The Hong Kong Polytechnic University

Institute of Textiles and Clothing

The Development and Validation of Agent-based Communication and Negotiation Models for Apparel Supply Chain Management

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CERTIFICATE OF ORIGINALITY

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Abstract

Agent-based technology, a new approach for managing the supply chain at the tactical and operational levels, has emerged in recent years. It views a supply chain as one composed of a series of intelligent (software) agents, who are responsible for one or more activities and interacting with other related agents in planning and executing their expected goals. The agent-based technology has many beneficial features for autonomous, collaborative, and intelligent systems in distributed environments, which make it one of the best candidates for managing complex supply chains.

Increasing pressures from customers for prompt deliveries and greater product variety at lower prices have impacted all entities of the supply chain ----- the net work of organizations from raw material suppliers to manufacturers and distributors of finished goods. In response, manufacturing firms are moving towards collaborative fulfillment, partnering closely with other firms both upstream and downstream in the apparel supply chain to meet market needs. As these strategic alliances grow, firms have come to recognize the importance of proper negotiation to establish the terms of collaboration and interaction with partners, and of effective coordination activities and decisions, in lowering costs and in improving service.

Automating negotiation as much as possible is a critical and challenging research problem. Solving this problem can benefit several areas of interest: electronic commerce, supply chain management, manufacturing resource planning and scheduling, distributed artificial intelligence, and multi-agent collaborative systems. This thesis presents methodologies and techniques needed for conducting automated negotiations along the apparel supply chain.

The thesis identifies the problem of incorrect communication among supply chain partners, the unbalance between production capacity and the product due date and the effects of bid/offer price on supply chain cost. To illustrate the decision process, the problems that cover three stages-----source, make and delivery-----of the apparel supply chain, featuring inter-functional relationship within customer, merchandiser, manufacturer and supplier are presented.

After reviewing the literature about the supply chain management, the relevant models and the application of agent technology in supply chain, in this research, the potential use of agent technology in the apparel supply chain has been explored. The knowledge flow through the supply chain processes has been depicted by unified modeling language (UML). The general research methodology adopted for investigating the application of agent technology in decision making in the negotiation process in the apparel supply chain has been specified.

In this research, agent technology is used to facilitate decision making in negotiation procedure among merchandisers, manufacturers, suppliers and customers so as to enhance the coordination in the apparel supply chain.

A simulation model based on Java platform is developed to emulate the interaction and communication of agents representing different partners in the apparel supply chain. The system describes the overall communication of agents in the apparel supply chain and represents a range of supply chain situations. To specify the negotiation process, another simulation model based on the software ZEUS® is built to display the negotiation procedure.

Based on the agent-based negotiation model, an optimized negotiation model has been developed. To study and compare different negotiation strategies, the optimized negotiation model is proposed to have two negotiators involved, namely the manufacture agent and the supplier agent. Delivery date and price are considered as two major negotiation issues in this model. Three negotiation strategies with artificial algorithms are embedded into the optimization model. The first is the linear method which is considered as the basic operating method. The second is a two-phase negotiation strategy based on simulated annealing (SA) and genetic algorithm (GA) which has been developed to decrease the production cost and achieve better profit. The last is a genetic simulated annealing algorithm (GSAA) which integrates the advantage of GA and SA has been proposed to optimize the searching method to find a more accurate point. These algorithms are embedded into the optimized simulation model to improve the negotiation performance. In addition, a mathematical decision model have been built to support the decision requirements of the determination on price and delivery date and to assist obtaining an optimal due date and bargain price so that mutual profit can be maximized and supply chain cost minimized.

Evaluation was achieved by comparison of different negotiation strategies adopting SA, GA and GSAA so that the optimal and ideal result can be verified. Industrial data was utilized to prove the feasibility of the agent-based negotiation model.

For this purpose, a simulation-based optimization model for negotiation strategy in the apparel supply chain was proposed. It considers both supply chain cost mainly from production cost and inventory cost and the constraints of the manufacturers' production capacity. This simulation based-optimization model consists of two main parts, namely, the model for simulating the supply chain negotiation and the optimization model with intelligent algorithms for searching optimal negotiation strategies. All the models identify new decision problems in collaborative supply chains and provide novel solution approaches to solve the decision problems in negotiation effectively.

On the whole, the simulation model was developed to explore the integration of artificial intelligence with human negotiation, probe on the improvement of negotiation strategy with optimized algorithms and study the effect of negotiation strategy (price, delivery date) on supply chain cost, mutual profit and production balance in an agent-based apparel supply chain.

List of Publications

Conference Paper

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A.Pan, S.Y.S.Leung, K.L.Moon and K.W.Yeung, The Conceptual Model of Knowledge Management in the apparel supply chain, proceeding of the 86th textile institute world conference, pp.284.

Journal Paper

A.Pan, S.Y.S.Leung, K.L.Moon and K.W.Yeung, Optimal Reorder Decision Making in the Agent-based Apparel Supply Chain, Expert system and applications, 36(2009), pp. 8571-8581.

A.Pan, S.Y.S.Leung, K.L.Moon and K.W.Yeung, An Agent-based Negotiation model on Price and Delivery Date in the Apparel Supply Chain, submitted to Expert system and applications.

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Chapter 1
Introduction

1.1 An Overview of Negotiation Strategies in Agent-based Apparel Supply Chain

"Supply chain management" (SCM), which refers to the integrated management of a network of entities, that starts with the suppliers' suppliers and ends with the customers' customers, for the production and delivery of goods and services to the final consumers (Lee and Ng, 1997), has, in recent years, been receiving increasing attention from academics, consultants and operational managers. According to SCM, companies do not seek to achieve cost reductions or profit improvements at the expense of their supply chain partners, but rather seek to make the supply chain more competitive as a whole (Romano and Vinelli, 2001).

Recently the issue of managing efficient supply chains has raised considerable interest. Supply chain management is an integrated management approach which executes the responsibility of logistics plan, production schedule, decision making and overall control from the suppliers to the final customers along the chain.

In earlier stages, the major task of SCM might probably be the management of storage and transportation as people laid more emphasis on the balance of quick delivery and the expense of production and storage. Nowadays with increasing globalization, the competition among enterprises has been the competition among supply chains. Thus supply chain management is facing more challenges rather than repertory management. Typically, the supply chain members follow different goals and possess different information. Therefore, to increase the supply chain's total utility, the main concern of supply chain management is coordination. The coordination has been one of the important tasks in supply chain management.

With the development of transnational enterprises and multinational trade, supply chains expand as they involve more partners, even in different area. For example, a South Korea apparel company may have its cotton and yarn supplied in Thailand, its product produced in mainland China and zip and button provided from Japan. The management of a supply chain accordingly seems to be difficult as it needs to coordinate the complex communication among customers, companies, factories, raw material suppliers and all the other related partners. The negotiation mechanism is an important means of supply chain coordination and effective communication.

Most apparel companies are scrambling these days to squeeze extra profit out of every single business transaction. They are already operating at maximum efficiency, doing more with less, and doing it faster than ever before. However, another obvious area to enhance profit potential is in the negotiation process. The negotiation between members of the supply chain is the basic and dispensable part of supply chain management, and the members of the supply chain cannot collaborate with each other without negotiation. Negotiation is a widely accepted practice when conducting business. According to Pruitt (1981), negotiation can be defined as "the process by which a joint decision is made by two or more parties. The parties first verbalize contradictory demands and then move towards agreement by a process of concession making or search for new alternatives." With the advancement of computer and information technologies, automated negotiation has become an important research topic in several areas: supply chain management (SCM), manufacturing and resource planning (MRP), distributed artificial intelligence (DAI), and multi-agent system (MAS). DAI and MAS use negotiation to coordinate intelligent agents to complete designated tasks. MRP uses negotiation as a dynamic and efficient mechanism to generate and execute manufacturing plans. SCM uses negotiation to establish a dynamic and profitable coalition for resource supplying and product delivery.

Another main application area that can benefit from automated negotiation is Internet-based electronic commerce (E-Commerce). In complex, non-electronic business transactions, individual consumers and companies want to negotiate price, delivery date, quality of goods and services and other purchase conditions. Traditionally, negotiations are conducted by people involved in business transactions.

The apparel enterprises are facing an environment featured with increasingly fierce market competition, uncertainty, individualization of customer demand, speedy development of hi-tech, short product life cycle, complex product structure, short production lead time and frequent style change. The apparel companies in HK take an important role of bridge between western and Asia countries due to its special geographical location. As an intermediate, the HK apparel companies need to negotiate with supply chain partners of different areas. Effective communication and negotiation strategies save human time, reduce decision delay and improve efficiency of supply chain operation. Therefore, negotiation strategy becomes the focus of not only the industry people but researchers as well.

Agent technology, a new approach for managing the supply chain at the tactical and operational levels, has emerged. It views a supply chain as one composed of a series of intelligent (software) agents, who are responsible for one or more activities and interacting with other related agents in planning and executing their expected goals. As agent technology has the beneficial features of intelligence, mobility and autonomy to deal with large amount of knowledge in the apparel supply chain, agent-based simulations have also been developed to model processes in the apparel industry.

Besides, agent approaches can particularly easily be introduced to support human activity, since human organizations can be considered themselves as inherently agent oriented. In particular, the use of an agent approach helps to reduce considerably the impedance mismatch between information systems, and the human organization that these systems support. Agent technology is suitable for distributed systems such as supply chains, especially suitable to be applied in negotiation process as negotiation involves people most and agents just have that certain feature of imitating human being.

The agent-based negotiation between enterprises is an important part of the supply chain management. First, the key constituent is analyzed in the supply chain management from multi-agent and single agent's perspective. Then, a general negotiation model according to negotiation features of the supply chain is presented. In the model, we design a flexible protocol and analyze the agent's decision model.

However the decision-making process is inherently complex in a supply chain. The reason is that supply chain problems are often very complicated and intricate owing to the interactions between the parties, the length of the supply chain, the lead time of manufacturing and shipping, the complexities of modeling the individual parties, the stochastic nature of the demands. Few analytical models exist to represent real-world problems occurring in the supply chain.

In such instances, one alternative form of modeling supply chain is simulation. In simulation models, one can represent many realistic features. It offers a comprehensive methodology by considering the strategic, tactical, and operational elements with much more details than any other approaches do. The development of simulation models to understand issues of supply chain decision-making has gained importance in recent years (Shapiro 2001; Yao et al 2002; Simchi-Levi et al 2003; Umeda et al 2006).

In the apparel industry, the simulation model has been used extensively in handling assembly line (Whitaker 1973) , modular manufacturing systems (Wang et al 1991), and issues relating to mass production sewing lines (Tyler 1989). Some studies in the literature relevant to the simulation model in the apparel supply chain, which were initiated at the North Carolina State University (NCSU), targeted the simulation of the supply chain, along with the development of QR in the mid 1980s (Hunter et al., 1996). Most of these simulation models are focused on evaluating the performance of QR strategy adopted in the apparel supply chain and the improvement observed, while little has been done on investigating the supply chain communication and negotiation system.

With the advent of the Internet and networking technology, more and more powerful software tools are being designed and engineered to bolster e-commerce activities. One of the most popular e-commerce activities is online trading of goods and services through Internet auctions. By implementing software agents to work for human users, a variety of tasks such as buying and selling products over the Internet and notification of transaction can be partially automated.

According to Guttman et al. (1998), it was noted that there are extant software agents for supporting e-commerce activities such as product brokering, merchant brokering and negotiation. While Sim and Chan (1999) have addressed issues of product and merchant brokering, this research plans to focus on agent-based automated negotiation. Negotiation is a difficult and time consuming process as trading parties often does not reach a consensus rapidly and easily. To partially automate a trading process, this research plans to explore the use of agents for negotiating deals on humans' behalf.

In this research, an automated negotiation environment is designed and established to facilitate decision making among trading agents during trading process to achieve better user satisfaction.

Negotiation stage determines the trading terms of the transaction and therefore it directly affects the degree of satisfaction of the consumer in the transaction. As negotiation can be considered as difficult and time consuming process for trading parties to reach a consensus rapidly and easily, development of agent-based negotiation systems has been a popular research area in recent years. In the literature, there are different agent-based negotiation systems employing different negotiation protocol and different agent decision strategies for negotiation such as AuctionBot (Wurman et al., 1998), Kasbah (Chavez, Maes, and Kasbah, 1996) and Tete-a-Tete (Guttman and Maes, 1998). The main contribution of this research aims to design and implement a multi-agent system for bolstering automated negotiation. Issues of interest include the design of the agent communication framework in a supply chain, the architecture of various types of agents in an apparel supply chain, the formulation of mathematical model to evaluate negotiation results and the decision strategy to accept or to make counter offers/bids.

In this research, the negotiation strategy between manufacturers and suppliers is discussed through analyzing the systematic framework of the negotiation between the manufacturer agent and the supplier agent. The decision mechanism of manufacturers and suppliers in the negotiation are described respectively. The Agent technology is applied to the negotiation system, and related application examples are also presented.

1.2 Objectives

The research plans to explore the use of agents for negotiating deals on humans' behalf to automate the time consuming negotiation process. The agents help human users to make optimal trading decision on price and due date. In this research, an agent-based simulation model is proposed to simulate the negotiation process of an apparel supply chain under dynamic environment.

Specifically, the objectives of this research are to:

1) Develop a simulation model for multi-agent communication system in the apparel supply chain.

2) Formulate a mathematical model for the supply chain agents to make negotiation decisions so as to minimize supply chain cost and to balance production capacity.

3) Examine the relationship of knowledge management with communication system in an agent-based apparel supply chain.

3) Develop an agent-based negotiation model for the apparel supply chain with negotiation strategies embedded in so as to obtain optimal negotiation decisions and improve efficiency.

4) Gain a better understanding and insight of the impact of different negotiation issues in terms of price, due date, quantity etc. on the performance of negotiation decisions.

5) Develop a genetic simulated annealing algorithm for negotiation strategy on price and delivery date in order to decrease supply chain cost and obtain a win-win situation for the negotiators.

1.3 Methodology

As negotiation process is quite complex in the apparel supply chain, the optimization negotiation model is focused on two major negotiators, the manufacturer and the supplier. The manufacturer agent procures the apparel raw material or apparel component from the supplier agent and discusses with him mainly about price and delivery date. In this research, the search space for the problem is a combination of these negotiation issues, including product due date and accepted price.

To fulfill the research objectives, a simulation optimization model for the agent-based apparel supply chain is developed in this research. The following are the steps used to establish and evaluate the proposed model.

Firstly, an agent-based simulation model is established based on JAVA to describe the communication flow along the apparel supply. Supply chain members are represented by multi-agents. The main purpose of the model is to explore how agents coordinate in a distributed environment and investigate whether agent technology is suitable for application in supply chain management. Based on this model, it is found that negotiation is an important part in supply chain communication system. Therefore, a negotiation model is built based on the software ZEUS® to imitate human negotiation by agents and analyze the performance of the negotiation process with agents in the apparel supply chain.

Secondly, the agent-based simulation model is extended to a simulation-based optimization model searching for an optimal solution for decision makers to implement negotiation rules and optimize the resources engaged in the apparel supply chain. The optimization model is aimed to study the relationship of negotiation issues (price, delivery date and quantity) with supply chain performance (cost, production capacity) in an agent-based apparel supply chain. Mathematical models are built to verify this relationship and to assist the simulation model. This optimization model is composed of two major parts, namely a two-phase negotiation strategy with simulated annealing (SA) and genetic algorithm (GA) model and a genetic simulated annealing algorithm (GSAA) embedded optimization model. The simulation model developed in the first stage is employed to find optimal due-date by SA and price by GA so that mutual satisfaction can be achieved. The second stage is GSAA which combines the merits of both GA and SA. It is promoted to search for the optimized values of negotiation strategy in the apparel supply chain simulation model to optimize some supply chain performance, in other words, minimize supply chain cost, balance the production capacity of the manufacturer and increase mutual benefit. The optimization algorithm GSAA, as a newly developed algorithm, is employed in negotiation strategy in this research to generate an optimal negotiation solution for decision makers so that the efficiency of negotiation process can be improved in the apparel supply chain.

Meanwhile, evaluation of the performance of the negotiation strategy is complex. Despite that there are various existing intelligent algorithms, GSAA offers an efficient searching technique suitable for large combinatorial problems and can converge to an optimal point, and is capable of connecting with a simulation model to evaluate the performance of the possible solutions to the optimization problem. GSAA is a combination of GA and SA, and to some extent, more optimal than any one of them. However, GSAA is seldom thought to be applied in recent research on supply chain management. That is why GSAA is selected as the explored optimization algorithm in the proposed model.

To validate the optimization of the proposed GSAA-based negotiation strategy used in the simulation model, two other algorithms, linear method, a two phase negotiation strategy with GA and SA have also been investigated as well. Comparisons of these algorithms are presented to demonstrate the reason why GSAA is adopted in the negotiation strategy and the unique benefit of GSAA-based negotiation strategy. Validation of the whole simulation-based optimization model is undertaken by comparing the performance of the proposed optimization model with that of the industrial practice.

In the last part of this research, full factorial experimentation is conducted based on the proposed optimization model for the agent-based negotiation strategy. The results of the analyses will show the implications on negotiation strategy of different intelligent algorithms for both academic research and industrial processes.

1.4 Significance of this Research

While research in the area of optimization of supply chain process receives increasing attention, in-depth studies on efficiency improvement of negotiation strategy of the apparel supply chain adopting the agent-based technology are limited. The contributions of this study are discussed as follows:

The first significant contribution of this study is to broaden the investigation and enrich our understanding on the agent-based apparel supply chain, both from the perspective of the academic research and industrial practice.

Past studies in the apparel supply chain have mainly focused on QR strategy and inventory control. Negotiation process has not been given enough attention in supply chain management as it involves too much human factor thus leads to the difficulty in imitation of real negotiation procedure.

People seldom think of improving supply chain efficiency from the aspect of improving negotiation performance. However, effective negotiation strategies can contribute to the overall efficiency of the supply chain as well. This research studies the improvement of negotiation strategy of the multi-echelon agent-based apparel supply chain which has not been addressed. The practice of the participants in the multi-echelon apparel supply chain (including customers, merchandisers, manufacturers and suppliers) is investigated. The benefits of the suppliers, the manufacturers and the customers are considered. The new optimization model proposed in this study is capable of seeking for the optimal negotiation decision and thus the optimal balance between the delivery date required by the customers and production capacity maintained by the manufacturers.

In the apparel industry, agent technology has not been employed long enough especially in the application of negotiation process. One of the obstacles that the apparel companies involved in negotiation encounter is the imbalance of their production capacity and cost. The optimization model based on agent technology with intelligent algorithms developed in this research could provide one effective solution to this problem.

From the perspective of the research methodology, simulation, fuzzy theory and genetic simulated annealing algorithm are engaged in the optimization model for the agent-based apparel supply chain. The synergistic effect of these three methods on the optimization of the performance of the agent-based apparel supply chain is demonstrated in the optimization model. These optimization algorithms are capable of improving the negotiation performance of the multi-echelon agent-based apparel supply chain.

This research also furthers the existing SCM research by strengthening the understanding of negotiation strategy adoption in the apparel industry. With full factorial experiments conducted using the simulation-based optimization model developed in this research, an investigation on the factors that may affect the performance of the agent-based negotiation strategy is made. Suggestions on the negotiation strategy to improve the performance of the whole supply chain will be given based on the results of the experiments.

1.5 Structure of this Research

The remaining part of this research is organized as follows: Chapter 2 is a literature review on previous studies related to apparel SCM that forms the framework for the research. An overview of supply chain management, the introduction of agent technology and the application of agents in supply chains are provided as the basis of this research. Simulation model as a research method to model the supply chain negotiation process as well as optimized algorithms applied in the negotiation are given. Chapter 3 presents the literature review on the modeling approaches adopted in the area of supply chain management. Previous application of these approaches has been provided. Chapter 4 explains the methodology employed in this study. Three steps including the development of a simulation model, optimization of the negotiation decision as well as the evaluation of the effect of different algorithms applied in the negotiation strategy on performance of the apparel supply chain are illustrated. Techniques involved in the model, including simulation, simulation-based optimization, fuzzy theory, GA, SA and GSAA are described. This chapter also introduces the application of agent technology in the communication system of the apparel supply chain. Chapter 5 illustrates the behavior of the agents in the apparel supply chain process and standardizes the agent communication with UML. A simulation model of agent communication system of the apparel supply chain is developed in Chapter 5. Chapter 6 provides the agent-based negotiation model based on the platform of ZEUS. Negotiation processes initiating from the customer to the supplier have been described. This chapter also introduces the procedures of the design and implementation of the agent-based negotiation model whose purpose is to generate appropriate negotiation strategies on price and due-date in order to build a win-win situation for the negotiators in the apparel industry. The simulation model to emulate the negotiation process in the agent-based apparel supply chain has been proposed as well. Chapter 7 integrates the algorithms into the simulation model in order to search for an optimal negotiation decision to satisfy the customer needs and minimize the supply chain cost. With consideration of the constraints of production capacity, delivery date and supply chain cost, negotiation strategies using different algorithms are formulated to optimize the supply chain negotiation in terms of production balance of manufacturers and customer satisfaction and mutual acceptance of the price. Three methods which are linear method, genetic algorithm and genetic simulated annealing algorithm are presented in this chapter. Comparisons of these three methods were made to demonstrate the optimization of the genetic simulated annealing method embedded in the negotiation strategy. Experiment to evaluate the negotiation result with proposed genetic simulated annealing algorithm was conducted based on real data from the apparel industry. The chapter also evaluates the impact of the three algorithms on the negotiation result of the supply chain using the simulation-based optimization model. The last chapter (Chapter 8) summarizes the findings of this study, the contributions, the limitations and recommendations for future research.

Chapter 2

Literature Review of Supply Chain Management

This chapter reviews previous studies of the apparel supply chain management (SCM). It consists of sections that report on previous studies on apparel supply chain management to explore meaningful concept for this research. The first section pertains to SCM in apparel industry. After providing an overview of research in apparel SCM, major problems in the supply chain are reviewed and the related technologies are provided. Agent technology which has the advantage of autonomy, intelligence, sociality and activity is presented as one of the latest technologies used in supply chains. The second section is focused on the simulation model, as one research method, in supply chains. After providing a general introduction of the simulation model in decision making in supply chains, the chapter moves on to agent application in negotiation-based models. The research gap is identified in the summary of the review at the end of this chapter.

2.1 Supply Chain Management (SCM) in the Apparel Industry

This section covers SCM in the apparel industry. The general overview of the apparel supply chain is first reviewed. After that, the uncertainties in the apparel supply chain are presented. A review on the supply chain simulation model which is capable of investigating the dynamic apparel supply chain is given in the last part of this section.

2.1.1 Research Background

Today's textile and apparel industries are still making a significant contribution to many national economies both in the developing and developed world (Abernathy et al., 2004). In 2003, international trade in textile and apparel industries reached US$395 billion, representing 5.4% of world trade, and it has been growing faster than world trade as a whole (Singhal et al., 2004).

However, the textile and apparel supply chain-from fiber to retail- is experiencing deflationary price trends, making cost reduction the key to survival (Sood et al., 2004). It is due to three main trends since the new millennium. Firstly, consumers are becoming more demanding, but are also more value driven. They are sometimes whimsical and their demand is unpredictable. Secondly, the industrial structure is changing. Mega-retailers and mega-brands are emerging, and their growth is accelerating. Their expanding global reach is putting increased pressure on local traditional textile and apparel retailers, as well as on traditional supply channels. Thirdly, international textile and apparel trade became quota-free on January 1, 2005- at least in the case of trade between members of the WTO. Apparently, sourcing will occur from the most competitive countries in terms of cost, quality and productivity. For suppliers, the ability to offer a full package service, from product development to delivery to smooth the operations of the supply chain, is critical to increase their competitive advantages. The above trends are having a profound impact on how and where textiles and apparel are produced, and how the supply chain is managed. No longer will firms compete against each other individually but rather they will compete with their respective supply chains (Schorr, 1998). The competition of different supply chain in textile and apparel industries will be even more intense, and managing the whole supply chain together by all participants is no doubtfully an essential prerequisite for the competition.

2.1.2 Definitions of Supply Chain Management

"Supply chain management"(SCM), which refers to the integrated management of a network of entities, that starts with the suppliers' suppliers and ends with the customers' customers, for the production and delivery of goods and services to the final consumers (Lee and Ng, 1997), has, in recent years, been receiving increasing attention from academics, consultants and operational managers. According to SCM, companies do not seek to achieve cost reductions or profit improvements at the expense of their supply chain partners, but rather seek to make the supply chain more competitive as whole (Romano and Vinelli, 2001).

There is little dispute that the concept of SCM, first appeared in the early 1980s has been an area of importance since then (Oliver et al. 1982; Houlihan, 1985; Jones et al, 1985). Due to the way the concept of supply chain has been developed, the definition of SCM lacks universal acceptance (Croom et al., 2000). Many definitions have been used to describe this topic. Stevens (1989) described SCM as a "connected series of activities which is concerned with planning, coordinating and controlling materials, parts, and finished goods from supplier to customer. It is concerned with two distinct flows (material and information) through the organization. " Oliver et al (1982), Cooper et al. (1993) and Chandra et al. (2001a) defined SCM as a single entity governed by strategic decision making. Their focus was on the integration, rather than on the interfaces in SCM. Some authors and practitioners from other disciplines highlighted an increasing dependence on relationships with suppliers (Sabel et al., 1987; Slack 1991; Harland, 1996). Still other scholars defined the SCM as strategic management of inter-business networks. For instance, Christopher (1992) defined SCM as the management of "the network of organizations that are involved, through upstream and downstream linkage, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer." Table 2-1 shows some definitions of supply chain management.

Table 2-1 Definitions of supply chain management

Authors	Definition
Alber and Walker (1997)	"The global network used to deliver products and services from raw materials to end customers through an engineered flow of information and physical distribution."
Cooper et al (1993)	"An integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user…greater coordination of business processes and activities…across the entire channel and not just between a few channel pairs."
(Chandra and Kumar, 2001)	"A society (a network of members, termed a group) formed by autonomous entities (and their systems) by bonding together to solve a common problem."
Lee & Ng (1997)	"A network of entities that starts with the suppliers' supplier and ends with the customers' customer via the production and delivery of goods and services."
Simchi-Levi et al (2001)	"A set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirement."

From the above definitions, we can conclude that Supply Chain Management encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. Supply chain management is the process of planning, implementing, and controlling the operations of the supply chain with the purpose to satisfy customer requirements as efficiently as possible. Thus the process coordination is important.

2.1.3 Importance of SCM in Textile and Apparel Industry

The term "supply chain management" was originally introduced by consultants in the early 1980s, and then analyzed by the academic community in the 1990s (Oliver and Webber, 1992).

The philosophy of SCM has been practiced in the apparel under the label of Quick Response (QR) which was originally initiated by the need to reinforce the U. S. domestic apparel manufacturers' competitive advantages against the global competition from low labor wage countries in the 1980's (Dickerson, 1999). According to the definition by researchers, three key issues were required in implementing QR in apparel industry: communication of information between trading partners, reduction in lead time along the soft goods pipeline and consumer responsiveness.

The textile and apparel industries are facing three main changes since the new millennium. The first one is consumers' rigorous demand and rational consumption. The second one is the dominant status of mega-retailers and mega-brands. And the third one is the influence of quota-free in international trade. The three macro trends make SCM an essential prerequisite for the competition. On the other hand, as the final product of textile and apparel supply chain, fashion products are unique, dynamic, emotional and cyclical, which makes change the lifeblood of the fashion industry and the rate of the change in the apparel industry much faster than in other business (Stone, 1994). Because of the synergy SCM can generate, it has been given much attention by textile and apparel industries.

2.1.4 SCM Research in Textile and Apparel Industry

The textile and apparel supply chain is complex. The supply chain is long with a large number of cross-country enterprises involved (Jones, 2002). Forza and Vinelli (1997) described the main participants in the textile-apparel supply chain. Consequently, careful management of the supply chain is required in order to reduce lead times and achieve quick responsive actions to changing market environments.

The well known supply chain initiative in apparel industry was the quick response (QR) program (Lummus and Vokurka, 1999). Owing to intense competition in the world-wide textile and apparel industries, leaders in the US apparel industry formed the Crafted With Pride in the USA Council in 1984 (Kurt Salmon Associates, Inc.,1993). In 1985, Kurt Salmon Associates were commissioned to conduct a supply chain analysis. The results of the study showed the delivery time for the apparel supply chain, from raw material to consumer, was 66 weeks long. About 40 weeks of 66 weeks were spent in warehouses or in transit. The long supply chain resulted in undesirable losses of resource and lack of right products launched in right place at the right time. QR is a phenomenon or process of partnership where retailers and suppliers work together to respond more quickly to consumer needs by sharing information. Significant changes as a result of the study were the industry adoption of universal product codes (UPC) and a set of standards for electronic data interchange (EDI) between companies. Retailers began installing point of sale (POS) scanning systems to transfer sales information rapidly to distributors and manufactures. QR incorporates marketing information on promotion, discounts, and forecasts into the manufacturing and distribution plan.

In recent years, there is still much research on QR. Forza and Vinelli (1997) underlined the importance of QR strategy in the textile and apparel industries and presented some considerations concerning the organizational, management and technological conditions necessary for its achievement. The support of information technologies was specially analyzed. Perry et al. (1999) described the processes that occurred as part of the Australian government funded QR program in the textiles, clothing and footwear industry. Birtwistle et al. (2003) surveyed fashion retailers in the UK about their implementation of QR. The study revealed that information technology is particularly important to the large, multiple "own brand" fashion retailers as it enables the various parties in the supply chain to communicate and to respond to demand. Yet, the results also indicated that retailers had not fully understood the benefits of implementing a QR strategy and perceived it more often as a strategy for internal supply chain rather than an external supply chain strategy.

In different stages of textile-apparel supply chain, more attention has been paid to garment manufactures. Au and Ho (2002) presented a business-to-business electronic commerce model for enabling SCM, using a leading clothing manufacture in Hong Kong as an illustrative case. Lee and Kincade (2003) found that US apparel manufacturer groups, based on their SCM activity levels, showed statistically differences in company characteristics including product fashion level, fabric supplier, deliveries, relationship with fabric suppliers and retail customers and relative size of retail customers. Bheda et al (2003) evaluated the productivity levels achieved by Indian apparel manufacturers vis-a-vis their counterparts from the rest of the world.

There also exist some gaps between theory and practice. For example, relationship management encompasses the management of the chain and the building of partnership between different parties within the chain. Througout the literature, collaborative relationships and partnerships are described as preferential situations, and as beneficial to all parties involved (Wong, 1999). However, in reality, it is questionable. The textile industry tends to be dominated at the end of the chain by large, powerful high-street retailers with multiple and often internationally dispersed outlets. Further back down the chain, the manufacturing sector of the industry consists of large numbers of small companies with a limited power. Although it may be argued that partnership agreements exist between these companies in the textile and apparel industries, it is questionable whether these are actually partnerships with benefits for all parties or whether they are a means by which the retailer sector is able to exert power over the smaller suppliers in order to push down prices. With the intensification of globalization and the quest to achieve greater profits through reduced purchase prices, the industries have moved away from partnership between organizations (Bruce et al., 2004).

The apparel industry has a long supply chain from raw material suppliers (i.e. fiber manufacturers) to end-users (i.e. consumers) (Lee, 2000). As defined by Dickerson (2003), the major segments in the apparel supply chain are component suppliers, finished product suppliers and retail distributors. Component suppliers refer to fabric and yarn manufacturers. Finished product suppliers include apparel and accessories to the consumers. A simplified definition of the apparel supply chain was given by Hammond (1993) that the apparel chain consists of fiber producers, textile manufacturers, apparel manufacturers, retailers, and consumers.

A traditional company involved in the apparel supply chain runs its business as a separate entity, which may cause conflicts in the relationship with its partners. According to Hammond (1992), "there was very little coordination among the companies. Each segment built production schedules based on its own forecasting method, which may not accurately represent the actual demand". The supply chain members would suffer from the long lead time and high level of inventory with consequent risks of obsolescence. In this case, the retailers would not maintain good relationship with their manufacturers. They may abuse their power to secure low prices by threatening their suppliers with order withdrawals (Aron, 1998).

Today, the level of competition in the supply chain is much higher than before. Greater effort is placed on the improvement of product quality and shortening of lead time. The life cycle becomes shorter and shorter, and demand is more uncertain in growing numbers of product categories. Fill rates, inventory turns, products obsolescence and other topics in the apparel industry have received increasing attention by managers.

The philosophy of SCM has been practiced in the apparel industry under the label of Quick Response (QR) which was originally initiated by the need to reinforce the US domestic apparel manufacturers' competitive advantages against global competition from low labor wage countries in the 1980s. There are many definitions for QR. In the remaining part of this section, the review on apparel supply chain focuses on the definition and advantage of the QR strategy.

One consolidation of the various definitions and descriptions is given by Lowson et al (1999): "QR is a state of responsiveness and flexibility in which an organization seeks to provide a highly diverse range of products and services to a customer/consumer in the exact quantity, variety and quality, and at the right time, place and price as dictated by real-time customer/consumer demand. QR provides the ability to make demand information driven decision at the last possible moment in time ensuring that diversity of offering is maximized and lead-times, expenditure, cost and inventory minimized. QR places an emphasis upon flexibility and product velocity in order to meet the changing requirement of a highly competitive, volatile and dynamic marketplace. QR encompasses a strategy, structure culture and set of operational procedures aimed at integrating enterprises in a mutual network through rapid information transfer and profitable exchange of activity”

Responding to customer’s tastes becomes important and dealing with variability in demand has been crucial to the manufacturers competing in the apparel supply chain. The apparel manufacturing industry in the US or EU after the industrial concentration changed from the high volume-low priced to the lower volume-higher priced garments for niche markets (Dickerson, 1999; Toni et al., 2000).

For the high cost companies in the textile, apparel, and other consumer products industries, the time-based strategy of Quick Response (QR) has been proposed as a manufacturing management system to create a new advantage (Kincade et al., 1993).
QR management of a variety of apparel manufacturers was investigated and the definition and organization were examined. QR was indicated as more than an inventory system or a rapid delivery system. After the survey of the US apparel manufacturers, the characteristics of apparel manufacturers that adopted QR strategy were studied. It was found that the size of operation and the type of retail customers were significantly related to the adoption of the QR strategy. (Ko and Kincade, 2000) evaluate the use of strategic-type classifications in analyzing apparel firms and examine the relationship between the strategic type of firms and the usage of Quick Response (QR) technologies. Demographic characteristics of apparel manufacturers and the usage of QR technologies are also detailed. A random sample of 306 US apparel manufacturers, without location limitation, was selected and stratified by firm size and product category (Abernathy et al., 2000).

It describes how information technologies have reconfigured retailing and in turn the operation of a core US manufacturing industry, apparel. "Lean retailers" exchange point-of-sales information with their suppliers and require them to replenish orders quickly based on actual sales. This shifts part of the risk arising from changing consumer tastes from retailers and onto suppliers. In response to this shift in risk, manufacturers must reshape planning methods, cost models, inventory practices, production operations, and sourcing strategies. They concluded that suppliers that adopt comprehensive changes to their manufacturing processes perform better along a number of dimensions compared to firms that have not. Rollins et al. (2003) developed a novel planning and control reference model for the UK apparel industry by considering the commercial environment with changing customer demand.

Case studies of apparel organizations, in two broadly distinguishable market groups in South Korea have been conducted for this research. One of the case study organizations, company A, sells high fashion knit wear products manufactured by a foreign supplier and the other, company B, deals fashionable ladies wear supplied by 8 to 10 domestic apparel manufacturers. The study identifies common issues and differences between these dissimilar apparel companies in their respective supply chain systems. The analysis was conducted as a pre-cursor to simulation studies to investigate the effects of apparel supply chain control parameters on the relevant business performance. The predominant costs are the product cost and the outlet rent, both of which reflect the product volumes ordered. The forecast errors are high for both apparel companies. Therefore, improving the forecasting techniques should significantly reduce the costs and improve the profits. The data derived from the case studies can contribute new information on, the globalized supply chain study area, especially the approach to compare the international to domestic apparel entrepreneurs' activities/finances will be a useful guideline to compare relevant supply chain systems in other countries as well as in Korea (Park and Harlock, 2003).

2.1.5 Technologies Adopted in Apparel Supply Chains

Web Technology plays an important role in the success of apparel supply chain management. Even though the supply chain concept pre-dates the Internet, only through the use of web-based software and communication can it truly reaches its full potential. Before the Internet, companies were limited because they were not able to receive or to send updates, feedback, or other important information in a timely fashion. Additionally, companies were limited in their ability to work with global partners because of language barriers and time differences. Using the Internet to handle most of the elements involved in supply change management, including procurement and communication, makes the exchange of data and the running of the supply chain faster .

Artificial intelligence (AI) is the technique that tries to create systems that exhibit intelligence by incorporating some form of learning. In recent years, agent-based technology, a new approach for managing the supply chain at the tactical and operational levels, has emerged. It views a supply chain as one composed of a series of intelligent (software) agents, who are responsible for one or more activities and interacting with other related agents in planning and executing their expected goals. The agent-based technology has many beneficial features for autonomous, collaborative, and intelligent systems in distributed environments, which make it one of the best candidates for complex supply chain management (SCM). Expert systems also fall under the umbrella of artificial intelligence. These systems capture an expert's knowledge in a database and use it to solve problems. Expert systems rely on an extensive database of knowledge, usually expressed as a set of rules. They can suggest alternative solutions that human decision maker has neither the time nor expertise to recognize in apparel supply chain. The neural network, major technique of AI, has the function of the human brain. One of the current trends in the development of neural networks is focused on the integration with other AI techniques to model complex problems in real industries (Lee 2006).

Mathematical models and algorithms are the tools which can be used to determine potential solutions to problems. For example, these tools may generate the best set of locations for new warehouses, an efficient route for a truck to take, or an effective inventory policy for a retail store (Simchi-Levi et al 2004). Fuzzy mathematics has been applied in economics and finance (Buckley et al 2002). Fuzzy logic and modules could be incorporated to handle the uncertainty in an apparel supply chain. Genetic algorithms, based on the different parent selection criteria, have been newly applied in supply chain management. A meta-heuristic approach based on a hybrid genetic algorithm has been adopted in some challenging issues like the coordination of just-in-time production and transportation in a network (Naso et al 2004). Chaos theory, the study of nonlinear dynamics, has also been developed to solve problems in dynamic environment, thus could be further researched in its potential use in apparel supply chains (Lee 2006).

Some researchers agree that the biggest benefit technology has given to the supply chain concept is the ability for companies to collaborate. These collaborations are designed for the mutual benefit of all parties (Govil & Proth 2002). For example, a supplier of consumer goods may be linked up via the Internet to one of its distributors so that when the supply gets too low an order for more of those goods can be placed automatically. In this way, the distributor never has to worry about running out of a product and disappointing customers and the supplier does not have to worry about maintaining a large inventory in expectation of demand. Similar systems have also been constructed to send out multiple requests to vendors when an order is placed. Collaborating this way makes better use of existing resources and paves the way for a larger profit margin on all sides of the equation.

While technology brings apparel supply chain management many benefits, using technology to achieve those benefits does have two main drawbacks: one is resistance from vendors and the other is resistance from employees. Suppliers of goods are often hesitant to jump onboard because of the initial costs involved in setting up their own end of supply chain management system and because most vendors do not have a trusting relationship with their buyers. To overcome this obstacle, the strong relationship must be present and the seller needs to be able to see the profit potential on their end of the arrangement. Likewise, many employees have learned to develop a hate-hate relationship with new technology. After all, it costs them their jobs and often makes them feel that their work is more tedious or more complicated. Plus, software mistakes, which are inevitable at the beginning, may cause other employees to lose faith in the system altogether. Employees need to trust the system, the company, and their ability to use the program if they are going to adopt the supply chain management software.

2.1.6 Problems and Implications for the Apparel Supply Chains in HK

Though supply chains develop quickly in HK apparel companies, they have not been put to full use and problems exist due to the various market needs and the quick-changing fashion styles. Apparel supply chain management is faced with even more challenges than ever before. Thus, the renovation of information technology provides a competitive advantage to apparel supply chains. Without an integrated IT solution, apparel manufacturers will not be able to access updated information and conduct detailed analysis on the order status, materials used or customer profile. The main problems of the present apparel supply chains are listed and some implications are given by the researcher after a comprehensive study of supply chains.

Order processing

One common problem in the Apparel Industry is that customers frequently request changes in quantity, size or other specifications in a sales contract. Such information may not be passed to the relevant divisions promptly and accurately, resulting in production delay or business loss. Integrated with e-commerce/business, apparel supply chains can overcome such problems. The Internet facilitates the data flow. Customer data and product style specified in a sales contract can be retrieved instantly from the system while the size/color breakdown can be calculated within seconds. Any changes in the contract will be updated and recorded in the system in real time. More importantly, each division will be notified of the changes automatically by email so that users are alerted and can take prompt actions.

Costing analysis

The importance of collecting data that reflect business to achieve competitive advantage is widely recognized now. Powerful systems for collecting data and managing it in large databases are in place in all large and mid-range companies (Chen et al., 2005). As the quantity of each order is getting smaller while the specifications are getting more complex, it becomes more difficult for apparel manufacturers to know which products are making or losing money. To better analyze the cost and profit margin, the computer system better provides functions for searching materials from the centralized database quickly. Data mining technology could be used. Data Mining is the process of extracting knowledge hidden from large volumes of raw data (Seifert, 2004). All relevant information will be retrieved immediately and the system will provide the recommended prices and suppliers for users to evaluate. Organizing the data is an extremely challenging activity and may require specialized database depending on the type of data. There are different types of databases like legacy databases, relational databases, object databases, data warehouses, data-marts and groupware databases. Among them, data warehouses are recommended as these databases combine data from other system databases to allow query by sophisticated analysis tools and they usually involve enterprise data and can hold extremely large amounts of data (Simchi-Levi et al, 2004).

Production

To many apparel manufacturers, the production order is a tedious consolidation of the sample order and sales contract that requires double entry of data. By deploying web technologies (e.g. .NET) and data analysis software, the time to generate a production order is greatly reduced as the relevant information can be imported from the centralized database. Through data import and the automated calculation function, not only the users can save time but calculation errors in specifications or size/color breakdown can also be avoided. For better control, the system could have a built-in amendment function that allows users to track all the changes made throughout the production order's history.

Material management

Inventory management is the major part of material management. Managing inventory in complex supply chains is typically difficult and may have a significant impact on the customer service level and supply chain system wide cost. (Simchi-Levi et al 2004). Similar levels of inventory are sometimes held for volatile and non-volatile items. As the market response sometimes lags, the suitable time and quantity of replenishment still have not been satisfied properly in supply chain inventory. As each production order requires a wide variety of materials, apparel manufacturers need to manage the inventory effectively in order to minimize the production cost and lead time. Artificial intelligence like expert system or agent-based technology can be picked to combine with the computer system for they both have the ability of intelligence, self-learning, judging and reacting in a dynamic environment. Such IT systems could be designed to have the functions of detecting the inventory level of different apparel products (Bendiksen and Dreyer, 2003). To optimize the material purchase process, Intelligent Agents might have the functions of considering the different sizes, colors and quantities, and then recommending the appropriate suppliers and material prices. The multi-agent system can also check whether the inventory is in stock so that apparel manufacturers do not have to acquire excess material. It might also list the information (e.g. price, supplier) about recent purchase of similar material for reference.

Order tracking

Apparel manufacturers often have problems of tracking each order's progress. Intelligent agent, one important branch of agent technology, has the ability of autonomy and proactivity which means agents can perceive their environment and respond timely and exhibit goal-directed behavior by taking the initiative (Wooldridge and Jennings 1995). By pre-defining check points in the computer system to monitor the order status, agents can be used to track the order's status, progress and take remedial action immediately if any problem occurs. Any changes in the contract will be updated and recorded in the system in real time. Control over delivery schedule does not only apply to internal operations but also to vendors and suppliers. The multi-agent system can be built in the production scheduling system (Cavalieri S. et al., 2000).

Information sharing and coordination

One issue many apparel companies are concerned is how information sharing between companies can be facilitated to improve the efficiency of supply chains. For example, sharing inventory levels of buyers helps predicting future demands more accurately, resulting in lower average inventory levels and higher service rates (Hyung and Sung 2003). Through better information sharing, apparel supply chain managers can better understand their business so that they can expand the more profitable business and control the operations that have higher costs. Grid technology has been used and bridged with supply chain integration and coordination. The agent grid computing has emerged as an important research direction which bridges the agent technology and special application, and has the in-depth research value of usage in textile and apparel industry (Shi et al., 2006).

Connectivity

Cross-border communication will definitely be increased because of web development. Connectivity is a key issue when adopting an IT solution as apparel manufacturers are operating in multiple locations (Sarkis J., Talluri S., 2004). Under a thin client architecture and advanced data compression technology, the IT solution does not require high bandwidth for data transmission. Virtual supply chains especially take effect with the development of virtual technology through the Internet. Cross-border communication via the Internet can hence be achieved more efficiently and at a lower cost. An agent-based apparel supply chain system might also be proposed which involves various emerging technologies with the distinct feature of the ability to cope with unexpected changes (Mele et al., 2007). It adapts the changes of environment dynamically. This system may allow supply chain members to communicate through the Internet and perform real-time information sharing.

