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Research Article

Mediating Dynamic Supply Chain Formation by Collaborative Single Machine Earliness/Tardiness Agents in Supply Mesh

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Nowadays, a trend of forming dynamic supply chains with different trading partners over different e-marketplaces has emerged. These supply chains, which are called "supply mesh," generally refer to heterogeneous electronic marketplaces in which dynamic supply chains, as per project (often make-to-order), are formed across different parties. Conceptually, in a supply mesh a dynamic supply chain is formed vertically, mediating several companies for a project. Companies that are on the same level horizontally are either competitors or cohorts. A complex scenario such as this makes it challenging to find the right group of members for a dynamic supply chain. Earlier on, a multiagent model called the collaborative single machine earliness/tardiness (CSET) model was proposed for the optimal formation of make-to-order supply chains. This paper contributes the particular agent designs, for enabling the mediation of CSET in a supply mesh, and the possibilities are discussed. It is demonstrated via a computer simulation, based on samples from the U.S. textile industry, that by using intelligent agents under the CSET model it is possible to automatically find an ideal group of trading partners from a supply mesh.

1. Introduction

In recent years, an increasing number of brick and mortar businesses have begun to provide services on the internet. Naturally, this means that the internet has become a common platform for interactions between supply chains and their customers and suppliers. These interactions have also been fuelled by the launch of e-commerce portals such as business-to-business (B2B) exchanges for trading commodities, electronic crossing networks (ECNs), business-to-customer websites, and consumer-to-consumer websites that host retailing services (http://pages.ebay.com/storefronts/start.html). The increasing number of traders, service providers, and manufacturers available on the internet has also led to the creation of online e-marketplaces. The interaction within an e-marketplace can be viewed as a model of an electronic hub system uniting various entities from different industries with seamless connectivity (see Figure 1).

Some organizations have already initiated research and development based on this new model. For example, World Wide Retail Exchange (WWRE) attracts more than 50 international retailers (including Kmart, Gap, Jusco Japan, and Marks and Spencer) with the intention of improving the efficiency of their supply chain activities, and the alliance of GNX and Transora in the retail sector created a mega-hub where members can share value chain services through a single connection point. The supply chain formation problem is one of the important research topics in the e-commence field, on top of technical infrastructure issues. In an e-marketplace where buyers and sellers meet and trade online, logical supply chains can be formed among them by software agents. Therefore, supply chain formation becomes a problem of determining the production and exchanging relationships across a number of companies engaged in a coalition. Traditionally, supply chains were formed and maintained over long periods of time through extensive human efforts, typically involving a small number of companies at a time [1]. The advancement of e-commerce technology, especially in e-marketplaces where companies can easily and quickly reach out and stay connected to a large virtual community, has made the supply chain formation process more dynamic.

Dynamic supply chain formation ensures that business interactions can be quickly and flexibly formed and easily dissolved to better respond to rapidly changing market conditions. As a result, some *built-to-order* or *make-to-order*

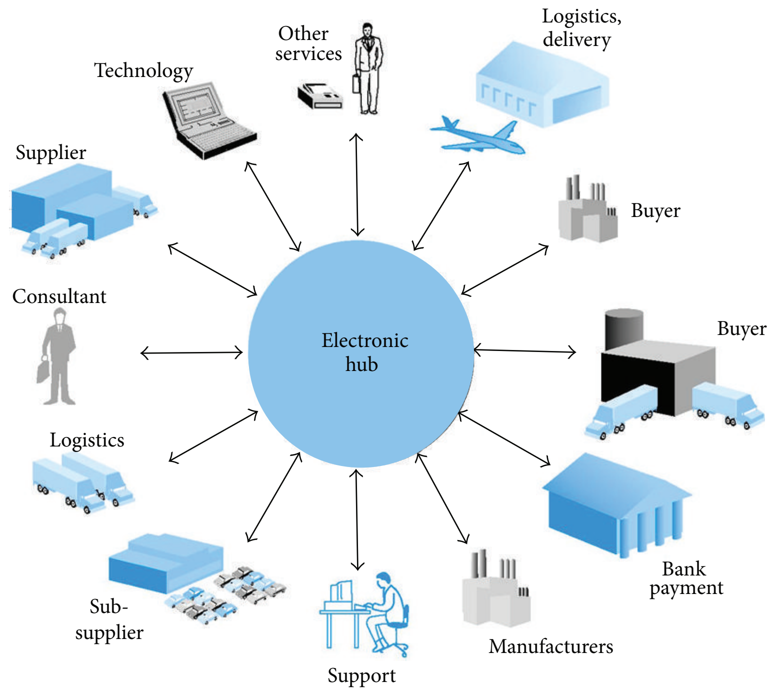


Figure 1: Electronic hub as an e-marketplace.

