in Supply Chains, *Operations Management and Research*, vol. 38, no. 3, pp. 93-102.

Lau, J.S.K., Huang, G.Q. and Mak, K.L. 2004, Impact of information sharing on inventory replenishment in divergent supply chains, *International Journal of Production Research,* vol. 42, no. 5, pp. 919–941.

Lee, K., Kim, W. and Kim, M. 2004, Supply Chain Management Using Multi-agent System, In Klusch, M. (ed.) *CIA 2004, LNAI 3191*, Springer-Verlag, Berlin Heidelerg, pp. 215-225.

Mentzer, J. T., Foggin, T. H. and Golicic, S. 2000, Collaboration: The Enablers, Impediments, and Benefits, *Supply Chain Management Review*, Sep/Oct, pp. 52-58.

McCullen, P. and Towill, D. 2002, Diagnosis and reduction of bullwhip in supply chains, *Supply Chain Management: An International Journal*, vol. 7, no 3, pp.164-179.

Matchette, J. and Seikel, A. 2004, How to win friends and influence supply chain leaders, URL http://www.logisticstoday.com/displayStory.asp?sNO=6828&pNum=1&OASKEY=CurrentIssue, Accessed 31 March 2005.

Neef, D. 2001, *e-Procurement from Strategy to Implementation*, Prentice Hall PTR, USA.

Parunak, H.V.D., Savit, R. and Riolo, R. L. 1998, "Agent-based Modeling vs. Equation-Based Modeling: A Vase Study and Users' Guide" In Sichman, J.S., Conte, R. and Gilbert, N. (ed.) *Multi-Agent Systems and Agent-based Simulation*, Springer, pp. 10-26.

Puckridge, D. S. and Woolsey, I 2003, "Information systems strategy for supply chains" In Gattorna, J. L. (ed.) *Handbook of Supply Chain Management*, 5th edition, Gower, England, pp. 406-425.

Persson, J.A. and Davidsson, P. 2005, Integrated optimization and multi-agent technology for combined production and transportation planning, *Proceedings of the 38th Hawaii International Conference on System Sciences.*

Quinn, F. J. 2001, Collaboration: More than just technology, *ASCET*, vol. 3.

Shapiro, J. F. 2001, *Modeling the supply chain*, Brooks/Cole-Thomson Learning, Pacific Grove

Simchi-Levi, D and Simchi-Levi, E. 2001, The Dramatic Impact of Internet on Supply Chain, *ASCET,* vol. 3, pp. 174-182.

Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E. 2003, *Designing & Managing the Supply Chain concepts, strategies & case studies*, 2nd edition, McGraw-Hill/Irwin, New York.

Swaminathan, J.M. and Tayur, S.R 2003, Models for supply chains in E-business, *Management Science*, vol. 49, no. 10, pp.1387–1406.

Taylor, D. A. 2004, *Supply chains: a manager's guide*, Addison-Wesley, Boston.

Umble, E. J., Haft, R. R. and Umble, M.M. 2003, Enterprise resource planning: Implementation procedures and critical success factors, *European Journal of Operational Research*, vol. 146, pp. 241-257

Wooldridge, M. and Jennings, N. 1995, Intelligent Agents: Theory and Practice, *Knowledge Engineering Review*, vol. 10, no 2, pp. 115-152.

Wooldridge 2002, *An Introduction to Multi-Agent Systems*, John Wiley & Sons Ltd, England.

Xue, X., Li, X., Shen, Q. and Wang, Y. 2005, An agent-based framework for supply chain coordination in construction, *Automation in Construction*, vol. 14, pp. 413-430.

Yuan, Y., Liang, T. P. and Zhang, J.J. 2001, Using Agent technology to support supply chain management: Potentials and challenges, McMaster University, Michael G. DeGroote School of Business, *Working Paper* Series no 453.

Yu, Z., Yan, H. and Cheng, T.C.E. 2001, Benefits of information sharing with supply chain partnerships, *Industrial Management & Data systems,* vol. 103, no. 3, pp.114-119.