Decision-making system

Some apparel companies cannot respond quickly and make appropriate decisions due to the large uncertainty and dynamics in apparel industry. Intelligent agents could be used to assist in decision making, especially in real time decisions (Simchi-Levi et al. 2004, pp. 277). Agent-based simulations have also been developed model decision-making process in apparel industry. Consumer traits, preferences, constraints on purchase decisions and apparel products could be modeled to offer the apparel executive a tool for exploring consumer response to proposed apparel products and scenarios based on specification of the target consumer and the characteristics of the product (Zhang.T. and Zhang D., 2007). Results may show the probability of purchase under various conditions. This approach could be used to perfect the supplier/consumer relationship by increasing responsiveness to consumers (Brannon et al. 2002).

2.2 Simulation Model in Decision Making in Supply Chains

In simulation models, many realistic features can be represented. A simulation model offers a comprehensive methodology by considering the strategic, tactical, and operational elements with much more details than any other approaches do. The development of simulation models to understand issues of supply chain decision making has gained importance in recent years (Shapiro, 2001; Simchi-Levi et al., 2003).

2.2.1 Decision Making Models in Supply Chains

Simulation models in supply chain management were largely applied in inventory control. Researches have been made on the decisions of VMI system of the apparel supply chain. The market forecasting and inventory management components of a Vendor Managed Inventory (VMI) decision support system (DSS) have been described and how this system was implemented by a major apparel manufacturer and over 30 of its retail partners. The DSS also helped the vendor and retailers arrive at jointly agreed upon customer service level and inventory turnover targets. Customer service levels improved dramatically, often coupled with a significant improvement in inventory turnover. (Achabal et al., 2000)

Because of the inherent complexity of the decision-making process in the supply chains, past studies on supply chain focused on modeling methodologies. Shapiro (2001) defined two types of mathematical models in SCM, namely descriptive models and normative models. Descriptive models were those “developed to better understand the functional relationships in the company and the outside world”, which included forecasting models, cost relationships, resource utilization relationships and simulation models. Normative models were those developed to help managers make better decisions, which was also termed as “optimization models”. Biswas et al. (2004) broadly classified the quantitative models of supply chain into optimization models, analytical performance models, and simulation models. In Truong (2002), the supply chain modeling methodology was categorized into six groups. They were linear programming-mixed integer programming, stochastic programming, network based approach, agent-based approach, discrete event simulation and system dynamic model.

Some models discussed above, such as analytical performance models, are high abstraction models for business processes under simplifying assumptions. Other models such as linear programming-mixed integer programming are widely used in the optimization of supply chain control systems. However linear programming-mixed integer programming approaches suffer from some pitfalls that limit their application to the design of supply chains. The size and complexity of a typical supply chain can involve a huge number of variables and constraints. The assumption of linearity may not hold.

In most of these models, because of complexity, stochastic relations and so on, not all real world problems can be represented adequately. Attempts to use analytical models for such systems usually require many simplified assumptions and the solutions are likely to be inferior or inadequate for implementation. Often, in such instances, one alternative form of modeling and analysis available to the decision maker is simulation.

In the apparel supply chain, a number of research initiatives at the North Carolina State University (NCSU) applied the simulation model as a consequence of the development of QR in the mid 1980s. These simulation models focused mainly on integrating domestic resources for achieving QR in the West.

A computer model is described that simulates the seasonal apparel-retailing process. The model is stochastic in nature and is designed to allow the investigation of the effects of improved retailing procedures on financial and other performance measures. Its principal value lies in the evaluation of Quick Response (QR) supply methodologies that allow frequent re-estimations of consumer demand and reorders of merchandise based on in-season point-of-sale (Pechoucek et al.) data at the stock-keeping-unit (SKU) level (Nuttle et al., 1991).

Hewitt et al. (1991) analyzed the US textile-apparel pipeline by comparing the traditional practice with QR. They examined the issues relating to various modes of supply chain through case study.

A novel apparel-supply system was described compatible with Quick Response retailing of apparel with a finite shelf life. The system was driven by a retail point-of-sale procedure, which regularly re-estimates customer demand and generates frequent reorders on the manufacturer and fabric supplier. The system was shown to come close to perfect supply over a range of operating conditions and thus allow greatly improved retail performance when compared with traditional retailing procedures (Hunter et al., 1992).

A stochastic computer-simulation model was used to quantify the retail-performance characteristics of traditional and quick-response (QR) procedures for seasonal and fashion apparel, The model allowed exploration of the underlying differences between the two systems, including patterns of stock-out, the impact of markdowns, and buyer-forecast error, as well as the limitations on QR effectiveness imposed by season length and the number of items offered per stock-keeping unit (SKU) (Hunter et al., 1996).

A useful insight into managerial decision making can be found from simulation of business systems. New technologies like multi-Agents have been applied in the supply chain management. Allwood and Lee (2005) proposed a new agent for the study of competitive supply chain network dynamics. The novel features of the agent include the ability to select between competing vendors, distribute orders preferentially among many customers, manage production and inventory, and determine price based on competitive behaviour. The agent will be of use for a broad range of studies on the long-run effect of management decisions on their network of suppliers and customers (Allwood and Lee, 2005).

The simulation model is extended to include the textile industry in the apparel supply chain. Segments of the supply pipeline such as spinning, yarn dyeing, knitting, weaving, dyeing and finishing were programmed using a stochastic simulation model. This modeling allows senior management to answer broad questions about the plants' ability to operate in a quick response (QR) environment (Nuttle et al., 2000b). An improved scheduling method and the construction of neural-network decision surface models are developed as a decision support tool. Research has also been done to explore the use of fuzzy mathematics to model the uncertainty and vagueness inherent in most supply-chain decision-making. (Nuttle et al., 2000a).

Some models and methodologies were thought to manage capacity, inventory, and shipments for an assortment of retail products produced by multiple vendors. The vendors differ in lead times, costs, and production flexibility. Product demand is uncertain and fluctuates over time. The optimization model was developed to choose the production commitments that maximize the retailer's expected gross profit, given demand forecasts and vendors' capacity and flexibility constraints. The model has been incorporated into a decision support system, developed in collaboration with supply chain planners at a global retailer of seasonal and fashion merchandise (Agrawal et al., 2002).

There is a complex, dynamic and highly competitive market for the textile and clothing industries in developed countries. Yeh and Yang (2003) constructed original and postponed garment dyeing cost models and used practical parameter data to simulate various situations, and then analyzes the differences and relations between the two cost models. The cost evaluation model provides a strategy and the basis for feasible judgment in evaluating dyeing postponement for the textile and clothing industries in garment supply chain management (Yeh and Yang, 2003).

Supply chain flexibility has significant potential and needs a greater research attention. Dynamic supply chain management requires integrated decision-making amongst autonomous chain partners with effective decision information synchronization amongst them. By employing decision flexibility and the associated dynamic control amongst autonomous supply chain nodes, many improvements are possible. A simulation model of a dynamic supply chain is used to advance the knowledge of dynamic control on effective flexibility exploitation. In this model each supply chain node involves decision-making. Based on the order and sample information available from the immediate buyers or customers, the supplier selection decisions are dynamically made. A seemingly good decision at a stage based on local information often ends up as detrimental not only to the total chain cost, but also to the total costs of the node itself. These observations are important for the designers and managers of the flexible supply chain systems to arrive at appropriate types and a judicious level of flexibility to attain significant improvements in total cost reduction. The modeling of dynamic supply chains with a focus on flexibility can offer enormous potential to the industry (Wadhwa et al., 2008).

The simulation of interaction between customers and suppliers in a three-tier supply chain system has been investigated. In such a simulation, customers respond to the price discount offer made by the supplier and the supplier makes adjusts the price according to stock held. The simulation shows that the behaviour of such interaction exhibits deterministic chaos.

2.2.2 Negotiation Strategy in Supply Chains

Models have been developed on an optimal pricing and replenishment policies in a "leagile" (lean and agile) supply chain system for a single vendor and multiple buyers. A pricing strategy with price reduction is incorporated to entice the buyers to accept the minimum total cost integrated system. Negotiation factors are incorporated to balance the cost saving between the players. The price reduction mechanism is a mutual beneficial strategic partnership between the vendor and the buyers (Wee and Yang, 2007).

Negotiation usually occurs in between enterprises. Thus a replicable, Internet-based negotiation server was developed for conducting bargaining-type negotiations between enterprises involved in e-commerce and e-business. Enterprises can be buyers and sellers of products/services or participants of a complex supply chain engaged in purchasing, planning, and scheduling. Each enterprise can select a trusted negotiation server to represent his/her interests. Web-based GUI tools are used during the build-time registration process to specify the requirements, constraints, and rules that represent negotiation policies and strategies. A cost-benefit analysis component is used to perform quantitative analysis of alternatives. (Su et al., 2001).

Bullwhip effect is a critical problem in the supply chain. Research has been done to show if a centralized operation can eliminate the bullwhip effect and reduce total cost. Some of this reduction can also be achieved with decentralized negotiation schemes. Their performance is evaluated under different modes of probabilistic supplier behavior. (Ouyanga and Daganzo, 2006).

In supply chain, a cell's agenda might be in conflict with supply requests within the network. The resolution of such conflicts requires a negotiation between client and supplier to harmonize their individual interests. A software agent was proposed to conduct an automated negotiation in the context of non-hierarchical production networks in order to assist the human decision-maker and accelerate the harmonization. The agent can perform an integrative negotiation about multiple interdependent properties of the supply contract, such as price, volume and delivery date. The agent model is flexible enough to be applied in supply scenarios requiring the negotiation of contracts (Neubert et al., 2004).

In an integrated inventory model, the way to allocate the cost savings to buyers and vendors is critical to the success of the joint relationship between both sides. An algorithm is presented to resolve the allocation of cost savings in the integration model. The coefficient of negotiation is adopted to determine the compromise between the buyer's and vendor's cost savings. the buyer and vendor can achieve an acceptable compromise solution for both sides in the supply chain management with such models (Chen and Kang, 2007).

The mechanism design problem of supply chain formation-the problem of negotiation mechanisms was addressed to coordinate the buying and selling of goods in multiple markets across a supply chain. As effective negotiation strategies can be difficult to design for supply chains, some researches are focus on incentive-compatible auctions (Neubert et al.), in which the agents' dominant strategy is to simply report their private information truthfully. The auctions produce higher efficiency for a broader class of supply chains than any other incentive-compatible, individually rational (IR), and budget-balanced (BB) auction we are aware of (Babaioff and Walsh, 2005).

Agent technology has been applied in the negotiation model in the supply chain. The multi-agent negotiation mechanism was added to enhance the existing methods to solve the distributed constraint satisfaction problem in the coordination of order fulfillment process. (Lin and Lin, 2006).

As an exercise in agent-based software engineering, Ulieru and Cobzaru (2005) proposes a holonic model for the domain of supply chain management with agents registered on a domain to find each other, access the knowledge base, communicate and negotiate with other agents. Agents are interacting through a price system embedded into specific protocols. The negotiation on prices is made possible by the implementation of an XML rule-based system that is also flexible in terms of configuration and can provide portable data across networks (Ulieru and Cobzaru, 2005).

Multi-agent computational environments are suitable for dealing with a broad class of coordination and negotiation issues involving multiple autonomous or semiautonomous problem solving agents. Jiao et al. (2006) applied the multi-agent system paradigm to collaborative negotiation in a global manufacturing supply chain network. An agent-based multi-contract negotiation system was proposed for global manufacturing supply chain coordination (Jiao et al., 2006).

Negotiation strategy was also used in production scheduling with the combination of agent-based approach in supply chains. A negotiation-based algorithm was proposed for solving distributed project scheduling problem (DPSP). This new algorithm not only acknowledged and accommodated the autonomy and independence of individual enterprises in making decisions in the entire supply chain, but also takes advantage of limited information shared among them to improve the quality and efficiency. Its emphasis is how to improve the convergence and quality of the solution by taking advantage of inter-enterprise information sharing especially the sharing of schedule flexibility information (SFI). (Lau et al., 2005).

Automated negotiation mechanism has been concentrated in contract manufacturing supply chains (Hsieh, 2005). In agent-mediated electronic markets, an agent may delegate part of the assigned tasks to other agents to achieve business objectives via establishment of contracts. Time and cost are two significant factors to be negotiated in contracts. Hsieh (2005) proposed a framework to model the negotiation processes in contract manufacturing, analyze the feasibility of the contracts and optimize contract awarding based on the proposed model.

The effect of trust mechanisms on supply-chain performance was examined in order to help net-enabled organizations select suppliers. Trust mechanisms with negotiation were proposed, and a multi-agent simulation platform was used to evaluate their supply-chain performance in respect to order quantity (Lin et al., 2005).

The problem of negotiation mechanisms was addressed to coordinate the buying and selling of goods in multiple markets across a supply chain. However, effective negotiation strategies were difficult to design for supply chains. Incentive-compatible (IC) auctions were designed, in which the agents' dominant strategy is to simply report their private information truthfully. (Babaioff and Walsh, 2005).

Non-hierarchical production networks are created by forming a co-operation of small autonomous manufacturing units, so called competence cells. The cell's autonomy in the network model allows each cell to pursue its own agenda of production tasks. Thus a cell's agenda might be in conflict with supply requests within the network. The resolution of such conflicts requires a negotiation between client and supplier to harmonise their individual interests.

The use of a multi-agent model can implement vertical and lateral coordination among the components of a non-centralized distribution chain. A model, which was developed to coordinate the supplier and the retailer with the help of the negotiation among agents, was applied to a real two-level distribution system of an electromechanical company, made up of a supplier and a geographically distributed network of retailers. (Cavalieri et al., 2003).

Neubert et al. (2004) demonstrated that their agent model was flexible enough to be applied in supply scenarios requiring the negotiation of contracts. A software agent was proposed to conduct an automated negotiation in order to assist the human decision-maker and accelerate the harmonization. The agent can perform an integrative negotiation about multiple interdependent properties of the supply contract, such as price, volume and delivery date. The negotiation protocol follows the offer-counteroffer principle and an adaptive offer generation strategy (Neubert et al., 2004).

2.2.3 Summary

Having received the literature of the relevant topics, the following remarks that inspire this research were derived.

The apparel supply chain has received considerable attention, along with the development of the QR strategy. Most of the past research studies in the apparel supply chain were focused on a certain problem in supply chain process to improve the overall efficiency. However, less notice has been given to the part of effect of human decision making in supply chains. In the apparel supply chain, negotiation among customers, merchandisers and suppliers takes time and decision delay usually exists in such process due to incomplete information and the bidding period in negotiation. Decision delay is a problem that has been neglected in the apparel supply chain. Agents with embedded negotiation strategy can consider related factors comprehensively and are effective in assisting human being to make decisions efficiently during negotiation.

Various studies on simulation models in the apparel supply chain were reviewed. It was noted that a simulation model could provide a comprehensive supply chain modeling method with much more details than any other approaches do. However, these simulation models focused mainly on evaluating the performance of the QR strategy adopted in the apparel supply chain and the improvement observed. Nowadays, merchandisers become important parts in the apparel supply chain. Merchandisers have to negotiate with suppliers and customers on price, time and other apparel specification. Decisions should be made immediately when large amounts of orders come during seasonal period. Merchandiser's negotiation with suppliers and customers on price setting and reorder strategy affect the efficiency of the supply chain management. The decision delay can be reduced by developing an agent-based simulation model embedded with negotiation strategies. The proposed simulation model provides a tool for merchandisers, suppliers and customers to negotiate with each other based on agents' interaction. If the agents cannot achieve agreement, the human being will involve then. Thus the simulation reduces the decision delay, eases the human operation and saves time for merchandisers during order peak time.

The benefit of multi-agent has been widely reported with its application in supply chain management. The merchandiser takes the responsibility for the decisions such as determining the price and the lead time when negotiating with the customers and the suppliers. Decision delay affects the efficiency of the supply chain. Decision delay exists in each supply chain process and is inevitable. However, if it could be reduced, the efficiency of the supply chain would be improved. Research on searching for optimal negotiation strategy for apparel merchandisers to reduce the decision delay of the supply chain was limited. Thus, the current exploratory research is undertaken in order to empirically examine and optimize the negotiation strategy in the agent-based apparel supply chain.

Chapter 3
Literature Review of the Modeling Approaches in SCM

The previous chapter gives the literature review of the background of the research. However, some modeling approaches are adopted to simulate the communication and negotiation process of the apparel supply chain in this research. Methods and artificial algorithms are used to improve the decision making performance in the agent-based negotiation environment. Thus, this chapter presents the review of these methods and algorithms used in the research.

3.1 Agent Technology

There has not yet been a universally accepted definition of agent yet, but most researchers agree that notionally, it should be a computer system or a program characterized by three leading properties: autonomy, social ability and reactivity (Verdicchio M. and Colombetti M. 2002).

A. Advantages of agents

Generally speaking, agents are active, persistent (software) components with the abilities of perceiving, reasoning, acting and communicating (Fung and Chen,2005). Their advantages are listed as follows:

1) Agency ability: They can represent the work or task of users, integrate and pack resources needed and instruct users to visit them.

2) Intelligence: They understand the information requirement of users, catch the interest and hobbies of users, infer or guess the intention of users.

3) Autonomy: They can also individually make plans of complex operation in a dynamic environment, and independently discover and extract useful resources and services. In addition, they can solve problems without the intervention of users.

4) Mobility: Agents can easily visit all kinds of resources through the Internet, and consult and cooperate with other agents.

B. Intelligent agent

The Intelligent agent is one major branch of the agent theory. It has the properties of autonomy, social ability, reactivity and pro-activeness (Wooldridge M. and Jennings N., 1995), which can be defined to distinguish it from other types of software applications. Intelligent agents usually have the ability of catching and manipulating the knowledge sensitively, to reason, learning new information, and communicating fluently. Given the above properties, the recent applications for intelligent agents are most related to electronic commerce, business management, planning and scheduling.

C. Multi-agent system

Agents cannot exist in a single environment; they have to communicate with each other and operate together. Thus more functional and effective multi-agent systems began to develop quickly (Hendler., 1999).The multi-agent system can address and share problems which are too large for a centralized single agent and provide solutions to inherently distributed problems like workflow management (Hayzelden and J.Bigham, 1999).The multi-agent system contains a number of simple task agents which utilize the service of other agents to perform tasks and achieve complicated goals (Payne et al., 2002).

D. Application of agent technology in Apparel Supply Chain Management (ASCM)

In recent years, agent and multi-agent system (MAS), which are rooted in DAI (distributed artificial intelligent), have become a powerful and wide-spread paradigm for developing complex systems (Smathers and Goldsmith, 2001). Successful applications of multi-agent system have been introduced to achieve common goals with collective agents communicating and working cooperatively (Huhns and Singh, 1998).

Agent-based simulations have also been developed to model the decision-making process in the apparel industry. Consumer traits, preferences, constraints on purchase decisions and apparel products could be modeled to offer the apparel executive a tool for exploring consumer response (Brannon, 2000). Research has also been done on agent-based supply chain integration & coordination (SCIC) and its application on business including apparel product transaction (Liu and Wang, 2003).

However, as for the apparel industry, application of agent technology still has yet to be explored. The next section explains the potential use of agent technology in the communication system in the apparel industry.

3.2 Brief Introduction of Agent Communication System

Negotiation between agents is based on certain agent communication mechanism. Before we talk about negotiation, we need to have the basic knowledge of agent communication and set up the communication framework for the agent-based apparel supply chain. A fundamental characteristic of multi-agent systems is that individual agents communicate and interact. This is accomplished through the exchange of messages and, to understand each other. It is crucial that the agents agree on the format and semantics of these messages.

The Foundation for Intelligent Physical Agents (FIPA) is a body for developing and setting computer software standards for heterogeneous and interacting agents and agent-based systems. FIPA was founded as a Swiss not-for-profit organization in 1996 with the ambitious goal of defining a full set of standards for both implementing systems within which agents could execute (agent platforms) and specifying how agents themselves should communicate and interact.

There are two most popularly-used standards for agent communication, Agent Communication Language (ACL) and Knowledge Query and Manipulation Language (KQML).

To make agents understand each other they have to not only speak the same language, but also have a common ontology. Ontology is a part of the agent's knowledge base that describes what kind of things an agent can deal with and how they are related to each other.

JADE, which is the most widely used agent software, follows FIPA standards so that ideally JADE agents could interact with agents written in other languages and running on other platforms. In JADE, messages adhere strictly to the ACL standard which allows several possibilities for the encoding of the actual *content*. In particular, JADE supports FIPA's semantic language, an encoding of *concepts*, *actions* and *predicates*.

There are many other systems using FIPA standard besides JADE. The Spyse agent platform, JACK, the April Agent Platform (AAP), ZEUS and the Fipa-OS agent platform (No longer actively developed).

3.3 Simulation Model

3.3.1 Brief Introduction of Simulation Model

Simulation has been used as a tool for supporting performance analysis of manufacturing and logistics systems since the primary work of Tocher et al. (1960). The application examples are demonstrated in several publications such as Banks et al (2001), Brooks et al. (2001) and Yao et al. (2002). The strength of simulation is to enable users to observe and analyze the dynamic behavior in the target system, often different from mathematical programming methods. Simulation consists of building a representation of the real world and experimenting with it. The combination of model creation and experimentation enables designers and managers to "reproduce and to test different decision-making alternatives upon more possible foreseeable scenarios, in order to ascertain in advance the level of optimality an robustness of a given strategy" (Terzi et al 2004).

3.3.2 Relevant Work of Simulation Model in SCM

Since the entities involved in the supply chain has complex interactions while the demand from the customers is stochastic, supply chain problems are often very large and complex to be addressed in analytical models. Even a few analytical models exist; they are often based on limiting assumptions. A simulation model was thus selected to investigate the supply chain.

The development of simulation models for understanding issues of supply chain decision making has gained importance in recent years. A vast amount of literature presented applications of simulation into real world specific cases. Here are some examples.

In order to support designing SCM operations, generic simulation models were developed recently to represent business process activities in SCM (Schunk et al 2000;

Wyland et al 2000; Chan et al 2001; Truong 2002; Hung et al 2004; Chan et al 2005; Umeda et al 2006). A few simulation models were developed to improve supply chain dynamics such as uncertain demand and external supply of raw material with the presence of many supply chain players (Towill et al 1992; Petrovic et al 1998; Petrovic 2001). Another group of studies in the literature reported the benefits of the simulation tool designed to do business consultation from practitioners' viewpoint (Bagchi et al 1998; Heita 1998; Ingalls et al 1999; Koks et al 2003; Lee et al 2000).

Supply chain simulation has gained considerable attention and momentum in various industries. Some of the examples are electrical and communication equipment (Connor et al 1995; Persson et al 2002), food and related product (Vorst et al 2000; Weng et al 2003), automotive parts and accessories (Waller 2005). Among them, textiles and apparel industry has been one of the most important branches (Nuttle et al 1991; Hunter et al 1992; Hunter et al 1996a; King et al 1996; Raman et al 2002). However the simulation model developed in the apparel industry mainly focused on integrating resources for achieving quick response and better communication. Little information can be obtained about how the thousands of decisions in the apparel supply chain can be facilitated by the simulation model and how decision makers can benefit from these models. Few studies have concerned about a certain supply chain process like the merchandise process and the role of the merchandisers who have to face huge amounts of decisions are neglected. The overall efficiency can be improved with the improvement of the efficiency of the merchandisers.

3.4 Knowledge Management (KM)

3.4.1 Knowledge and Information

Knowledge is often confused with information. However, they are different. Information generally includes facts, observations, sensations, and messages. Information is usually defined as organized data (Saint-Onge, 2002), data endowed with relevance and purpose (Drucker, 2001), interpreted data. Simply speaking, information is the content which informs our minds.

Accumulating information is of no use. Only useful information will be valuable to enterprises in the supply chain. That's why we talk about knowledge. Knowledge is what our minds do with all the information, is processed and useful information. Knowledge is defined as the condition of knowing something gained through experience or the condition of apprehending truth or fact through reasoning (Bouthillier and Shearer, 2002). Namely, knowledge can only reside in one's mind and is the result of human experience and reflection based on a set of beliefs that are at the same time individual and collective (Terra and Angeloni, 2005).

3.4.2 KM in apparel supply chain

The effective use of knowledge is a key component in every successful supply chain no matter what field or business function they may be in or what services the organization provides. Effective knowledge management enhances products, improves operational efficiency, speeds deployment, increases sales and profits, and creates customer satisfaction.

By integrating knowledge management into the supply chain activities, the apparel firms can automate existing processes and reduce lead-time throughout the supply chain. They can enhance communication, collaboration, and corporation between knowledge teams (including virtual teams) using intranet technologies and between the organization and members of its external constituent organizations using extranet technologies (Sugumaran, 2002).

Apparel supply chain and KM strategies should complement each other. Indeed, success in a competitive marketplace depends on the quality of knowledge that organizations apply to their key business processes.

3.5 Fuzzy Theory

3.5.1 Brief Introduction of Fuzzy Theory

The fuzzy concept was initiated by Zadeh (1965). The fuzzy set theory provides a strict mathematical framework in which vague conceptual phenomena can be precisely and rigorously studied. It can also be considered as a modeling language well suited for situation in which fuzzy relations, criteria and phenomena exist. Details of the fuzzy set theory and its application can be found in Taerno et al (1992), Klir et al (1988), and Zimmermann (2001).

3.5.2 Relevant Work of Fuzzy Theory in SCM

There were a number of studies applying the fuzzy set theory under uncertainty in SCM in the past. A series of relevant research can be found in Petrovic et al (1996, 1998, 1999, 2001). The authors addressed uncertainties associated with customers' demand, supply deliveries along the supply chain and external or market supply by vague and imprecise phrases. Petrovic et al (1996) applied the fuzzy set theory to models for the newsboy problem. Sources of uncertainties inherent in the external environment, namely customer demand and external supply of raw material, were also identified and modeled using the fuzzy concept (Petrovic et al., 1998). Interpreting and representing those uncertainties by fuzzy sets, a supply chain fuzzy model was developed to determine the order quantities at each inventory level in the supply chain (Petrovic et al. 1999). A special purpose simulation tool was developed to analyze the supply chain behavior and performance in the presence of uncertainty (Petrovic, 2001). Multi-criteria ranking of inventory replenishment policies was devised in the presence of uncertainty in customers' demand (Petrovic et al., 2001).

Some other researchers also addressed the uncertainties in the supply chain with fuzzy concepts. Vujosevic et al. (1996) considered the EOQ formulation with the impressively estimated inventory cost. Defining the imprecise parameters by fuzzy numbers, the approaches to determine the optimal order quantity in a fuzzy environment was developed. Giannoccaro et al (2003) presented a methodology to define a supply chain inventory management policy, which was based on the concept of echelon stock and fuzzy set theory. More recently, Wang et al. (2005) developed a fuzzy decision technique to determine the order-up-to level of SKUs in the supply chain to minimize the inventory cost and to fulfill the target fill rate of finished product (Wang et al. 2005).

In the textiles and apparel industry, little research has been conducted on the study of supply chain behavior and performance using fuzzy logics. Nuttle et al. (2001a, 2001b) proposed a soft computing guided simulation system to provide a vehicle for soft goods supply chain modeling, analysis, and optimization incorporating the uncertainties and impression inherent in real system. Fuzzy logic was employed into the simulation model so as to identify whether the specific management goals (such as "we want customer service to be HIGH and inventories to be LOW") were obtained. In Fang et al. (2003), a mixed integer fuzzy linear programming model was established to allocate fuzzy ship capacity to meet customers' specified due-dates in a textile supply chain. Here, the fuzzy set theory was engaged to model and capture the impression inherent in 'ship capacity' and the customers' specified due-dates in terms of the tolerance level.

However, most of the previous research concentrated on applying the fuzzy set theory to inventory control in SCM. Studies investigating the role of merchandisers and the decision making in a merchandise process in the supply chain are limited.

3.6 GA

3.6.1 Brief Introduction of GA

GA is an evolutionary optimization approach which is an alternative to traditional optimization methods. GA is most appropriate for complex non-linear models where location of the global optimum is a difficult task. It may be possible to use GA techniques to consider problems which may not be modeled as accurately using other approaches. Therefore, GA appears to be a potentially useful approach.

GA follows the concept of solution evolution by stochastically developing generations of solution populations using a given fitness statistic (for example, the objective function in mathematical programs). They are particularly applicable to problems which are large, non-linear and possibly discrete in nature, features that traditionally add to the degree of complexity of solution. Due to the probabilistic development of the solution, GA does not guarantee optimality even when it may be reached. However, they are likely to be close to the global optimum. This probabilistic nature of the solution is also the reason they are not contained by local optima.

3.6.2 Relevant Work of GA in SCM

Recently, some researchers successfully used GA on the optimization problems in SCM simulation models. The optimization using GA mainly focuses on two domains. One is the optimization of the performance of a system. For example, Dengiz et al. (1997) optimized an (s, S) periodic review inventory control system with stochastic lead time by GA. The result of the optimization with GA was compared with that of exhaustive search and random search method. It was reported that GA performed better than random search. Disney et al. (2000) described a procedure for optimizing the performance of an industrially-designed inventory controls. GA was designed to optimize the system performance via determining the weight of appropriate “benchmark” performance characteristics. Ding et al. (2004) proposed a simulation-based multi-objective optimization method for joint decision-making on strategic souring and inventory replenishment. A multi-objective genetic algorithm was developed to determine the optimal supplier portfolio and inventory control parameters in order to reach best compromise of the two conflicting criteria: costs and demand fill rate.

Another group of research applied GA in the field of testing or fitting of quantitative models in SCM. For instance, Azadivar et al. (1999) proposed a simulation optimization method for optimizing the qualitative variables and the structure of a supply chain, such as the number of machines in a station or the in-process inventory. A GA method was suggested by the authors to continually generate the satisfactory solution to the selection of the structure of the model. It was reported that GA outperformed random search on three sample problems. GA also consistently achieved a larger fraction of the possible improvement at iteration.

However there is no research on using GA in the optimization of the negotiation strategy in an agent-based apparel supply chain.

3.7 SA

3.7.1 Brief Introduction of SA

Simulated annealing (SA) is a generic probabilistic meta-algorithm for the global optimization problem, namely locating a good approximation to the global minimum of a given function in a large search space. It is often used when the search space is discrete (e.g., all tours that visit a given set of cities). For certain problems, simulated annealing may be more effective than exhaustive enumeration — provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution.

3.7.2 Relevant Work of SA in SCM

SA, though widely used in recent supply chain research, has been applied in some aspects of supply chain management. SA based heuristic algorithms are presented to solve the parallel machine problem of synchronized scheduling of assembly and air transportation to achieve accurate delivery with minimized cost in consumer electronics supply chain (Li et al., 2008). A multi-echelon integrated just-in-time (JIT) inventory model with random delivery lead times for a serial supply chain in which members exchange information to jointly make purchase, production, and delivery decisions was proposed by some researchers. Accordingly, a proposed search method for finding the optimal solution and a simulated annealing algorithm used successfully to obtain a near-optimal solution were developed (Chiu and Huang, 2003). Distribution network design problems, which are characterized by multiple product families, a central manufacturing plant site, multiple distribution center and cross-docking sites, and retail outlets (customer zones) which demand multiple units of several commodities have been addressed. The overall system generates globally feasible, near optimal distribution system design and utilization strategies utilizing the SA methodology. The computational performance under a variety of problem scenarios and SA control parameter settings has been systematically evaluated (Jayaraman and Ross, 2003). Extended factories consisting of geographically dispersed independent production facilities are already a reality in the global economy. Production facilities concentrate on core technologies and create partner networks for the manufacturing of their products. Simulated annealing and stepwise search procedures were used to improve plans and make-or-buy decision processes to solve resource constraints (Frederix, 2001). The problem of planning an incoming customer order to be produced in a distributed (multi-site) and multi-stage production system has also been addressed by Azevedo and Sousa (2000). The problem is tackled in a hierarchical model, in two levels: a global network planning procedure, and a set of local capacity models associated to the different production units reflecting their particular features. An approach based on simulated annealing is presented, as well as a specially designed constructive heuristic that takes into account many of the real world constraints and complexities. The general performance of the simulated annealing algorithm is assessed through some preliminary computational experiments. (Azevedo and Sousa, 2000). Some studies are focused on a supply network problem where resource inputs are constrained to achieve performance goals for the reconfigured distribution system. Simulated annealing is applied for solving this reconfiguration problem. Computational results suggest that the simulated annealing heuristics generate near optimal solutions quickly and are well suited for evaluating supply network reconfiguration. Computational results also suggest that enhanced annealing heuristics proposed are better than the standard annealing approach. The supply network problem structure was exploited to achieve very good solution results (Ross, 2000).

3.8 GSAA

GA and SA described has is own strengths, because some good characteristics of GA and SA are maintained when combining GA and SA together. GSAA has been a newly developed algorithm in recent years. It integrates the benefit of both GA and SA. However, the algorithm has not been used in supply chain modeling till now.

3.9 Summary

This chapter introduced the approaches briefly and gave a review of their previous application in SCM. The related works for both the simulation-based optimization methodology and the techniques in SCM were reviewed. The chapter lays a basis for the next chapter where more details will be discussed including the reason why the modeling approaches are selected and how to use them.

Chapter 4

Methodology

The aim of this chapter is to specify the research strategy adopted for investigating the application of agent technology in decision making in communication system and negotiation process in the apparel supply chain. There are large amounts of decisions existing in the overall communication through the apparel supply chain. For example, merchandisers who communicate with customers, suppliers and production schedulers have to make decisions about quantity, time and price every day. In fashion industry, it is even thornier for people to make quick decisions especially in negotiation process as there are more uncertainties and dynamics due to the market change and customer demand variety. Thus, it is necessary to improve efficiency of the decision making cycle in communication and negotiation process in the apparel supply chain. The aims and objectives of this research, further refined from identified gaps in the literature, are used to shape the methodology of this chapter.

4.1 Overview

A mathematical model of optimal negotiation strategy for the apparel supply chain agents has been built and a simulation-based negotiation model of agents has been established in the apparel supply chain. The steps of the research on decision making in the agent-based apparel supply chain are illustrated as follows.

Firstly, five apparel companies which are famous for their own features of supply chains are selected as the typical cases to study the different structure and characteristics of the apparel supply chain (appendix A). These cases are used as the basis for further formulation and development of negotiation model of the apparel supply chain. The similarities and differences are compared among these five apparel supply chains. Based on the comparison, we divide the supply chain management into five common processes for clear investigation of decision making in each process. From the five case studies, decisions are categorized and common decisions of each process in the apparel supply chain are summarized. Agent technology is used to facilitate the decision making in the supply chain management. Multi-agents are designed to represent the supply chain members and unified modeling language (UML) is applied to model the merchandise and production schedule processes in the agent-based supply chain environment with the exhibition of the interaction and coordination of agents in the apparel supply chain. The architecture of web-based knowledge management in supply chain is provided and the knowledge sharing model in the apparel supply chain is built.

Secondly, we focus on the decision making in the order and negotiation cycle in the merchandise process in order to reduce the decision delay and improve decision efficiency. Among the five processes, we find that most of the information and knowledge exist in the merchandise process as the merchandisers deal directly with the customers, the suppliers and the apparel data like color, size and style. The merchandisers have to face large amounts of decisions everyday and they need to make decisions, no matter important or slight, as quick as possible. In order to reduce the work of merchandisers and facilitate the decision making process, a simulation model was designed for the negotiation within merchandiser agent and supplier agent to realize an automatic communication. The development of the simulation was assisted by the software ZEUS. The apparel merchandisers also need to make order strategy. The market variety and the seasonality will all affect the reorder point and quantity. Therefore, intelligent algorithms like genetic algorithm (GA), simulated annealing (SA) and genetic simulated annealing algorithm (GSAA) was employed as the optimization algorithms in the model so as to generate an optimal combination of negotiation strategy on price and delivery date for the decision makers in the apparel supply chain to improve the performance of the apparel supply chain. Mathematical models are built and the model was assisted by the commercially available software Origin. The model was compared with that without using agent technology to verify the advantage.

Finally, the research will be analyzed with the factors which influence the performance of the decision making. The analysis will be verified by the industrial expert and compared with the real practice in the industry. The results of the analysis will be expected to show implications on the decision making efficiency in the field of apparel merchandise for both academic research and industrial processes.

4.2 Research Design

The section introduces the design of the whole research including the problem met in the apparel supply chain and the approaches used in the research.

4.2.1 Research Problem

Given the uncertainty of the global apparel supply chain, complexity and dynamics of communication among supply chain parties and the intricacy of the decision making in supply chain processes, the research problems fell into the realm of 'how' and 'why'. People have to make thousands of decisions in different supply chain processes in time so that decision delay would occur due to any tiny pause or incorrect communication. Especially in the negotiation process, human interacts, responds and make decisions in a dynamic environment and sometimes can not consider comprehensively due to information explosion in the complicated apparel supply chain. Decisions, which belong to the scope of the tacit knowledge in the apparel supply chain, are human-involved and difficult to describe in a positivist way. Therefore, in this research, the methodologies for researching the decision-making in negotiation process adopted the simulation with mathematical formula with artificial algorithms as the major approach.

The objectives of the research were therefore set as follows:

To understand the needs and process of reengineering the supply chain communication system using IT and artificial intelligence (AI)

To explore the use of agent technology in decision making, especially in negotiation process in the apparel supply chain.

To identify the strategies adopted by well-known apparel supply chain companies to maintain competitiveness and to develop a communication model based on agent technology

To have a better understanding of knowledge management and its difference from information management and build architecture and model in the apparel supply chain

To model the knowledge flow and represent the coordination among supply chain partners in supply chain process with Agent UML

To investigate the advantage of multi-agents in solving negotiation problems and reducing the decision delay

To explore the feasibility of integration of intelligent algorithms with negotiation strategy in the proposed simulation model

To understand the way in which apparel supply chain can make use of computer simulation to manage negotiation problems in global apparel supply chains

To consolidate the findings of this research and identify new knowledge that can be added to existing theories

Communication is thought to be the most difficult problem by many industrial people. To achieve objectives, computer simulations are built to emulate the communication system and negotiation process in the apparel supply chain so that coordination and efficiency could be achieved by adopting artificial intelligence. Multi-agents are developed to represent major supply chain members and consistent communication structure has been built so that overall cooperation can be obtained. Negotiation strategy employed in the simulation model is facilitated by intelligent algorithms. Related mathematical formulas about negotiation between the manufacturer agent and the supplier agent are created in order to minimize supply chain cost and expand mutual profit.

4.2.2 Case-study Based Modeling

The case study method is an approach to studying a social phenomenon through a thorough analysis of an individual case. The case may be a person, group, episode, process, community, society or any other unit of social life. It provides an opportunity for the intensive analysis of many specific details often overlooked by other methods. This approach rests on the assumption that the case being studied is typical of cases of a certain type so that, through intensive analysis generalizations may be made that will be applicable to other cases of the same type. (Kumar, 2005)

Several cases of characteristic apparel supply chains are selected as the basis of the simulation modeling and the operations performed by apparel enterprises were analyzed (Appendix A). They were also used to provide additional evidence to understand the strategic issues in the apparel supply chain processes especially in the decision making part. Simulation has been a powerful tool for decision-making and testing options. This research aims to use simulation to model the processes in the agent-based apparel supply chains to identify whether agent technology can facilitate the decision making process.

4.2.3 Overview of Research Methodologies Using Quantitative Modeling

Quantitative modeling has been the basis of most of the initial research in operations, labeled as operational research in Europe, and was also the basis of initial management consulting and operations research (OR) in the USA. Initially, quantitative modeling in operational research was oriented very much towards solving real-life problems in operations management (OM) rather than towards developing scientific knowledge. Especially in the USA, a strong academic research line in OR emerged in the 1960s, working on more idealized problems and thus building scientific knowledge in operations management. During that same period, however, much of this research lost its empirical foundations, and research methods have been primarily developed for these more or less theoretical research lines, leaving the more empirically-oriented research lines for more than 30 years in the blue with regard to research methodology. Recently, this tide has however turned, and the need to develop explanatory and predictive theory regarding operational processes and OM has become apparent. Articles have been published that formulate requirements for theory development in OM (Schmenner and Swink, 1998; Amundson, 1998; Wacker, 1998) or that try to connect the knowledge generated along the various research lines into a more general theoretical framework (Melnyk and Handfield, 1998a).

Quantitative model based research can be classified as a rational knowledge generation approach (see Meredith et al., 1989). It is based on the assumption that we can build objective models that explain (part of) the behavior of real-life operational processes or that can capture (part of) the decision-making problems that are faced by managers in real-life operational processes. It is important to stress that the relationships between the variables are described as causal, meaning that it is explicitly recognized that a change of value in one variable will lead to a change of $f(\alpha)$ in another variable. In other types of quantitative research, such as survey research, also relationships are defined between the variables that are under study. However, generally in survey research the range over which the variables vary is not always defined explicitly, and the relationship between the variables is usually not causal, and in most cases not quantitative. With 'quantitative' in this observation, the extent to which the dependent variable changes is quantitative when a specified change in the independent variable occurs. An important consequence of the fact that relationships are causal and quantitative is that the models can be used to predict the future state of the modeled processes rather than be restricted to explaining the observations made. Within the model, all claims are therefore unambiguous and verifiable. It is important to realize that this is not valid for claims that pertain to the world outside the model. For the world outside, unambiguous and verifiable predictions are very hard to make and this issue will be shown has hardly been addressed in the academic literature. As a consequence, there is a clear distinction between empirical quantitative modeling research and axiomatic quantitative modeling research (Bertrand and Fransoo,2002).

4.2.4 Quantitative Research Using Simulation

A slightly different approach is taken when the result is not obtained with mathematical analysis but with computer simulation. This technique is used in case the model or problem is too complex for formal mathematical analysis. This type of research generally leads to lower scientific quality results than research using mathematical analysis, but the scientific relevance of the process or problem studied may be much higher. This is because computer simulation can deal with a much wider variety of scientific models than can mathematical analysis. So the trade-off here often is between scientific relevance of the process or problem studied and scientific quality of the result.

Research that uses computer simulation requires a number of additional steps. A very important step in simulation research is the justification of the research method. Since the scientific quality of the results generally will be lower – rather than mathematical proofs, only results with some statistical significance can be reached, it is only justified to use this method if it can be shown that it is not possible to solve the problem in an analytical way. A well-known example here is use of computer simulation to test heuristic methods for solving combinatorial optimization problems. Articles that report on this research always contain a section in which it is demonstrated that the problem cannot be solved to optimality in polynomial time of the problem parameters. This is an accepted standard for justifying research on heuristics (Bertrand and Fransoo, 2002).

4.3 Simulation Model

Simulation models can provide a comprehensive supply chain modeling methodology considering the strategic, tactical and operational elements with much more details than any other approaches do. By using simulation techniques, the performance of a supply chain model can be evaluated extensively and can be quantified, which can avoid subjective decision making (Chan et al, 2005). In this research, a simulation model was designed for investigating the behavior of decision making in the apparel supply chain and develop a new method to evaluate the performance of the apparel supply chain.

4.3.1 Overview of simulation model

The important features included in a simulation model include "ability to experiment with the model by changing any part of it" and ability to collect a variety of statistics to measure the performance of the simulated system" (Brook et al, 2001). Its importance also lies in its ability to mimic the behavior of a real system through the creation of a model to represent the system and subsequent experimentation. Experimenting in real systems is seldom possible as it is both costly and time-consuming. However by experimenting with the confines of a model, important behavior and knowledge of a system can both be observed and learned. Simulation modeling therefore has the advantage of allowing the decision makers to test ideas in a virtual environment.

As stated in Pidd (1998), computer simulation involves experimentation on a computer-based model of the real system. The model is used as a vehicle for experimentation, often in a "trial and error" way to demonstrate the likely effects of various policies. Thus, those which produce the best results in the model would be implemented in the real system.

Sometimes these experiments may be quite sophisticated, involving the use of statistical design techniques. This is due to the aspects of the real system being modeled changing from occasion to the next in unpredictable ways. In other words, there is some inherent "random" behavior in the system such that a given situation does not always "play out" the same. These stochastic can be captured by computer simulation using the built-in statistical function. In most cases, the overall behavior of a variable characteristic in the long term can be described using a probability distribution. The simulation model can then simulate the characteristic by choosing a value at random from the distribution. The sampling of values at random from a distribution is done using random numbers (Brooks et al, 2001).

4.3.2 Reasons for Using Simulation Model

To solve the decision making problem and reduce decision delay in the negotiation process in the agent-based apparel supply chain, it is necessary to improve the efficiency of negotiation. Decisions exist in every process in the apparel supply chain especially in the negotiation processes. For example, the major job of a merchandiser is to process orders and to negotiate. They need to decide about the reorder point and the quantity in an uncertain environment, negotiate with customers and determine the price and due date about the apparel product. A manufacturer needs to negotiate with suppliers on the procurement as well. Any small communication problem will cause decision delay. The decision delay problems have become more complicated owing to the interactions between the entities, the length of the supply chain, the inaccurate or incomplete information and wait time. Furthermore, the apparel supply chain is facing a series of dynamics both internally and externally such as the fluctuating production capacity and stochastic nature of customers' demand. These uncertain factors make the analyzing and evaluating of the supply chain performance more difficult. A powerful tool to help the decision makers to save the time on the negotiation strategy and evaluate the outcomes of these decisions is simulation.