supply chain management models have emerged. Make-to-order is a contemporary production approach in which a confirmed order for a product is received and then the product is tasked to be built. This approach is widely used for highly configured products [2]. Although the make-to-order approach effectively minimizes storage costs by maintaining a sufficiently low inventory level, supply chains that adopt it often face the problem of sudden spikes in the demand/supply ratio. This uncertainty on both the retailer and supplier sides creates the need for a more flexible way of forming supply chains. Dynamic supply chain formation is suitable in situations where the number of orders received from the customers and the orders sent out to the suppliers fluctuate significantly due to a highly dynamic market environment. These dynamic supply chains are often short-lived, quickly formed per project and then dispersed when the service is no longer needed. They are characterized by high-speed automated mediation aided by software agents [3, 4] that are used to mediate the formation and subsequent coordination of supply chains. Techniques and protocols that enable dynamic supply chain formation coalitions among agents have been widely proposed in the literature. However, they are typically focused on the technical aspects of the formation (e.g., system integration, communication protocols, etc.) and do not address the big picture of how a supply chain will operate. Thus, a high-level view is desired that shows how a dynamic supply chain is formed by selecting the right candidates from all the available parties connected in an e-marketplace. This inclusive view is important because it helps supply chain managers to visualize the anticipated outcome of the formation from a decision-making/support perspective before an actual commitment is made.

A supply mesh is a new way of conceptualizing complex, interdependent, loosely-coupled, and demand-driven business relations knitted within an e-marketplace. In real life we have examples of supply mesh consortiums that only allow the participation of certain (usually qualified) companies with the potential to mutually benefit one other. Logically, it functions like a conceptual relation map that depicts the links between supply chain participants across several tiers, with multiple supply chains as conceptual business corporations/partnerships among these participants functioning simultaneously. When viewed from the perspective of a single supply mesh, the selection problem is similar to a combination of resource allocation and resource scheduling problems determining who the participants in the supply chain are, each participant's share of the jobs, and the timely sequence of job executions among the participants. For example, in Figure 2 there are three conceptual supply chains being formed through retailers, manufacturers, and material suppliers that are electronically connected in an e-marketplace; however, their demand/supply relationships as supply chains are reflected on a supply mesh. Each supply chain exists to execute a particular project and the relationship only lasts for the project's lifetime. The distribution of resources crosses all partners in the supply chain during the lifetime of a project including retailers, tiers of manufacturers, and raw material suppliers.

Before forming a dynamic supply chain on a supply mesh, decisions must be made regarding the selection of the right participants to support and fulfill the production of the product. Supply chains are formed on a supply mesh using two general approaches: (global) computation-based and (local) negotiation-based. A computation-based

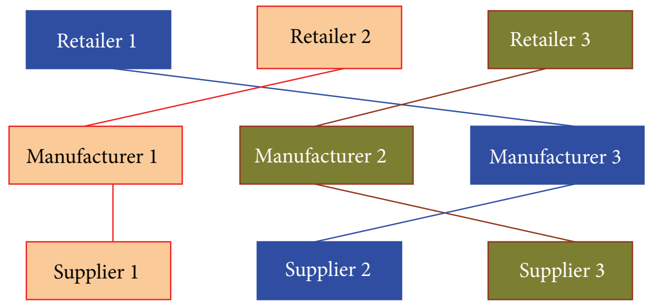


Figure 2: Examples of supply chain formation in a supply mesh.

approach extensively considers all the complex factors from a global view to find a solution that best satisfies high-level goals. In this case, a high-level central authority finds an optimal group of participants for a particular project in a supply mesh and instructs them to collaborate. The Pareto-optimal principle is usually applied in this method to ensure the majority of the participants' gains without jeopardizing anyone. Following this principle it allows jobs to be shared among multiple winners, which encourages cooperative competition. Cooperative competition is based on promoting mutual survival—an "everyone wins" mentality. It is a process where individuals compete in a cooperative manner through peaceful exchanges and without violating others to improve their level of satisfaction. Cooperative competition focuses entities against the environment [5] and jobs are shared as much as possible.