A simulation model is capable of capturing complexities of real-world large-scale multi product, multi-echelon supply chain, presenting inherent features of activities in the apparel supply chain such as purchasing, manufacturing, inventory replenishment and order fulfillment. Simulation is a methodology that can be used to directly model the complexities of the entire supply chain without many assumptions.

In the communication simulation model, the interactions between the individual factors are quite complicated. The merchandiser receives orders from the customer and gets the price specification. Then the merchandiser negotiates the price with different material supplier with consideration of the lead time and material quality. For instance, if the lead time can be agreed to a bit longer period, the price can be reduced within a certain range. The complex negotiation takes time in real life and the merchandisers have to determine the price of each material quickly. With the negotiation strategy put into the simulation, the computers will replace the human being to negotiate with each first. If by any possibility the negotiation cannot achieve agreement within two parties, then the computer will inform the merchandisers to make decisions based on the computer negotiation. Therefore, the computer simulation saves time for negotiators and shortens the decision time.

During negotiation, calculating price and delivery date are quite complicated since the production capacity must be balanced to a certain degree and the total supply chain cost should be also taken into consideration. In addition, the uncertain factors like seasonality and market change affects. To solve these problems, the decision makers should investigate not only the performance of an individual part, but also the system as a whole. Simulation is a tool that uses a system approach to tackle problems. The system approach of simulation is based on the fact that "even if each element or subsystem is optimized from a design or operational viewpoint, overall performance of the system may be suboptimal because of interactions among the parts" (Pegden et al 1995). With the simulation model, the significance of individual factors and the resultant consequences due to their interactions could be obtained.

4.4 Knowledge Management

Apparel supply chain is complicated as there are lots of changes and dynamics in fashion industry. Apparel industry concerns varieties of information like color, size, style, raw material, customer demand, delivery time and even the feeling. Thus, to catch helpful information and use information effectively is important in an apparel supply chain. Knowledge management takes effect. When customer orders are received, merchandisers can share the information with other supply chain members through knowledge management network portal. In this way, they can easily get the information they want from the database instead of always stopping to consult others. Time is saved, cost is reduced and the overall efficiency will be improved.

4.4.1 Knowledge Types

Knowledge can be categorized according to two different standards.

According to the knowledge holder, knowledge in the supply chain can be categorized into personal knowledge and collective knowledge. Personal knowledge is the basis of the existence of collective knowledge, while collective knowledge is not simply the accumulation of personal knowledge. Collective knowledge is the spread, share and creation of personal knowledge.

According to the description of knowledge, knowledge in the supply chain can be classified to explicit knowledge and tacit knowledge. Explicit knowledge is data, reports, and procedures retained within an information technology system. Explicit knowledge can be read, arranged, saved and can exchange between different knowledge holders along the apparel supply chain. Tacit knowledge built on the personal experience, value, methodology and some other invisible elements is deeper experience, expertise, and know-how of the organization. This knowledge is undocumented and exists in the minds of employees (Yuva, 2002). Tacit knowledge is usually not easy to spread within different knowledge holders. Two examples of these two types of knowledge are listed as follows.

Explicit supply management knowledge ---- For example, an apparel supply manager inputs the number of orders received each week into an information repository system. This data can be retrieved and explained explicitly to others in the apparel supply management department or organization.

Tacit supply management knowledge ---- For example, a retiring senior supply management executive demonstrates how to analyze various reports to forecast the next year's inventory. Without sharing this knowledge with the supply management staff, the department may be unprepared to effectively gauge the inventory needs of the organization after the executive retires (Yuva, 2002).

4.4.2 Overview of Knowledge Management

Several studies have proposed definitions of KM. Newman defined knowledge management as 'the collection of processes that govern the creation, dissemination, and utilization of knowledge' (Newman, 2002). According to Newman, KM treats knowledge as a resource by exercising selectively, imposing priority on information resources, adding structure and categorizing the organization and formulation of ill-structured information (such as insights, understanding and intuition of experts for solving specific problems) to increase its value, and proactively capturing information that might be useful in the future. According to O'Leary, knowledge management is a business concept, which includes concerted, coordinated, and deliberate efforts to manage the organization's knowledge through the process of creating, structuring, disseminating, and applying it to enhance organizational performance (O'Leary, 1999).

4.5 Fuzzy Theory

As there are lots of dynamics such as the market change or the seasonality in the apparel industry, we should take the uncertain factors into consideration. When determining the optimal quantity for seasonal products, one of the tasks is to forecast the future popularity of the apparel products and the future customer demand, thus the feasible tool is using the fuzzy theory, one of the artificial intelligence (AI) techniques.

4.5.1 Overview of Fuzzy Theory

A fuzzy set is a set without a crisp, clearly defined boundary. It consists of characteristic function which allows various degrees of membership for the elements of a given set. If X is a collection of objects denoted generically by x, then a fuzzy set $\tilde{A}$ in X is a set of ordered pairs:

$$\tilde{A} = \{(x, \mu_A(x)) \mid x \in X\}$$

$\mu_A(x)$ is the membership function or grade of membership of x in $\tilde{A}$ to the membership space. A fuzzy set $\tilde{A}$ is characterized by its membership function $\mu_A(x)$, which maps each element of the universe X to the interval $[0,1]$. $\mu_A(x)$ is a continuous function that indicates the degree to which each element belongs to the set. While a classical (crisp) set could be described using the member elements by using the member elements by using the characteristic function, in which 1 indicated membership and 0 indicates non-membership, a fuzzy set could be represented using the membership function which is a continuous function with range [0,1].

In fuzzy logic, the propositions are fuzzy propositions which are represented by fuzzy sets. The ultimate objective of the fuzzy logic is to provide the foundations for approximate reasoning with imprecise propositions using the fuzzy set theory as the principal tool. This is analogous to the role of quantified predicate logic for reasoning with precise propositions (Klir et al, 1988).

Since its inception, the fuzzy set theory has advanced in a variety of ways and in many disciplines. Fuzzy set theory provides an alternative and a convenient framework for handling uncertain parameters (eg. forecasting error caused by dynamic customers' demand), while there is a lack of certainty in data or even a lack of available historical data. According to Zadeh (1965), the possible range of a parameter and the most plausible value within that range can often be estimated and specified by experts (Wang et al, 2005). This estimation is simpler than asking managers to design a probability function. They only need to estimate the values that do or do not belong to its domain (fuzzy set). Therefore, it is easy to be defined to handling uncertain parameters. Applications of this theory can be found, for example, in artificial intelligence, computer science, control engineering, decision theory, expert systems, logic, management science, operations research, pattern recognition, and robotics (Zimmermann, 2001).

4.5.2 Reasons for the selection of Fuzzy Theory

The supply chain simulation model can explain and deal with the uncertain factors and the model should be able to express the dynamic behaviors during the simulation run. In the proposed apparel supply chain model, forecasting error, which is caused by demand uncertainty, is one of the most critical factors affecting the performance of the supply chain. Demand uncertainty can result in over-or-under-production, leading to excessive inventories or inability to meet customer needs, respectively (Jung et al.,2004).

To study the uncertainties systematically, two methodologies were applied to the supply chain modeling. Some researchers addressed the uncertainties using stochastic models; one of the pioneering works dealing with the stochastic nature of the supply chain was Midler (1969). In these models, the analysts usually transferred those uncertain factors into probability distribution of corresponding random variables based on past records; examples see Federgruen (1993) and Porteus (2002). However the distribution of random variables may not be obtained in the modeling process usually due to the difficulties in collecting data.

It is natural that the uncertain factors are expressed by suing some inaccurate language. The reason is that there exists a need to handle different sources and kinds of uncertainties, particularly the uncertainties in judgment, and lack of evidence. In such cases, it is convenient to express uncertainties in parameters using various imprecise linguistic terms, such as "Customers' demand is about d_m, but definitely not less than d_l and not greater than d_u", and so on (Petrovic et al., 1998). The possible range of a supply chain parameter and the most plausible value within that range can often be estimated and specified by experts.

Therefore, the fuzzy set theory, due to its conceptual and computational simplicity as a useful tool to represent approximate qualifier that corresponds to these natural language expressions, may be more appropriate to be selected for handling the uncertain factors in the apparel supply chain model.

4.6 Genetic Algorithm for Negotiation Strategy

The development and use of optimization models is well established. However, the use of many models has been restricted in some fields of economic analysis where the problem is large in size and there are a large number of non-linear interactions. In most cases, the use of linear approximations or simplification of the model has been necessary in order to derive a solution. Rapid developments in computing and soft technologies have given rise to the development of different types of new optimization methods. In contrast with the exact and deterministic traditional mathematical methods (for instance, linear programming, dynamic programming and gradient-based methods), genetic algorithm (GA) is a stochastic search technique. It can obtain good solutions after a number of iterations when there is sufficient computing power.

4.6.1 Overview of GA

GA is an attempt to simulate Darwin's Theory of Evolution. Darwin stipulated that more favorable characteristics in an individual would increase the individual's chance of passing those favored characteristics to the next generation via reproduction. The important struggle for life filtered out the weaker individuals and fitter individuals survived to pass on their genes to the next generation. The fitness of the population increased over the generations as individuals inherited the favored designs of their ancestors. It was recognized that his theory could develop into a very useful technique of the computer-based directed random searches (Holland, 1975). Comprehensive descriptions of the concepts and techniques in genetic algorithms are presented in Goldberg (1989) and Davis (1991).

GA starts with a population of chromosomes which represents potential solutions to a problem. In real-life application, a population pool of chromosomes is installed and set initially. This can be done either randomly or by seeding. Once the initial population is generated, each individual is evaluated using the objective function. To generate the next generation, a subset of the population is selected as parent. A probabilistic selection is performed such that the fittest individuals have higher priority to be selected into the subset of the next generation. New population is generated from the parents using genetic operator. The two basic types of the genetic operators are crossover and mutation.

Through crossover, a random position on the string is selected and the segments, either to the right or to the left of this point, are exchanged with another string sectionalized similarly. The reproduction mechanism with crossover causes the best scheme to proliferate in the population by combing and recombining to create high quality combinations of scheme on a single chromosome. GA creates new generations of improved solutions by this reproduction in which parents that have higher fitness ratings are having greater probability to be contributors. The crossover rate, which is the ratio of the number of offspring produced in each generation to the population size, controls the expected number of chromosomes to undergo the crossover operation. Mutation operator produces spontaneous random changes in various strings by changing one or more genes. The mutation rate, which is the percentage of the total number of genes in the population, controls the rated at which new genes are introduce into the population for trial. The operations of crossover and mutation are conducted randomly.

The difference between GA and the traditional optimization search techniques were summarized in Goldberg (1989). Firstly, GA works from a population of strings, climbing many peaks in parallel; thus, the probability of find a false peak is reduced over methods that go points to points. Traditional methods usually start on a single solution, and keep iterating sequentially to other solutions. GA also does not require any auxiliary information such as derivatives in gradient techniques to work. GA only requires the fitness (objective function values) associated with individual strings.

The basic procedure of GA is explained as follows.

Let P(g) and C(g) be parents and offspring respectively in the existing generation g
g=0, initialize a population of chromosomes P(g);
Evaluate P(0);
g=1;
Recombine P(g) to generated C(g);
Evaluate C(g);

Select P(g+1) from P(g) and C(g);

g=g+1;

Repeat steps of Recombination, Evaluation and Selection until some termination is reached;

Report best solution found.

4.6.2 Reasons for Using GA

Over the past years, many researchers have proven that GA is more efficient than other optimization and search techniques for computationally complex problems. The operation research committee has reviewed the five meta-heuristic search techniques, namely simulated annealing, genetic algorithm, tabu search, target analysis, and neural network and concludes that they all have great potential to handle the real-life optimization problems. This family of methods uses, in fact, a hyper-neighborhood technique on a population of solutions instead of on a single solution. Michalewicz (1996) compared the differences among hill-climbing search, random search and genetic search. GA is shown to be a class of general-purpose search method which combines the elements of directed and stochastic search. It can make a balance between the exploration and exploitation of the search space. The disadvantage of other two search strategies, hill-climbing search and random search, was either having the problem of only exploiting the best solution for possible improvement or exploring the search space. The comparison of GA and other search techniques was also reviewed in Tekin et al. (2004).

Unlike other optimization techniques, genetic algorithm (GA) does not make strong assumptions about the form of the objective function (Michalewicz, 1996). Whereas traditional search techniques use characteristics of the problem (objective function) to determine the next sampling point (e.g. gradients, linearity, and continuity), the next sampling point in GA is determined based on stochastic sampling/decision rules, rather than a set of deterministic decision rules. Therefore, so far as the minimal requirement of the evaluation function is satisfied, many forms of the evaluation function could be employed (e.g. the simulation results of a supply chain model). This minimal requirement of the evaluation function is its ability to map the population into a totally ordered sets.

In complex problems such as the negotiation strategy in the supply chain, it is usually difficult to define one function form for measurement of goodness for solution. Therefore, evaluation functions of many forms can be used. Although GA usually relies on some sort of functional form to evaluate each individual, there have been a few successful applications that used GA for simulation optimization of SCM or manufacturing systems in recent years. For example, a general framework was proposed in Tompkins et al. (1995) for applying a combination of GA and discrete simulation model into a complex system with qualitative variables. It was shown that GA created a robust tool and is very promising for qualitative and structural, strategy decision variables. Other examples could be found in Azadivar et al. (1999) and Gokce (2002).

One difficulty for the optimization in this research is the complexity of the uncertain factors in the apparel supply chain and the complexity of the evaluation of the performance of the negotiation strategy. In a dynamic environment the required amount of products, which changes with the sales, the season and fashion change, is also dynamic. In addition, the required quantity is usually decided without consideration of minimizing the overall supply chain cost. The genetic algorithm does not depend on large sales data and it can generate the offspring with the aim of achieving minimal total cost. Therefore, genetic algorithm (GA) was used to make optimal decision about price and quantity.

4.7 Simulated Annealing for Negotiation Strategy

Simulated annealing (Kirkpatrick, 1983) is an iterative procedure that continuously updates one candidate solution until a termination condition is reached. A candidate solution is randomly generated, and the algorithm starts at a high starting temperature. Then the temperature decreases slowly until the optimal result is reached.

4.7.1 Overview of SA

The name and inspiration of SA come from annealing in metallurgy, a technique involving heating and controlled cooling of a material to increase the size of its crystals and reduce their defects. The heat causes the atoms to become unstuck from their initial positions (a local minimum of the internal energy) and wander randomly through states of higher energy; the slow cooling gives them more chances of finding configurations with lower internal energy than the initial one.

By analogy with this physical process, each step of the SA algorithm replaces the current solution by a random "nearby" solution, chosen with a probability that depends on the difference between the corresponding function values and on a global parameter T (called the *temperature*), that is gradually decreased during the process. The dependency is such that the current solution changes almost randomly when T is large, but increasingly "downhill" as T goes to zero. The allowance for "uphill" moves saves the method from becoming stuck at local minima—which are the bane of greedier methods.

4.7.2 Reasons for using of SA

Simulated annealing is an enhanced version of local search. Annealing refers to the process when physical substances are raised to a high energy level and then gradually cooled until some solid state is reached. The goal of this process is to reach the lowest energy state. In this process physical substances usually move from higher energy states to lower ones if the cooling process is sufficiently slow.

The genetic algorithm has the advantage of finding a near global optimal solution quickly; however, it can not converge to the optimum very well. The simulated annealing algorithm has a strong local searching ability and can converge to the global optimum relatively accurately. That means simulated annealing can converge to a better optimal point within a certain region when compared with genetic algorithm. In this research, a mathematical model is built to calculate an optimal due date with total production cost of the manufacturer and the supplier minimized. The objective function is formulated as the sum of production cost.

We adopted the SA procedure because of its ability to quickly combine the strategic and operational planning scheme into a single large problem. The methodology of SA has broad appeal in many areas. It provides near optimal solutions to combinatorial problems. SA was seldom used in negotiation process in supply chains in previous research. Actually it has a satisfying searching ability in solving negotiation problems. That is why SA is selected as a feasible algorithm for negotiation strategy.

4.8 Communication Framework in the Agent-based Apparel Supply Chain

Supply chain management typically spans many functional areas within a company and is affected by the way the various groups communicate and interact. A better communication system can help to achieve fluid information flow which is critical for effective supply chain management (Simchi-Levi et al., 2004). Communication standardization allows systems to work together. This can lower the cost and sometimes enhance the feasibility of implementation. Fig. 1 shows the functions of standardized communication in the apparel supply chain and the means to achieve it. The common communication system helps to collect, access, analyze and collate data of customers. IT infrastructure is the basic element of supply chain capabilities. Electronic commerce has improved not only internal efficiencies but also the partnership in the apparel supply chain. Apparel supply chain system components comprise the various systems that are involved directly in the whole chain planning. These are typically systems that combine short-and-long term decision-support system and intelligence elements (Simchi-Levi et al., 2004). To facilitate the management of the linkages in the supply chain, many types of software tools have been developed (Fredendall and Hill, 2001). Agent is one of the newly applied technologies.

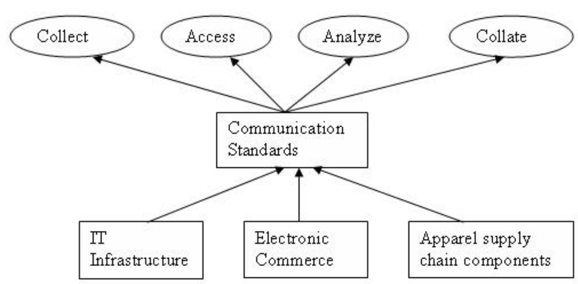


Figure 4-1 Goals and means of communication system in apparel supply chain

A. Communication standard

The communication system in the apparel supply chain has continued to evolve to a high level of standardization for the following reasons:

1) Market forces: Corporate users need standards in order to reduce the cost of the whole supply chain system development and maintenance.

2) Interconnectivity: The need to connect different companies in the apparel supply chain and work across networks has accelerated the development of standards.

3) Coordination: Different companies along the apparel supply chain may have conflicting goals. The goals of one partner may support another's at some moments but conflict at other times. These conflicts necessitate a common language between partners.

4) Economies of scale: Standards reduce the price of apparel supply chain components, development, integration, and maintenance (Reilly, 1999).

The apparel supply chain generally includes such components as raw material vendors, fiber and textile manufacturers, apparel makers, distribution center, retailers and consumers. Agents could be used to represent the different components shown in Fig. 2 along the apparel supply chain and to render these components compatible with each other in a specific standardized agent communication protocol so that different parties can build their agents to interoperate and implement tasks. The collection of agents that work together can be viewed as a small society and for any society to function coherently a specific standardized agent communication is needed (Reilly, 1999).

B. Standard agent communication language (ACL)

ACL is a language with precisely defined syntax, semantics and pragmatics and is the basis of communication between independently designed and developed software agents (FIPA '97 Specification, 1998).

1) *Speech Act:* Speech Act theory is a theory of communications which is used as the basis for ACL (Vasudevan, 1998). Speech act theory is derived from the linguistic analysis of human communication. It is based on the idea that with language the speaker not only makes statements, but also performs actions.

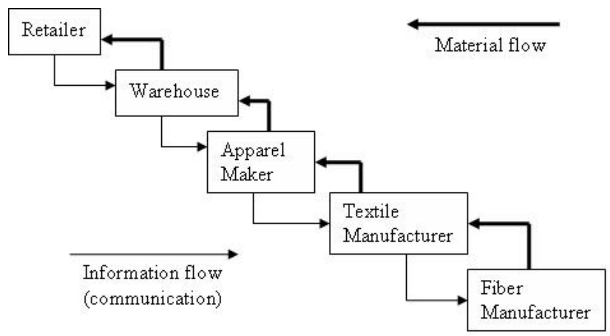


Figure 4-2 Flows and components in apparel supply chain

2) KQML: KQML is a high-level, message-oriented communication language and protocol for information exchange independent of content syntax and ontology. It is a proposed-standard language and protocol for communication among software agents and knowledge-based systems. Experimental prototype systems support concurrent engineering, intelligent design, intelligent planning, and scheduling. It is both a message format and a message-handling protocol to support real-time knowledge sharing among agents (Finin et al., 1994).

3) FIPA (The Foundation of Intelligent Physical Agents) ACL: FIPA is an IEEE Computer Society standards organization that promotes agent-based technology. FIPA ACL, a proposed standard language for agent communication, is associated with FIPA's open agent architecture. As with KQML, FIPA-ACL maintains orthogonal with the content language and is designed to work with any content language and any ontology specification approach (Vasudevan, 1998).

The last two languages rely on speech act theory and establish a set of performatives which define the permissible operations that agents may attempt on each other's knowledge base.

C. Communication structure

There are five major agents designed in this structure (see Figure 4-3). They are customer agent, retailer agent, apparel component agent, factory agent and supplier agent. Of these factory agent includes two subagents, warehouse agent and producer agent. The customer agent receives orders from the customers and decides what offers to respond with. The customer agent also communicates with the factory agent to obtain the updated inventory levels and the factory agent to obtain the updated inventory levels and to send the relevant customer orders. The apparel component agent decides which orders to send to the corresponding suppliers. The producer agent receives the supplies delivered from the suppliers, decides based on the available resources (apparel components and factory cycles) in what sequence the customer orders should be produced, and determines the schedules for delivering the finished apparel products to the customers.

D. Communication message delivery model

Similar to high-tech goods, fashion apparel products, which change from season to season, have a very short life cycle and need a correspondent sense-and-respond supply chain. Thus, an effective apparel supply chain should have an improved communication system which can easily help various supply chain members negotiate and compromise (Chandra and Kumar, 2001).

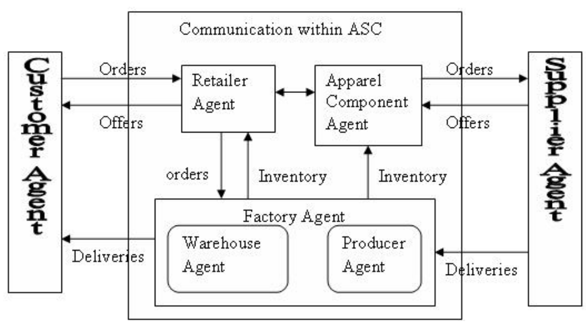


Figure 4-3 Basic Communication structure of apparel supply chain (ASC)

The performance of the communication system in ASCM can be evaluated from two aspects, the velocity of information and the content of information. Fast information delivery can help apparel makers to be sensitive to the market and fashion trends and achieve a quick response. Accurate content of information conveyed could be useful with effective forecasts and reduce uncertainty. In addition, smooth communication could bring about increased coordination and thus lead to reduction in lead time and costs. To achieve all these, comprehensible and standardized messages exchanged in between members are needed.

Figure 4-4 shows the model of a message passing model in the apparel supply chain.

Agent j or Agent k in this model can be used to represent two relative parties along the apparel supply chain. In abstract terms, Agent j has its mental attitudes like some goal or objective G, and some intention I. Deciding to satisfy G, the agent adopts a specific intention, I. To make the other agent (Agent k) understand, accept and respond, the message which Agent j wants to transport to Agent k is unified by speech act theory which states that individual communication can be reduced to primitive speech, or more generally communicative acts, which shape the basic meaning of that communication. The full meaning is conveyed by the meaning that the speech act itself imparts the content of the communication. The following example about conversation between manufacturer and supplier illustrates the message format supported by the service (Fox et al., 2000):

(propose ;; communicative action
:sender A (manufacturer)
:receiver B (supplier)
:language list: speech act or KQML
:content (or (supply n1 apparel component1)
(supply n2 apparel component2)….)
:conversation
:intent (explore production possibility)).
N= {n1, n2, n3…} represents the number of pieces of apparel components.

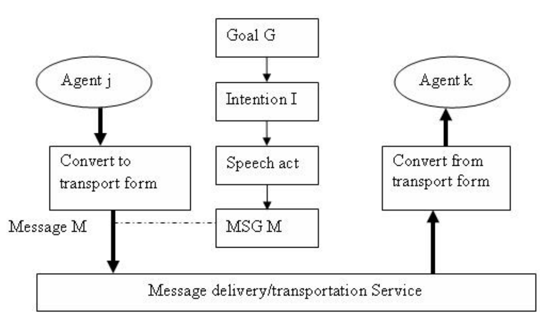


Figure 4-4 Message passing model between two agents

The message delivery service will be able to determine the correct transport mechanism (TCP/IP, SMTP, http, etc.). The message transportation service provides for the reliable and timely delivery of messages to their destination agents, and also provides a mapping from agent logical names to physical transport addresses.

In summary, an apparel agent plans to meet its goals ultimately by communicating with other agents, i.e. sending messages to them and receiving messages from them. The agent will select acts according to the given speech based on the relevance of the act's expected outcome or rational effect to its goals.

4.9 Summary

This chapter provided details of the methodology adopted in the research on decision making in the negotiation and communication process in the apparel supply chain. Quantitative modeling and simulation were used as the major research method. A section on the advantages of simulation was provided and its limitations were addressed. Knowledge management was used to give a unified framework of the apparel supply chain and makes communication easier. Fuzzy set theory engaged into the simulation was applied in the communication system to achieve better responsiveness in dynamic environment and to minimize the total supply chain cost. The reasons for the selection of the research methodology and the technologies were described after analyzing the research problem. The conceptual models of agent-based communication system have also been illustrated in this methodology part. The next chapter provides the detail simulation building process of communication system in agent-based environment in the apparel supply chain with the aim of identifying gaps in theories and justifying the research activities described in this chapter.

Chapter 5

Knowledge Models and Simulation of Communication System in Agent-based Apparel Supply Chain

Successful SCM requires a change from managing individual functions to integrating activities into key supply chain processes. Supply chain business process integration involves collaborative work between buyers and suppliers, joint product development, common systems and shared information. Thus coordination is a key factor in the supply chain operation. Agent technology and knowledge management are explored to apply in the apparel supply chain management to achieve better coordination.

Owing to the high complexity and uncertainty of the supply chain in the apparel industry, a traditional centralized decisional system seems unable to manage all the information flows and actions easily.

The existing theories of knowledge management, its difference with information management and its application in apparel supply chain management will also be reviewed in this section. It also explains why agent technology is suitable for managing knowledge in the apparel supply chain. It also explores the potential use of representing the coordination of agents in supply chain with Unified Modeling Language (UML).

5.1 Knowledge Management in Supply Chain

The informational supply chain is critical to the success of supply chain organizations. Without information, no supply chain would be able to function successfully or competitively. However, as huge amounts of information flows through the supply chain especially in apparel industry, only useful and valuable information grasped could we manage the whole operation effectively. Thus Knowledge management comes to the front upon information management.

Knowledge management has become increasingly critical for the success of companies in the era of supply chain management. As business activities increasingly shift to the web, the challenge facing corporate management is maintaining competitive advantage by building strong relations with employees, customers, and upstream/downstream suppliers and partners. A good knowledge management strategy can help achieve this goal. Unfortunately, many companies use knowledge management technologies that do not suit today's new information era. Therefore, it is important to understand how companies can successfully implement knowledge management programs that will help them to gain competitive advantage (Oppong, Yen & Merhout).

5.1.1 Structure of Knowledge Management in the Apparel Supply Chain

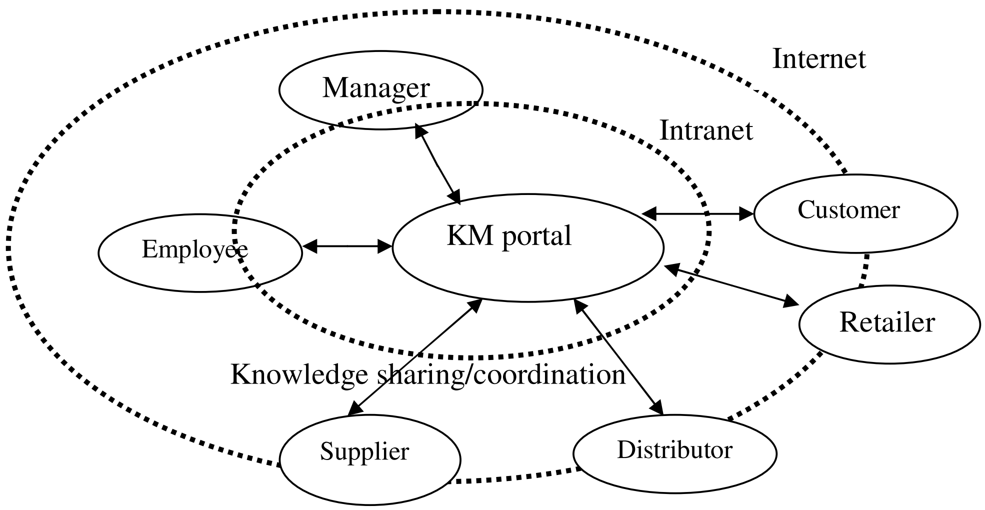


Figure 5-1 The network structure of knowledge integration in supply chain based on Internet/ Intranet

In supply chain, key resource, core knowledge should be shared and spread along the whole operation. A web-based structure of knowledge management is designed for supply chain. (Figure 5-1)Users register from the KM portal and then can share knowledge through network (Yang et al., 2004). However, not all the knowledge can be shared and spread. Knowledge will be recognized and set priority first and then sent to relevant partners. Generally speaking, users within an enterprise can completely share knowledge while outer users like suppliers, distributors and retailers can not fully get the access to all the information.

Apparel supply chain is complicated as there are lots of changes and dynamics in fashion industry. Apparel making concerns with large amounts of information like color, size, style, raw material, customer demand, delivery time and even the feeling. Thus, to catch helpful information and use information effectively is important in an apparel supply chain. Knowledge management takes effect. When customer orders are received, merchandisers can share the information with other supply chain members through knowledge management network portal. In this way, they can easily get the information they want from the database instead of always stopping to consult others. Time is saved, cost is reduced and the overall efficiency will be improved. Figure 5-2 shows the architecture of web-based knowledge management which is made up of interface layer, database layer, application layer and web service layer. Among them, interface layer is the entry of knowledge managers. Application layer and web service layer are supporting environment and foundation facility. Database in the database layer is the core of the KM system. All the knowledge management is developed on data, information (Yang et al., 2004).

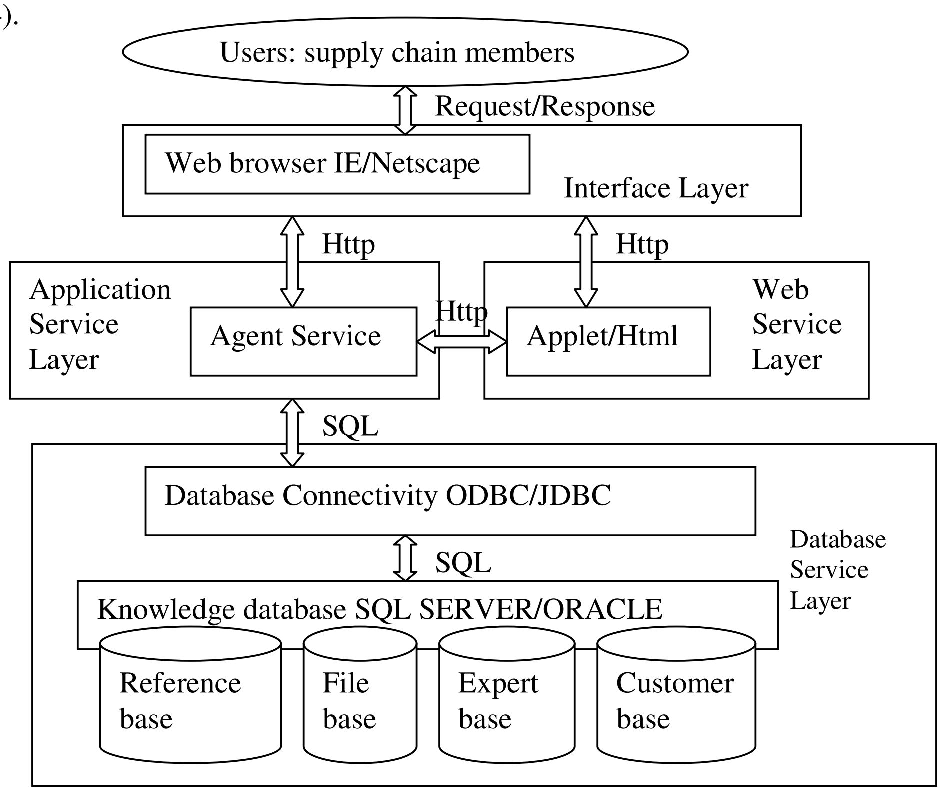


Figure 5-2 Architecture of web-based Knowledge management in supply chain

5.1.2 Knowledge Sharing in the Apparel Supply Chain

Knowledge sharing is a critical part in knowledge management and it helps a lot in coordination in the apparel supply chain. The knowledge sharing process model is shown in Figure 5-3. The model is divided into 4 layers: application layer, knowledge sharing base, knowledge selecting layer and the enterprise alliance strategy layer (Zhu and Zhang, 2005).

Application layer mainly serves node enterprise along the apparel supply chain to assure the company can get the right knowledge from the right knowledge database at the right time. Portal service provides enterprises characteristic user interface and dynamic interaction. Each user can have his own personal interface to display the knowledge he is interested in and to share, exchange knowledge with others. Searching service offers different kinds of knowledge searching methods and helps supply chain enterprises find needed knowledge quickly. Cooperation service realize the synchronic non-synchronic and communication between supply chain member enterprises through e-community, expert system and net discussion. Knowledge Evaluation Service makes the enterprises clearly know their own place in the whole supply chain.

Knowledge sharing base saves all the enterprise knowledge that could be shared. This kind of knowledge includes two parts. One is the explicit knowledge of the node enterprises in apparel supply chains and the other is the non kernel knowledge of other supply chains or the external market or public knowledge which facilitates the knowledge assimilation and creation of this apparel supply chain.

Knowledge selecting layer mainly select which kind of knowledge could be shared from the aggregate knowledge of all the enterprises. The collected knowledge will firstly be enumerated and then recognized, sorted and extracted. If the knowledge belongs to the kernel knowledge, it will not be allowed to share with other enterprises. Or it could be put into the knowledge-sharing base and could be read and learnt by others.

Enterprise alliance strategy layer helps supply chain node enterprises reach a common consensus on the shared knowledge and set a win-win situation for the members along the apparel supply chain. When the core apparel company organizes the supply chain, it will choose his strategic partner according to the knowledge sharing level and will also build an enterprise knowledge sharing system. Factors affecting knowledge sharing comprises employee knowledge level, knowledge sharing degree, importance of knowledge, knowledge inventory quantity, knowledge contribution grade and etc. The core company will evaluate on these standards, compare the knowledge sharing level of his partner enterprises and then form the knowledge sharing alliance under the effect of win-win coordination, stimulation mechanism and company culture. Finally the sharing performance will be written into the contract.

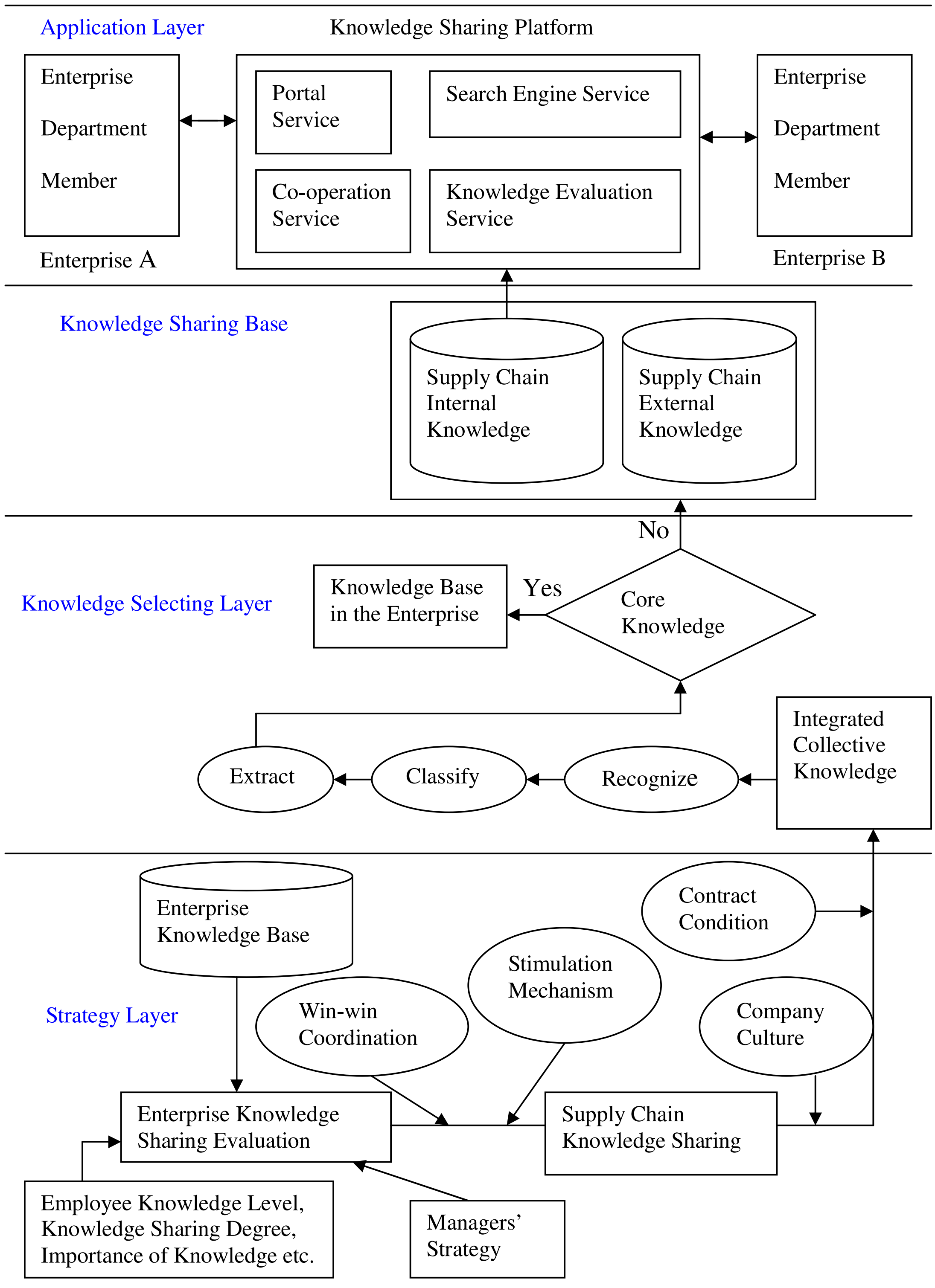


Figure 5-3 Knowledge Sharing Model in Apparel Supply Chain

5.2 Application of Agent Technology in the Domain of Knowledge Management

Agent technology is appropriate for designing and developing knowledge management in the changeable environment in supply chain. Software agents have the common features of autonomous, reactive, proactive characteristic and it is also knowledge-based. Agents can represent users in a large extent and show social action. In supply chains, software agents are computer programs that can help automate a variety of tasks, such as those involved in buying and selling products over the Internet. The point is how we can design multi-agent mechanisms for coordination and knowledge sharing in supply chains when each agent has multiple optimal solutions for its own self-interest (Wu, 2001).

Agent approaches and technologies have in particular been applied for the design of Knowledge Management systems. This domain, which is often very complex and distributed, and for which the human component is important (for instance an important source of knowledge is present in the person's head) appears to represent a very good candidate to benefit from all the advantages promised by the agent approaches.

The application of these concepts in the domain of knowledge management is relatively straightforward: a knowledge management environment is constituted of an environment which contains a set of knowledge resources, some mechanisms, and in which different categories of agents (knowledge workers, artificial knowledge agents), access the resources, participate in the creation of new knowledge resources in the system, interact, exchange and trade knowledge, etc. This approach is actually relatively similar to the one that Thomas H. Davenport and Laurence Prusak prone with the concept of information ecology (Davenport and Prusak, 1997) which comprehend the relations between people, processes, support structures and the other elements of a company's information environment, as an ecological system that has to be managed as such. In this context, a knowledge management system is constituted by the subset of the digital components (services, mechanisms, artificial knowledge agents) of this environment that contribute to support and to accelerate of the knowledge related processes.

Within the supply chain, the type of knowledge exchanged and its usage can be a deciding factor in how strategic an organization becomes in the marketplace. Unless knowledge is accessed or shared and then used by supply chain managers, there is little chance that any competitive advantage will be realized.

5.3 Supply Chain Process with Agent UML Diagrams

The Unified Modeling Language (UML) is gaining wide acceptance for the representation of engineering artifacts in object-oriented software. Our view of agents as the next step beyond objects leads us to explore extensions to UML and idioms within UML to accommodate the distinctive requirements of agents. The result is an Agent UML (AUML) (Odell, 2000).

Agent UML is certainly the most well-known graphical modeling language for describing multi-agent system but until now, it is not applied to real-world applications (M.P. Huget, 2004). In this paper Agent UML will be used in the operation of apparel supply chain management especially in the order and production scheduling process to prove that Agent UML can be applied to real-world applications. From the graphs in UML, we can also discover knowledge exchange and sharing procedure during the coordination between the apparel supply chain members.

To leverage the acceptance of existing technology UML, we present agents as an extension of active objects, exhibiting both dynamic autonomy (the ability to initiate action without external invocation) and deterministic autonomy (the ability to refuse or modify an external request). In other words, an agent can be defined as “an object that can say ‘go’ (dynamic autonomy) and ‘no’ (deterministic autonomy).” This approach leads us to focus on fairly fine-grained agents. More sophisticated capabilities can also be added, such as mobility, BDI mechanisms, and explicit modeling of other agents (Odell, 2000).

1) Agent decomposition

The supply chain management models the production in companies from placing an order to the delivery. This application implies receiving an order as well as generating a plan for producing this order, negotiating the price and the delay, modifying the plan if some constrains are violated, producing the product and finally, delivering it.

Several agents are involved in the application of supply chain. They are merchandise agent, transport agent, production schedule agent, inventory agent, supply agent and dispatch agent (work assign agent). These agents are called actors in UML.

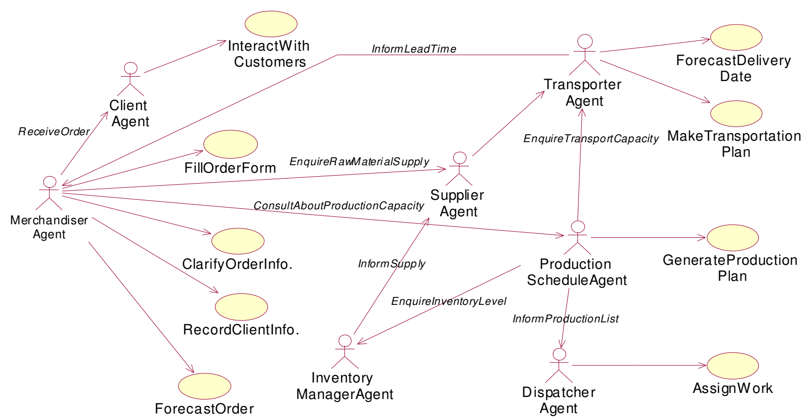


Figure 5-4 Use case paragraph of the supply chain agents

2) Use case diagram

Use case diagrams represent the use cases, the actors and the relationships between the actors and the use cases. A use case can be seen as a scenario in the system. In multi-agent systems, use cases are useful when realizing the requirement analysis. It is easier for users to seize the different elements of the system. The main advantage of the use cases is to focus on "what" and not on "how", that is to say on the system behavior and not how the system is implemented (Zhang et al., 2004). Figure 5-4 shows the jobs of the supply chain agents and mainly presents the use case diagram of the main supply chain agents.

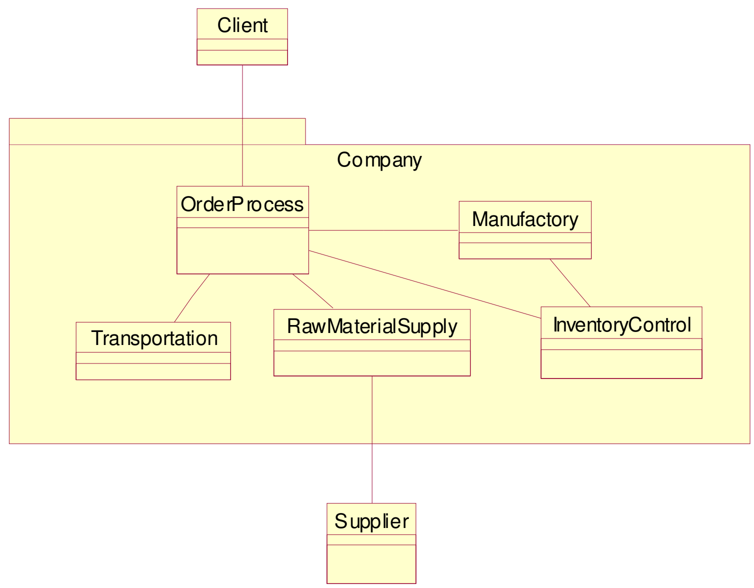


Figure 5-5 Conceptual level of the supply chain management

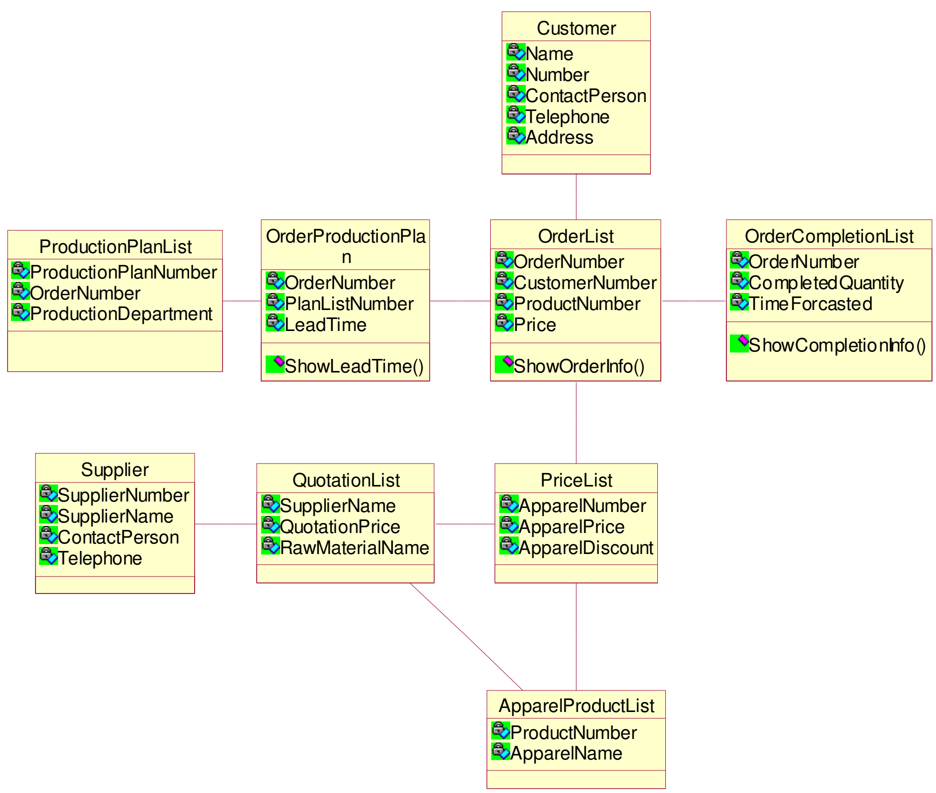


Figure 5-6 Implementation level of the order process management

3) Class diagram

Class diagrams in UML represent the different classes and their connections. Class diagrams correspond to the architecture of the system (P.X. Wang and H.L. Wang, 2005). Class diagrams seem to represent the different agent roles and relations between the roles. Since agents and objects are not exactly the same, class diagrams have to be updated to consider agent features like beliefs, intentions, plans or knowledge. Agent UML allows representing several levels of abstractions when designing class diagrams. Actually, sometimes it is no need to have an accurate view of the system with all the dependencies and all the attributes. High-level class diagrams allow seizing the system in its entirety. We consider here two levels: the conceptual level and the implementation level (Figure 5-5 and Figure 5-6). The conceptual level is a high-level view of the system getting rid of the details such as how agents are implemented or the connected classes. The implementation level is a detailed view of the system with all the information (Huget, 2004). Figure 5-6 shows the information including useful data which can be regarded as explicit knowledge for apparel orders. The parameters and the functions in this figure are the basic and common data an apparel company needs. They are summarized based on the investigation of the apparel companies listed in the Appendix A.

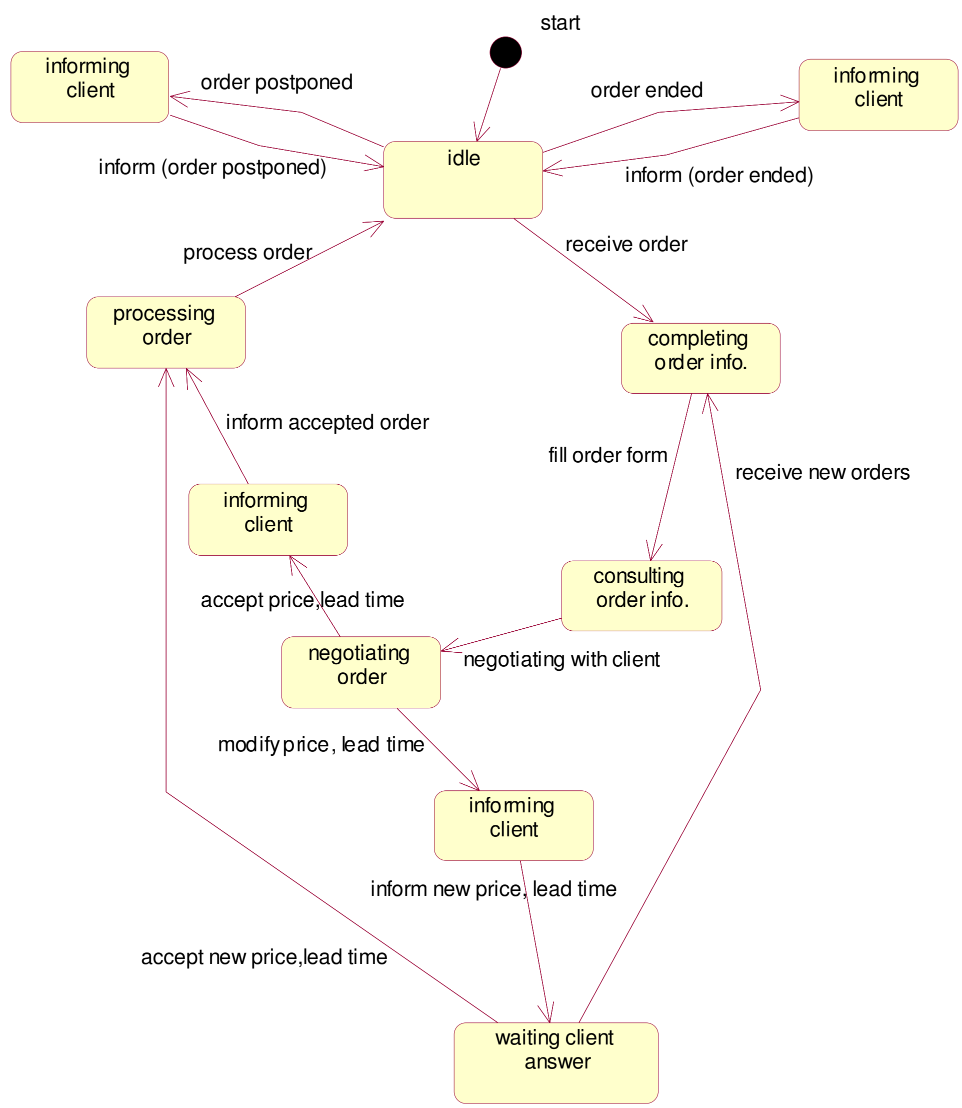


Figure 5-7 Statechart diagram of merchandise agent

4) Statechart diagram

Statechart diagrams belong to interaction diagrams in UML. This diagram represents the dynamic of the system and particularly, the flow between elements in the system. Statechart diagrams consider the different states of the system and how to go from one state to another one through actions.

Statechart diagrams are kind of approaches to represent agents' behaviors. Indeed, agents behave according to actions in the environment or inner actions. Each time actions occur,

agents move from one state to another one. The statechart diagram of negotiation operation on orders is considered in Figure 5-7.
Agent states are rendered as a rectangle with rounded corners. The connections between two states correspond to either an action or an event. The initial state is the state idle.

We can see the procedure of order process and production schedule from the statechart graph, however, when considering multi-agent systems, statechart diagrams seem to be unable to represent concurrent actions. Actually, it is possible that the merchandise agent receives an order while negotiating another one. In this case, the client has to wait that the merchandise agent has to move to the initial state.

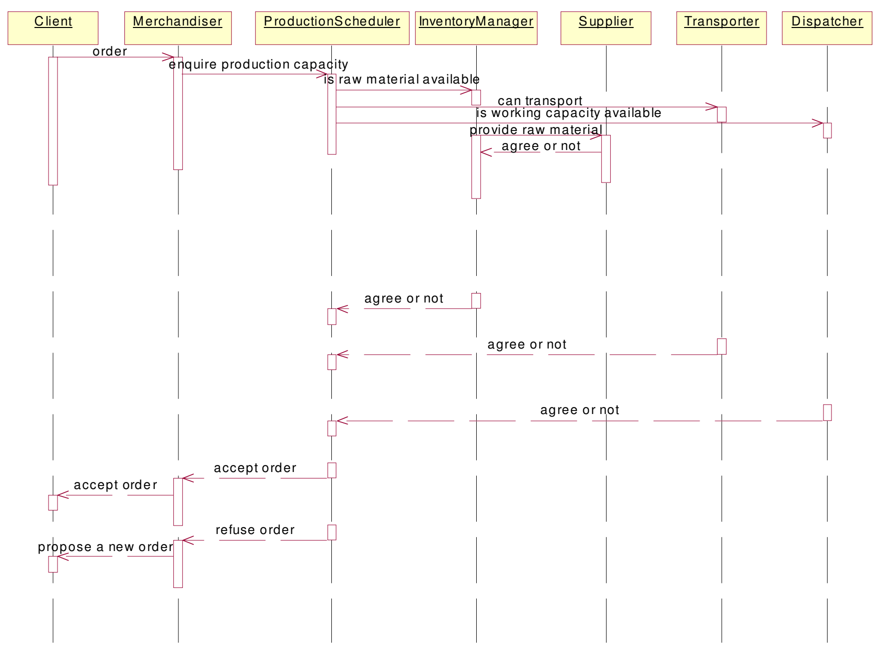


Figure 5-8 Protocol diagram for the order process

5) Protocol diagram

Protocol diagrams called Sequence diagrams in UML describe the message flow between agents. In fact, messages do not go from one agent to another one but from one role to another one (Odell, 2001). These messages contains both explicit knowledge like order information and tacit knowledge like decision making of accepting or refusing customer order.

Several interactions exist in our example of supply chain management given numerous protocol diagrams. Here is the list of scenarios given interaction protocols:

Order a product where all the agents in the multi-agent system intervene.

Modify an order where all the agents in the multi-agent system intervene.

Cancel an order where the agents of merchandiser, production scheduler, transporter, inventory manager, work-assigner and supplier intervene.

Deliver a product where the agents of merchandiser, transporter intervene.

Postpone the delivery of a product where the agents of merchandiser, transporter and production scheduler intervene.

We focus here on the order of some kind of apparel product. This protocol interaction is central in the multi-agent system and all agents are used. The client passes an order. The merchandise agent receives an order and negotiates the price and the delivery time with the client and the transporter agent. The transporter agent makes a choice of an optimal route for the product delivery and computes the transportation price and the time according to the information coming from the scheduler agent. The scheduler agent needs to ask the transporter agent, inventory manager agent for generating a production plan and calculating the lead-time. The supply agent is called if the inventory manager agent does not have the raw material (cloth, fiber, cotton, yarn and etc.) for the order. The corresponding protocol diagram is shown on Figure 5-8.

6) Conclusion

The above four parts described the potential application of knowledge management in the apparel supply chain and designed the architecture for the system. It points out that the agent-based technology can facilitate knowledge flow in the apparel supply chain.

It also explores to extend UML to exhibit the interaction and coordination of agents in the apparel supply chain. UML provides tools for:

• Specifying agent interaction protocols as a whole, as in (Michael et al., 2000);

• Expressing the interaction pattern among agents within a protocol, as in (Parunak, 1996); and

• Representing the internal behavior of an agent, as in (Singh, 1998).

5.4 Communication System of Supply chain processes

Successful SCM requires a change from managing individual functions to integrating activities into key supply chain processes. Supply chain business process integration involves collaborative work between buyers and suppliers, joint product development, common systems and shared information. According to Lambert (2008) operating an integrated supply chain requires continuous information flow. However, in many companies, management has reached the conclusion that optimizing the product flows cannot be accomplished without implementing a process approach to the business. In this part, different agents are defined and they will be integrated to simulate the communication system of supply chain processes.

5.4.1 Knowledge of Agents

The abstract view of agents can be formalized. First, we assume that the environment may be in any of a finite set E of discrete, instantaneous states: E = {e,e',…}. Second, agents are assumed to have a repertoire of possible actions available to them, which transform the state of the environment. Let Ac= {α, α'…} be the action of agents. The agents can be defined as Ag: $R^E \rightarrow$ Ac, an agent makes a decision about what action to perform based on the history of the system. Thus, the multi-agents in the apparel supply chain can be defined as AG = {$Ag_{merchandiser}$, $Ag_{retailer,}$ $Ag_{factory,}$ $Ag_{component}$, $Ag_{supplier}$}. There are cooperation, negotiation and even conflict between the agents in the apparel supply chain. To make the analysis easier, each agent is assumed to have two possible actions that it can perform. We will call these two actions 'C' for 'Cooperate', and 'D' for 'Defect'. Let Ac= {C, D} be the set of these actions. The way the environment behaves is then determined by a function, $\tau: Ac \times Ac \rightarrow \Omega$. If the environment maps each combination of actions to a different outcome, the environment is sensitive to the actions that each apparel supply chain agents perform. The two agents will choose an action to perform in the environment, and as a result of the actions they select, an outcome in Ω will result. The actual outcome that will result depends on the particular combination of actions performed. Thus, both agents can influence the outcome, which means the actions of any of the agents in AG will affect the performance of the apparel supply chain.

Agents have the ability of deduce according to the deduction rules. In the apparel supply chain, the retail agent needs to replenish from time to time to control the inventory level in case of sudden orders and stock out. Thus, fuzzy rules are designed to help to make negotiation decision. Here the fuzzy rules are regarded as the deduction rules to instruct the retail agent's behavior. Suppose F as the set of fuzzy logic membership function. Let D= F(α) be the set of internal states of an agent. The retail agent's decision making process is modeled through a set of deduction rules, ρ. An agent's perception function *See* is defined as:

See: $S \rightarrow Per$.

The next function of the retail agent is defined to have the form of

Next: $D \times Per \rightarrow D$.

It thus maps a database and a percept to a new database. However, the retail agent's action selection function,

Action: $D \rightarrow Ac$, is defined in terms of the fuzzy rules.

The idea is that the agent programmer will encode the deduction rules and database in such a way that if a fuzzy membership function f(α) can be derived, where α is a term that denotes an action, then α is the best action to perform(Wooldridge M., 2002).

In abstract terms, agents can be defined using (Fallah-Seghrouchni A.E. and Suna A., 2003):

```
defineAgent agentName {
   authority = null;| agentName;
   parent=null;| agentName;
   knowledge=null;| {(knowledge;) +}
   goals=null;|{(goal;) +}
   messages=null;| {(queueMessage;) +}
   capabilities =null;| {(capability;)+}
   processes=null;| {(process |)* process}
   agents=null;| {(agentName;)+}
}
```

After the definition of different members in the apparel supply chain with the agent technology, fixed days (DAY) will be given to see the performance of these agents in terms of inventory and throughput within this period of time. In the following part, some parameters will be concerned. They are inventory which includes component inventory (CI), current product inventory (I_{cur}), customer demand (D), replenishment (R), throughput (TH), delivery time (DT), material flow time (FT), simulation days (DAY). A fixed quantity of finished apparel products is given as the average inventory (I_{ave}).

1) Apparel Component Agent

On the first day, all the suppliers have their full capacity available. Therefore, it makes sense to order a large number of apparel components at first. However, the components now attract a storage cost. Thus the more the agent stores and the longer it stores, the higher the storage cost. This means the key challenge of the apparel component agent is to attain an appropriate balance between availability and timeliness. This is hard because if the apparel component agent buys more units early (at lower prices) it has to pay for storage and some components may be unused. However if the agent just buys what it needs when it is needed, it may end up without the necessary components at the necessary time (since there is often a delay between the actual delivery date and the one the suppliers promise). Given this, the apparel agent is designed to make a trade-off between placing a big order on the first day and replenishing gradually during the rest of the time.

Then the function of the apparel component agent can be defined as follows.

1) Purchase large orders of apparel components at first
2) Test apparel component inventory

    While (day <= DAY- FT)

        If $CI_{ave} > CI_{cur}$ then

            {

                Replenishment occurs

                Communicate with the supply agent, go to 3)}

        Else day = day +1

3) Decide on acceptance of the offer from the suppliers

        If the DT < FT, then

            Accept the offer from the suppliers

        Else negotiate with the supply agent

The agent accepts the corresponding offer if the delivery date will not exceed the fixed deadline. Or the apparel component will further discuss with the supply agent to see if there is possibility to have the supplies delivered earlier.

2) Merchandise Agent

The agent will receive customer RFQs, send their orders to the retail agent, get feedback and return offers to the customers. The merchandise agent receives customer RFQs requesting a quantity of apparel products for delivery on a specific day. When selecting which RFQs to respond to, the agent will rate them according to the potential profit that they may bring and according to the inventory it holds. In addition, the merchandise agent also helps to adjust price of apparel products for they directly contact with the customers and the marketplace. If the price is set too low, the companies will receive a low profit and if it is too high it will probably fail to win orders (because customers choose the lowest price).

Thus the function of merchandise agent can be defined as follows.

1) Receive RFQs from customers
2) Determine in which sequence RFQs will be bid for by the total profit
3) Record the prices, quantities of each customer order for price analysis use.
4) Send offers to customers

Here the constraint of merchandise agent is defined as ordering just one type of garment.

3) Retail Agent

The retailer should have a certain amount of apparel products to meet the needs of customers immediately. However, the apparel products will increase the storage cost thus leading to a rise in the total cost of the retailer inventory. To satisfy the customers and keep the inventory at a low level, fuzzy control on the inventory is an effective way to balance these two aspects. A Fuzzy set is characterized by fuzzy boundaries: unlike crisp sets in which a given element does or does not belong to a given set, each element in fuzzy set belongs to a set with a certain membership degree. The function that returns the membership degree of each fuzzy set element is called membership function. Thus, the retail agent is designed to use fuzzy rules to make replenishment for the retailer inventory.

The method can be summarized as below.

i) The membership functions are given by Gaussian curve:

$$G(x;\sigma;\gamma) = \exp(-(\gamma - x)^2 / 2\sigma^2)$$

The Gaussian curve is defined with two parameters: the single value from the domain around which the curve is built (γ) and a value that indicates the width of the bell-shaped curve (σ). Naturally the width parameter (σ) plays a critical role in the shape and scope of the fuzzy set. Table 5-1 demonstrates respectively three degrees of the input data (demand, inventory) and the output data (r). These data are provided to show the fuzziness of the parameters and the reasoning.

Table 5-1 Fuzzy degree of parameters

	Low degree			Medium degree			High degree		
	σ	γ	range	σ	γ	range	σ	γ	range
Demand	1	4	[0,8]	2	10	[4,16]	1	16	[12,20]
Inventory	0.5	1.5	[0,3]	1	5	[2,8]	0.6	8	[6,10]
r	0.3	1	[0,2]	0.5	3	[1.5,4.5]	0.3	5	[4,6]

ii) The fuzzy rules are set.

A database of fuzzy rules constitutes the principal component of the fuzzy controller, allowing the translation of the heuristic rules used by the human operator into a set of rules that can be used by the automatic controller. For the calculation of the replenishment, a set of fuzzy rules was defined.

The average inventory is set as a baseline, whenever the current product inventory tested by the retail agent is less than the average retailer inventory, a replenishment order is initiated. How far the amount of current product inventory deviates from the average inventory determines the fuzzy degree. Therefore, the fuzzy rules are designed as follows.

In this rule base, the retail agent considers the current customer demand state and the inventory level of the in-stock apparel product inventory. There are nine such rules within this base and the following three are representative examples:

Rule1: if D is high and I_{cur} is low then r1 is big

Rule2: if D is medium and I_{cur} I is high then r2 is medium

Rule3: if D is low and I_{cur} is high then r3 is small

The inference process of the output value through the fuzzy rules is based on the composition rule of inference (Zadeh, 1984). Suppose a fuzzy relation R $\equiv$ A $\Rightarrow$ B (IF A THEN B). The membership function of the relation is given by

$$\mu_R(x, y) = \min[\mu_A(x), \mu_B(y)], x \in X, y \in Y$$

Consider a fuzzy relation R and a fuzzy subset A' $\subset$ A. The fuzzy subset B' $\subset$ B is inferred by the composition rule of inference B'= A' $\circ$ R= A' $\circ$ (A$\times$ B) and the membership function is given by

$$\mu_{B'}(y) = \max_x \min[\mu_{A'}(x), \mu_R(x, y)]$$

When more than one rule exists, the global membership function takes the maximum over all the membership functions defined for each relation, i.e.,

$$\mu_R(x, y) = \max_i \min[\mu_{A_i}, \mu_{B_i}]$$

Among the rules, the customer demand (D) is expressed in the fuzzy linguistic terms high, medium, and low, and the current inventory level (I) in the terms high, medium, and low. The output of each rule is a fuzzy variable (r1 to r3). Thus, the outputs of all the rules are combined by the Sugeno controller (Sugeno, 1985) to give a single scalar result, r that represents the *adjustment factor* used to generate the reference replenishment for apparel products. It is described as big, medium and small. When r is big, the amount of replenishment approaches the highest. Whilst it is small, the amount of replenishment approaches the lowest. Thus, rule R1 captures the fact that if the customer demand for this type of clothes is high and the agent has a low inventory in stock, then the replenishment should be large to keep the inventory at a safe level before the next order comes. All these rules are defined in the Matlab fuzzy system editor (Figure 5-10). Figure 5-9 shows the member function of the inputs and the output.

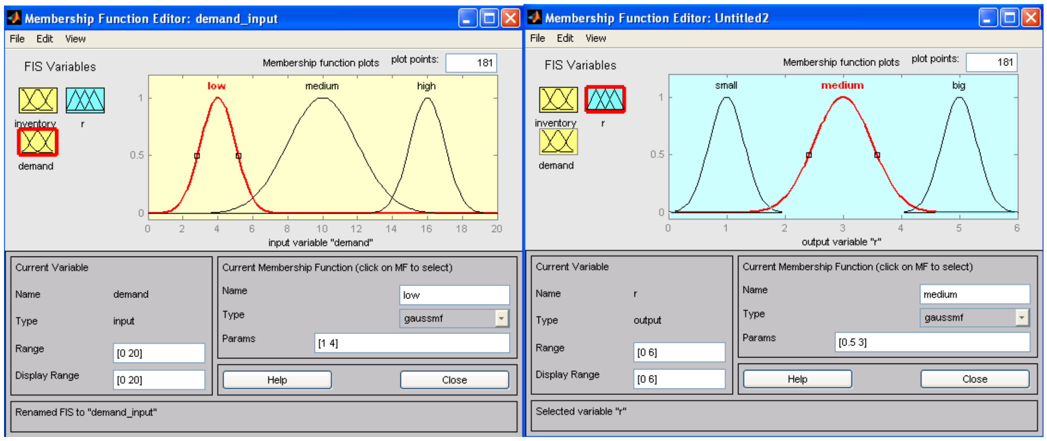


Figure 5-9 Membership function of the inputs and output

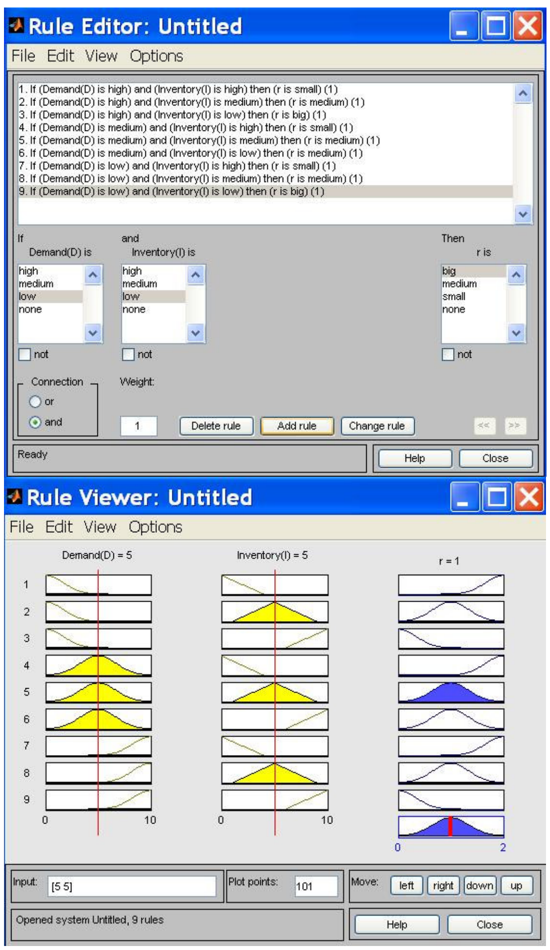


Figure 5-10 Fuzzy rules and simulation view

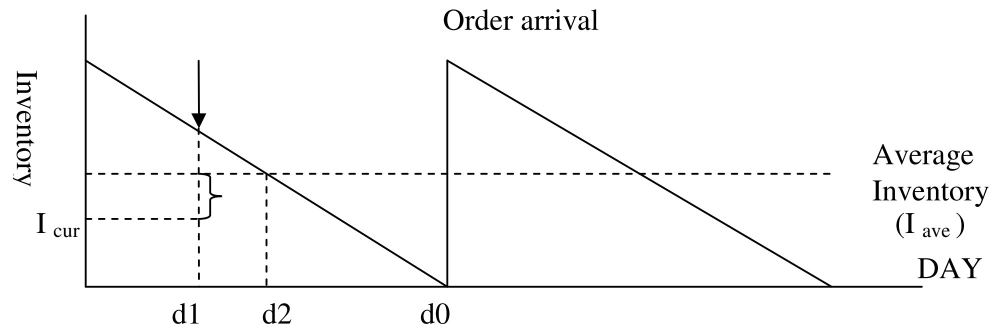


Figure 5-11 Retailer inventory performance cycle

Figure 5-11 shows the retailer inventory performance cycle of the supply chain. Customers deplete inventory until the stock level reaches its minimum. Prior to the stock level reaching the minimum, a replenishment order is initiated so that inventory will arrive before the out-of-stock occurs. Usually a replenishment order is initiated on DAY d2 in the figure and order arrives just on d0. However, unexpected large amount of orders might come someday (d1) in real case. The retailer inventory will suddenly drop to a very low point and then it might not be able to offer products for the forthcoming orders. Thus, when the retail agent finds that the current inventory is less than the average inventory, a replenishment order is initiated.

Now the agent needs to consider the amount of replenishment which will be offered according to the RFQ. Based on the demand in the market, the inventory level and etc, the agent first computes the replenishment (R).

$R = (I_{ave} - I_{cur}) * r$

$I_{cur} = I_{cur} + (I_{ave} - I_{cur}) * r \qquad r = \{r1, r2, r3\ldots\}, r \in (0,2)$

Where I_{cur}, I_{ave} are the current inventory and the average inventory of apparel products at the retailing stage.

The second rule base is employed with consideration of inventory level of apparel components. It is much more complicated as a finished garment has many apparel components and all these components have different level of inventory. However, here one component inventory is used to nearly represent all the inventory level of different apparel components. When the retail agent finds that there are items out of stock, it will connect with the inventory agent to see if there are enough finished products there. If not, it will check the apparel component inventory to determine the final replenishment. Three such rules in this rule base are listed as follows:

Rule1': if D is high and I is high and CI is high then r_1' is big

Rule2': if D is high and I is medium and CI is medium then r_2' is medium

Rule3': if D is low and I is high and CI is low then r_3' is small

Here, the component inventory of apparel products is expressed in the fuzzy linguistic terms of high, medium, low. We can also use Matlab fuzzy system to simulate such rules like Figure 5-9 and Figure 5-10 do but with three inputs.

The constraints of the retail agent are the value of average inventory (I_{ave}) and the fixed material flow time (FT). The above calculation of replenishment quantity is under the premise of fixed flow time. However, in fact, the flow time of apparel product delivery is also changeable due to the large uncertainty in apparel industry.

4) Factory Agent

The factory agent includes the inventory agent and the production schedule agent. The factory agent plays an important role in the apparel supply chain. The factory also has its inventories of finished apparel products and component products, which differ from the retailer inventory. The retailer may have a small amount of product inventory to meet the needs of customers, while the factory should have enough products to serve the retailers when stock-out appears in the retailer stage in the apparel supply chain. The factory warehouses store the products and the component products and try to keep them at a low level to reduce the total cost of the manufacture. The production schedule agent will have a close communication with the inventory agent and make apparels with enough components supplied according to the make-to-order strategy.

5) Inventory Agent

The retail agent will share the customer orders with the inventory agent. For each request for quotation (RFQ) in the order list, the agent first checks whether it can be supplied from its stock of finished apparel products. If it can, the corresponding apparel inventory is decreased. Otherwise, the agent checks whether it holds sufficient components within both its current inventory and its expected delivery queue (i.e. components that have been ordered, but have not yet arrived), and also whether it has a sufficient remaining production capacity to manufacture the required clothes. If it does, the agent decreases its available component inventory. The function of the inventory agent is defined.

1) Record I_{cur}, CI_{cur} of the warehouse
2) Inform the status to the retail agent
3) Manage inventory

   If ($I_{cur} > D$) then

   {

   Offer products to the retail agent

   $I_{cur} = I_{cur} - D$}

   Else

   If (CI_{cur} is enough) then

   Inform the production schedule agent

   Else

   Ask for component supplies from the supply agent
4) Inform the production schedule agent to schedule what to produce and when to produce

In order to reduce the risk of out-of-stock, a safety stock should be set. When the retailer inventory cannot satisfy the customer demand, the warehouse inventory will take effect. Thus, the constraint of warehouse is defined as the safety stock level which means the warehouse should keep its inventory at a certain level.

6) Production Schedule Agent

The production schedule agent receives information from the inventory agent to make scheduling. Production scheduling for days (d) is listed as follows.

- list the orders within due date d+2 in list 1;
- list late orders (but still valid $d-3 <= d_{due} <= d+1$) in the decreasing order of the due date into list 2;
- list the future orders ($d_{due} >= d+3$) in the increasing order of the due date into list 3;
- for each order in the combined list

- if apparel products in the inventory can fill the order then deliver the products;
- else if components are available and factory capacity is not full, then produce more pieces to fill the order;

- If there is extra factory capacity left and enough components, then check whether additional apparel products should be produced.

The production schedule agent can also be responsible for the throughput. Here the factory is designed to use build-to-order strategy and the throughput is made when the factory inventory of finished apparel products cannot satisfy the retailers' demands (D_{ret}). Suppose WI_{cur} is the current product inventory of the warehouse, WI_{ave} is the average product inventory of the warehouse, then the average throughput is defined as $TH_{ave} = WI_{ave} / FT$. Material flow time (FT) is set as a static parameter. When the component inventory drops below the average level of component inventory, the production schedule agent will ask the suppliers for component supplies. The function of the production schedule agent is defined as follows.

If $WI_{cur} <= D_{ret}$

    If CI is available, then

        $TH = WI_{ave} / FT$

    Else

        Inform the supply agent for supplies

Else

        Replenish the orders

In order to see the performance of the apparel factory with the application of agent technology, a simple operation of the production schedule agent is designed based on the following procedure (Table 5-2). Seven days are given as the delivery time. An apparel production schedule agent will be implemented to realize a simple manufacture process (Table 5-2). Details are given in the next section of implementation.

Table 5-2 Manufacture procedure of the production schedule agent

day + 0	The customer sends an RFQ to the agent The agent responds with an offer
day + 1	The customer sends an order to the agent The agent sends RFQs to the suppliers
day + 2	The suppliers respond with offers to the agent The agent submits orders to the suppliers

day + 3	The suppliers produce the requested components
day + 4	The suppliers deliver components to the agent The agent submits a production schedule to the factory
day + 5	The factory makes the requested apparels The agent submits a delivery schedule to the factory
day + 6	The factory delivers the apparel products to the customer

The constraint of the production schedule agent is the product capacity (P). If there are factory production cycles left and the numbers of finished apparel products are below a certain threshold then the production schedule agent produces additional apparel products (if there are enough components) to maximize the factory utilization.

7) Supply Agent

The main function of the supply agent is interacting with the factory agent, informing the suppliers to deliver apparel supplies according to the requests.

While (messages from factory agent = = (supplies needed) {

Record product information (quantity, size…) needed

Inform the suppliers to deliver apparel supplies ordered}

The constraint of supply agent is that the deliver time (DT) should be shorter than the material flow time (FT).

5.4.2 Agent Implementation for the Communication in the Supply Chain Communication Process

1) SCMAgent

SCMAgent is a developing agent providing the following features for:

- Automatic bookkeeping of RFQs, orders, and inventory.
- Support for creating production and delivery schedules based on inventory and capacity.
- Provides an easier API for handling messages.

1) Customer RFQ bundle

The latest customer RFQ bundle is accessible with the getCustomerRFQs. It is updated each day when new RFQ arrives from the customers (and before the call to handleCustomerRFQs).

2) Customer order store

The customer order store is accessible with the getCustomerOrders method and contains all active orders in due date order. The orders are automatically marked as delivered when corresponding delivery request is added to the factory's delivery schedule. To cancel an order simply calls the setCanceled method in the order.

Currently the order store contains all orders but future implementations might remove inactive orders to save memory.

3) Supplier RFQ store

The supplier RFQ store is accessible with the getSupplierRFQs method and contains all RFQs sent to all suppliers.

Currently the RFQ store contains all RFQs but future implementations might remove inactive RFQs to save memory.

4) Supplier order store

The supplier order store is accessible with the getSupplierOrders method and contains all active orders in due date order. The orders will automatically be marked as delivered when corresponding delivery notice arrives from the suppliers.

Currently the order store contains all orders but future implementations might remove inactive orders to save memory.

5) Support for creating production and delivery schedules

SCMAgent provides methods for generating delivery and production schedules for submission to the factory. The inventory for next day is used to determine what can be delivered and produced the next day.
addDeliveryRequest()

Add a delivery request if possible. This is determined by looking in the inventory for next day and this inventory is also modified to include the delivery.

All delivery requests are bundled together in a delivery schedule and not sent to the factory until sendFactorySchedules is called. Note that this method sends both the delivery schedule and the production schedule.

addProductionRequest()
Add a production request if possible. This is determined by looking in the inventory for next day and the free factory capacity for next day. Both the inventory and the factory capacity are modified to include this production request if it was possible.

All production requests are bundled together in a production schedule and not sent to the factory until sendFactorySchedules is called. Note that this method sends both the delivery schedule and the production schedule.

6) API for handling messages

The SCMAgent helps with the message handling. Received messages are interpreted and a corresponding method is called (see below).

a. Sending messages

addCustomerOffer()

> Add an offer in response to a customer RFQ. All offers are bundled together and not sent until sendCustomerOffers is called.

addSupplierRFQ()

> Add a RFQ to be sent to a specified supplier. All RFQs are bundled together and not sent until sendSupplierRFQs is called.

addSupplierOrder()

> Add an order in response to an offer. All orders are bundled together and not sent until sendSupplierOrders is called.

sendFactorySchedules()

> This method will send the schedules created using addProductionRequest and addDeliveryRequest to factory.

sendAll()

Sends all pending RFQs, offers, orders, and schedules to customers, suppliers, and factory by calling corresponding send methods.

b. Receiving messages

The following methods are called when a message from the server arrives. Methods marked as optional do not need an implementation (they have a default implementation in the SCMAgent which does nothing).

handleCustomerRFQs()

Called when RFQs from the customers is received. Only one such RFQ bundle is received each day.

handleCustomerOrders()

Called when new orders are received from the customers in response to offers. Customer orders are only received at most once per day and the new orders are added in the customer order store before the call to this method.

handleSupplierOffers()

Called when offers from a supplier are received in response to RFQs. Supplier offers are received at most once per day from each supplier.

handleSimulationStatus()

Called when all messages from the server for this day have been received. This is when all information for this day is known.

handleSupplierDelivery (optional)

Delivery notification from suppliers

handleFactoryStatus (optional)

Inventory and factory status from the factory

handleBankStatus (optional)

Status from the bank with information about the bank account and penalties for the previous day

handlePriceReport (optional)

Statistics from the customer orders for previous day

handleMarketReport (optional)

Statistics from the supplier production and deliveries for previous market period

The following methods mark the beginning and the end of an agent instance life cycle.

simulationStarted()

Called when the simulation has started and all start information is known. Note that nothing can be done until this method has been called.

simulationEnded()

Called when the simulation has ended and the agent should free all resources. The AgentWare will create a new instance of the agent when another simulation is started.

2) MyAgent

After investigation of five apparel companies, suppliers, manufacturers, and customers are found to be three major parties in the overall communication process. Thus, MyAgent inherited from the SCMAgent is designed in the environment consisting of these three supply chain partners to simplify the implementation of factory functionality in an apparel supply chain. As production schedule can be executed by the apparel company or by the manufacturer, it is separated as an individual part for Figure 5-12 to illustrate. In this simulation, the whole communication is centered on the production schedule agent who contacts closely with the other three partners. Figure 5-12 shows the communication process of supplier, factory and customer.

The manufacturer uses the strategy of make-to-order (MTO). In this case, suppose components are not enough and the total delivery time will be 6 days (including one day for the suppliers to produce the supply).

Day D:

Receive RFQ from the retailer customers and send offers to them

Day D + 1:

Receive order from the retailer customers and send RFQ to suppliers

Day D + 2:

Receive offers from suppliers and send orders for supply

Day D + 3:

Suppliers produce the requested supply

Day D + 4:

Delivery of supply from suppliers

Day D + 5:

Assembling and producing apparel products

Day D + 6:

Delivery to the retailer customers

This means that the example manufacturer will never bid for requests with a too short due date.

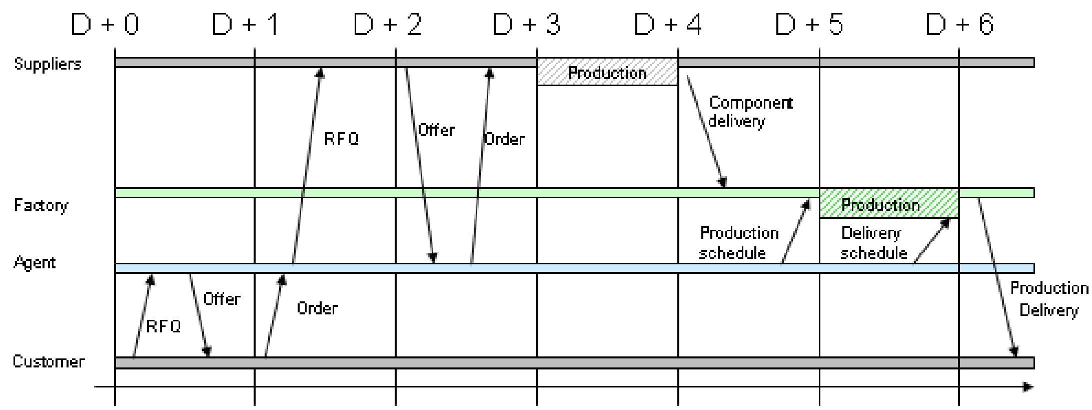


Figure 5-12 build-to-order delivery of MyAgent

3) Communication

Each day the merchandiser agent will receive and send a large number of RFQs, offers, and orders to the built-in actors (e.g. suppliers, customers, and the factory). Since handling all the RFQs to and from the server as separate messages would cause a lot of communications with the server, all RFQs, for one day, between agents and the built-in actors are bundled into an RFQBundle. This makes the communication much less time and bandwidth consuming. The same bundling is also made for all other types of "business documents" like offers, orders, etc.

a. Start Messages

In the start of the simulation the server will send a number of messages. These messages are:

- BOMBundle - lists all products, and for each product, the components that are needed to produce it
- ComponentCatalog - lists the suppliers of each component
- StartInfo - contains information about the simulation length, number of minutes or hours per day, etc. The simulation time here is randomly set for 219 days.

b. Daily Messages

Each day the agent receives the following messages

- RFQBundle from the customer. It contains all the RFQs from customers, this bundle is sent out to the merchandise agent. If the customer does not generate any RFQs no RFQBundle will be sent. The RFQ includes apparel parameters such as quantity, color, size, style and etc. The server which simulates the customers will ask for apparel product quantity randomly from 2000 to 8000 pieces.
- OrderBundle from the customer. This contains all the orders that the customers have decided to order from the agent. If the agent did not get any orders from the customer, no OrderBundle will be sent.
- OfferBundle from each supplier that have received an RFQBundle from the agent (and have something to offer)
- DeliveryNotice from each supplier that have delivered components to the agent
- FactoryStatus from the factory containing information about the apparels in the inventory

Each day the agent sends the following messages:

- RFQBundle to each supplier that it wants to request quotes for components from (up to 10 RFQs / bundle)
- OrderBundle to each supplier that it wants to order components from
- OfferBundle to the customer if it has something to offer
- ProductionSchedule to the factory if production is desired
- DeliverySchedule to the factory if deliveries are desired

c. Periodic Messages

In regular intervals the agents also receive market reports that contain information about the market supply and demand during the period.

4) Built-in Actors of the Simulation

a. Suppliers

The suppliers produce the components needed for the apparel production. They are simulated based on the following assumptions:

- Suppliers operate in a make-to-order basis.
- If multiple days of production are required to satisfy the order, inventory is carried over. Inventory carrying costs are assumed to be zero.
- However, the order is only shipped on the due date (or later if not possible to deliver fully that day).
- A random walk is used to determine the production capacity for each day (constrains the number of units that can be produced each day).
- If an order cannot be met due to reduced capacity, the order is given priority over later orders. Thus, delays ripple across the production schedule.
- Suppliers will never offer anything beyond the end of the simulation.

Agents communicate with suppliers using RFQs, offers, and orders, and a typical buying scenario is:

- The agent sends a RFQBundle [Day D]
- The supplier sends back an OfferBundle [Day D + 1]
- The agent sends back an OrderBundle for the offered components that it wants to order [Day D + 1]
- At the specified due-date the supplier delivers the components (given that no production disturbances occurred)

b. Customer

The Customer will each day, from day 1, send a RFQBundle to all participating agents (day 0 is free from RFQs so that agents will have time to set-up). A typical interaction with the customer would be:

- The customer sends an RFQBundle [Day D]
- The agent responds with an OfferBundle containing at least one winning offer (matching the RFQ, and with the best price) [Day D]
- The customer sends an OrderBundle containing orders for the winning offers [Day D + 1]
- On the day before the requested due-date the agent submits a delivery schedule to its factory, to ensure delivery at the due-date.

- The customer receives the apparel products and if the delivery is correct (e.g. matches the requested apparels), it will do a payment transaction to the Bank.

c. Factory

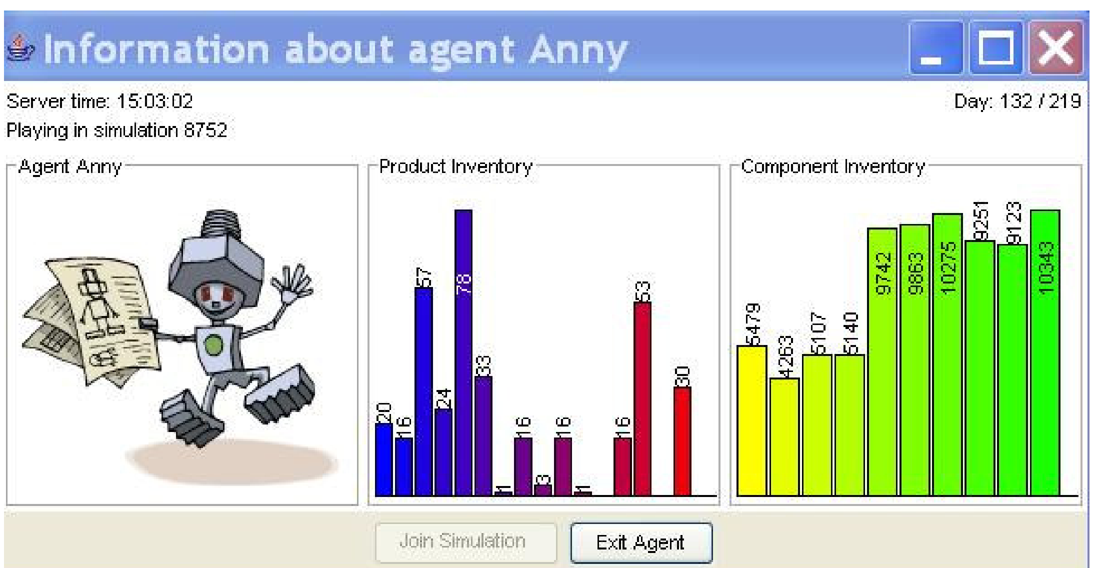
Each agent has a simple factory which consists of an production line and an inventory.

The preconditions for the factory to produce a batch of apparel products are:

- The required components were available the day before, either in the inventory (see FactoryStatus) or delivered (see DeliveryNotice).
- A production schedule was submitted the day before (describing the above batch)
- The factory has enough production capacity

When the days have passed, the produced apparel products are moved to the inventory, or sent to the retailer customers (based on the delivery schedule). If the produced apparel products are not delivered to customers they can be found in the factory status message.

5.4.3 Result of the Agent-based Communication System



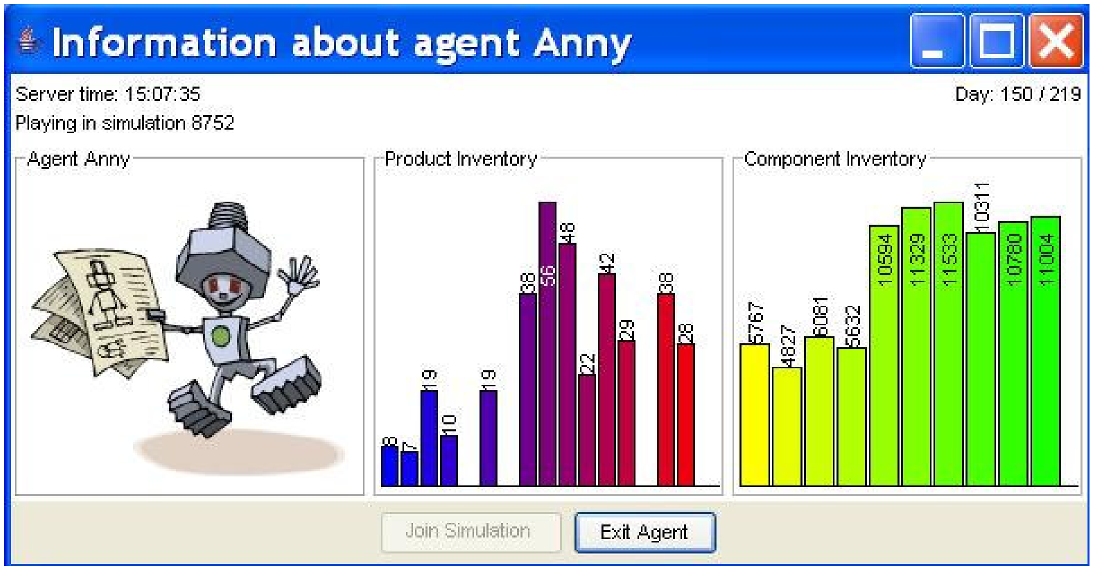


Figure 5-13 The Implementation of the factory agent

Fig.5-13 shows the apparel product and component inventory changes, the result of cooperative communication of supply chain members. MyAgent receives an inventory update from the server each day but it also updates its own inventory per hour during the days to constantly know what is available.

MyAgent is simple and could not handle overloaded factory very well. Thus it should have some finished products stored beforehand. However, the purpose of the simulation model has been obtained that the multi-agents of the apparel supply chain convey knowledge fluently and achieve the same final goal in a cooperative manner. The model is built based on JAVA platform and supply chain members interact in the same agent communication protocol. The manufacturer agent and the supplier agent have performed their own tasks in this model, yet in real industry, the communication between the two members is not that simple and they need more discuss on price and delivery date of procurement. That is negotiation. In order to explore whether agents can solve real communication problem and how they represent human to negotiate, a further agent-based simulation model is proposed with algorithm employed to have further study on agent communication in the next chapter.

Chapter 6

Agent-based Simulation Model for Negotiation Process in the Apparel Supply Chain

6.1 The Framework of the Agent-based Negotiation Model

Supply chain management is one of the most important strategic aspects of any business enterprise. Decisions must be made about how to coordinate the production of goods and services, how and where to store inventory, whom to buy materials from and how to distribute them in the most cost-effective, timely manner. In apparel industry, the supply chain environment is especially dynamic due to the fast fashion, short product cycle, changing market needs and different apparel parameters. In simplest terms, negotiation is a discussion between two or more disputants who are trying to work out a solution to their problem. Each party in the apparel supply chain has its own interest and goals and sometimes conflict. So negotiation is needed to work out a solution that could be accepted by both parties in order to achieve bilateral benefit.

Autonomous agents have a high degree of self-determination - they decide for themselves what, when and under what conditions their actions should be performed. (Faratin et al., 1998). They need to interact with other agents to work together in a multi-agent system. However, the agents have no direct control over one another, they must persuade their acquaintances to act in particular ways (they cannot simply instruct them). The type of persuasion we consider is negotiation - a process by which a joint decision is made by two or more parties (Pruitt D.G., 1981). In the apparel supply chain, the customer himself sometimes cannot give the accurate information when making orders to the merchandiser, thus changes of the orders occur after the order is initialized. Negotiation thus will begin due to any change of the orders that will probably affect production schedule, lead time and even price. To make agents cooperate in a relatively dynamic way to adapt to such changes, a negotiation strategy is proposed in this research. As for the negotiation in the agent environment, a deal between agents was generally a joint plan. The plan was “joint” in the sense that the agents might share the load, compromise over which agent does which actions, or even compromise over which agent gets which parts of its goal satisfied (Zlotkin G. and Rosenschein J.S., 1993).

6.1.1 Research on Negotiation

Negotiation is a form of decision making in which two or more parties talk with one another in an effort to resolve their opposing interests. (Pruitt D.G., 1981) Negotiation can be described in terms of strategies and protocols. The protocol of a negotiation mechanism is the set of rules by which market participants come to agreements. It specifies the kind of deals they can make, as well as the sequence of offers and counter-offers that are allowed. The negotiating procedures have included the exchange of partial global plans, the communication of information intended to alter other agents' goals, and the use of incremental suggestions leading to joint plans of action.

Negotiation is by no means the only method of making decisions where interests are opposed. Agreements are often reached by tacit bargaining, in which the parties coordinate nonverbally on a particular solution by a process involving move and countermove.

6.1.2 Negotiation Issues and Basic Strategies

The topics under discussion in negotiation can usually be divided into distinct issues requiring separate (though related) decisions by the bargainers. Some negotiations involve only one issue, but multiple issues are more common. Weber concluded that net price, delivery lead time, and quality are most commonly applied as criteria to select suppliers (Weber et al., 1991). Verma and Pullman (1998) showed that although most managers perceive quality as the most important factor, in practical decision making, cost and on-time delivery are considered more important than quality. Thus, in this research, we choose price, delivery due date as the negotiation issues in the agent-based supply chain negotiation model.

The outcome of a bidding competition may depend on many different factors, but price often plays a significant role in successful bidding. Usually firms bidding for jobs typically establish their prices using a standard mark-up approach (Kingsman and etc., 1993; Wisner, 1995). Mark-up is the amount that a firm adds to its estimated direct costs for the project to cover overhead, unplanned expenses, and desired profit (Ahmad, 1987). Much of the competitive bidding literature focuses on this key decision variable (King, 1988). Prospective customers also appreciate short lead times (Zeithaml, 1990). Duenyas (Duenyas, 1995) and Li and Lee (Li and Lee, 1994) demonstrate, make to order (MTO) firms with fast delivery times tend to have a powerful marketing advantage over competing firms. If a firm's faster delivery times are enabled by shortened flow times, then its lower work in process inventories and inventory carrying costs may provide another competitive advantage. Thus the apparel firms that can promise (and deliver) short lead times are likely to win more orders, and may earn higher profits on each successful bid, than their near competitors.

However, Weber et al. (Weber, 1991) point out that if a MTO firm promises its customer an overly-optimistic delivery date it risks penalties for tardy deliveries and diminished prospects for future business. Therefore, accurate delivery time estimates are extremely important to the success of a MTO firm.

In many situations, delivery time is as critical as price in winning orders. However, the firms risk penalties for late (tardy) deliveries and the loss of future business if they are unable to maintain the lead times promised their customer (Duenyas, 1995; Dempsey, 1978). These penalties may be proportional to either the percentage of jobs that were delivered late, the amount of tardiness, or both (Vig, 1993). Therefore, the long term success of the MTO firm may depend upon its ability to accurately determine lead times given the firm's available capacity and backlog.

There are three basic strategies for moving toward agreement for a bargainer (Pruitt D.G., 1981).

-----to concede unilaterally, which has the goal of reducing the distance between the two parties' demands

------to stand firm and employ pressure tactics to persuade the other party to concede and thus to reduce the distance between demands

------to collaborate with the other party in search of a mutually acceptable solution

In this research we begin to characterize the relationship between contract price, delivery date, and expected contribution for the apparel company with contingent orders. Our goal is to help the apparel manufacture firm establish a contract price and delivery time for the customer's project.

6.2 Negotiation Modes of the Apparel Supply Chain

In the apparel supply chain, negotiation basically happens in between the final customer, the apparel merchandiser, the manufacturer and the raw material supplier. The later three participants can be organized within an apparel company or act as individual companies, but of course, has cooperation with each other. It depends on different apparel supply chain forms.

Before we distinguish negotiation modes, it is necessary for us to clarify the structures of different apparel supply chains. Five apparel companies are selected and studied as the cases so that the categories of structures are representative (See Appendix A).

In a vertical-integrated apparel supply chain, all the supply chain members, from the cotton producer, fabric supplier till the last final garment manufacturer are all managed under the centralized apparel company. Thus, negotiation processes mostly happen between the merchandiser, the customer and the manufacturer as the apparel company produces and owns the raw material itself thus can better control the yarn and fabric supply. The vertical integrated supply chain is a quite special case as few apparel companies have the centralized control of all the supply chain processes.

In a manufacturer-lead apparel supply chain, the manufacturer is the coordinator of the whole apparel supply chain. Thus, the negotiation mainly takes place between the customer, the manufacturer and the supplier as this apparel company has its own apparel factory and fixed fabric supplier thus less time will be spent on the negotiation of raw material procurement.

In a third-party apparel supply chain, the negotiation process mainly involves around the merchandiser of the apparel company as it starts from the merchandiser to the other three parties as this kind of apparel companies do not own any factory, but would rather outsource all production to various manufacturers. It acts as a supply chain manager coordinating all the supply chain processes.

Basically, apparel products are divided into fashion and ordinary. For supply chain selling fashion clothes, replenishment is seldom needed due to the changing vogue. Negotiation has to be processed each time when customer makes order. While for supply chain of basic garments where reorders need to be made, negotiation is influential as price and lead time are decided at the first order time and will be reference for later reorders.

Based on the above, herein two negotiation modes are proposed in the present research. One is defined as the parallel negotiation which is characteristic of the parallel delivery situation in one line from the upstream customer to the downstream supplier in the whole procedures (See Figure 6-2). The other is radial negotiation, defined as the connection arrows radiating from the merchandiser who interconnects with the customer, the manufacturer and the supplier in the dealing process (See Figure 6-3).

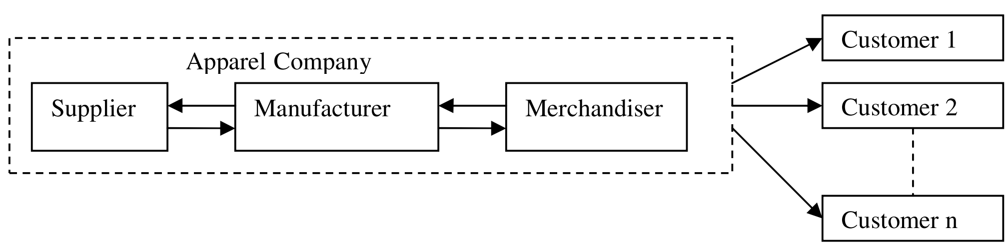


Figure 6-1 Parallel negotiation process of the apparel supply chain

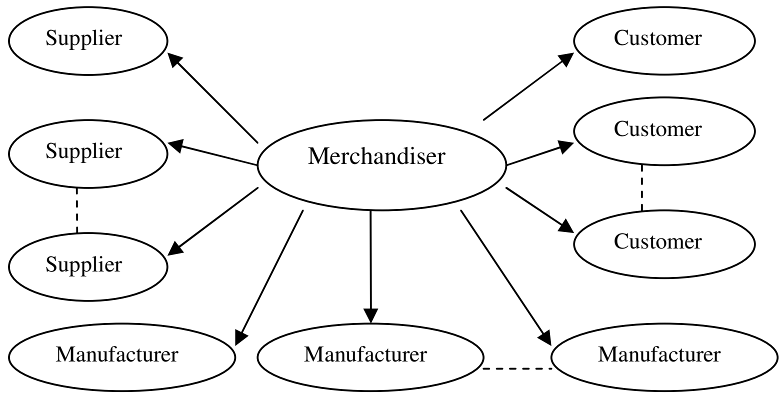


Figure 6-2 Radial negotiation process of the apparel supply chain

Big apparel companies in HK usually have their own garment supply and production factory, the merchandiser negotiates with the customer to decrease the bidding price and prolong delivery date with the aim of maximizing the profit. Then the merchandiser will discuss with the factory on production schedule to decrease the total cost of the supply chain and to satisfy the customer needs. Most of the small apparel companies in HK have contract-based factory partners and yarn and fiber suppliers, thus the merchandiser plays the role of sourcing to find suitable manufacturers.

Considering the above fact, negotiation processes of the apparel supply chain in this research is proposed between the customer, the manufacturer and the supplier. The merchandiser acts as an intermediate and connects with customers and manufacturers.

In a negotiation process, the negotiation parties have different even conflicted purposes. For instance, for the buyer part the prices are expected to be low to decrease cost while on the contrary for the seller part prices are anticipated to be as high as possible to increase profit. Moreover, concerning with the delivery date, the manufacturer hopes to have a longer lead time while the customer prefers a quicker delivery. Thus in this research, price and due date are considered as the input parameters while cost is considered as the output parameter.

6.3 Negotiation model design

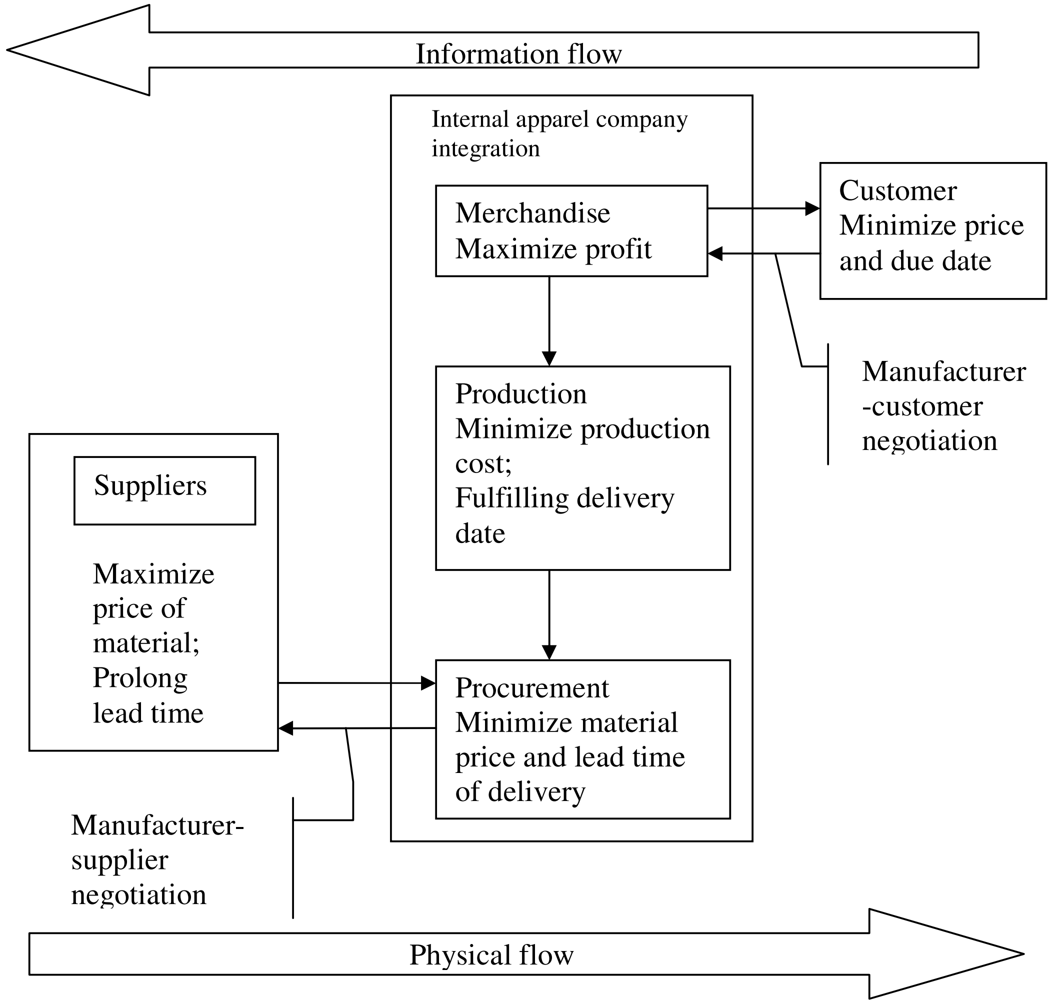


Figure 6-3 Framework of the negotiation model

There are three types of agents used in this research: supplier agent, manufacturer agent and customer agent.

The supplier agent will have a reservation price, which is the lowest price which the manufacturing resources can be "sold" to a particular production engineer. This is to avoid insider trading which might result in ridiculously low numbers of tokens being used to win a certain bid for certain manufacturing resources, to protect the resources supplier.

The manufacturer agent represents and purchaser who is eligible to use the manufacturing process. Similar to the supplier agent, each buyer agent connects with the buyer agent's system and has a unique identification number. There also has a ceiling price. The buyer agent will be willing to use a certain number of tokens to bid for a particular manufacturing resource. The ceiling price is the maximum price he is willing to, or is able to afford to pay in order to win a bid. This ceiling price should be set very carefully as it directly affects the possibility of winning a bid which protecting the bidder from paying too much, which will lead him having insufficient tokens to bid for other manufacturing resources.

During negotiation, it is essential to define the decision-making steps for the agents involved in the negotiation model.
Customer Agent: representative of foreign apparel brand owner companies
Merchandiser Agent: merchandisers of the HK apparel company
Manufacturer Agent: responsible for the production control and planner
Supplier Agent: raw material and apparel component suppliers

The proposed negotiation system is described as follows (Figure 6-3). The customer agent sends orders to the merchandiser agent. The merchandiser agent receives the order and starts negotiation with the customer agent. They may discuss on many issues and major issues are price and due date. The merchandiser agent connects with the manufacturer agent and checks if there is enough production capacity for the coming order. The manufacturer agent will make further forecast of the possible delivery date of the apparel orders and share the information with the merchandiser agent simultaneously. Based on such information, the merchandiser agent provides the reserved price and minimum delivery time to the customer agent and negotiates to reach an appropriate price and due date of delivery. On the contrary, the customer agent gives the ceiling price and maximum delivery time.

After reaching an agreement with the customer, the manufacturer agent will contact suppliers to get the suitable raw material and apparel components. The manufacturer agent gives the ceiling price and maximum delivery time. The supplier agent has his own reservation price and responds to the manufacturer agent with the aim of aggrandizing price and prolonging delivery time. Both the negotiators hope to obtain higher profit for their own.

6.4 Conceptual Model for Negotiation

Before we talk about the negotiation in the apparel supply chain, a conceptual negotiation model has been built to give a general description of negotiation on price and delivery date. Consider a negotiation with m states played by n negotiators in a limited time horizon $\max T$. In each time period $t = 0,1,...\max T - 1$, each negotiator takes an action simultaneously. Driven by the joint actions taken by all the negotiators, the negotiation transfers to another state at time $t+1$. For each negotiator i the following information is associated with it.

Public information (shared with all other negotiators)

A_i : a finite set of all possible actions negotiator i may take.

T_i : a finite set of all possible types negotiator i may be.

$M = \{S, s_0, JAS, \Theta\}$: a transition automaton that defines the structure of the negotiation. Where

S is a finite set of states. S consists of terminal states and non-terminal states.

s_0 is the initial state of the negotiation.

JAS which stands for Joint Action Sets is the input alphabet of the automaton, where $JAS = \prod_{i=1}^{n} A_i$ is the Cartesian production of n negotiators' action sets. Each member in the JAS is a n-tuple, the ith element of this tuple corresponds to the action taken by negotiator i. The fact that the input symbols are n-tuples means that the state to which the negotiation would transfer depends on all negotiators. For any individual negotiator, even after taking a certain action, it doesn't know what the next state would be.

Θ : transition function of the automaton, which maps a joint action to a state, i.e. $\Theta(s, y)$, where $s \in S, y \in JAS$, denotes the state to which the automaton would transfer from state s given the joint action y.

Generally, negotiators divided into the buyer part and the seller part. For the buyer part, they ask for a lower price and shorter lead time while on the contrary, the seller wants a higher price and respectively longer lead time for production. Though they have conflict objectives, for both negotiators, they hope to get maximized payoff and minimized production cost.

Private information (only known to negotiator itself):

r_i: the real type of negotiator i, $r_i \in T_i$.

$U_i(s, r_i)$: utility function of negotiator i, which denotes the payoff negotiator i will get if the game ends at state $s \in S$ and its real type is r_i.

$\Pr ob_i(a_j)$: the probability negotiator i believes that negotiator j would take action a_j.

At each time period $t < \max T$, if current state is a terminal state s, the negotiation ends and all negotiators obtain their final payoffs $U_i(s, r_i)$. Otherwise, the negotiation goes forward, negotiator i computes its payoff by the following formula,

$$Payoff_i^t(s) = \max\{\prod_{j=1\, j\neq i}^{n} \Pr ob_i(a_j) \times Payoff_i^{t+1}(s')\}, \qquad a_i \in A_i$$

$$Cost_i^t(s) = \min\{\prod_{j=1\, j\neq i}^{n} \Pr ob_i(a_j) \times Cost_i^{t+1}(s')\}, \qquad a_i \in A_i$$

Where $s' = \Theta(s, a)$ is the state to which the negotiation transfers from state s, driven by the joint action $a = \prod_{k=1}^{n} a_k$ taken by all the negotiators.

To maximize its expected payoff, negotiator i should take action a_i^* such that

$$a_i^* = \arg\max\{\prod_{j=1\, j\neq i}^{n} \Pr ob_i(a_j) \times Payoff_i^{t+1}(s')\}$$

At the last period $\max T$, the payoff is realized as utility function of negotiator i. i.e.:

$$Payoff_i^{\max T}(s') = U_i(s', r_i)$$

The accepted lead time by both negotiators is realized as utility function of negotiator i within negotiation time period $\max T$.

$$Cost_i^{\max T}(s') = U_i(s', r_i)$$

In our model, negotiators observe their opponents' actions, interpret those actions based on some subjective beliefs and then take corresponding action to maximize their own payoffs. Every negotiator's subjective beliefs are its own "personal experiences", not shared with anyone else. Just as "experiences" of a human negotiator will determine his strategy, "beliefs" held by an agent in our model will determine its behavior in negotiation.

In the formal model, the uncertainty is rooted in the negotiation process itself: agents are uncertain about what actions their opponents may take and use different negotiation strategies to interact with each other.

6.5 Negotiation Model

After having a basic knowledge of ZEUS, the negotiation model will be designed in the following part. The model is based on the manufacturer-lead apparel supply chain and the apparel factory is in a make-to-order mode (Hendry and Kingsman, 1989).

6.5.1 Definitions of Negotiators

There are four proposed supply chain negotiators in the negotiation model. The customer agent, the manufacturer agent and the supplier agent are used to represent the negotiators. These four members are mainly involved in negotiation process in supply chains. To better illustrate the performance of possible negotiation occurred in the apparel supply chain, we select them among the members designed in the communication model in Chapter 5. The customer sends apparel product order to the merchandiser of the apparel company and discusses about what the price can be accepted by both partners and when the apparel product can be delivered. The merchandiser receives the order and forwards the information to the manufacturer about the price and due date and sees if enough production capacity can be reserved for the coming order. The manufacturer makes response and negotiates until acceptable price and due date are reached. When confirming with the customer, the manufacturer turns to the supplier for procurement. The manufacturer proposes a price and delivery date based on previous transaction, and then makes further negotiation.

As this model is developed based on ZEUS, we need to consider the entities of the standard Zeus Application role model, upon which this role model is based. We will need an agent in the ANS role, but as the Broker duplicates the functionality of the Facilitator only one needs to be created (see Table 6-1).

It is possible for each of the identified roles to be played by an individual agent, and which interact together to accomplish a common cause. Alternatively, a single agent could play several roles.

After deciding on the domain and considering its constituent role models we have decided to base our solution on the apparel supply chain negotiation role model. Then we have decided to create several agents to fulfill the roles found within the role model:

Table 6-1 Agent names

Agent Name	Roles Played
Supplier	Trader (Buyer, Seller, Inquirer, Registrant)
Manufacturer	Trader (Buyer, Seller, Inquirer, Registrant)
Customer	Trader (Buyer, Seller, Inquirer, Registrant)
Broker	Broker (Facilitator)
Visual	Visualiser
ANS	Agent Name Server

Having identified what roles should exist within the application, we can begin thinking about how agents will realize each role.

6.5.2 Agent Responsibilities

Each role played by an agent entails some responsibilities, e.g. resources that will need to be produced or consumed, interactions with external systems etc. Hence the next stage is to use the role descriptions to create a list of responsibilities for each agent.

From the descriptions in the negotiation role model, the list of responsibilities can be obtained for the four constituent roles of a Trader agent. As some responsibilities are shared between roles they only need to be considered once. The responsibilities involved can be categorized as social or domain responsibilities, the former involving interaction with other agents, and the latter involving some local application-specific activity; this results in the following:

Table 6-2 Social responsibilities of traders

TRADER - Social Responsibilities	
Origin	**Responsibility**
Seller-Registrant	To register and de-register presence in marketplace
Buyer-Inquirer	To request information on known sellers
Buyer	To send bids to potential vendors
Seller	To receive and respond to bids

Table 6-3 Domain responsibilities of traders

TRADER – Domain Responsibilities	
Origin	**Responsibility**
Buyer	To facilitate the entry of user transactions
Buyer	To interpret vendor responses
Buyer, Seller	To exchange payment and ownership
Seller	To facilitate user selling preferences
Seller	To interpret bids

The next role to consider is the Broker:

Table 6-4 Social responsibilities of broker

BROKER - Social Responsibilities	
Origin	**Responsibility**
Broker	To receive notifications from participants
Broker	To respond to queries on market participants

Table 6-5 Domain responsibilities of broker

BROKER – Domain Responsibilities	
Broker	To store information on market participants

Finally, as the functionality of the Visualiser role is already present in the standard Zeus Application role model we shall adopt the pre-built Visualiser tool; hence no design is necessary for this role.

6.5.3 Negotiation Strategy-----Linear Method

Among these three methods, linear method is the basic one. Characteristics of the mutual biding price between the sellers and the buyers show the monotonically changing behavior as they stay in the same dealing environment.

Based on the conceptual model developed in the above section (6.4), we apply the model above to develop a basic negotiation scenario involving one apparel producer, one material supplier and one fashion apparel product. The producer and the supplier have reservation prices v_p, v_s on the commodity, respectively. In each negotiation iteration, the buyer and the seller offer price proposals simultaneously. If the producer's offer p_t is no less than the supplier's offer s_t, the negotiation ends. Otherwise, the negotiation goes to next iteration until reaching the maximal time horizon $\max T$. v_p, the reservation price of the apparel producer, is a crucial piece of information to characterize the producer. Similarly, the seller is v_s. To explicitly express the states of the negotiation game, we make two assumptions:

There is a price range $[\min P, \max P]$ agreed by both negotiators, and $v_p, v_s, p_{t,} s_t$ all belong to this range;

The players have set a minimal price increase/decrease unit before the negotiation begins.

The state set of the negotiation is defined as $[\min P, \max P] \times [\min P, \max P]$. A state s is an ordered pair (x, y), where x is the seller's price offer, y is the buyer's price offer. If $x \leq y$, s is a terminal state, otherwise it is a non-terminal state. The action sets and the type sets for both players are $[\min P, \max P]$. The transition function of the game is defined as $\Theta(s,a) = a$ for non-terminal state s, i.e., from a non-terminal state, the negotiation can transfer to any other state defined by two negotiators joint actions. For example, if the current time is t and the current state is (10, 5), since the seller's offer 10 is greater than the buyer's offer 5, it is a non-terminal state. If the seller offers 9 and the buyer offers 6, then the negotiation transfers to state (9, 6) in the next iteration $t+1$. For a terminal state, Θ is undefined since the game ends in this state.

Every negotiator maintains a vector of beliefs over its opponent's action set. During each iteration, the beliefs are fixed. A negotiator may update its beliefs between iterations. The methods of updating the beliefs will be discussed next.

In a real-world negotiation, a buyer always prefers to bid a lower price for a certain commodity. Our model incorporates this observation by requiring that the buyer's utility function be monotonic, i.e. U_{buyer} satisfies $U_{buyer}(s_1, v_b) \geq U_{buyer}(s_2, v_b)$ for any states s_1, s_2 such that $s_1 = (x, y_1), s_2 = (x, y_2)$ and $y_1 \leq y_2$. If the negotiation ends at a non-terminal state, the negotiators do not agree with each other and hence no trade will happen. In this case, both the buyer and the seller get nothing. So, $U_{buyer}(s, v_b)$ should equal to 0 for any non-terminal state s, i.e., there is no penalty for both players if they fail to make an agreement.

Through out this section, both players use the linear utility functions. The producer's utility function and the supplier's are defined as:

$$U_{producer}((x, y), v_p) = \begin{cases} v_p - \frac{x+y}{2}, x \leq y \\ 0, \quad otherwise \end{cases}$$

$$U_{\sup plier}((x, y), v_s) = \begin{cases} -v_s + \frac{x+y}{2}, x \leq y \\ 0, \quad otherwise \end{cases}$$

In above formulas, $s = (x, y)$ is a state. $x \leq y$ means s is a terminal state.

The seller and the buyer in our negotiation model are the apparel supplier and the apparel producer. Suppose at time t, the supplier's offer is s_t, and the producer's offer is p_t. We compare the following belief updating methods (abbreviated as methods in the following part). Here the methods are stated from the producer's perspective. It is easy to give the corresponding formulas for the supplier.

1. The buyer doesn't update at all, and always uses the uniform distribution over the price interval $[\min P, \max P]$.
2. The buyer sets a uniform distribution over interval $[\min P, s_t]$
3. The buyer sets an exponential distribution over interval $[\min P, s_t]$, and s_t has the highest probability:

$$\Pr ob_{producer}(\alpha) = \frac{1}{z}\exp\{\frac{\alpha - s_t}{\beta(\max T - t)}\}$$, Where $\alpha \in [\min p, s_t]$, z is a normalization factor, t is the current time, $\max T$ is the time horizon, β is a parameter characterizing the aggressiveness of a negotiator.

4. The buyer sets an exponential distribution over interval $[\min P, s_t]$, and $\min P$ has the highest probability.
5. The buyer sets a uniform distribution over interval $[b_t, s_t]$
6. The buyer sets an exponential distribution over interval $[b_t, s_t]$, and s_t has the highest probability
7. The buyer sets an exponential distribution over interval $[b_t, s_t]$, and b_t has the highest probability

In the method 3, 4, 6 and 7, the time horizon of the negotiation has been taken into consideration. In the method 3 and 6, the less time left, the more the buyer believes that the seller will not change his current offer s_t. While in method 4 and 7, the buyer does not believe that the seller is offering her a reasonable price. The less time left, the more she believes that the seller will decrease his current offer s_t.

a. Negotiators use the same method

For the buyer, the updating methods 2, 3 and 4 set probabilities over interval $[\min P, s_t]$. For the seller, the interval is $[b_t, \max P]$. In Figure 6-4, the trade prices are shown for the cases where both the buyer and the seller use the same method in this group (method 2, 3 and 4). The buyer's reservation price is fixed to be 100, increase the seller's reservation price from 0 to 100 with linear step length 5. We set $\beta = 5$ for method 3 and $\beta = 100$ for method 4. In Figure 6-4, the x-coordinate is the seller's reservation price; and the y-coordinate is the final trade price. From the results, it is found that method 4 produces the "hardest" negotiator among these three belief updating methods: only when the seller's reservation price falls between 0 and 30, the players make a deal. If the seller's reservation price is higher than 30, even though there exists a potentially wide negotiation range, no agreement is reached. On the other hand, method 3 produces the "easiest" negotiator: for the seller's reservation price varying from 0 to 90, a deal can always be found. Method 2 stands between the "easiest" and the "hardest". The range for method 2 to make a deal is [0, 45]. With a bigger β , method 3 will become "harder", and method 4 will become "easier". A bigger β will make the exponential distributions of methods 3 and 4 (with opposite tail directions) converge to a uniform distribution.

In method 5, 6 and 7, all the settings are the same as those in the first experiment except that the updating methods are changed to method 5, 6 and 7. We can see that method 5,6 and 7 are more efficient than the methods used in the first experiment: with the buyer's reservation price fixed at 100 and the seller's reservation price varying from 0 to 95, the players can always reach a deal by using any one of these three methods. An explanation to these results is that since both players have more "reasonable" beliefs on what price their opponent will offer, it is easier for them to negotiate successfully. Similarly, increasing β will make method 6 and 7 converge to method 5.

b. Negotiators use different methods

In this part, we will show what will happen when negotiators use different belief updating methods. The settings are the same as those in previous subsection.

Figure 6-4 shows the cases where both players use method 4 and method 2. Figure 6-6 shows the case where the seller uses method 4 and the buyer uses method 2. In order to compare with those results, we show the results of those two cases here again. Compared to the case where both player use method 4, now the buyer switches to a "weaker" updating method, so the seller manages to sell his item at a higher price, and also extends the reservation price range on which he is willing to make a deal with the buyer. Compared to the case where both players use method 2, now the seller uses a harder updating method, so he still manages to sell his item at a higher price but shrinks the reservation price range on which he is willing to make a deal.

In the case where the seller uses method 2, and the buyer uses method 3, as shown in Figure 6-7, we see that the seller is better off than the buyer. Compared to the case where both players use method 2, the fact that the buyer switches to a weaker method 3 is exploited by the seller, so he can manage to sell his item at a much higher price while extending the reservation price range simultaneously. Compared to the case where both players use method 3, although the seller decreases the reservation price range a little, the trade prices are much higher than those observed in Figure 6-5.

Figure 6-8 shows the case where the seller uses method 7 and the buyer uses method 5. Here we only compare the results with those in the case where both players use method 5 because the results obtained by using method 5 and method 7 are very close, as shown in Figure 6-5. In Figure 6-8, we also show the results where the seller uses method 5 and the buyer uses method 6. In this case, since the seller uses a weaker method, the trade prices are lower than those in the case where he uses method 6. In Figure 6-8, we show the trade prices where the seller uses method 4, the buyer uses method 7 both with $\beta = 100$ .We can see that the seller takes obvious advantage of the buyer.

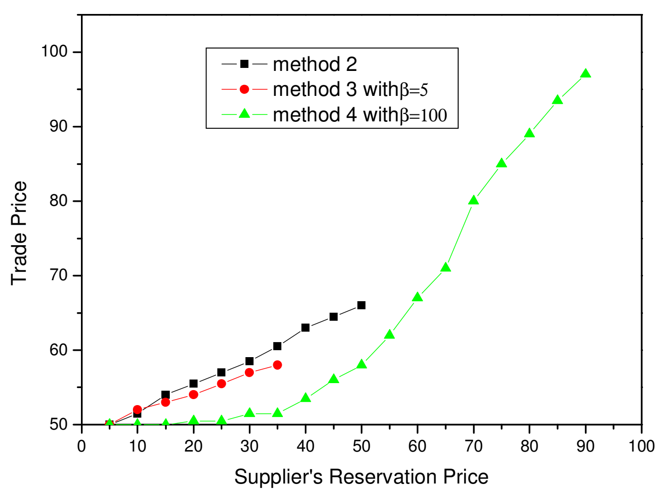


Figure 6-4 Price negotiation using belief updating method 2,3 and 4

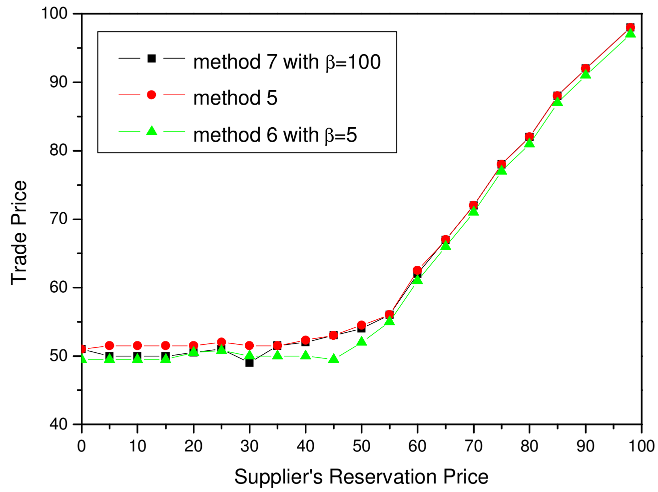


Figure 6-5 Price negotiation using belief updating method 5,6 and 7

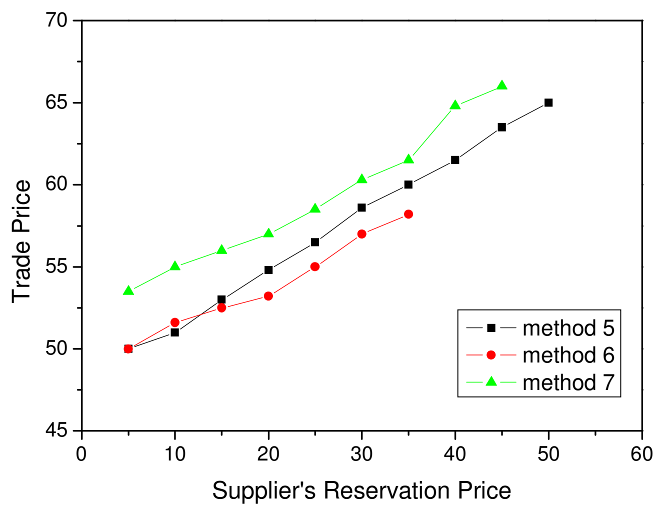


Figure 6-6 Price negotiation using different method 5,6 and 7

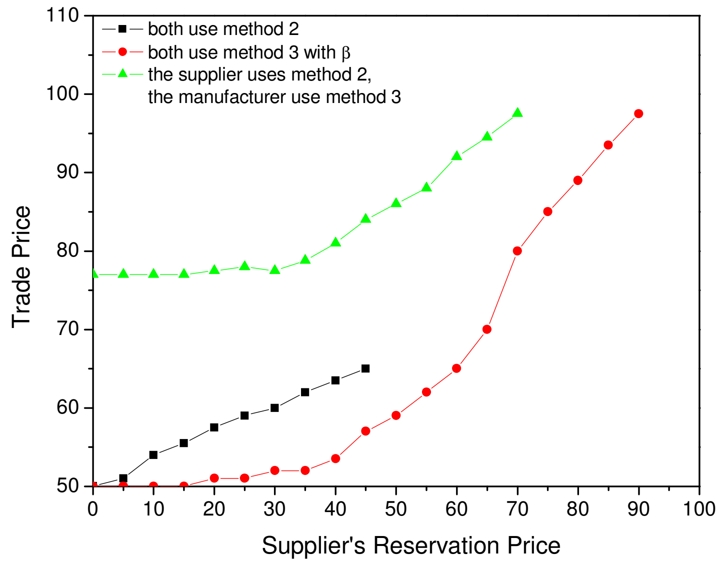


Figure 6-7 Price negotiation using different method 2 and 3

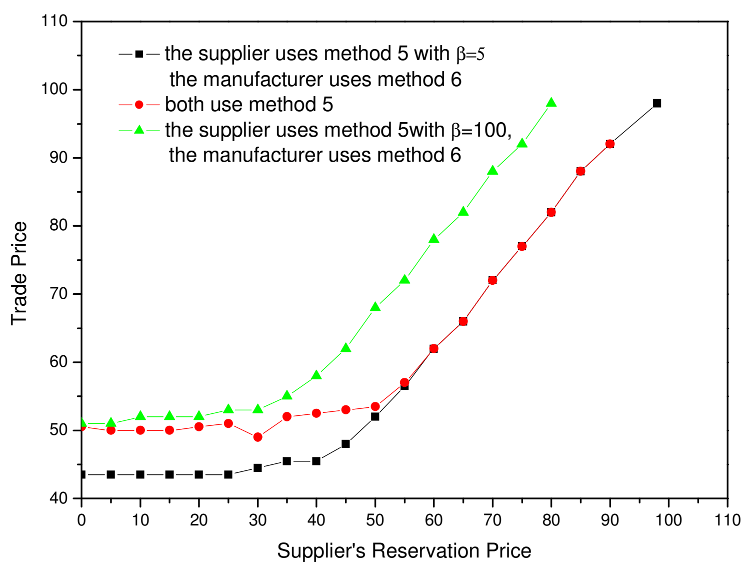


Figure 6-8 Price negotiation using different method 5 and 6

6.5.4 Negotiation Process Described in ZEUS

ZEUS® provides an agent-based environment for simulating negotiation process among the supplier, the manufacturer and the customer of the negotiation.

Based on the platform of ZEUS®, a simple demo was made to demonstrate the electric negotiation result of the supplier agent, the manufacturer agent and the customer agent with linear negotiation strategies embedded in. The demo is mainly aimed to illustrate the linear change of price negotiation.

The trading starts up in the premium of the agents' interaction. The customer sends an order to the apparel manufacturer for apparel products. These two parties negotiates on price and delivery date. After that, the manufacturer agent procures apparel raw material from the supplier agent and also discusses on different materials such as fabric or some apparel component like zip. The interaction of the two negotiation parties follows such procedures. We can consider each negotiation happen between a buyer agent and a seller agent. The buyer agent set a highest price he would be willing to pay for this item in the Maximum Price field. This value will be kept secret and used by the embedded negotiation strategy to create a bid price, which will be offered to the seller. The seller agent creates a reserve price which is the lowest price he would be willing to accept for the apparel material or component. This value will be kept secret and used by the embedded negotiation strategy to create an asking price, which will be the price quoted to potential buyers. The bidding price is adjusted step by step in a linear change trend till it is accepted by the seller. Each step is defined by the negotiation strategy.

In the simulation application, sellers need to determine their replies to incoming bids using the LinearInitiatorEvaluator strategy which embodies the linear method, whilst LinearRespondentEvaluator is used by potential purchasers to formulate their bids.

There are three parameters in the negotiation model, which are min.percent, no.quibble and max.percent.

min.percent: the fraction of the commodity's perceived value at which the agent will begin bidding no.quibble: the difference in price considered insignificant by the agent; when the offer price higher than the bid price but within the 'no quibble' range the offer will be accepted. This avoids spending several rounds negotiating over proverbial pennies, (this can be important especially when negotiation needs to be resolved as soon as possible).

max.percent: the fraction of the commodity's perceived value up to which the agent will be willing to continue bidding.

These parameters define the linear degree of each negotiation. The value can be changed so that the degree can be controlled

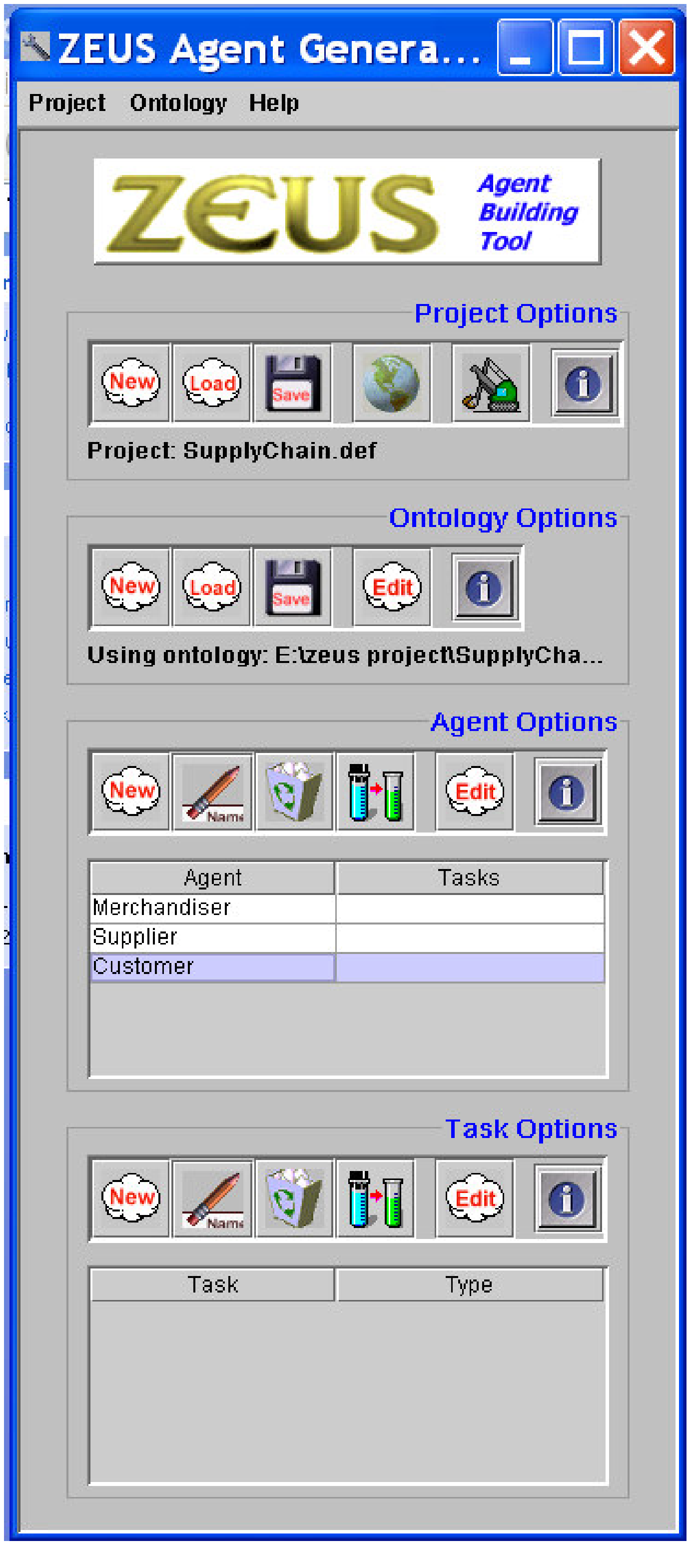


Figure 6-9 Three agents of the negotiation

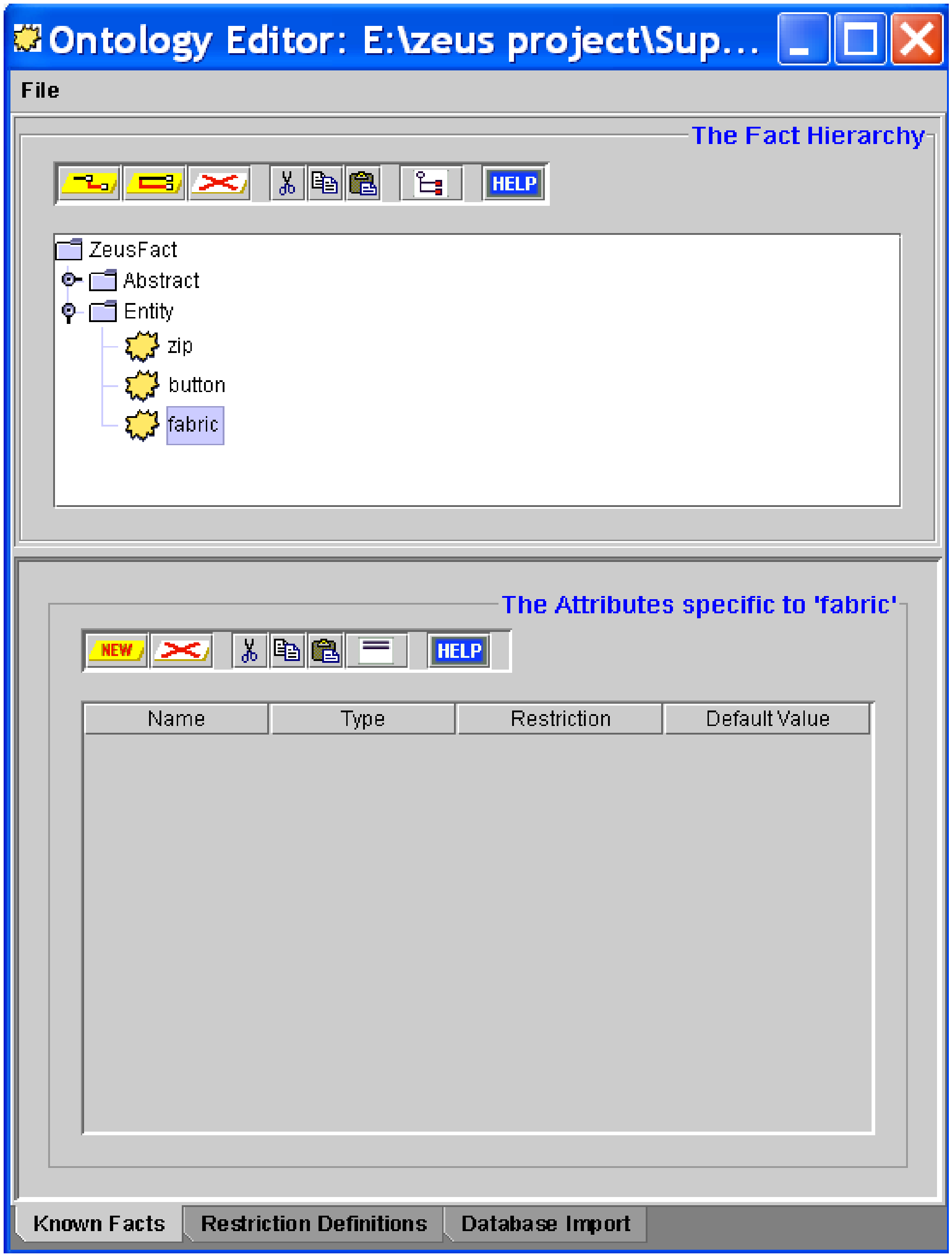


Figure 6-10 Negotiation entities of fabric, zipper and button

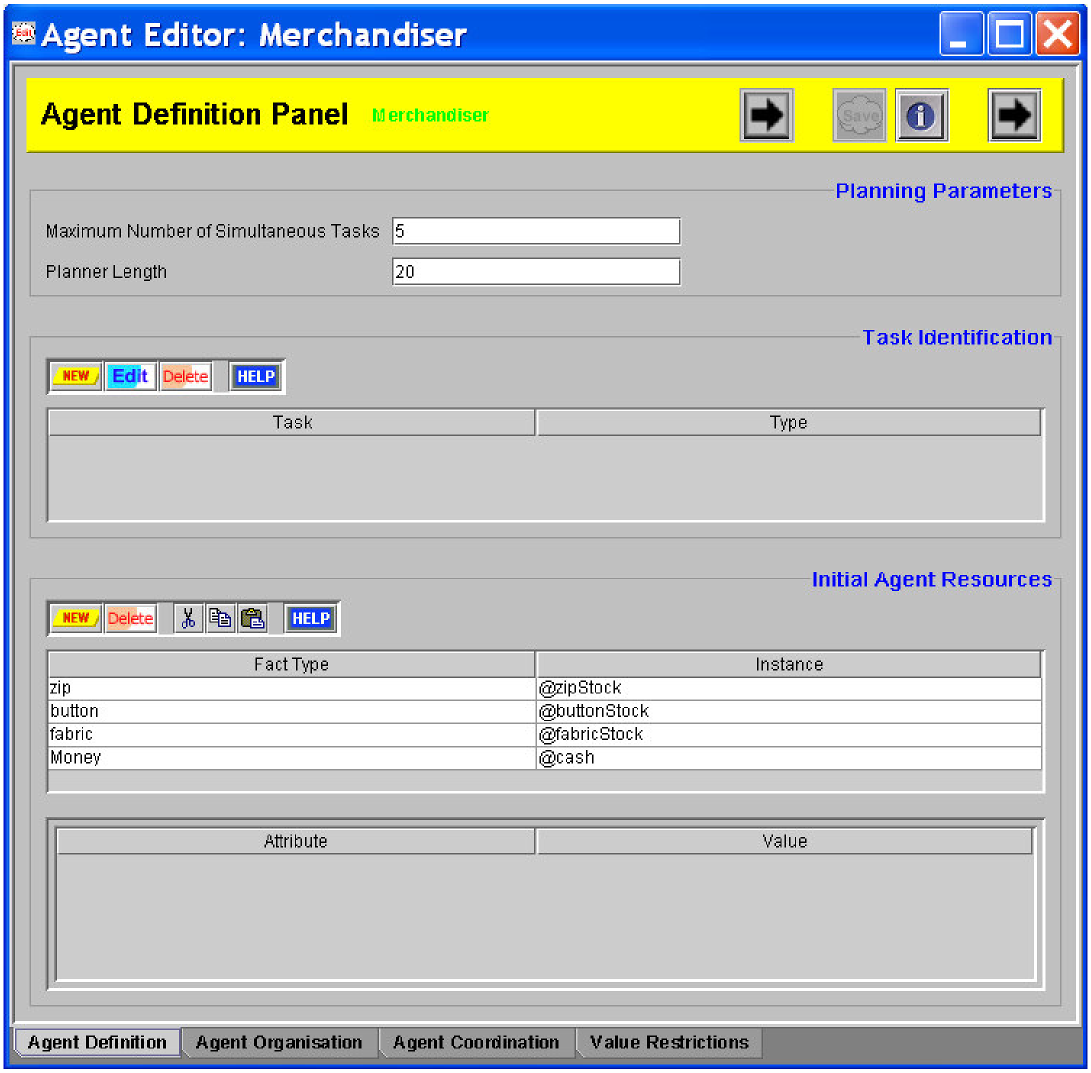


Figure 6-11 Definition panel of negotiation content

6.6 Summary

This chapter firstly illustrates the belief updating method for the negotiators to interact with each other. The six belief updating methods, which can be described in different mathematical distributions, reflect six different reactions for the buyer and the seller in the negotiation process. Secondly, the chapter has presented the basic negotiation strategy, linear method in the negotiation model. Utility functions are given and simulation for the negotiation process has been depicted. In the next chapter, artificial algorithms will be adopted as improved methods to optimize the negotiation strategy.

Chapter 7

Agent-based Optimization Model of Negotiation Process in the Apparel Supply Chain

In the previous section, an overall agent-based negotiation process has been simulated. Agents use belief updating method to emulate human thoughts and use linear method as a negotiation strategy to negotiate with each other on price and due date. In this section, we propose optimized negotiation strategies so that supply chain cost and production capacity can be taken into consideration. Therefore, a systematic mathematical model will be built in the following part. Intelligent algorithms have been applied in the proposed optimized negotiation strategy. A two-phase negotiation strategy with genetic algorithm (GA) and simulated annealing (SA) is adopted so that optimal negotiation can be achieved. Based on this, a genetic simulated annealing algorithm (GSAA) is explored to try to find better result.

7.1 Mathematical Model of Negotiation

In this research, negotiation with suppliers addresses two issues: (1) the price of the material and (2) the material's arrival time. Therefore, the decision space for the manufacturer in negotiating with suppliers is defined in terms of these two variables. The essential conflict is that the manufacturer would like to have the material arrive on its preferred schedule ($DD_{j,t}^{M}$) and pay as little as possible ($P_{j,t}^{M}$), while the supplier asks a higher price ($P_{j,t}^{S}$) and prefers to have a long delivery due date ($DD_{j,t}^{S}$). The decision space is bounded by the levels of limit and aspiration. Pruitt (1981) explains that a limit level is a bargainer's ultimate fallback position, the level of benefit beyond which he/she is unwilling to concede. On the other hand, the aspiration level is the level of benefit sought at any particular time; that is, the value to the bargainer of the goal toward which he/she is striving. The aspiration level is always higher than or equal to the limit level. Normally, the aspiration level is proposed in the initial offer of a negotiation.

We will first present an analytical model of a negotiation between an apparel manufacturer and a raw material supplier who contract on price and due date, following the standard approach used in bargaining theory (Binmore K., 1992; Binmore and Dasgupta, 1987). The utility functions of the agents should be constructed first with consideration of the fact that the supplier's utility increases while the customer's decreases. Concerning the due date, the two parties have opposite preferences to delay or to anticipate delivery, in accordance to their own production plans and costs. To reflect such preference of the agents, utility functions are described in power-form, with utilities given in currency units and assuming other parameters to be consistent with the unit. To simplify the parameters, we use s as the subscript to indicate supplier and p to indicate producer.

$$U_s = p + K_s d^{\gamma_s} \qquad (7\text{-}1)$$

$$U_p = p - K_p d^{\gamma_p} \qquad (7\text{-}2)$$

U_s : the utility of the supplier

U_p : the utility of the producer

K_s : preference of the supplier in anticipating or delaying delivery

K_p : preference of the producer in anticipating or delaying delivery

p : contracted price

d : due date

γ_s : the weight of the supplier

γ_p : the weight of the producer

Parameters K_s and K_p can take values ± 1, and represent the preference of the agents in delaying or anticipating the delivery. K_s=+1 means the supplier prefers to delay, since in such a case his utility increases by increasing the due date (the opposite when K_s=-1). Similarly, K_p=+1 means that the producer wishes to anticipate as his utility increases by decreasing the due date. Parameters $\gamma_s \geq 0$ and $\gamma_p \geq 0$ weight the marginal effect of changing due dates. Figure 7-1 shows the supplier's utility as a function of due date d and fixed price p, in both cases of $K_s = \pm 1$.

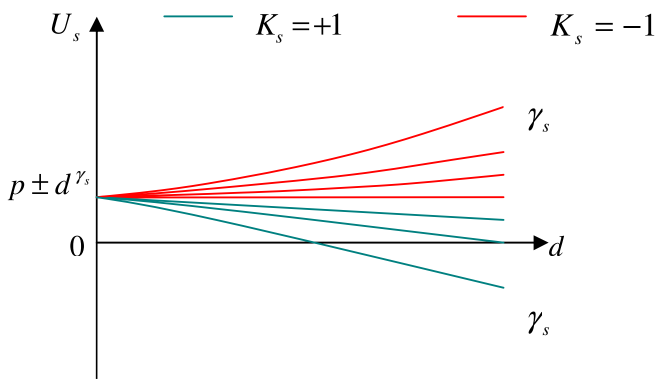


Figure 7-1 Utility function of the supplier agent in the analytical model

From the previous equations, an expression of the customer's utility as a function of the supplier's utility can be found.

$$p = U_s - K_s d^{\gamma_s} \tag{7-3}$$

$$U_p = U_s - K_s d^{\gamma_s} - K_p d^{\gamma_p} \tag{7-4}$$

U_p, as a function of U_s is a negatively sloped straight line that switches when d changes. Formula (4) represents the relationship between the supplier and the customer. $K_s = K_p = +1$, the function shows that the supplier wants to delay delivery, while the customer would prefer the opposite.

In the following parts, the related mathematical models will be presented in detail. One basic thing to emphasize is that the premiums of the optimization models are: 1) the negotiation is between the manufacturer agent and the supplier agent and 2) the negotiation issues are due date and price for model development.

7.2 Optimization of Negotiation Model with GA

Genetic algorithm has been explored to apply in many aspects in the supply chain such as the ordering process and inventory control or supply chain performance.

Negotiation, which is a human activity, is difficult to be imitated systematically. However, we integrated multi-agents with intelligent algorithms in order to make simulated negotiation model more humanized. In this research, genetic algorithm is applied in the mathematical model of the negotiation strategy in the fashion supply chain under a dynamic environment with consideration of mutual benefit, production capacity and supply chain cost mainly in production and inventory. The following sections will construct mathematical models from the view of production and profit and provide an optimization of apparel negotiation strategy with GA method.

The main function of the production model is to assure that the counter-offers generated by the model are technically and economically feasible to be conducted in the shop floor. The basic assumption is that agreement has been reached with the mutual negotiators on price (p) and due date for delivery (dd_p). Subsequent activities will thus be determined by the production schedule and the initiation of materials purchasing activities. We consider a simple manufacturing situation with a series of k production stages $(k = 1,2,...,K)$ and one material j needed at each stage. Since one material j corresponds to each operation k , the number of suppliers required to fulfill the manufacturer's order are $J = K$. A different supplier supplies each material, so we use the same index (j) for the supplier and the material supplied.

7.2.1 Parameters of the Negotiation Model

Parameters

α_k, β_k : parameter of operation

π : minimal profit margin (%)

h_{IP} : end product inventory cost (\$/time)

h_{IMj} : material j inventory cost (\$/time)

h_{WIP} : WIP inventory cost (\$/time)

τ : transportation time (time)

dd_P : end-product delivery due date (time point)

p : end-product price (\$)

$T_k^{\max}$: maximum time of operation k (time)

$T_k^{\min}$: minimum time of operation k (time)

Indices:

i : index of objective ($i = 1,2,3$)

j : index of supplier (and material)

($j = 1,2,...J$)

k : index of operation (k =1,2,…, K)

Variables:

Δ : profit ($)

A : distance for the Tchebycheff measure

$CO_k(T_k)$: production cost-function of operation k

CI_{IMj} : cost of material j inventory ($)

CI_{WIPk} : cost of WIP inventory after operation k ($)

CI_P : cost of end-product inventory ($)

F_D : end-product arrival time at customer (time point)

F_k : finished time of operation k (time point)

R_D : end-product delivery time (time point)

S_k : starting time of operation k (time point)

T_k : duration of operation k (time)

TC : total cost ($)

Negotiation variables:

$DD_{j,t}^M$: manufacturer's offered due date for material j at round t (time)

$DD_{j,t}^S$: supplier's offered due date for material j at round t (time)

$P_{j,t}^M$: manufacturer's offered price for material j at round t ($)

$P_{j,t}^S$: supplier's offered price for material j at round t ($)

"Round" means negotiation times.

The objective of the negotiation model is to minimize the total production cost, which consists of the material cost (P_{jt}^{M}), material inventory cost (CI_{Mj}), operation cost (CO_k), work in progress (WIP) inventory cost (CI_{WIPk}), and end-product inventory cost (CI_P).

7.2.2 Procedure of GA-based Negotiation

With the basic parameters defined, we can take a close look at GA. GA is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination). Fig. 7-2 shows the procedure of genetic algorithm.

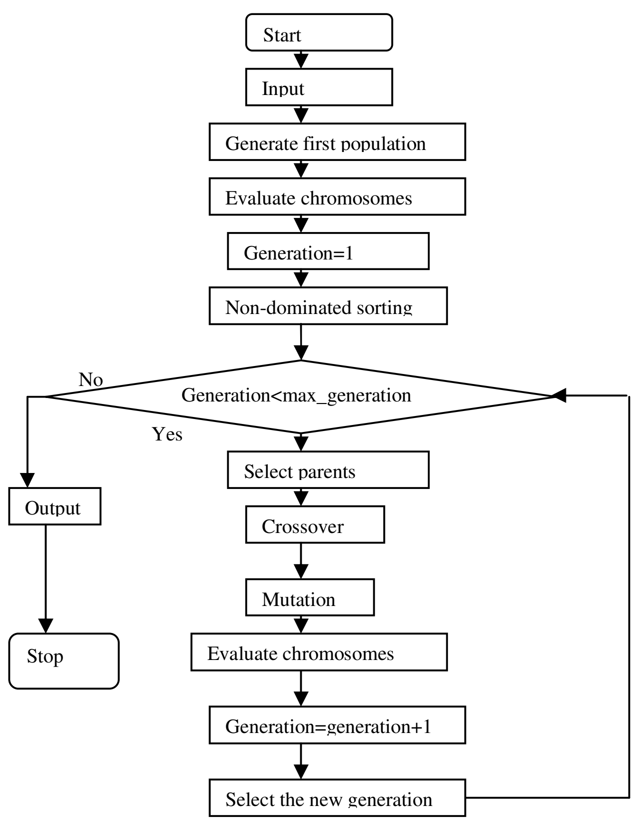


Figure 7-2 The procedure of genetic algorithm

Genetic algorithm is applied to decide on the proper price and delivery date to balance the aspect of production cost, production capacity and the customer satisfaction for the manufacturer agent and the supplier agent. However, human negotiation is based on the manager's experience and history data. The genetic algorithm does not depend on large previous data and generate the offspring with the aim of achieving minimal total cost.

1) Fitness function

In GA, a fitness function determines what the best chromosome is in all generations and decides when to stop evolution. The proposed fitness object function uses the cost function. The total production cost of the supply chain is formulated as (7-2).

2) Crossover

In order to keep the variety of the chromosome, we adopt the entire crossover strategy which is described as follows.

$$x_{oi} = \alpha_i x_i + (1-\alpha) y_i$$

$$y_{oi} = \alpha y_i + (1-\alpha) x_i \text{ , } \alpha \in (0,1)$$

x_{oi}, y_{oi} are the new generation chromosome, while x_i and y_i are the parents. α is randomly selected between 0 and 1.

3) Mutation

Mutation is defined in a traditional way: if $x_i = (x_{1,} x_2 \ldots\ldots x_n)$ is a chromosome, then each element x_k has an exactly equal chance of undergoing the mutation process. The generation y_k which mutates from x_k is defined as follows.

$$y_k = \frac{(x_k - a_k)a_k + (b_k - x_k)b_k}{b_k - a_k} \text{ , } x_k \in (a_{k,} b_k)$$

$$\min TC \text{ .... (7-1)}$$

s.t.

$$TC = \sum_j^J P_{jt}^M + \sum_j^J CI_{Mj} + \sum_{k=1}^K CO_k + \sum_{k=1}^{K-1} CI_{WIPk} + CI_P \text{ .... (7-2)}$$

$$CO_k(T_k) = \alpha_k \cdot e^{-\beta_k \cdot T_k}, T_k^{\min} \le T_k \le T_k^{\max} \text{ .... (7-3)}$$

$$CI_{Mj} = h_{IMj} \cdot (R_k - DD_{j,t}^M), \forall (k = j) \text{ .... (7-4)}$$

$$CI_{WIP} = h_{WIPk}(R_k - F_{k-1}) \text{ .... (7-5)}$$

$$CI_{IP} = h_{IP}(R_D - F_k) \text{ .... (7-6)}$$

$$(1+\pi) \cdot TC \le p \text{ .... (7-7)}$$

$$F_D - dd_P = 0 \text{ .... (7-8)}$$

$$F_D - R_D = \tau \quad (7\text{-}9)$$

$$F_k - R_k = T_k \quad (7\text{-}10)$$

$$R_D \geq F_k \quad (7\text{-}11)$$

$$F_k > R_k \quad (7\text{-}12)$$

$$R_k \geq F_{k-1} \quad (7\text{-}13)$$

$$R_k \geq DD_{j,t}^{M}, \forall (k = j) \quad (7\text{-}14)$$

$DD_{j,t}^{M}$ are positive integers; $k = 1,2,\ldots, K$; $j = 1,2,\ldots, J$ .... (7-15)

In this evolution process, two agents are used: 1) the manufacturer agent provides his offered price and expected due date for GA calculation; 2) the supplier agent also makes his offer price and scheduled due date as a response to the manufacturer agent. The real-coded algorithm is described as follows:

Step 1. Initialization. Generate a population of size $|P|$ (the number can be defined by the user), and each chromosome has 6 genes, whose value was randomly generated from range $[0, X]$. X is a predefined aspiration value of the supplier agent. Usually the supplier who is the seller expects higher price for his raw material product.

Step 2. Evaluation. Evaluate each population member of $[P]$ according to the fitness function that is the total production cost.

Step 3. Selection. Select part of $[P]$ using the roulette wheel method (Holland, 1992) according to the fitness function.

Step 4. Crossover. Crossover each two members of the selected part of $[P]$ in turn to form a new population member with the above crossover strategy.

Step 5. Mutation. Mutate the child strings with the mutation probability and place them into the new population. The chromosome is randomly selected and its value is changed based on previous rules. In this research the mutation rate is assumed as 0.01. The mutation method is described with the corresponding operator equation mentioned in the above 3).

Step 6. Repeat Step 2–5 iteratively until the population converges, no better chromosome is found, or time is out. The optimal price which can be accepted by both negotiators is then found. For example, if the initial value of the price negotiation is (58 42 21 76 63 32), after GA calculation the final chromosome is represented as (67 50 25 67 50 25), where 67is the final optimal result that both negotiators are satisfied with.

The real-coded genetic algorithm is coded with Matlab 6.0. The upper generation is 80, the crossover rate 0.9, and the mutation rate 0.01. The input is the initial price of the supplier and the manufacturer. The fitness function is the production cost.

7.2.3 Numerical Example

Consider an apparel manufacturer who has received an order with a contract that specifies a sales price of $178 and delivery within 60 days. The manufacturer expects to obtain a profit of at least 10% from the total cost. To complete the order, three operations, the production and delivery of fabric, zipper and button in sequence are needed. To supply the lower-stage product, two suppliers are required. In each negotiation round the decision-maker would like to have five alternative offers. The operational parameters to process the order are given in table 7-1.

Table 7-1 Parameters of the numerical example

Parameter	Value
T_1^{min}	5 days
T_2^{min}	5 days
T_3^{min}	5 days
T_1^{max}	30 days
T_2^{max}	30 days
T_3^{max}	30 days
α_1	100
α_2	150
β_1	0.1

β_2	0.15
h_{11}	\$2/day
h_{12}	\$2/day
h_{IP}	\$5/day
h_{IWP}	\$3/day
τ_l	2 days

The supplier agent offer the first bidding price as Table 7-2 lists. The manufacturer agent initializes his offer as Table 7-3 shows.

Table 7-2 Initial offer of the supplier

Variable	Value (\$)
$P_{1,1}^{S}$ (fabric)	12/yard
$P_{2,1}^{S}$ (zipper)	1.5/yard
$P_{3,1}^{S}$ (button)	10/each

Table 7-3 Initial offer of the manufacturer

Variable	Value (\$)
$P_{1,1}^{M}$	5/yard
$P_{2,1}^{M}$	1/yard
$P_{3,1}^{M}$	7/each

From Figure 7-3 we can see that before optimization the total cost rises quickly to a high level while after agent's optimization the cost varies in a small range. That means the optimization with fuzzy logic and genetic algorithm can reduce the supply cost. Figure 7-4 and Figure 7-5 show the difference of price variation in the negotiation before and after using genetic algorithm. From the comparison, we can find that the genetic algorithm can effectively reduce the total cost and the price trend becomes smoother.

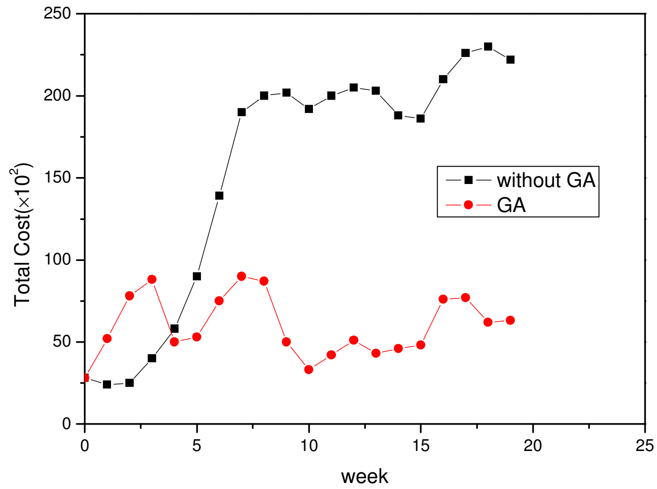


Figure 7-3 The comparison of total cost between two approaches

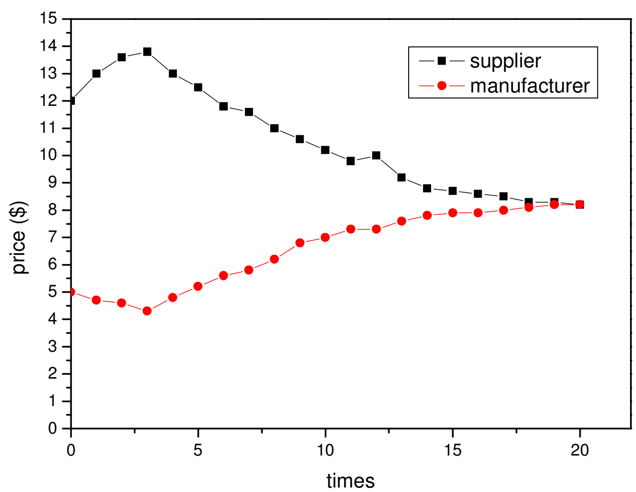


Figure 7-4 Price negotiation before using genetic algorithm

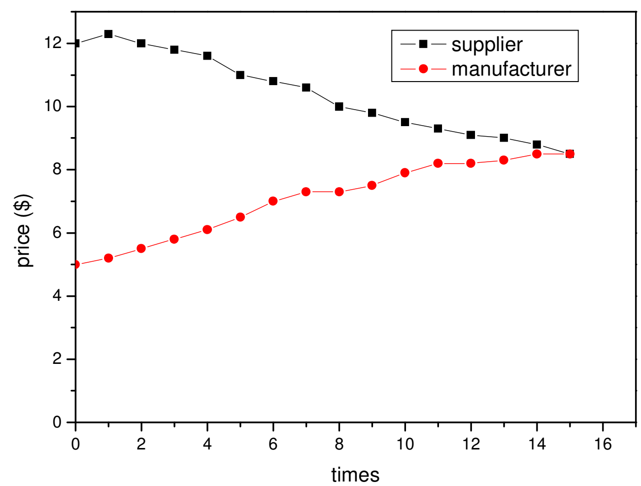


Figure 7-5 Price negotiation after using genetic algorithm

Figure 7-4 and Figure 7-5 are the results of negotiation on fabric. The initial offers of the manufacturer and the supplier are 12 and 5. The manufacturer as the buyer hopes to get the product cheaper and the supplier as the seller anticipates a higher price for the product to sell. Before we use GA, the mutual parts do not take supply chain cost into their consideration. Thus the supplier raises the price and respectively the manufacturer turns down the price at first so that the profit can be increased and then gradually reach the agreement on the final negotiation price. In Figure 7-5, the curve fluctuates less than that of Figure 7-4 which means the supplier considers the factor of cost and he hoists the price gently. In addition, the manufacturer also cooperates well with the supplier in negotiating price compared with the former one. The negotiation times are obviously less than that of the negotiation without using GA method.

7.2.4 Model of manufacturer to supplier

During the negotiation process, decisions on offers and counter-offers during negotiation are determined by two forces: (1) concession and (2) resistance. The force of concession represents the force acting on the negotiator to make concessions. The force of resistance, on the other hand, is the force acting on the negotiator that represents his/her natural disinclination to concede (Balakhrishnan and Eliashberg, 1995). The fundamental objective of the negotiation model 2, is to achieve agreement in terms of due date and price while maximizing profit. Effort in achieving agreement is formulated by minimizing the distance between offers from the two parties in terms of both issues. Therefore, equations (14) and (15) both represent the force of concession exerted by the manufacturer. On the other hand, in equation (16), maximizing the profit means that the manufacturer will be forced to have the material arrive on the preferred schedule generated by the previous negotiation model with the lowest possible price. Thus, this objective represents the resistance of the manufacturer to making concessions to suppliers.

$$\min z_{1j} = (DD^S_{j,t} - DD^M_{j,t}) \quad \text{(7-16)}$$

$$\min z_{2j} = (P^S_{j,t} - P^M_{j,t}) \quad \text{(7-17)}$$

$$\max z_3 = \Delta_t \quad \text{(7-18)}$$

$s.t.$

$$\Delta_t = p - TC_t \quad \text{(7-19)}$$

$$DD^M_{j,t} \geq DD^M_{j,t-1} \quad \text{(7-20)}$$

$$P^M_{j,t} \geq P^M_{j,t-1} \quad \text{(7-21)}$$

$j = 1,2,\ldots\ J$; $t = 1,2,\ldots\ T$; DD^M_{jt} are positive integers.

Kersten et al. (1991) explained that when offers and counter-offers are made in a negotiation, a compromise is reached by selecting an alternative that is acceptable to both parties. Thus, concession making should lead to a decrease in the distance between the alternatives selected by the players. This leads to the concept of an effective alternative as follows:

Alternative $x \in S$ is effective with regard to alternative x_1 if for a given alternative x_2 :

$x \in S = \{x : L(x, x^2) < L(x^1, x^2)\}$, where L is a distance function.

We hope to find an effective alternative as an offer where the price of the material and its due date move in the direction of supplier preference (to a higher price and a later due date than a previous offer) but keep the profit margin above the target level. Constraints

(18) and (19) are required in model 2 to satisfy the requirement of the defined effective alternative.

The model we have developed in this paper is designed to support the manufacturer's decision-making with mathematical formulae in the process of negotiation with suppliers, rather than automating the process. The support for the decision-maker is provided by obtaining a set of alternative counter-offers in response to the suppliers' offers. This structure allows the decision-maker some degree of freedom to choose the single most preferable feasible alternative.

Consider the multiple objectives:

$$\max\{f_1(x) = z_1\} \qquad (7\text{-}22)$$

.

.

.

$$\max\{f_k(x) = z_k\} \qquad (7\text{-}23)$$

$s.t. x \in S.$

Let $Z \subset R^k$ be the set of all feasible vectors in the criterion space. We hope to find a $\bar{z}$ which can be sufficiently close to the ideal criterion vector z^{**}.

$$\min A + \rho\{[\sum_{i=1}^{2}\sum_{j=1}^{J} z'_{i,j} - z^{**}_{i,j}] + (z^{**}_3 - z'_3)\} \qquad (7\text{-}24)$$

$s.t.$

$$A \geq \lambda_{i,j}(z'_{i,j} - z^{**}_{i,j}), i = 1,2; j = 1,2,...,J \qquad (7\text{-}25)$$

$$A \geq \lambda_3(z^{**}_3 - z'_3)$$

$$z'_{1j} = (\frac{DD^S_{j,t} - DD^M_{j,t}}{DD^S_{j,t}}) \times 100\% \qquad (7\text{-}26)$$

$$z'_{2j} = (\frac{P^S_{j,t} - P^M_{j,t}}{P^S_{j,t}}) \times 100\% \qquad (7\text{-}27)$$

$$z'_3 = (\frac{\Delta_t}{p}) \times 100\% \qquad (7\text{-}28)$$

7.3 Optimization of Negotiation Model with SA

SA and GA are two stochastic methods currently in wide use for difficult optimization problems

SA is a generic probabilistic meta-algorithm for the global optimization problem, namely locating a good approximation to the global optimum of a given function in a large search space. It is often used when the search space is discrete (e.g., all tours that visit a given set of cities). For certain problems, simulated annealing may be more effective than exhaustive enumeration — provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution.

GA is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination).

Some researchers think the key difference between SA and GA is while SA creates a new solution by modifying only one solution with a local move, GA creates solutions by combining two different solutions (J. Kohonen, 1999).

7.3.1 Mathematical Negotiation Model of the Supplier Agent

$$\min ZS_1 = CRG(\sum_{t=1}^{T}\sum_{i=1}^{M} y_{it} - \sum_{t=1}^{T} o_t) + COV\sum_{t=1}^{T} o_t \quad \text{...... (7-29)}$$

$$\max ZS_2 = \sum_{i=1}^{K} p_i \quad \text{...... (7-30)}$$

s.t $$\sum_{t \le d_i} y_{it} \ge r_{ij,} \forall i, j \quad \text{...... (7-31)}$$

$$\sum_{i} y_{it} \le CAPRr_{jt} + o_{jt}, \forall j, t \quad \text{...... (7-32)}$$

$$o_{jt} \le CAPO_{jt}, \forall j, t \quad \text{...... (7-33)}$$

$y_{it} \geq 0, \forall i, j, t$ .... (7-34)

$o_{jt} \geq 0, \forall j, t$ .... (7-35)

ZS_1 : the cost of the supplier

ZS_2 : the profit of the supplier

T : working period, t =1, 2, 3… T

M : the order volume of the supplier

K : the order volume from the manufacturer to the supplier

r_{ij} : the demand of resource j for order i

$CAPO_{jt}$: the capacity of resource j for usual time

$CAPR$: the capacity of resource j for overtime

CRG_j : the cost of usage of resource j for usual time

COV_j : the cost of usage of resource j for overtime

Negotiation parameters:

d_i : the delivery time of order i

p_i : the price of each order

Inbound parameters:

y_{it} : the volume of resource assigned to order i during period t

o_t : the demand of resource for overtime during period t

Mediator agent coordinates the operation between the supplier and the manufacturer. The supplier agent received orders (e.g. zipper, button) from the mediator agent. If the needed supplies are already in stock, the orders will be satisfied. If not, the supplier agent will assign the factory to make the related apparel component for the orders.

Function (7-29) minimizes the overall production cost of the supplier

Function (7-30) maximizes the total profit of the supplier when negotiating with the manufacturer

Restriction (7-31) ensures to assign enough resource to the production of each order

Restriction (7-32) is the production capacity limit

Restriction (7-33) is the overtime production limit

Restriction (7-34) and (7-35) are the ranges of the parameters

7.3.2 Mathematical Negotiation Model of the Manufacturer Agent

The major issues between the manufacturer agent and the supplier agent are focused on price and due-date. In this model, the manufacturer is supposed to collect all the necessary components from the suppliers and then makes the final apparel product.

$$\min ZM_1 = \sum_{a=1}^{A}\sum_{j=s_a}^{e_a} h_j^C d_a + \sum_{i=1}^{I}\sum_{t=0}^{T}(h_i^P I_{i,t} + s_i) \quad \text{......} (7\text{-}36)$$

$$\min ZM_2 = \sum_{k=1}^{K} pr_k \quad \text{......} (7\text{-}37)$$

s.t

$$\sum_{t=ES_j}^{LS_j}(t + p_{e_a})x_{e_a,t} \le d_a, (a = 1,...A) \quad \text{......} (7\text{-}38)$$

$$\sum_{t=ES_j}^{LS_j} x_{j,t} = 1 \quad \text{......} (7\text{-}39)$$

$$\sum_{t=ES_h}^{LS_h}(t + p_h)x_{h,t} - \sum_{t=ES_j}^{LS_j} t x_{j,t} \le -t_{h,j}^{\min} \quad (j = 1,...J; h \in \rho_j) \quad \text{......} (7\text{-}40)$$

$$\sum_{j=1}^{J}\sum_{t=\max\{0,t-p_j\}}^{t-1} c_{j,r}x_{j,t} \le C_{r,t}^P \quad (r = 1,...R^A, t = 1,...T) \quad \text{......} (7\text{-}41)$$

$$\sum_{t=1}^{pd_k} x_{j,t} = 0 \quad (j = 1,...J; k \in K_j) \quad \text{......} (7\text{-}42)$$

$$x_{j,t} \in \{0,1\} \quad (j = 1,...J; t = 1,...T) \quad \text{......} (7\text{-}43)$$

$$y_{j,t} \in \{0,1\}, Q_{i,t} \ge 0, I_{i,t} \ge 0 \quad (i = 1,...I; t = 1,...T) \quad \text{......} (7\text{-}44)$$

j : number of the production process, $j = s_a,...e_a$

$I_{i,t}$: the inventory of component i at time t

d_a : the delivery date of order a

ES_j : the beginning of the assembling time

LS_j : the end of the assembling time

h_j^C : the holding cost of component j

h_i^P : the inventory cost of product i

a : the customer order, $a = 1,...A$

$q_{j,i}$: the quantity of component i in assembling work j

pr_k : negotiated price for component k

pd_k : negotiated delivery date of component k

r : resource, $r = 1,...R^P$

R^P : production resource

p_j : process time for assembling work j

$c_{j,r}$: consumed resource for production process j

$C_{r,t}^P$: the available resource for production during period t

s_i : fixed production cost of component i

$q_{j,i}$: the required quantity of component i during assembling work j

Function (7-36) minimizes the total manufacturing cost
Function (7-37) tries to minimize the negotiation price
Restriction (7-38) guarantees the manufacturing for each order complete before due date
Restriction (7-39) ensures each manufacturing process complete
Restriction (7-40) expresses the sequences of the apparel making process
Restriction (7-41) is the restriction of the production capacity
Restriction (7-42) ensures the apparel making begins after all the components arrive
Restriction (7-43) and (7-44) define the ranges of the parameters

In the make-to-order supply chain, the manufacturer and the supplier are in the relationship of competitive coordination. The two parties will coordinate to make the apparel products, satisfy the customers and improve the overall supply chain efficiency. ZM_1 and ZS_1 reflect such relationships. At the same time, the two parties enlarge their own benefit respectively. The profit allotment is in confronting positions for the manufacturer hopes to pay less and the supplier wants to get more. ZM_2 and ZS_2 reflect such competitive relationship.

7.3.3 Due-date Negotiation based on SA

The approach to the problem of negotiation can be divided into game theory and AI. Game theory lacks the instruction to real negotiation, while agent technology, as a branch of AI, can better represent human bargain. AI approach can be further divided into concession based method and joint gains seeking method. The former is usually used in distributive bargain with alternative negotiation protocol while the later is applicable in integrative bargain with single negotiation text protocol. Both of the two methods aim to maximize the social welfare.

SA is a generic probabilistic meta-algorithm for the global optimization problem, namely locating a good approximation to the global optimum of a given function in a large search space. It is often used when the search space is discrete (e.g., all tours that visit a given set of cities). For certain problems, SA may be more effective than exhaustive enumeration — provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution.

By analogy with this physical process, each step of the SA algorithm replaces the current solution by a random "nearby" solution, chosen with a probability that depends on the difference between the corresponding function values and on a global parameter T (called the temperature), that is gradually decreased during the process. The dependency is such that the current solution changes almost randomly when T is large, but increasingly "downhill" as T goes to zero. The allowance for "uphill" moves saves the method from becoming stuck at local minima—which are the bane of greedier methods.

7.3.4 Computation of Due-date Negotiation Model

Let i ($i \in \{a,b\}$) represents the negotiating agents and j ($j \in \{1,...n\}$) be the decision variables under negotiation. Negotiations can range over quantitative (e.g., price, delivery time, and penalty) or qualitative (e.g., quality of service) decision variables.

Suppose two computer programs are negotiating on behalf of their users in a supply chain management scenario. Agent 1 is the producer (supplier) agent and Agent 2 is the buyer agent. These two agents are involved in a negotiation process where a detailed contract concerning product mix, delivery date, price, etc., is expected to be achieved. The overall negotiation process can be modeled as exchanging proposals and counterproposals, as typically happens in human negotiations.

Based on the group rationality of the manufacturer and the supplier and the nature of the cooperation of the two parties in the due-date negotiation process, single negotiation text protocol is adopted and the merchandiser agent as the mediate agent is introduced. The mediated agent raises new proposals and the manufacturer agent and the supplier agent evaluate on the proposal according to their own utility function and then return feedback to the mediate agent to achieve better joint gains. Simulated annealing is a searching algorithm which is good in global optimization. Thus, in this paper simulated annealing is used as the searching algorithm for the merchandiser agent.

Step 1. The manufacturer agent (MA) develops optimized strategy of the production plan in order to get the minimized production cost $ZM_{1,0}$ and required due-date of the needed apparel component pd_k ($k = 1,2...K$). The reservation value (pr_{mr}) and the aspiration value (pr_{ma}) are determined. MA sends the related information of ZM and pd_k to the intermediate merchandiser agent (IA). IA then informs the supplier agent of the due-date requirement.

Step 2. The supplier agent (SA) makes optimized production plan and get the minimized production cost $ZS_{1,0}$ according to the received due-date requirement from MA. SA determines the reservation value (pr_{sr}) and the aspiration value (pr_{sa}). SA sends the information of pr_{sr}, pr_{sa} and $ZS_{1,0}$ to IA as well.

Step 3. IA initializes the parameters of the simulated annealing. The initialization is $x_i = pd_{k,0}$. The objective function $fx_i = ZM_{1,0} + ZS_{1,0}$, $t_0 = t_{\max}$

Step 4. IA selects x_j randomly from the neighbor region $N(x_i)$ and sends to MA and SA.

Step 5. Repeatedly, MA makes the optimized production plan with restriction of the due-date and sends the revised minimized production cost $ZM_{1,j}$ to IA.

Step 6. Repeatedly, SA makes the optimized production plan with restriction of the due-date and sends the revised minimized production cost $ZS_{1,j}$ to IA.

Step 7. IA calculates $\Delta f_{i,j} = f(x_i) - f(x_j), f(x_j) = ZM_{1,j} + ZS_{1,j}$, if $\Delta f_{i,j} \leq 0,\ x_i = x_j$, else if $\exp(-\Delta f_{ij} / t_s) > random(0,1)$, $x_i = x_j$;

Step 8. IA decreases the temperature $t_{s+1} = d(t_s); s = s+1$; if the termination condition is satisfied, MA and SA are informed of the final optimal due-date.

Step 9. MA adjusts the reservation value and the aspiration value of the purchase price of the apparel components.

$pr_{mr,e} = pr_{mr,0} + ZM_{1,0} - ZM_{1,e} - ESTC_{m,}$, $pr_{ma,e} = pr_{ma,0} + ZM_{1,0} - ZM_{1,e} - ESTC_m$,

$ESTC_m$ is the estimated value which the manufacturer can get from the total cost.

$ZM_{1,e}$: optimized production cost of the manufacturer after due-date negotiation.

Step 10. SA adjusts the reservation value and the aspiration value of the selling price of the apparel components.

$pr_{sr,e} = pr_{sr,0} - ZS_{1,0} + ZS_{1,e} + ESTC_s$, $pr_{sa,e} = pr_{sa,0} - ZS_{1,0} + ZS_{1,e} + ESTC_s$, $ESTC_s$ is the estimated value which the supplier can get from the total cost.

$ZS_{1,e}$: optimized production cost of the supplier after due-date negotiation.

7.3.5 Price Negotiation

After the due-date negotiation, based on the individual rationality of the manufacturer and the supplier and the competence nature on the price issue, the two parties will negotiate on price in this phase adopting the interactive proposals. The manufacturer and the supplier make concession from their own evaluation within the acceptable range. $[pr_{ma,e}, pr_{mr,e}]$ ($[pr_{sa,e}, pr_{sr,e}]$) defines the price range that MA (SA) can accept. Within time period $T(T = 1,2...)$, the two parties communicate interactively and evaluate the new proposals of the other side via the intermediate agent (IA). MA (SA) has the time limit of $p^t_{m \to s}$ ($p^t_{s \to m}$) which means the manufacturer agent makes a price proposal to the supplier agent at point t.

Step 1. SA evaluates on the proposal with U^s. If $U^s(p^t_{m \to s}) \geq U^s(p^{t'}_{m \to s}), t' = t+1$, SA will accept the proposal. Or further negotiation is needed. U represents the utility function.

Step 2. If $t > T^s$, the negotiation time is due and SA will terminate the negotiation.

Step 3. Or SA raises a reversed proposal $p_{s\to m}^{t'}$ at time t', $t'=t+1$

Step 4. If the proposal ends, SA terminates the negotiation.

Research has been made on the price negotiation in recent years (Zeng and Sycara, 1998) and we use the negotiation model which takes time restriction and incomplete information into consideration. The utility functions of MA and SA are defined as follows.

MA: $U^m(p,t) = U_p^m(p)U_t^m(t),\ U_p^m(p) = pr_{mr,e} - p$, $U_t^m(t) = (\delta^m)^t$

SA: $U^s(p,t) = U_p^s(p)U_t^s(t),\ U_p^s(p) = p - pr_{sr,e}$, $U_t^s(t) = (\delta^s)^t$

The reversed proposals of MA and SA are:

MA: $p_{m\to s}^t = pr_{ma,e} + \phi^m(t)(pr_{mr,e} - pr_{ma,e})$

SA: $p_{s\to m}^t = pr_{sr,e} + (1-\phi^s(t))(pr_{sa,e} - pr_{sr,e})$

$\phi^m(t)$ and $\phi^s(t)$ are negotiation decision function (NDF) (Faratin et al., 1998), it is defined as $\phi^a(t) = k^a + (1-k^a)(\frac{t}{T^a})^{1/\Psi}$, $a \in \{m,s\}$

Ψ determines the concession rate. On the whole, the reversed proposal depends on the reservation value, the aspiration value, t and Ψ.

The social welfare which is the profit an agent achieves has been maximized and the acceptable price range has been adjusted in the due-date negotiation phase. However, the production cost may have been changed in the first stage. Thus in the price negotiation phase, MA and SA can achieve a win-win situation through appropriate utility function and proposal strategies.

7.3.6 Result

The two-phase negotiation separates the issues on due-date and price. In the first stage, negotiation focus on the due-date which is a coordination issue of the two parties in the apparel supply chain. The overall production cost is minimized and the social welfare of the supply chain is maximized. The simulated annealing algorithm provides a global optimization searching method and the Pareto optimization can be quickly achieved. In the second stage, the two agents negotiate on the competitive issue of price and they make concession with interactively exchanging proposals based on the adjusted reservation price and aspiration price in the first stage. The allotment of the production cost is changed and the payment is transferred from the manufacturer to the supplier to achieve a win-win situation for the two negotiator agent.

The parameters of the manufacturer agent negotiation model are listed as follows.

$A=2, d_1=5, d_2=3, s_1=1, e_1=3, s_2=e_2=4,$
$\rho_3=\{1,2\}, R^C=1, C_{1,t}^C=3, p_1=1, p_2=1, p_3=1, p_4=1,$
$c_{1,1}=2, c_{2,1}=2, c_{3,1}=1, c_{4,1}=1; h_1^C=5, h_2^C=10, h_3^C=5,$
$h_4^C=5, R^P=1, C_{1,t}^P=10, I=3, c_1=1, c_2=1, c_3=1,$
$s_1=20, s_2=10, s_3=10, h_1^P=1, h_2^P=2, h_3^P=1, q_{11}=5,$
$q_{22}=5, q_{31}=5, q_{43}=5.$

The parameters of the supplier agent negotiation model are listed as follows.

$T=5, M=K=2, N=2, r_{11}=15, CRG_1=1,$
$COV_1=3, CAPR_1=10, CAPO_1=8, r_{22}=30,$
$CRG_2=1.5, COV_2=2.5, CAPR_2=20, CAPO_2=10.$

The manufacturer agent initializes the delivery date of the orders d_1 and d_2, the reservation price $pr_{mr,0}$ and the aspiration price $pr_{ma,0}$ when the negotiation begins between the two parties. The supplier agent also sets its own parameters including reservation price $pr_{sr,0}$, aspiration price $pr_{sa,0}$ and etc.

$d_1=1, d_2=1, pr_{mr,0}=100, pr_{ma,0}=80, \delta^m=1,$
$K^m=0, \Psi^m=0.9, pr_{sr,0}=85, pr_{sa,0}=110, \delta^s=1,$
$K^s=0, \Psi^s=1.1$

Table 7-4 The result of the negotiation of the supplier agent

	Supplier Agent				
	Reservation Value	Aspiration Value	Production Cost	Profit	Negotiation Point
1st mode	85	110	80	12.05	(1,1, 92.05)
2nd mode	75	100	70	13.31	(2,1, 83.31)

Increased utility				1.26	
Negotiation point (due-date of component 1, due-date of component 2, total price)					

Table 7-5 The result of the negotiation of the manufacturer agent

	Manufacturer Agent				Total Supply Chain Cost
	Reservation Value	Aspiration Value	Internal Production Cost	Overall Cost	
1st mode	100	80	120	212.05	200
2nd mode	92	72	125	208.31	195
Increased utility				3.74	5
Total Cost: the total production cost of the manufacturer and the supplier					

To compare with the negotiation result, we use another negotiation mode as a contrast. Two groups of data are obtained from these two negotiations. The first mode is the manufacturer agent sets the delivery due-date according to the production capacity and then communicates with the supplier agent to decide on the price. The second mode is what we previously described in the paper (See Table 7-1 and Table 7-2). From these two tables, we can find that the second one gains more and costs less. The supply chain profit is 5 units (1.26+3.74) more than that of the first one, reflecting in the reduced value of the total supply chain cost. The utility of the manufacturer agent is increased, reflecting in the decreased overall cost, which is 3.74 units lower than that of the first mode. Meanwhile, the utility of the supplier agent is increased, reflecting in the increased profit which is 1.26 units than the first mode. Thus, the negotiation strategy of the two-phase discussion on due-date and price can expand the total profit and reduce the total supply chain cost. With such negotiation strategy, the social welfare of the agents can be maximized and the supplier and the manufacturer both benefit. In this paper, the negotiation model is focused on the price and due-date. Actually, in the apparel industry, there are more factors need to be considered when negotiating, like quality, season and etc. To improve the accuracy of the negotiation result, the model can be extended to apply to multi-issue negotiation for further research. In addition, the two-phase negotiation can also be considered to be integrated into one stage so that price and due-date can be discussed simultaneously.

7.4 Optimization model of Genetic Simulated Annealing Algorithm (GSAA)

In the previous two optimization models, we apply artificial algorithms to two optimization models. In the first model, GA is adopted in the price negotiation so that production cost can be minimized. However, in the first model, the production cost is only limited to the manufacturer's and the production capacity has not been taken into consideration. To improve such situation, we propose the second two-phase negotiation model with overall cost considered and use more reasonable algorithms and methods to solve the negotiation problems------cost and mutual benefit.

When we look into the previous negotiation strategies, GA and SA have their own advantages. GA has the advantage of finding a near global optimal solution quickly; however, it cannot converge to the optimum very well. The SA algorithm, though it has a strong local searching ability and can converge to the global optimum more accurately, it is not efficient in searching. Considering these two aspects, a GSAA is proposed in this research to integrate the merits of the two methods and to offset their weakness so that the performance of data generation can be improved.

7.4.1 GSAA negotiation model

The GSAA method has three typical characters

1) The algorithm includes the benefit of both GA and SA.

2) It has two-layer parallel searching ability. GA and SA are executed in sequence and the generations are optimized in a parallel manner.

3) The convergence rule takes two roles, one is the searching condition of GA, the other is the changing condition shifting from GA to SA

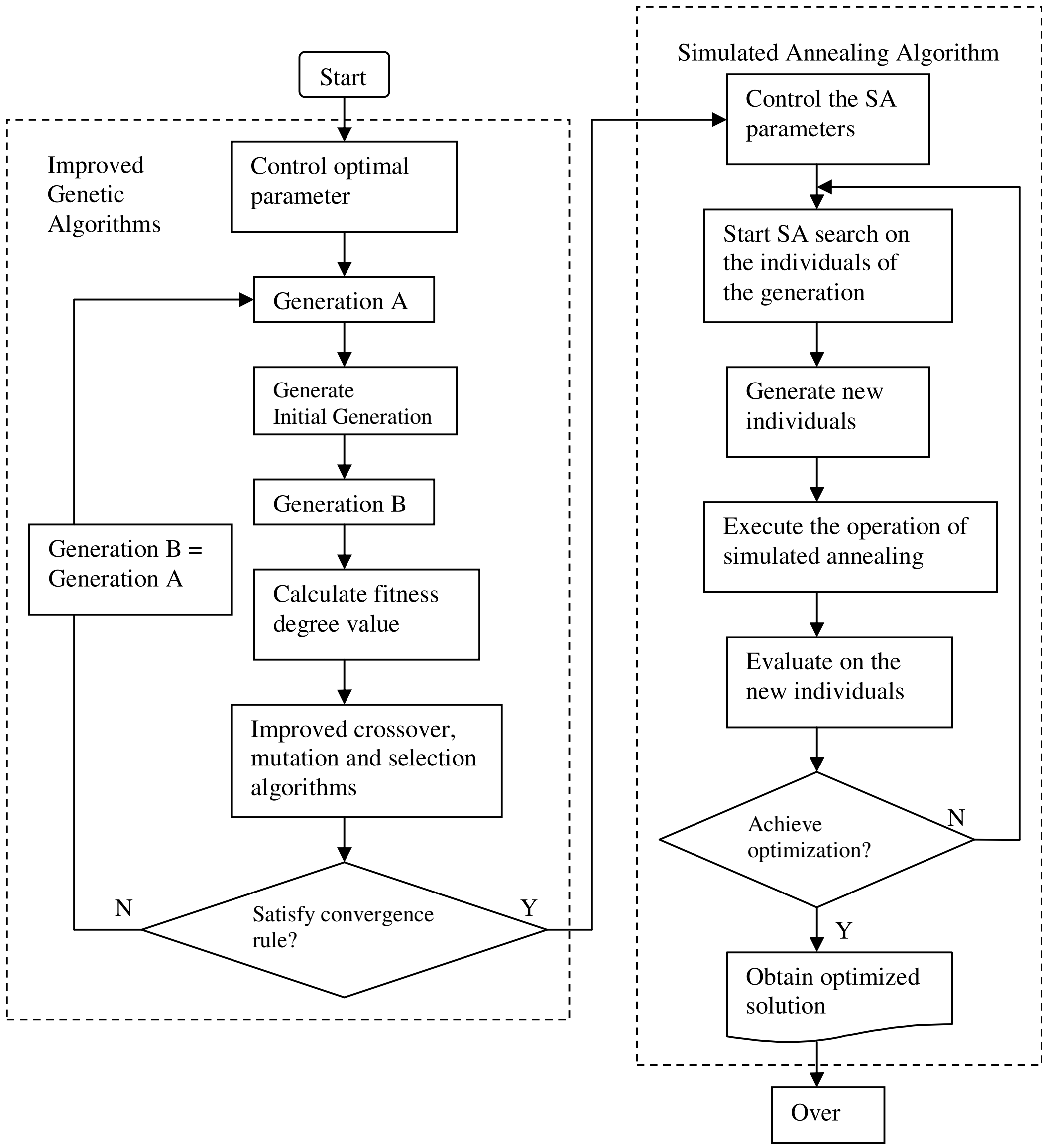


Figure 7-6 The flowchart of the genetic simulated annealing algorithm

In the GA part of GSAA, the same fitness function, crossover and mutation equations are used as mentioned in the previous GA negotiation strategy. Minimizing supply chain cost is also used as the objective function. That is,

$$\min TC \quad \text{(7-1)}$$

s.t.

$$TC = \sum_{j}^{J} P_{jt}^{M} + \sum_{j}^{J} CI_{Mj} + \sum_{k=1}^{K} CO_k + \sum_{k=1}^{K-1} CI_{WIPk} + CI_P \quad \text{(7-2)}$$

In the SA part of GSAA,

SA adopts the Metropolis accepting rule to decide whether the optimization result is achieved, which is

$$p = \left\{ \begin{array}{l} 1 \quad , f(i) \le f(i-1) \\ \exp\left[\dfrac{f(i) - f(i-1)}{t}\right], f(i) > f(i-1) \end{array} \right\}$$

$f(i)$: Objective function, here it can be defined as the function of supply chain cost

t: control parameter, similar to the time parameter in SA. We use the same numerical example as Table 7-1, Table 7-2 and Table 7-3 do.

7.4.3 Comparison

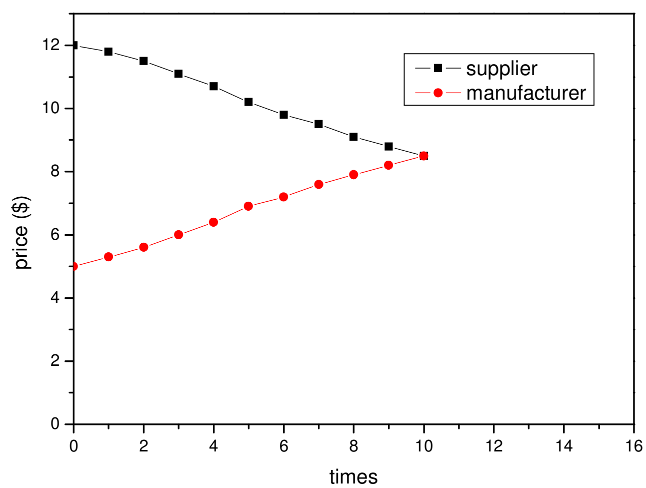


Figure 7-7 Price negotiation after using GSAA

Figure 7-7 shows the price negotiation procedure after using the negotiation strategy of GSAA. Compare with Figure 7-3 and Figure 7-4, we can find that the negotiation curves cross at a point more stably compared with the former algorithms and negotiation times are shortened. The reason is GSAA integrates the advantage of GA and SA and has a strong local searching ability. With GA, the supply chain cost is minimized but final agreement has to be negotiated for many rounds. While SA has better local searching ability so that it shortens the negotiation time. GSAA has better convergence ability and it finds an optimal result quicker than the other algorithms do.

Chapter 8
Conclusions and Future Research

This chapter starts with a summary which concludes the study. It also states some limitations of the study and suggestions for future research based on these limitations.

8.1 Knowledge models with UML

With the forthcoming of economic globalization, the apparel companies in HK are under the pressure to establish close coordination with their partners especially customers and manufacturers. To have better cooperation with others, communication becomes the first important thing. The apparel supply chain is quite complicated and dynamic due to fast fashion change, complex manufacturing processes, season variety and other uncertainties. Communication is easy to get mistaken during when information is conveyed from person to person. The focus of SCM is shifting from production process engineering, whose purpose is to obtain point-wise efficiency, to supply chain activity coordination, aiming at global efficiency (Verdicchio, M., 2002). The need for a suitable management and communication frame-work is thus becoming more and more evident.

Information sharing has been long considered as the enabler of tight coordination of a supply chain. While in this research rather than information sharing, we stressed that knowledge sharing is a critical factor for successful business process management. We argued that one of the most effective ways to achieve the above-mentioned knowledge sharing is to build an agent-based framework which models the dynamic structure of today's supply chain networks. The structure of the knowledge integration and the architecture of web-based knowledge management in supply chain were provided and the knowledge sharing model in the apparel supply chain was built. UML graphs have been developed in the major processes of the apparel supply chain so as to clarify the relationships between agents, make knowledge easily understood, and reduce errors, gaps and inconsistencies in the knowledge flow. Communication and knowledge sharing can be finally improved based on these knowledge models.

8.2 Agent-based Communication and negotiation model

In recent years, many researches about how to efficiently handle information on logistics in supply chain have been proposed. Some focus on applying artificial intelligence to solving the problem. Agent techniques have recently become very popular since they possess the characteristics of ongoing execution, environmental awareness, agent awareness, autonomy, adaptiveness, intelligence, mobility, anthropomorphism, and reproduce (He, M. and Leung, H., 2002). Agents are thus widely applied in computer science, e-commerce, supply-chain management, decision support systems, and among others. Most of the previous approaches, however, usually consider multiple agents and simulation systems in single companies. Besides, the study on the application of agent technology in the overall interaction and cooperation among supply chain members is limited.

In apparel industry, large sum of data need to be faced with and decisions about accepted price, product delivery date or replenishment quantity should be made quickly even as soon as possible. Therefore, in such situation, human beings sometimes can not respond so quickly that optimal decisions can not be made. As supply chain processes connect circle by circle, any tiny delay in the decision round of negotiation leads to huge delay in the following rounds like the game of dominoes.

This research constructed an agent-based simulation model for the overall communication of the apparel supply chain partners. In this model, major supply chain members like a customer, a manufacturer and a supplier were represented by multi-agents. They interoperated with each other to complete basic simulated apparel supply chain processes from ordering to delivering and from inventory control to product schedule. The simulation model was provided which can support the construction of an effective communication standard for the agents interacting throughout a supply chain network based on Java platform. To show the collaboration of these agents, inventory change is illustrated within assumed days in the simulation. Through this model, different agents execute different tasks to achieve the purpose of integration and communication. The framework of this model can thus effectively handle information and data in supply chains.

Previous work has not given enough attention in simulating negotiation process. Neubert (2004) proposed a software agent to conduct an automated negotiation in the context of non-hierarchical production networks in order to assist the human decision-maker and accelerate the harmonization. The agent can perform an integrative negotiation about multiple interdependent properties of the supply contract, such as price, volume and delivery date (Neubert et al., 2004). However, his work developed only one agent to execute the negotiation work with the other side. It may be auxiliary to human decision-maker, but it can not achieve the coordination which is the most important thing in supply chains. This research proposed an agent-based negotiation model as a fundamental platform for the later optimized negotiation model. The model was developed based on ZEUS® which could provide an easy-to-use interface for the users. The agent-based negotiation simulation model integrated customer, merchandiser, manufacturer and supplier agents in the dynamic supply chain for the apparel industry. The demo model depicted the negotiation procedures of the multi-echelon supply chain from the downstream supplier to the upstream customer. Price, due date are considered as the negotiation issues and input parameters in this simulation model. How agents negotiate for human being in the apparel supply chain was demonstrated through this model.

8.3 Artificial algorithms embedded in negotiation strategy

Negotiation which is an inseparable part of the supply chain exists in several processes of the apparel supply chain. As negotiation can be considered as a difficult and time consuming process for trading parties to reach consensus rapidly and easily, it is quite necessary to enhance negotiation performance so as to enhance the efficiency of a supply chain. However, unlike other problems of supply chains, negotiation involves more human factor and it is not easy to imitate human behavior well with computer because of uncertainties and diversity.

8.3.1 Intelligent negotiation strategies for limited human capacity

In the apparel supply chain, there are usually two problems in negotiation process. The first is the time delay and waste as human beings have to wait until they have complete information. For example, when a merchandiser negotiates with a customer about the delivery date of a certain apparel product, he (she) will not respond to the customer at once unless he (she) knows clearly about the production capacity of the factory and current inventory. Probably the merchandiser will contact a product scheduler or search from files to enquire about the related situation. Any delay during this period decreases the whole supply chain efficiency. The second is incapability to make correct decisions because of huge amount of information and knowledge. When facing so many data and digits, people sometimes get dizzy and mistakes occur. For example, when a merchandiser receives several customer orders and negotiates with them at the same period, he (she) is probable to get confused on price and due-date. The third is decision making without considering cost and mutual benefit. When people negotiate, they will more focus on the profit of their own company while regardless of the total supply chain cost. The objectives and the goals of supply chain partners conflict and that is why negotiation gets difficult in a supply chain. Due to the above three problems, researches are trying to find suitable methods to solve the problems thus to enhance negotiation quality. Agent technology has been considered as an effective tool to be applied in human negotiation through agents ensures speed, consistency, freedom from human errors, and all-time availability (Murugesan, 2000). However, most researches have concentrated on building negotiation architecture or creating mathematical model of the negotiation process. How to improve negotiation strategies with agent technology receives little work.

Based on the above model, this research optimized the negotiation performance of a multi-echelon supply chain using the proposed simulation model with negotiation strategies which are supported by different methods like linear method, genetic algorithm (GA) method and simulated annealing (SA) method. The model was built based on the investigation of the major negotiation problems in the apparel supply chain. Specifically, genetic simulated annealing algorithm (GSAA) which is an advanced method which integrates the merits of both GA and SA is developed to better the negotiation strategy in this optimization negotiation model for agent-based apparel supply chain. The negotiation simulation model uses agents to represent the major supply chain members and enables them (eg. a customer and a merchandiser) to adopt the negotiation strategies assisted with different algorithms so as to understand how the various methods affect the negotiation performance. The simulation-based negotiation model optimizes the supply chain cost of the apparel company while maintaining the balance of production capacity of the factory and the required delivery date of the customer. In general, the model achieves a win-win situation for the negotiation partners.

8.3.2 Gap filling for previous research

Most researchers focused on the mechanism or paradigm of the negotiation model. Jiao et al. (2006) applied the multi-agent system paradigm to collaborative negotiation in a global manufacturing supply chain network. An agent-based multi-contract negotiation system was proposed for global manufacturing supply chain coordination, but it more concerns about the overall framework. Lin and Lin (2006) added the multi-agent negotiation mechanism to enhance the existing methods to solve the distributed constraint satisfaction problem in the coordination of order fulfillment process. Hsieh (2005) proposed a framework to model the negotiation processes in contract manufacturing, analyze the feasibility of the contracts and optimize contract awarding based on the proposed model. These researches gave theoretical descriptions of negotiation process; however, they did not pay much attention to the simulation of negotiation process. In Lau's work (2005), a negotiation-based algorithm was proposed for solving distributed project scheduling problem (DPSP). This algorithm raised the convergence and the solution quality; however the algorithm was aimed to solve the scheduling problem and the optimization of the algorithm can be improved. In previous research, artificial algorithms were seldom adopted in simulating negotiation performance, let alone the combination of SA and GA. In Chen and Kang's work (2007), a simple solution algorithm is presented to resolve the allocation of cost savings in the integration model. GA was usually used in the inventory control problem. Ding et al. (2004) proposed a GA-based multi-objective optimization method to determine the optimal supplier portfolio and inventory control parameters for joint decision-making on strategic souring and inventory replenishment. SA was more adopted in problems regarding scheduling or delivery lead time. (Li et al., 2008) ever presented SA-based heuristic algorithms to solve the parallel machine problem of synchronized scheduling of assembly and air transportation to achieve accurate delivery with minimized cost in electronics supply chain. However, till now, GSAA has not been employed in the field of supply chains especially in optimization of negotiation problem. While in this research, GA, SA and GSAA were explored and integrated with the negotiation models so that optimum result can be reached.

8.3.3 Novel negotiation model with algorithms

The simulation model enclosed a set of negotiation strategies with different algorithms (linear, GA, SA, GSAA) to choose. Specifically, in order to make comparison of these algorithms clear, we focus on the negotiation cycle between the manufacturer and the supplier in which tremendous information and data are involved. The supplier provides apparel raw material to the manufacture. As negotiation process is complicated in mathematical description, we select price, due date as two major negotiation issues in the optimization model as they are most representative and important. After required parameters are input through the interface, the model executes according to the selected negotiation strategy. These methods embedded in the simulation model were used to display the performance of different negotiation strategies. They were compared to demonstrate that GSAA is a better algorithm in considering mutual benefit of the negotiators.

Firstly, linear method was adopted as the most basic and the easiest method. The buyer agent sets a highest price he would be willing to pay for this item in the maximum price field. The seller agent creates a reserve price which is the lowest price he would be willing to accept for the apparel material or component. Through the linear strategy, the bidding price is adjusted step by step in a linear change trend till it is accepted by the seller. The negotiators compromise linearly and reach an agreement at last. However, the linear method just makes the negotiation run as two persons interact without considering supply chain cost and production capacity.

Secondly, GA and SA were applied as optimized algorithms in the negotiation strategy. They have their own benefits respectively in searching for an optimal result. SA and GA are two stochastic methods currently in wide use for difficult optimization problems. With SA one usually talks about *solutions*, their *costs*, and *neighbors* and *moves*; while with GA one talks about *individuals* (or *chromosomes*), their *fitness*, and *selection*, *crossover* and *mutation*.

In this research, a simulation-based optimization negotiation model was developed based on GA and SA. This model considers the interests of manufacturers and suppliers mainly in terms of production cost, price and delivery date. Two phases were proposed in this negotiation model. The first phase is the optimization of negotiation on delivery date implemented with SA. In this phase, mathematical functions of production cost of the manufacturer and the supplier were produced. The summary of the two production cost was used as the objective function in simulated annealing. The algorithm executes in order to minimize the total cost of these two agents. The model also generates a price region for the second phase negotiation through reservation price and aspiration price in SA.

Based on the previous phase, the optimization of negotiation on price was implemented with the utilization of GA. The payoffs of the two agents were used as the fitness function. The genetic algorithm was used to help the system search the negotiation space and present the best mutually beneficial agreement. All parties tried to maximize individual payoff through negotiation. Each negotiation offer was represented as a gene, so that GA could apply genetic operators such as mutation and crossover to create a population of offers and evolve those offers to find the most beneficial one(s).

The two-phase negotiation model adopted SA to have optimal due date and price which can be accepted by both parties and meanwhile obtain a win-win situation. However, GA and SA, though intelligent algorithms have their own defects. GSAA, a combination of GA and SA were developed to improve the searching method and have a better convergence of data so that the negotiation result can be more ideal.

Experiments using the simulation-based optimization model to validate the feasibility of optimization model were conducted. The experimental results indicated that the proposed simulation-based optimization model could reduce supply chain cost while balancing the production capacity significantly so that mutual benefit can be reached. Actual data from the industry was employed to validate the model. From the view of decision making, the performance of the agent-based negotiation system is more efficient and considerate than that of the industrial experience.

8.4 Principles

The principles can be described from the model structure, the negotiation issues and the negotiation strategies.

The multi-echelon apparel supply chain involves different partners from the upstream supplier to the downstream customer. Negotiation happens all along the supply chain and the negotiators in each loop play different roles. Thus, firstly, it is necessary to define which echelon the agent-based negotiation model will focus on and. Make a list of the agents who are concerned in the negotiation. For example, the multi-agents in the apparel supply chain can be defined as AG = {Ag $_{merchandiser}$, Ag $_{retailer}$, Ag $_{factory}$, Ag $_{component}$, Ag $_{supplier}$}. In this research, manufacturer agent and supplier agent are used as the major negotiators. Better design a clear conceptual structure to make sure about the purposes which are planned to be achieved with the execution of the negotiation model. In this research, cost and payoff or profit are considered as the factors of objectives.

$$Payoff_i^t(s) = \max\{\prod_{j=1\, j\neq i}^{n} \Pr ob_i(a_j) \times Payoff_i^{t+1}(s')\}, \qquad a_i \in A_i$$

$$Cost_i^t(s) = \min\{\prod_{j=1\, j\neq i}^{n} \Pr ob_i(a_j) \times Cost_i^{t+1}(s')\}, \qquad a_i \in A_i$$

However, more supply chain negotiators can be taken into consideration and in that situation the model structure and the negotiation mechanism will be more complicated. Relationship among negotiating agents and the responsibility of each agent involved should be clarified with UML diagrams and then further development can be made.

In apparel industry, negotiation issues needed to be considered are more than those in other industry due to the variety of apparel raw material and apparel products. Price, delivery date, quality, color, size and even the hand-feel of cloth are issues which negotiators should concern with. In this research, only price and due-date are considered as the negotiation issues. Price and due-date have impact on each other and affect the final result of negotiation. However, the more issues you absorb in the model, the more precise the result you will get. Thus, secondly, when developing the agent-based negotiation model, the negotiation issues should be refined beforehand and then those most concerned issues can be selected. The relation and impact among negotiation issues cannot be neglected and they should be reflected in the algorithm so that accurate result can be generated from the model.

Negotiation strategies are critical in model developing as they directly affect the outcome of the negotiation. Thus, finally, when developing the model, negotiation strategies should be carefully proposed with objectives, conditions and restrictions properly defined to simulate the negotiation process of agents.

Suitable algorithms also need to be selected to fit the requirement of optimization. This research embedded GA, SA and GSAA with the negotiation model due to their unique characteristics to get the optimum point. When using GA, fitness function, crossover and mutation functions need to be clarified. Supply chain cost is adopted as the fitness function so that the negotiation aims to reduce the total cost involved and increase the profit. Basically, the total cost should include the material cost, the raw material inventory cost, the operation cost and the production inventory cost (See previous function 7-2).

$$TC = \sum_{j}^{J} P_{jt}^{M} + \sum_{j}^{J} CI_{Mj} + \sum_{k=1}^{K} CO_k + \sum_{k=1}^{K-1} CI_{WIPk} + CI_P \longrightarrow \text{Fitness function}$$

$$\left.\begin{aligned} & CO_k(T_k) = \alpha_k \cdot e^{-\beta_k \cdot T_k}, T_k^{\min} \le T_k \le T_k^{\max} \\ & CI_{Mj} = h_{IMj} \cdot (R_k - DD_{j,t}^{M}), \forall (k = j) \\ & CI_{WIP} = h_{WIPk}(R_k - F_{k-1}) \\ & CI_{IP} = h_{IP}(R_D - F_k) \end{aligned}\right\} \text{Definition of each cost}$$

$$\left.\begin{aligned} & x_{oi} = \alpha_i x_i + (1-\alpha) y_i \\ & y_{oi} = \alpha y_i + (1-\alpha) x_i , \alpha \in (0,1) \end{aligned}\right\} \text{Crossover function}$$

$$y_k = \frac{(x_k - a_k)a_k + (b_k - x_k)b_k}{b_k - a_k}, x_k \in (a_k, b_k) \longrightarrow \text{Mutation function}$$

When adopting SA, the objective function and the move of temperature decreasing are important. The objective function can be regarded as the summation of the production cost of manufacturer and the supplier.

The initialized due date is defined as $x_i = pd_{k,0}$, The objective function $fx_i = ZM_{1,0} + ZS_{1,0}$, $t_0 = t_{\max}$

Each move is calculated as $\Delta f_{i,j} = f(x_i) - f(x_j), f(x_j) = ZM_{1,j} + ZS_{1,j}$,

Temperature is decreased in each move $t_{s+1} = d(t_s); s = s+1$; if the termination condition is satisfied: if $\Delta f_{i,j} \le 0,\ x_i = x_j$, else if $\exp(-\Delta f_{ij} / t_s) > random(0,1)$, $x_i = x_j$;

Agents of the two parties are informed of the final optimal due-date.

8.5 Practical Impacts

An important practical contribution in this study is the agent-based negotiation system of the apparel supply chain. Though agent technology has not been widely used in the apparel industry, the agent system can be a new trial for practical use. Industries can directly use this agent system to proceed with negotiation in between agents who represent supply chain partners instead of human negotiation so as to reduce mistakes caused by incomplete and wrong information among human communication. Using this agent-based negotiation system, decisions which are originally made by human beings are now considered to be executed by agents with negotiation strategies employed so that human operation can be eased and decision delay can be reduced.

The simulation model provides a helpful decision support system for the organizations so that time and energy can be saved for industrial people. As agents convey information and knowledge fluently and clearly, communication gets easy and convenient in the apparel supply chain.

In addition, multi-agents are capable of making optimal decisions with negotiation strategies. When facing large sum of data in the apparel industry, it will not be easy for human beings to make decisions, let alone optimal decisions. Therefore, with the negotiation model performed by agents, the industry can take the outcome of agent negotiation as a reference and then determine the final result.

8.6 Future Research

While the current research made significant contributions from both a theoretical and practical point of view, it also has some limitations, which are acknowledged below.

Firstly, the research proposed an overall agent-based apparel supply chain process and created it with simulation model based on JAVA platform so as to investigate how agents communicate in a supply chain and whether it is feasible to use multi-agents to represent human being. The simulation is built under the premium that the factory has enough capacity to load customer requirement.

However, in real apparel industry a lot of uncertainties exist and negotiations are always needed. When the selling peak comes, sometimes the customers will send orders at the same time. The amount will even surpass the production capability of the factory. Thus, further study can be made to perfect this model with considering uncertain customer needs or limited production capacity.

Secondly, the research developed a series of UML diagrams to depict the agent-based apparel supply chain processes. However, the research has provided the major diagrams which are normally used in modeling. If certain action in negotiation processes needs to be depicted more understandably, further UML diagrams like deployment diagram, activity diagram and collaboration diagrams can be made to identify the coordination of agents in the apparel supply chain processes (eg. the ordering and production scheduling process). In addition, the UML model semantics need to be explored to represent the knowledge exchange between supply chain members.

Thirdly, in the construction of the agent-based negotiation model, price and due-date are considered as the major negotiation issues. However in real apparel industry, negotiation is more complex and more issues like quantity, quality, color, style and etc. need to be concerned. However, considering all these factors will make the negotiation model rather complex and hard to execute. The point is that the nature of the negotiation issues should be differentiated. Due date and price are competitive issues for the bilateral negotiators, while quality, color and style are collaborative issues. That means negotiating parties will have conflicting opinions on delivery date and price, but they will have to settle an agreement or standard on quality, color and style. Thus, concerning with the coordinative issues, the negotiation strategies need to be adjusted accordingly to meet the needs of standard requirement. Or two negotiation strategies can be designed with one is for competitive issues and the other for collaborative issues.

In human negotiation, people pay much attention on price and due date as they are the most critical factors affecting supply chain cost, respective profit and customer satisfaction. Therefore, these two were selected to build the negotiation model in order to explore the affection of negotiation performance on supply chain management. Future research can be expanded the negotiation issues to quality so that comprehensive study would be made.

Fourthly, to make evaluation convenient the research made an assumption of one-manufacturer to one-supplier situation for the negotiation model without considering multi-suppliers to one-manufacturer. Actually a real apparel manufacturer has two or three suppliers of a certain kind of raw material (cotton, yarn, etc.) or apparel component (button, zip, etc.) so as to deal with large requirement that one supplier sometimes may not be able to manage. However, the one-to-one mode is fundamental because the negotiation at last occurs between two parties. Thus, the multi-to-one mode can be built based on one-to-one negotiation in future research as well. For example, a selecting process can be programmed and included in the model to get the final decision.

Fifthly, though artificial algorithms are applied in the negotiation strategies of this simulation model, human negotiation is difficult to imitate and evaluate due to the agility of human being and the uncertainty of supply chain environment. In order to realize intelligent negotiation, artificial algorithms are merged with the simulation model. As the negotiation strategies involve lots of formulae, parameters and data, the programming is easy to get wrong with any mistake occurred in the mathematical equations. So the functions of restrictions and conditions need to be considered and checked carefully to prevent going into the dead end or any unexpected outcome. For example, the manufacturer's expects of price and due date are contradictive to the supplier's. Thus, the related functions of the two parties should reflect the different trend. Both the manufacturer and the supplier have their reserved price which is the last acceptance of the price they would take. This is an important restriction in the negotiation programming, or the negotiation will not stop. When designing the respective model of the supplier and the manufacturer, the production capacity should not be neglected, or it will also lead the program result into an inaccurate situation.

Though negotiation strategies have been optimized with mathematical algorithms to minimize production cost, increase profit, satisfy customer needs on delivery date and balance production capacity, the optimization algorithms still need to be fine-tuned especially that GSAA is a newly developed algorithm in negotiation strategy. Besides, the mathematical models could be improved with more uncertainties considered such as season variety, order change, transport fault or currency exchange which may affect negotiation price and delivery date

The negotiation model in this research is aimed at achieving mutual benefit and win-win situation for the two negotiation parties. However, how to define a win-win situation is still a problem. As there are no public standards for a negotiation performance, the model evaluates the proposed different strategies from the aspect of production cost and profit. There will be a worthy-researching direction to develop metrics to evaluate whether the negotiation strategy is efficient or not so that decision makers can have helpful references about the value and feasibility of the negotiation strategy. With these standards, the quantitative evaluation result can be transferred to the fuzzy numbers for further calculation.

Finally, future research should pay more attention to the related implications of the results of negotiation performance. The digits and graphics should tell the decision makers what is the story about and how to improve in future.

And, the validation conducted in this research is proved by graphs and digits generated from the simulation model. We need to evaluate the negotiation performance from more real data of the apparel supply chain as quantitative data are preferable for accurate comparison. Nevertheless, it is quite difficult because not a single company, but companies in a supply chain should be integrated to get information for the evaluation. Most of them do not preserve the data of negotiation procedure in hand and are reluctant to put their information in public domains. In addition, there has not been a feasible method to evaluate agent behavior in a computer environment imitating human behavior.

Appendix A-Case Study on Apparel Companies

AA.1 Five categories of the apparel supply chain structures

1. Sport Obermeyer

Structure: traditional, customer order driven

Major characteristic: accurate response, risk-based production sequencing

In the fashion skiwear business, demand is heavily dependent on a variety of factors that are difficult to predict – weather, fashion trends, the economy and the peak of the retail selling season is only two months long. Sport Obermeyer is able to eliminate almost entirely the cost of producing skiwear by using accurate response which helps the company increase its profits by between 50% and 100% over 3 years.

To contend with lengthening supply chains, limited supplier capacity, and retailers' demands for early delivery, Sport Obermeyer undertook quick-response initiatives to shorten lead times. First, the company slashed the time it took to process orders and compute raw-material requirements by introducing computerized systems. Second, the company began to anticipate what materials it would require and pre-position them in a warehouse in the Far East. Third, the company turned to air freight to expedite delivery from the Far East to Denver distribution center. The delivery lead time was reduced, but the stock-out and markdown still exist.

The problem was rooted in Sport Obermeyer's inability to predict what people would buy and accurate response approach evolved as a result. Individual forecasts of the committee members were used to take the place of consensus forecast. Similar independent forecasts tend to be more accurate. The production-planning approach will be made according to the forecasts. Sport Obermeyer can base production decision on the signals it is receiving from the marketplace and on its more accurate forecasts. Sport Obermeyer adopted the strategy of risk-based production sequencing to allow the company to be as responsive to the market as possible in the areas where payoffs are the greatest. Order-entry systems are also changed to capture orders that can't be filled because of insufficient inventory.

Sport Obermeyer convenes a panel of experts to make independent forecasts and use the variance in their predictions to measure the accuracy of the forecasts.

2. Zara

Structure: vertical integrated

Major characteristic: fast fashion

The following three principles brought about the success of Zara.

• Close the communication loop. Zara's supply chain is organized to transfer both hard data and anecdotal information quickly and easily from shoppers to designers and production-staff. It's also set up to track materials and products in real time every step of the way, including inventory on display in the stores. The goal is to close the information loop between the end users and the upstream operations of design, procurement, production, and distribution as quickly and directly as possible.

• Stick to a rhythm across the entire chain. At Zara, rapid timing and synchronicity are paramount. To this end, the company indulges in approach that can best be characterized as "penny foolish, pound wise." It spends money on anything that helps to increase and enforce the speed and responsiveness of the chain as a whole.

• Leverage the capital assets to increase supply chain flexibility. Zara has made major capital investments in production and distribution facilities and uses annually, from which 10,000 are selected for production. Some of them resemble the latest couture creations. But Zara often beats the high-fashion houses to the market and offers almost the same products, made with less expensive fabric, at much lower prices. Since most garments come in five to six colors and five to seven sizes, Zara's system has to deal with something in the realm of 300,000 new stock-keeping units (SKUs), on average, every year.

This "fast fashion" system depends on a constant exchange of information throughout every part of Zara's supply chain-from customers to store managers, from store managers to market specialists and designers, from designers to production staff, from buyers to subcontractors, from warehouse managers to distributors, and so on. Most companies insert layers of bureaucracy that can bog down communication between departments.

But Zara's them to increase the supply chain's responsiveness to new and fluctuating demands. It produces complicated products in-house and outsources the simple ones.

3. Esquel

Structure: vertical integrated

Major characteristic: internal integration, customer-focused

Esquel produces high quality cotton woven and knit fabrics. The Extra Long Staple Cotton, grown at the Esquel's cotton farms, produces a high-count yarn that has a silken texture and is extremely fine and lightweight - making it the ideal fabric for garments of the highest quality. As part of its continuous effort to enhance product quality, Esquel has extended its cotton operations to include ginning and cotton seed breeding.

To provide customers with the finest possible yarn, Esquel has introduced ComforSpin technology at its spinning plants. This state-of-the-art technology has a number of advantages over conventional ring-spinning, improving yarn characteristics, process costs, and the properties of the end product. In essence, fabric woven from this yarn is much cleaner than fabric made with regular yarn.

Woven

With a capacity of 90 million yards a year, Esquel is China's largest manufacturer of cotton yarn dyed woven fabric. The newly expanded, state-of-the-art factory is located in Gaoming, China. It boasts best-of-class machinery from around the world and focuses on high end products. The company specializes in high yarn-counts with a focus on 80s and above in a wide range of fabrications such as Dobby, Pinpoint Oxford, Twill, Poplin. The variety of fabric finishes we offer includes standards, such as mercerization, brushing and peaching to highly popular proprietary finishes such as Silky Finish and UltemaTM.

Knit

Esquel produces 13,000 tons of cotton knit fabric annually, including piece dyed, yarn dyed and heather. With a focus on higher yarn-counts, we offer several fabrications including Jersey, Interlock, Pique, Lacoste, Rib, French Rib, Jacquard and Auto-stripe.

Our fabric finishes include standard and innovative proprietary qualities, such as UltemaTM and Salon Finish.

Esquel manufactures for the world's best known and highly respected brands, including Tommy Hilfiger, Hugo Boss, Brooks Brothers, Abercrombie & Fitch, Nike, Lands' End and Muji, and major retailers such as Marks & Spencer, Nordstrom and Jusco.
Esquel has garment-manufacturing facilities in mainland China, Hong Kong, Malaysia, Mauritius, Sri Lanka and Vietnam, and is renowned for the quality of its products and customer service.

Esquel's integration means that in addition to producing garments the Group owns plants that make accessories such as buttons, labels, and hand tags, and packaging materials including plastic and paper bags, stickers and carton boxes.
In addition to serving Esquel's internal needs, these plants produce accessories for our clients, meeting their exact quality demands.

4. TAL
Structure: manufacturer-lead
Major characteristic: synchronization and flexible manufacturing

TAL is the world leader in the production of innovative clothes and one of most outstanding apparel companies in HK. The company’s business model has evolved to an integrated synchronization services provider with capabilities for rapid design, flexible manufacturing, and collaborative planning, forecasting, and replenishment, including vendor managed inventory (VMI).

TAL is famous for its VMI system. Inventory on the customers’ side, either at the warehouse or in the store, is monitored directly by the company. With advanced VMI system, direct POS links to the customers and TAL’s sophisticated pack and ship-to-store systems, the company can deliver the products direct to the store before the customers know they need them.

TAL use continuous replenishment for the fabric and accessory procurement. Appropriate just-in-time material ensures the company to streamline the production process and continuously deliver the right products at the right time.

In TAL, the synchronization business model responds not just to its customers' demand but its customers' customers' demand as well. With CPFR (collaborative planning, forecast and replenishment), the company works closely with the customers to produce "replenishment model" based on seasonal variations, market trend and relevant sales data. Close collaboration with certain customers has allowed TAL to design products for them. On the supply side, TAL shares its own rolling, three month demand information with its largest fabric suppliers every two weeks. CPFR allows the company to see and synchronize with demand on the final consumer level. By adopting FRM (floor ready merchandise) system, all the TAL garments are packaged, tagged and priced before they leave the factory. In addition, TAL's cross-docking system eliminates the costly inventory and shortens the lead time from order to store. All products are packed to stores and barcoded at the factory.

TAL's synchronization services capabilities, including VMI, completely frees the customer from the burden of inventory management and maintenance. It also creates a tightly coupled, true partnership between supplier and customer via visibility into the demands of the customer's customers—the final consumer—through sharing of point-of-sales (POS) data. On the whole, TAL's successful synchronization of supply and demand results from a melding of discrete entities—TAL itself, its suppliers, and its customers—into a collaborative business model that responds holistically to demand.

5. Li & Fung

Structure: third-party coordinated, trading company
Major characteristic: dispersed manufacturing, global supplier network

For a company to be competitive, its supply chain must be flexible, agile, cost-effective and responsive. Nowadays it is more common for companies to collaborate in a global context where each of them focus on its core competency and outsource the rest. As a consequence their success becomes increasingly dependent on how well they can orchestrate the different aspects and how well they can manage the external parties involved along the supply chain. Equally important are companies' abilities to satisfy their customers' needs, shorten production lead time and lower cost.

Li & Fung has evolved from a sourcing agent to a global supply chain manager by being an innovator in the development of supply chain management. They have seven principles can be concluded as the pillar of Li & Fung's supply chain management. They are “Be customer-centric and market demand driven; Focus on one's core competency and outsource non-core activities, in order to develop a positioning in the supply chain; Develop a close, risk and profit-sharing relationship with business partners; Design, implement, evaluate and continuously improve the work flow, physical flow, information flow and cash flow in the supply chain; Adopt information technology to optimize the operation of the supply chain; Shorten production lead time and delivery cycles; and Lower costs in sourcing, warehousing and transportation.” The seven principles serve as a guideline for Li & Fung to resolve many complex decisions, e.g. which channels to use for customers and suppliers, whether to manage operations internally or outsource, and how to implement new technologies to optimize the supply chain etc. By mastering the supply chain, Li & Fung can provide better customer service and establish a long-lasting supplier relationship, which becomes an enduring competitive advantage over its competitors and leads to market share gains.

The globalization trend and its resulting competitive pressures will continue to underpin the development of supply chain management. As consumers and suppliers increasingly demand for quality and efficiency along the entire supply chain, Li & Fung's track record as a pioneer in global supply chain management certainly reaffirms the company as the partner of choice to those who are keen on expanding their businesses.

The above five apparel supply chains are representatives of five different structures. The leader and core decision maker in these apparel supply chains is different and takes different roles in the operation. However, we can still find the common points of these apparel supply chains: responsiveness, short lead time, quality assurance and low cost.

Appendix B-Agent Communication with ZEUS

AB.1 ZEUS introduction

The ZEUS tool-kit is a synthesis of established agent technologies with some novel solutions that provide an integrated environment for rapid software engineering of collaborative agent applications. In this research, ZEUS is used as the tool to build agent communication environment.

ZEUS combines two major emphases in agent development namely communication facilities and internal infrastructure. ZEUS comprises a set of components, which are running concurrently in separated threads. These components are Mailbox, Message Handler, Coordination Engine, Execution Monitor and the Planner and Scheduler. Facilitating the implementation of agents, ZEUS provides comprehensive graphical user interfaces including a multi-agent system project editor, an ontology editor, an agent editor and a task editor. The ZEUS Agent Generator produces Java source code that can be directly adapted by the developer. These tools decrease the effort of programming directly in Java source code and therefore speed up the development of the multi-agent systems.

AB.2 ZEUS agent platform architecture

An agent platform provides the infrastructure in which agents can be deployed, including operating systems, agent support software and multi-agent system managing components.

The ZEUS agent platform comprises two utility agents, the Agent Name Server (ANS) and the Directory Facilitator (DF). The ANSs maintains a registry of known agents, enabling them to map agent identities to a logical network location. The DF's responsibility is managing the system's yellow pages, which map the agents' abilities to the according agent names. These two utility agents can support a highly agile and robust shop floor control. Processing machines are equipped with a local machine control and a local intelligence the high-level control. So the machine and the belonging control units can be seen as an autonomous entity. Which machines, or of more interest, which tasks are currently available to the system are automatically managed by the ANS and the DF agents. ANS and DF agents query periodically all agents about their capabilities and update their registries. If a machine changes its possessed tasks due to system reconfigurations, these tasks are announced through the DF to the others. This allows soft degradation of the systems overall performance in cases of breakdowns, thus the system keeps running.

AB.3 Agent communication in ZEUS

Communication opens the door to collaborative behavior and is the basis of multi-agent systems. ZEUS agents are exchanging messages encoded in a simple ASCII character sequence. The message structure is defined by the FIPA-ACL (FIPA Organization, 2000). An issue of the FIPA-ACL is to provide a pattern of communicative acts and their meanings. The message content is embedded in the ACL structure. In conjunction with FIPA-ACL the 'semantic language' is recommended and used by ZEUS to encode the message content (FIPA Organization, 2000). But the semantic language (SL) itself cannot convey information among agents. Concepts of shared ontology equip SL statements with meaning. Obeying standards is a precondition to become agents accepted by manufacturing companies. A major issue of FIPA is concerning interoperability of different agent systems and offering a paradigm for a proved multi agent system.

The ZEUS tool-kit was motivated by the need to provide a generic, customizable, and scalable industrial strength collaborative agent building tool-kit. The tool-kit itself is a package of classes implemented in the Java programming language, allowing it to run on a variety of hardware platforms. Java is an ideal language for developing multi-agent applications because it is object-oriented and multi-threaded, and each agent consists of many objects and several threads. Java also has the advantage of being portable across operating systems, as well as providing a rich set of class libraries that include excellent network communications facilities.

a) The agent component library

The agent component library is a package of Java classes that form the 'building blocks' of individual agents. Together these classes implement the 'agent-level' functionality required for a collaborative agent. Thus for communication the tool-kit provides:

- a performative-based inter-agent communication language,
- knowledge representation and storage using ontologies,
- an asynchronous socket-based message-passing system.

In order to maximize future compatibility, the components of the ZEUS tool-kit utilize 'standardized' technology whenever possible; for instance, communication takes place through TCP/IP sockets using a language based on the Knowledge Query Management Language (KQML) (Finin and Labrou, 1997). In this spirit, it is planned that the Agent Communication

Language that has recently been specified by the Foundation for Intelligent Physical Agents (FIPA) (O'Brien and Nicol, 1998) be adopted.

Logically, each ZEUS agent is composed of three layers— a definition layer, an organizational layer and a coordination layer. The definition layer comprises the agent's reasoning abilities, its goals, resources, skills, beliefs, preferences, etc. The organization layer describes the agent's relationships with other agents, e.g. the agencies to which it belongs, what abilities it believes other agents possess, and what authority relationships exist between it and these other agents. At the co-ordination layer each agent is modeled as a social entity, i.e. in terms of the coordination and negotiation techniques it possesses. Built on top of the co-ordination layer are the protocols that implement inter-agent communication, while beneath the definition layer is the API that enables the agent to be linked to the external programs that provide it with resources and/ or implement its skills. Figure 2 shows how this logical agent model is realized using the classes of the ZEUS agent component library. The generic agent of Fig 2 includes the following components.

- Mailbox

This handles communications between the agent and other external agents. It is a complex entity consisting of several other threads such as the server, which accepts and stores incoming messages.

- Message handler

This processes incoming messages from the mailbox, dispatching them to other components within the agent.

- Co-ordination engine

This makes decisions concerning the agent's goals, e.g. how they should be pursued, or when to abandon them. It is also responsible for co-ordinating the agent's overall activities with other agents using its known coordination strategies. This not only enables tasks to be contracted and delegated, but also ensures that agents jointly working towards a shared goal all behave in a coherent manner.

- Acquaintance model

This describes the agent's relationships with other agents in the society, and its beliefs about the capabilities of those agents.

- Planner and scheduler

This plans the agent's tasks based on decisions taken by the co-ordination engine and the resources and task definitions available to the agent.

- Resource database

This maintains a list of resources that are owned and available to the agent.

- Ontology database

This stores the logical definition of each fact type — its legal attributes, the range of legal values for each attribute, any constraints between attribute values, and any relationships between the attributes of the fact and other facts. Agents must use the same ontological information if they are to understand each other.

- Task/plan database

This provides logical descriptions of planning operators (or tasks) known to the agent. It also stores a set of scripts that the agent uses to behave reactively to

- Execution monitor

This starts, stops and monitors external systems that have been scheduled for execution or termination by the planner and scheduler. It also informs the coordination engine of successful and exceptional terminating conditions of the tasks it is monitoring.

Communication is facilitated by the mailbox and the ontology database; the former provides agents with the ability to transmit messages in a universally recognized format, while the latter enables each agent to understand what its correspondent is communicating.

b) Network communication protocol

Communication is accomplished via point-to-point TCP/IP sockets, which is constituted by using a least common denominator for message transportation.

c) Agent interaction protocols

An agent interaction protocol (AIP) describes a communication pattern as an allowed sequence of messages between agents and the constraints on the content of those messages (Bauer, 1999). ZEUS agents can be equipped by default with ContractNet protocol and iterated ContractNet protocol, which is a widely-used protocol. Unfortunately other interaction protocols like the FIPA-request protocol or the FIPA-query protocol (FIPA Organization, 2000) are not supported yet.

Bibliography

ABERNATHY, F. H., DUNLOP, J. T., HAMMOND, J. H. & WEIL, D. (2000) Retailing and supply chains in the information age. *Technology in Society,* 22**,** 5-31.

ABERNATHY, F. H., DUNLOP, J. T., HAMMOND, J. H. & WEIL, D. (2004), Globalization in the apparel and textile industries: what is new and what is not? in Martin, K. and Richard, F.L. (Eds), *Locating global advantage: industry dynamics in the international economy*, Stanford University Press, Stanford, CA.

ACHABAL, D. D., MCINTYRE, S. H., SMITH, S. A. & KALYANAM, K. (2000) A decision support system for Vendor Managed Inventory. *Journal of Retailing,* 76**,** 430-454.

AGRAWAL, N., SMITH, S. A. & TSAY, A. A. (2002) Multi-vendor sourcing in a retail supply chain. *Production and Operations Management,* 11**,** 157-182.

ALLWOOD, J. M. & LEE, J. H. (2005) The design of an agent for modelling supply chain network dynamics. *International Journal of Production Research,* 43**,** 4875-4898.

Amundson, S.D. (1998), ''Relationships between theory-driven empirical research in operations management and other disciplines'', Journal of Operations Management, Vol. 16, pp. 341-59.

Aron, L.J., (1998), From push to pull: the supply chain management shift, Apparel Industry Magazine 59(6), 58-59.

Au, K. F. and Ho, D.C.K. (2002), "Electronic commerce and supply chain management: value-adding service for clothing manufacturers", Integrated Manufacturing Systems, Vol.13 No.14, pp.247-254.

Azadivar, F. and Tompkins, G., (1999), Simulation optimization with qualitative variables and structural model changes: AGenetic Algorithm approach, European Journal of Operational Research 113, 169-182.

AZEVEDO, A. L. & SOUSA, J. P. (2000) Order planning for networked make-to-order enterprises - a case study. *Journal of the Operational Research Society,* 51**,** 1116-1127.

BABAIOFF, M. & WALSH, W. E. (2005) Incentive-compatible, budget-balanced, yet highly efficient auctions for supply chain formation. *Decision Support Systems,* 39**,** 123-149.

Bagchi, S.J., Ettl, M. and Lin, G.Y., (1998), Experience using the IBM supply chain simulator, Proceedings of the 1998 Winter Simulation Conference, Washington, D.C.,1387-1397.

Banks, J., Carson, J.S., Nelson, B.L. and Nicol, D.M., (2001), Discrete-Event System Simulation, 3rd Eds., Prentice Hall, Upper Saddle River, NJ.

Bauer, B. (1999) FIPA TCC Agent Communication – Extending UML for the Specification for the Agent Interaction Protocols, FIPA/OMG.

Bazzan, A. and Bordini, R. (2000) Wayward Agents in a Commuting Scenario (personalities in the Minority Game). In Proceedings of the 4th International Conference on MulitAgent Systems, pages 55-62, Boston, MA.

Bendiksen B. I., Dreyer B.(2003), Technological changes – – the impact on the raw material flow and production, European Journal of Operational Research, 144 (2003) pp.237 – 246.

Bertrand, J. W. M. and Fransoo, J. C., (2002). MODELLING AND SIMULATION Operations management research methodologies using quantitative modeling. Operations and Production Management Research. 22 (2), pp. 241-264.

Bheda, R., Narag, A. S. And Singla, M.L. (2003), "Apparel manufacturing: a strategy for productivity improvement", Journal of Fashion Marketing and Management, Vol. 7 No.1, pp. 12-22.

Binmore, K., (1992), Fun and games. A text on game theory. Lexington, MA: D.C. Heath and Company; 1992.

Binmore, K and Dasgupta P. (1987), The economics of bargaining. London: Basil, Blackwell.

Birtwistle, G., Siddiqui, N. and Fiorito, S.S. (2003), "Quick response: perceptions of UK fashion retailers", International Journal of Retail & Distribution Management, Vol. 31 No.2, pp.118-128.

Biswas, S. and Narahari, Y., 2004, Object oriented modeling and decision support for supply chain, European Journal of Operational Research 153, 704-726.

Bouthillier F. and Shearer K., (2002) Understanding knowledge management and information management: the need for an empirical perspective, Information Research, 8(1).

Brooks, R. and Robinson, S., (2001), Simulation, Palgrave, Basingstoke.

Bruce, H. (1997), "Demand chain management-the future paradigm for the 21st century", 1997 Conference Proceedings, American Production and Control Society.

CAVALIERI, S., CESAROTTI, V. & INTRONA, V. (2003) A multiagent model for coordinated distribution chain planning. *Journal of Organizational Computing and Electronic Commerce,* 13**,** 267-287.

CAKRAVASTIA, A. & NAKAMURA, N. (2002) Model for negotiating the price and due date for a single order with multiple suppliers in a make-to-order environment. International Journal of Production Research, 40, 3425-3440.

CAKRAVASTIA, A. & TAKAHASHI, K. (2004) Integrated model for supplier selection and negotiation in a make-to-order environment. International Journal of Production Research, 42, 4457-4474.

CALOSSO, T. & CANTAMESSA, M. (2003) Evaluating a negotiation-production system through Markov chains. Production Planning & Control, 14, 578-584.

CALOSSO, T., CANTAMESSA, M. & GUALANO, M. (2004) Negotiation support for Make-To-Order operations in business-to-business electronic commerce. Robotics and Computer-Integrated Manufacturing, 20, 405-416.

Carabelea, C. (2002) Adaptive agents in argumentation-based negotiation. In Marik, editor, Conference MASA 2001, Lecture Notes in Artificial Intelligence 2322, 180-187. Springer.

Chan, F.T.S., Humphreys, P. and Lu, T.H., (2001), Order release mechanisms in supply chain management: a simulation approach, International Journal of Physical Distribution and Logistics Management 31, 124-133.

Chan, F.T.S. and Chan, H.K., (2005), Simulation modeling for comparative evaluation of supply chain management strategies, International Journal of Advanced Manufacturing Technology 25, 998-1006.

Chandra C. and Kumar, S. (2000), An application of a system analysis methodology to manage logistics in a textile supply chain, Supply Chain Management: An International Journal, Vol.5 No 5, pp.234-244.

CHANDRA, C. & KUMAR, S. (2001) Enterprise architectural framework for supply-chain integration. *Industrial Management & Data Systems,* 101(6)**,** 290-303.

Chavez, A. and Maes, P. (1996), Kasbah, An Agent Marketplace for Buying and Selling Goods, *Proceedings of the First International Conference on the Practical Application of Intelligent Agents and Multi-Agent Technology*.

Chen M.C., Huang C.L., Chen K.Y. and Wu H.P.(2005) Aggregation of orders in distribution centers using data mining, Expert Systems with Applications 28 (2005) pp. 453–460

CHEN, L. H. & KANG, F. S. (2007) Integrated vendor-buyer cooperative inventory models with variant permissible delay in payments. *European Journal of Operational Research,* 183**,** 658-673.

CHENG, T. C. E. (1989) A Heuristic for Common Due-Date Assignment and Job Scheduling on Parallel Machines. Journal of the Operational Research Society, 40, 1129-1135.

CHENG, T. C. E. & CHEN, Z. L. (1994) Parallel-Machine Scheduling Problems with Earliness and Tardiness Penalties. Journal of the Operational Research Society, 45, 685-695.

CHENG, T. C. E. & GUPTA, M. C. (1989) Survey of Scheduling Research Involving Due Date Determination Decisions. European Journal of Operational Research, 38, 156-166.

CHIU, H. N. & HUANG, H. L. (2003) A multi-echelon integrated JIT inventory model using the time buffer and emergency borrowing policies to deal with random delivery lead times. *International Journal of Production Research,* 41**,** 2911-2931.

Christopher, M., (1992), Logistics and Supply Chain Management, Pitman Publishng, London.

Connor, D., An, C., Buckley, S., Feigin, G., Levas, A., Nayak, N., Petrakian, R., Srinivasan, R. and Jayraman, R., (1995), Dynamic modeling for re-engineering supply chains, IBM research Division.

Cooper, M.C. and Ellram, L.M., (1993), Characteristics of supply chain management and the implications for purchasing and logistics strategy, International Journal of Logistics Management 4(2), 13-24.

Cooper, M.C. and Lambert, D.M., (1997), Supply chain management: more than a new name for logistics, International Journal of Logistics Management 8(1), 1-12.

Croom, S., Romano, P. and Giannakis, M., (2000), Supply chain management: an analytical framework for critical literature review, European Journal of Purchasing and Supply Management 6(1), 67-83.

Davis, L., (1991), Handbook of Genetic Algorithms Eds., Van Nostrand Reinhold, New York.

Davenport, T. H., Prusak, L., (1997) Information Ecology : Mastering the Information and Knowledge Environment, Oxford University Press.

DAVIS, R. & SMITH, R. G. (1983) Negotiation as a Metaphor for Distributed Problem-Solving. Artificial Intelligence, 20, 63-109.

Dengiz, B., Sen, F. and Bulgak, A., (1997), Optimization of stochastic systems using genetic algorithms, Transactions on Operational Research 9, 43-62.

Deschner, D., Lang, F.and Bodendorf, F. (2002) Strategies for software agent based multiple issue negotiations. Lecture Notes in Computer Science 2115, 206-216. Springer.

Dickerson, K. G. (1999) Textiles and Apparel in the Global Economy, 3nd Ed. Englewood Cliffs, New Jersey: Prentice-Hall

Dickerson, K.G., (2003), Inside the Fashion Business, 7th Ed., Pentice Hall, Upper Saddle River, NJ.

Disney, S.M., Naim, M.M. and Towill, D.R., (2000), Genetic algorithm optimization of a class of inventory control systems, International Journal of Production Economics 68, 259-278.

Ding, H.W., Benyoucef, L. and Xie, X.L., (2004), A multi-objective optimization method for strategic sourcing and inventory replenishment, Proceedings of the IEEE International Conference on Robotics & Automation, New Orleans, LA, 2711-2716.

Drucker, P. (2001), Management Challenges for the 21st Century, New York: Harper Business Press..

Fallah-Seghrouchni A.E. and Suna A. (2004), CLAIM: A Computational Language for Autonomous, Intelligent and Mobile Agents, LNAI, Vol. 3067.

EASTON, F. F. & MOODIE, D. R. (1999) Pricing and lead time decisions for make-to-order firms with contingent orders. European Journal of Operational Research, 116, 305-318.

Forza, C. and Vinelli, A. (1997), Quick Response in the textile-apparel industry and the support of information technologies, Integrated Manufacturing Systems, 8(3), pp.125-136.

FARATIN, P., SIERRA, C. & JENNINGS, N. R. (1998) Negotiation decision functions for autonomous agents. Robotics and Autonomous Systems, 24, 159-182.

FARATIN, P., KLEIN, M., SAYAMA, H. & BAR-YAM, Y. (2002a) Simple negotiating agents in complex games: Emergent equilibria and dominance of strategies. Intelligent Agents Viii: Agent Theories, Architectures, and Languages, 2333, 367-376.

FARATIN, P., SIERRA, C. & JENNINGS, N. R. (2002b) Using similarity criteria to make issue trade-offs in automated negotiations. Artificial Intelligence, 142, 205-237.

FIPA '97 Specification. (1998). *Agent Communication Language*. [Online]. Available: http://www.fipa.org/specs/fipa00019/OC00019.pdf

Finin, T., Fritzson, R., McKay, D. and McEntire, R. (1994) "KQML as an Agent Communication Language," in *The Proceedings of the Third International Conference on Information and Knowledge Management*, pp. 456-463.

Finin, T. and Labrou, Y., (1997). KQML as an agent communication language, in Bradshaw J M (Ed): 'Software agents', MIT Press, Cambridge, Mass, pp 291—316.

Fox, M.S., Barbuceanu, M. and Teigen, R. (2000) Agent-Oriented Supply Chain Management, *The International Journal of Flexible Manufacturing Systems*, vol. 12, no. 2000, pp. 165-188.

Fredendall L. and Hill E. (2001), Basics of Supply Chain Management, USA: St. Lucie Press, pp. 215.

FREDERIX, F. (2001) An extended enterprise planning methodology for the discrete manufacturing industry. *European Journal of Operational Research,* 129**,** 317-325.

Fung R.Y.K and Chen T. (2005) A multiagent supply chain planning and coordination architecture, *International Journal of Advanced Manufacturing Technology*, 25(7-8), pp. 811–819.

Gorce, M.A., (1999), Optimal Production and Inventory Control to Meet Peak Season Demand, Department of Industrial Engineering, North Carolina State University.

Goldberg, D.E., (1989), Genetic algorithms in search, optimization, and machine learning, Addison-Wesley, Reading, Mass.

Govil, M. and Proth, J.M. (2002), Supply Chain Design and Management Strategic and Tactical Perspectives, California, U.S.A: Academic Press.

Guttman, R., Moukas, A. and Maes, P., (1998), Agent-mediated Electronic Commerce: A Survey, Knowledge Engineering Review.

Guttman, R.H. and Maes, P., (1998), Agent-mediated Integrative Negotiation for Retail Electronic Commerce, Proceedings of the Workshop on Agent Mediated Electronic Trading (AMET'98).

Hammond, J.H., (1992), Coordination as the basis for Quick Response: a case for "Virtual" integration in supply networks, Harvard Business School Working Paper.

Hammond, J.H., (1993), Quick Response in Retail Manufacturing Channels, In: Globalization, Technology, and Competition: the Fusion of Computers and Telecommunications in the 1990s, Boston, Mass, Harvard Business School Press.

Hayzelden A. L. G. and Bigham J. (1999) Agent Technology in Communications Systems: An Overview, Knowledge Engineering Review, 14(4), pp. 341-375.

Hendler J. (1999). Is There an Intelligent Agent in Your Future?, *Nature* [Online].Available: http://www.nature.com/nature/webmatters/agents/agents.html.

He,M. and Leung, H., (2002), Agents in e-commerce: state of the art, *Knowledge and Information Systems*, Vol. 4, No. 3, pp. 257-282 .

Heita, S., (1998), Supply chain simulation with LOGSIM-simulator, Proceedings of the 1998 Winter Simulation Conference, Washington, D.C., 323-326.

Hewitt, W.C., Hunter, N.A. and King, R.E., (1991), Analysis of the benefits of quick response implementation for the domestic retail, Apparel and Textile Industries.

Holland, J.H., (1975), Adaptation in Nature and Artificial Systems, University of Michigan Press, Michigan.

Houlihan, J., (1985), International supply chain management, International Journal of Physical Distribution and Logistics Management 15 (1), 22-38.

HSIEH, F. S. (2005) Automated negotiation based on contract net and Petri net. *E-Commerce and Web Technologies, Proceedings,* 3590**,** 148-157.

Huang, P. and Sycara, K. (2002) A Computational Model For Online Agent Negotiation. In Proceedings of the 35th Hawaii International Conference on System Sciences.

Huget M.P. (2004) An Application of Agent UML to Supply Chain Management. ULCS–02-015, University of Liverpool.

Huhns M.N. and Singh M.P. (1998) *Readings in Agents*, Scotland: Morgan Kaufmann Publishers, pp. 36-45.

Hung, W.Y., Kucherenko, S. and Samsatli, N.H., 2004, A flexible and genetic approach to dynamic modeling of supply chains, Journal of Operational Research Society 55, 801-813.

HUNTER, N. A., KING, R. E. & NUTTLE, H. L. W. (1992) An Apparel-Supply System for Qr Retailing. Journal of the Textile Institute, 83, 462-471.

Hunter, N.A., King, R.E., Nuttle, H.L.W. and Wilson, J.R., (1993), North Carolina apparel pipeline modeling project, International Journal of Clothing Science and Technology 5, 19-24.

HUNTER, N. A., KING, R. E. & NUTTLE, H. L. W. (1996) Evaluation of traditional and quick-response retailing procedures by using a stochastic simulation model. *Journal of the Textile Institute,* 87**,** 42-55.

Ingalls, R.G. and Kasales, S., 1999, CSSAT: the Compaq supply chain analysis, Proceedings of the 1999 Winter Simulation Conference, Phoenix, AZ, 1201-1206.

James, J., Odell, H., Parunak V.D. and Bauer B.(2000) Extending UML for Agents. Proceedings of the Agent-Oriented Information Systems Workshop at the 17th National conference on Artificial Intelligence, pp.1-15.

James, J., Odell, H., Parunak V.D. and Bauer B.(2001) Bauer Bernhard. Representing Agent Interaction Protocols in UML. First international workshop AOSE 2000 on Agent-oriented software engineering, pp. 121-140.

JAYARAMAN, V. & ROSS, A. (2003) A simulated annealing methodology to distribution network design and management. *European Journal of Operational Research,* 144**,** 629-645.

JIAO, J. X., YOU, X. & KUMAR, A. (2006) An agent-based framework for collaborative negotiation in the global manufacturing supply chain network. *Robotics and Computer-Integrated Manufacturing,* 22**,** 239-255.

Joines, J. A., Gupta, D., Gokee, M. A., King, R. E. & Kay, M. G. (2002) Supply chain multi-objective simulation optimization, Proceedings of the 2002 Winter Simulation

Conference Yilcesan, E., Chen, C-H., Snowdon, J. L. & Charnes, J. M. Ed. pp.1306-1314

Jones, T.C. and Riley, D.W., (1985), Using inventory for competitive advantage through supply chain management, International Journal of Physics Distribution and Logistics Management 15(5), 16-26.

Jones, R.M. (2002), the Apparel Industry, Blackwell Science, Oxford.

KINCADE, D. H., CASSILL, N. & WILLIAMSON, N. (1993) The Quick Response Management-System - Structure and Components for the Apparel Industry. *Journal of the Textile Institute,* 84**,** 147-155.

King, R.E. and Hunter, N.A., 1996, Demand re-estimation and inventory replenishment of basic apparel in a specialty retail chain, Journal of the Textile Institute 87(2(1)), 31-41.

Kirkpatrick, Gelatt, and Vecchi, (1983), Optimization by Simulated Annealing, *Science*, Vol.220, No. 4598, pp. 671-680.

Klir, G.J. and Folger, T.A., (1988)， Fuzzy Sets, Uncertainty, and Information, Prentice Hall, Englewood Cliffs, NJ.

Krishna, V., (2002) Auction Theory. San Diego: Academic Press.

Kohonen, J., (1999), A brief comparison of simulated annealing and genetic algorithm approaches, [Cited from] http://www.cs.helsinki.fi/u/kohonen/papers/gasa.html

Koks, T. and Nordqvist, A.R., (2003), Using discrete event simulation to analyze product utilization, International Conference on Mechatronics, Loughborough University, 117-122.

Kumar, R., (2005), Research methodology, 2nd Eds., Sage Publications, London

KO, E. & KINCADE, D. H. (2000) The value of strategic-type classification for identifying the usage of new technologies. *Journal of the Textile Institute,* 91**,** 1-9.

Lambert, D.M., (2008), Supply Chain Management: Processes, Partnerships, Performance, 3rd edition.

LAU, J. S. K., HUANG, G. Q., MAK, K. L. & LIANG, L. (2005) Distributed project scheduling with information sharing in supply chains: part I - an agent-based negotiation model. *International Journal of Production Research,* 43**,** 4813-4838.

LI, K., SIVAKUMAR, A. Y. & GANESAN, V. K. (2008) Complexities and algorithms for synchronized scheduling of parallel machine assembly and air transportation in consumer electronics supply chain. *European Journal of Operational Research,* 187**,** 442-455.

Lee, H. L. and Ng, S. M. (1997), "Introduction to the special issue on global supply chain management", *Production and Operations Management,* Vol. 6 No. 3, pp.191-192.

Lee, Y. and Kincade, D.H. (2003), "US apparel manufacturers' company characteristic differences based on SCM activities", Journal of Fashion Marketing and Management, Vol. 7 No.1, pp. 31-48.

Lee, Y., (2000), Study of Relationships between Apparel Manufacturer's Supply Chain Management, Company Characteristics, and Inventory Performance, Virginia Polytechnic Institute and State University.

Lee, Y.H. and Kim, S.H., (2000), Optimal production-distribution planning in supply chain management using hybrid simulation-analytic approach, Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, 1252-1259.

LIN, F. R. & LIN, Y. Y. (2006) Integrating multi-agent negotiation to resolve constraints in fulfilling supply chain orders. *Electronic Commerce Research and Applications,* 5**,** 313-322.

LIN, F. R., SUNG, Y. W. & LO, Y. P. (2005) Effects of trust mechanisms on supply-chain performance: A multi-agent simulation study. *International Journal of Electronic Commerce,* 9**,** 91-112.

LING, L. Y., LIANG, L. & PU, X. J. (2006) ATC based coordination of distributed production planning and supplier selection. Applied Mathematics and Computation, 182, 1154-1168.

Liu S. and Wang H.(2003)"Agent Architecture for Agent-based Supply Chain Integration & Coordination," *ACM SIGSOFT Software Engineering Notes*, 28(4), pp.5-5.

Lowson, B., King, R.E. and Hunter, N.A., 1999, Quick Response: Managing the Supply Chain to Meet Consumer Demand, John Wiley & Sons, New York.

Lummus, R.R. and Vokurka, R.J. (1999), "Defining supply chain management: a historical perspective and practical guidelines", Industrial Management & Data System, Vol.99 No.1, pp.11-17.

Magretta, J. (1998), "Fast, Global, and Entrepreneurial: Supply Chain Management, Hong Kong Style: A Interview with Victor Fung", Harvard business Review, September-October, pp.103-114.

Melnyk, S.A. and Handfield, R.B. (1998a), ''Preface: may you live in interesting times . . . the emergence of theory-driven empirical research'', Journal of Operations Management, Vol. 16, pp. 311-19.

Meredith, J.R., Raturi, A., Amoako-Gyampah, K. and Kaplan, B. (1989), ''Alternative research paradigms in operations'', Journal of Operations Management, Vol. 8, pp. 297-326.

Michalewicz, Z., 1996, Genetic algorithms + Data structures = Evolution Programs, 3rd Eds., Springer-Verlag, New York.

Morris, P. (1994) Introduction to Game Theory. Springer, New York.

Murugesan, S., (2000), Negotiation by software agents in electronic marketplace, *Proceedings of 2000 Technology, Educating, & Networking Conference*,2, pp. 286-290.

Naso, D. and Turchiano, B. (2004) "A coordination strategy for distributed multi-agent manufacturing systems", *International Journal of Production Research*, Vol. 42, n. 12, pp.2497-2520.

NEUBERT, R., GORLITZ, O. & TEICH, T. (2004) Automated negotiations of supply contracts for flexible production networks. *International Journal of Production Economics,* 89**,** 175-187.

NUTTLE Newman, B., (2002) The knowledge management forum. URL: http://www.km-forum.org/htm.

Nuttle, H.L.W., King, R.E. and Hunter, N.A., (1991), A stochastic model of the apparel retailing process for seasonal apparel, Journal of the Textile Institute 82, 247-259.

NUTTLE, H. L. W., KING, R. E., FANG, S. C., WILSON, J. R. & HUNTER, N. A. (2000a) Simulation Modeling of the textile supply chain - Part II: Results and research directions. *Journal of the Textile Institute,* 91**,** 51-64.

NUTTLE, H. L. W., KING, R. E. & HUNTER, N. A. (1991) A Stochastic-Model of the Apparel-Retailing Process for Seasonal Apparel. *Journal of the Textile Institute,* 82**,** 247-259.

NUTTLE, H. L. W., KING, R. E., HUNTER, N. A., WILSON, J. R. & FANG, S. C. (2000b) Simulation Modeling of the textile supply chain - Part 1: The textile-plant models. *Journal of the Textile Institute,* 91**,** 35-50.

OUYANGA, Y. F. & DAGANZO, C. (2006) Counteracting the bullwhip effect with decentralized negotiations and advance demand information. *Physica a-Statistical Mechanics and Its Applications,* 363**,** 14-23.

O'Leary, D.E. Enterprise knowledge management. IEEE Comput 1998;March.

O'Brien, P.D. and Nicol, R.C. (1998). 'FIPA — towards a standard for intelligent agents', BT Technol J, 16, No 3, pp 51—59 .

Oliver, R.K. and Webber, M.D., (1982), Supply Chain Management: Logistics Catches Upwith Strategy, In : Logistics: The strategic Issues, London, Chapman and Hall, 63-75.

PANWALKAR, S. S., SMITH, M. L. & SEIDMANN, A. (1982) Common Due Date Assignment to Minimize Total Penalty for the One Machine Scheduling Problem. Operations Research, 30, 391-399.

PARK, G. A. & HARLOCK, S. C. (2003) The analysis of the apparel supply chain systems with specific reference to the Korean apparel organisations of the overseas and domestic brand products. *Fibers and Polymers,* 4**,** 38-47.

Parunak, H. Van Dyke, ed.(1996) Visualizing Agent Conversations: Using Enhanced Dooley Graphs for Agent Design and Analysis.

Payne T.R., Paolucci M. and Sycara K.(2002). Communicating Agents in Open Multi Agent Systems. *First GSFC/JPL Workshop on Radical Agent Concepts (WRAC)*[Online].Available: http://www.ecs.soton.ac.uk/~trp/Publications.html.

PECHOUCEK, M., VOKRINEK, J., HODIK, J., BECVAR, P. & POSPISIL, J. (2004) ExPlanTech: Multi-agent framework for production planning, simulation and supply chain management. *Multiagent System Technologies, Proceedings,* 3187**,** 287-300.

Pegden, C.D., Shannon, R.E. and Sadowski, R.P., (1995), Introduction to Simulation Using Siman, 2nd Eds., McGraw-Hill, New York.

Perry, M., Sohal, A.S. and Rumpf, P. (1999), "Quick Response supply chain alliances in the Australian textiles, clothing and footwear industry", International Journal of Production Economics,Vol.62, pp.119-132.

Persson, F. and Olhager, J., (2002), Performance simulation of supply chain designs, International Journal of Production Economics 77, 231-245.

Petrovic, D., Roy, R. and Retrovic, R., (1998), Modelling and simulation of a supply chain in an uncertain environment, European Journal of Operation Research 109, 299-309.

Petrovic, D., (2001), Simulation of supply chain behavior and performance in the uncertain environment, International Journal of Production Economics 71, 429-438.

Pidd, M., (1998), Computer Simulation in Management Science, 4th Eds. Wiley, Chichester.

Pruitt, D.G., (1981), Negotiation Behavior, Academic Press, New York.

Romp, G. (1997) Game Theory - Introduction and Applications. Oxford University Press, Oxford.

Raman, A. and Kim, B. (2002), Quantifying the impact of inventory holding cost and reactive capacity on an apparel manufacturer's profitability, Production and Operation Management 11(3), 358-373.

Reilly,D.(1999).Agent Communication.[Online]. Available:http://www.webdevelopersjournal.com/articles/agent_communication.html.

Romano, P. and Vinelli, A. (2001), "Quality management in a supply chain perspective: strategic and operative choices in a textile-apparel network", *International Journal of Operations & Production Management,* Vol. 21 No. 4, pp. 446-460.

Rollins, R.P., Porter, K. and Little, D., (2003), Modelling the changing apparel supply chain, International Journal of Clothing Science and Technology 15(2), 140-156.

Shaprio, J.F., (2001), Modeling the Supply Chain, Duxbury/Thomson Learning, Pacific Grove, Calif.

ROSS, A. D. (2000) A two-phased approach to the supply network reconfiguration problem. *European Journal of Operational Research,* 122**,** 18-30.

Sabel, C., Herrigel, G., Kazis, R. And Deeg, R., (1987), How to keep mature industries innovative, Technology Review 90(3), 26-35.

Salmon K. (1993), Efficient Consumer Response: Enhancing Consumer Value in the Grocery Industry, Food Marketing Institute, Washington, DC.

Saint-Onge, H. (2002),Linking Knowledge to Strategy, presentation at the Strategic Planning for KM Conference. Toronto, May 28-29.

Semchi-Levi, D., Kaminsky, P. & Simchi-Levi, E. (2003) Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies, 2nd Ed. New York: Mcgraw Hill

SEIDMANN, A. & SMITH, M. L. (1981) Due Date Assignment for Production Systems. Management Science, 27, 571-581.

Seifert, J.W. (2004), Data Mining, an Overview, CRS Report for Congress.

Schmenner, R.W. and Swink, M.L. (1998), ''On theory in operations management'', Journal of Operations Management, Vol. 17, pp. 97-113.

Schorr, J.E. (1998), Purchasing in the 21st Century, John Wiley & Sons, Inc., New York.

Schunk, D. and Plott, B., (2000), Using simulation to analyze supply chains, Proceedings of the 2000 Winter Simulation Conference, Piscataway, NJ, 1211-1216.

Shapiro, J. F. (2001) Modeling the Supply Chain, Pacific Grove, Calif.: Duxbury/Thomson Learning, pp. 10-11

SHAPIRO, D. T. (2001) Modeling supply and demand for arts and sciences faculty - What ten years of data tell us about the labor market projections of Bowen and Sosa. *Journal of Higher Education,* 72**,** 532-+.

SIERRA, C., FARATIN, P. & JENNINGS, N. R. (1997) A service-oriented negotiation model between autonomous agents. Multi-Agent Rationality, 1237, 17-35.

Singh, M. P., ed.(1998) Developing Formal Specifications to Coordinate Heterogeneous Autonomous Agents IEEE Computer Society, Paris, FR.

Singhal, A., Agarwal P. and Singh, V. (2004), "A new era for global textile and clothing supply chains", Textile Outlook International, November-December, pp.121-143.

Sim, K.M. and Chan, R. (1999), An Agent-Based Information Brokering System for Securities Trading, In the *proceedings of the Australian Workshop on AI in Electronic Commerce*.

Simchi-Levi, D. Kaminsky, P. and Simchi-Levi,E. (2004), "Managing the Supply Chain". USA: The McGraw-Hill Companies. pp. 245-250, 274-277

Smathers D.C. and Goldsmith S.Y.(2001) Agent Concept for Intelligent Distributed Coordination in the Electric Power Grid, *SANDIA REPORT*, USA: Sandia National Laboratories.

Sood, S., Singhal, A., and Singh, V. (2004), "Creating and preserving value in the textile and apparel supply chain: from fiber to retail", Textile Outlook International, January-February, pp.135-156.

Stevens, G.S., (1989), Integrating the supply chain, International Journal of Physical Distribution and Logistics Management 19, 3-8.

Stone, E. (1994), Exporting and importing fashion: A global perspective, Albany, N.Y.: Delmar Publishers.

SU, S. Y. W., HUANG, C. B., HAMMER, J., HUANG, Y. H., LI, H. F., WANG, L., LIU, Y. Z., PLUEMPITIWIRIYAWEJ, C., LEE, M. S. and LAM, H. (2001) An Internet-based negotiation server for e-commerce. *Vldb Journal,* 10**,** 72-90.

Sugumaran, V. (2002), An agent-based knowledge management framework for the e-commerce environment. J Comput Inf Syst; 42(5):63–73.

Sugeno M.(1985) An introductory survey of fuzzy control. Information Sciences, 36:59–83.

SYCARA, K. P. (1998) Multiagent systems. Ai Magazine, 19, 79-92.

Tan, S. (2004), "Luen Thai Announces Proposed Listing on SEHK". Available from: http://www.luenthai.com/news1.htm [cited 26 March 2006]

Taerno, T. Asai, K. and Sugeno, M. (1992), Fuzzy Systems Theory and Its Application, Academic Press, San Diego.

Tekin, E. and Sabuncuoglu, I. (2004), Simulation optimization: a comprehensive review on theory and application, IIE Transactions 36, 1067-1081.

Terra J. C. and Angeloni T. (2005) Understanding the difference between Information Management and Knowledge Management. TerraForum Consultores. Available: http://jobfunctions.bnet.com/whitepaper.aspx?&compid=25035&docid=165239 [22 Dec, 2006]

Terzi, S. and Sabuncuoglu, I., (2004), Simulation in the supply chain contest: a survey, Computers in Industry 53, 3-16.

Tocher, K.D. and Owen, D.G., (1960), The automatic programming of simulation, Proceedings of the 2nd Conference of IFOR, Aix en Providence, 50-68.

Tompkin, S. and Aadivar, F., (1995), Genetic algorithms in optimizing simulated systems, Proceedings of 1995 Winter Simulation Conference, Arlington, VA, 757-762.

Toni, A.F.D. and Zamolo, E., (2004), From a traditional replenishment system to vendor-managed inventory: a case study from the household electrical appliances sector, International Journal of Production Economics 96, 63-79.

Towill, D.R., Naim, M.M. and Wikner, J., (1992), Industrial dynamics simulation models in the design of supply chain, International Journal of Physical Distribution and Logistics Management 22, 3-13.

Truong, T.H., (2002), Simulation Based Optimization for Supply Chain Configuration Design, Department of Industrial and Manufacturing System Engineering, College of Engineering, Kansas State University.

Tyler, D., (1989), Managing for production flexibility in the clothing industry, Textile Outlook International (September), 63-84.

ULIERU, M. & COBZARU, M. (2005) Building holonic supply chain management systems: An e-logistics application for the telephone manufacturing industry. *Ieee Transactions on Industrial Informatics,* 1**,** 18-30.

Umeda, S. and Zhang, F., (2006), Supply chain simulation: genetic models and application examples, Production Planning and Control 17(2), 155-166.

Vasudevan, V. (1998). Comparing Agent Communication Languages. *OBJS Technical Note*. [Online]. Available:
http://www.objs.com/agility/tech-reports/9807-comparing-ACLs.html.

Verdicchio. M and Colombetti.M. (2002)Commitments for Agent-Based Supply Chain Management," *ACM SIGecom Exchanges*, 3(1), pp.13-23.

Verma, R. and Pullman, M.E., (1998), An analysis of the supplier selection process. Omega, International Journal Management Science, 26, 739-750.

Vorst, J.G.A.J.V.D., Beulens, A.J.M. and Beek, P.V., (2000), Modeling and simulating multi-echelon food systems, European Journal of Operational Research 122, 354-366.

Wacker, J.G., (1998), ''A definition of theory: research guidelines for different theory-building research methods in operations management'', Journal of Operations Management, Vol. 16, pp. 361-385.

WADHWA, S., SAXENA, A. & CHAN, F.T.S., (2008) Framework for flexibility in dynamic supply chain management. *International Journal of Production Research,* 46**,** 1373-1404.

Wang, J., Schroer, B.J. and Ziemke, M.C., (1991), Unerstanding modular manufacturing in the apparel industry using simulation, Proceedings of the 1991 Winter Simulation Conference, Phoenix, Arizona, 441-447.

Waller, M., Johnson, M.E. and Davis, T., (1999), Vendor-managed inventory in the retail supply chain, Journal of Business Logistics 20(1), 183-203.

Wang, J. and Shu, Y.F., (2005), Fuzzy decision modeling for supply chain management, Fuzzy Sets and Systems 150(1), 107-127.

Wang P.X. and Wang H.L.(2005) Design of Management System Based on UML for Managing Supply Chain Ordering. Journal of Zhongyuan Institute of technology, 16(1):26-29

WEBER, C. A., CURRENT, J. R. & BENTON, W. C. (1991) Vendor Selection Criteria and Methods. *European Journal of Operational Research,* 50**,** 2-18.

WEE, H. M. & YANG, P. C. (2007) A mutual beneficial pricing strategy of an integrated vendor-buyers inventory system. *International Journal of Advanced Manufacturing Technology,* 34**,** 179-187.

Weng, Z.K. and McClurg, T., (2003), Coordinated ordering decisions for short life cycle products with uncertainty in delivery time and demand, European Journal of Operational Research 151,, 12-24.

Whitaker, D., (1973), A study of a production line in the aarment industry, Clothing Institute Journal 21, 113-120.

Wilson, R. (2004). 15th Annual State of Logistics Report. Council of Supply Chain Management Professionals. Available online: http://www.cscmp.org/.

Wooldridge, M., Jennings, N. R. and Kinny D.(2000) The Gaia Methodology for Agent-Oriented Analysis and Design, International Journal of Autonomous Agents and Multi-Agent Systems.

Wooldridge M. (2002) An introduction to multi-agent Systems, Britain: Biddles Ltd.

Wong, A.(1999) “Partnering through cooperative goals in supply chain relationships”, Total Quality Management, Vol.10 No.4/5, pp.786-792.

Wu, D.J. (2001) Software agents for knowledge management: coordination in multi-agent supply chains and auctions. Expert Systems with Applications, 20 (2001),pp.51-64.

Wurman, P.R., Wellman, M.P. and Walsh, W.E., (1998), The Michigan Internet AuctionBot: A Configurable Auction Server for Human and Software Agents, *Proceedings of the Second International Conference on Autonomous Agents*.

Wyland, B., Buxton, K. and Fuqua, B. (2000), Simulating the supply chain, IIE Transactions 32, 37-41.

YANG, M.C., Ling C. and Wang, H.L.(2004) The Knowledge Management System for Supply Chain. R &D Management, 16(1), pp.44-48

Yao, L.,Feng, Y. and Ju, Y., (2002), A survey of supply chain simulation, Proceedings of Asian Simulation Conference on System Simulation and Scientific Computing, Shanghai, 51-57.

YEH, C. & YANG, H. C. (2003) A cost model for determining dyeing postponement in garment supply chain. *International Journal of Advanced Manufacturing Technology,* 22**,** 134-140.

Yuva, J. (2002) Knowledge management: The supply chain nerve centre. Inside Supply Management, pp. 35-43.

Zadeh, L.A., (1965), Fuzzy set, Information and Control 8, 338-353.

Zadeh L. A., (1984) "Making computers think like people," IEEE Spectrum

ZENG, D. J. & SYCARA, K. (1998) Bayesian learning in negotiation. International Journal of Human-Computer Studies, 48, 125-141.

Zhang, X.M., Luo, Y., Nian, J.F.(2004) Research of Multi - Agent System Modeling Based on Agent UML. Journal of Changchun University of Science and Technology, 27 (3), pp.33-35.

Zhu Q., Zhang X.M.(2005) The research on mechanism of knowledge sharing among enterprises in the supply chain, Science and Technology Management Research, No.10, pp. 69-71.

Zimmermann, H.J., (2001), Fuzzy Set Theory and Its Application, 4th Eds. Kluwer Academic Publishers, Boston/Dordrecht/London.

Zlotkin, G. and Rosenschein, J.S., (1993), In Proceedings of the Thirteenth International Joint Conference on Artificial Intelligence