A negotiation-based approach assumes an environment in which the companies across each level of a supply chain compete for jobs through private negotiations or bidding efforts. The supply chain formation decisions in this approach are made individually by the companies using local knowledge. This negotiation-based method requires that each agent serves as a mediator to coordinate negotiation among bidders at each level and find the best deals. This competitive approach is usually cost-driven and results in few competitive winners who acquire the majority of the jobs and can almost always achieve the lowest cost in each production project. The supply chains that result from this approach usually cover a few elite industrial players who absorb the majority of the jobs and charge low prices.

Many researchers have recommended applying Pareto-optimal resource allocation in theories to supply chain management. In this paper we extend this philosophy by introducing a CSET model, powered by intelligent agents for mediating supply chains towards a Pareto-optimal situation. So that every member in the supply mesh can attain a state of Pareto optimality and everyone can be mutually benefited. This paper demonstrates with an experiment has to find the optimal allocation of jobs as represented by the formation of dynamic chains given by some samples taken from a U.S. textile industry. The results show that it is possible to form such Pareto-optimal group of supply chains by heuristic search from a supply mesh.

The remainder of this paper is structured as follows. A literature review of the relevant topics covered in this paper is in Section 2. Our proposed CSET model for framework and system architecture is presented in Section 3. The interaction details of the agents that support the CSET model and the information flows are described in Section 4. The experiment for verifying the proposed model is shown in Section 5. The application of CSET in some industrial scenarios is discussed in Sections 6 and 7 concludes the paper.

2. The Literature Review

To embrace quick changes and fluctuations in market demands, decisions about dynamic supply chain formation usually rely on demand forecasting and negotiation techniques. The former is a preemptive approach that often takes proactive action in resource planning, although forecasting based on historical data is known to be somewhat unreliable [6] and this approach is sometimes inadequate to offset the surges in supply and demand brought on by pricing adjustments [7]. The latter approach, implemented through intelligent agent negotiation, is reactive. With no regard for past data, negotiations in this approach ensure the optimal matching of participants by forming a dynamic supply chain giving its best effort during any changes in market conditions. Many researchers [8–10] have recently favored this approach of dynamic supply chain formation through automated negotiation in contrast to forecasting.

Lim and Benbasat [11] proposed a theoretical model for a negotiation system that is composed of two major components: a decision aid component and an electronic communications component. As the result of the information processing capability of the decision aid component, solutions with automated negotiation displayed better performance than those without [12]. The concept of a web-based intelligent agent system is not entirely new. As early as 1996, Chavez et al. [13] developed an agent that assisted users with the exchange of goods through negotiation capability in an e-marketplace. This model proactively sought out potential buyers or sellers and automatically negotiated with them on behalf of the users. This model seeded a flexible multiagent framework for multilateral negotiation. However, these agents were somewhat "unguided" because their designs were general and primitive regarding direct buying and selling and the negotiation was based only on price.

From the perspective of a supply mesh, which maps the logical supply chains within an e-marketplace, the participants in multiple supply chains must serve in certain roles. The relationship between any two tiers is usually collaborative because one tier needs the other to supply the supplies and fulfill the demands. The relationships between participants in the same tier could be competitive because they are fighting for jobs. This kind of workflow, when viewed as a whole on a supply mesh, should be optimized in a way that is similar to resource allocations that coordinate across the different relationships and intelligent agents in the different supply chains [14, 15]. In addition to buy/sell, collaborative and competitive relationships should also be considered. Tian et al. [16] developed an extended contract net mechanism for supply chain formation in a semi-governed scenario. Their negotiation protocols worked on a semimonopolized vertical market, China petroleum. Homburg and Schneeweiss [17] extended the negotiation structure to cover two main features, the strategic changing of the supplier's production facility and the uncertainty of the retailer's future demand. The negotiation takes place with respect to different demand scenarios, yielding a variety of possibilities for avoiding negotiation deadlocks. However, both Tian's and Homburg's studies were based on long-term production supply chains. In other words, all of the production capabilities and transportation capabilities in their studies were based on long-term scheduling. Thus, both their agent systems are only suitable for optimizing mid-/long-term, contract-based dynamic supply chain formation rather than for short-term dynamic supply chains.

Ideally, a supply mesh should be equipped with negotiation agents that are capable of forming tightly coupled internal supply chains, each fitting into a suitable role within the overall supply chain production. It should also have the flexibility to solicit qualified participants in an open e-marketplace. Such a supply mesh would be able to react to the ripple effects [18] of major economic changes including the impact of new technology, sudden terrorist/natural disaster threats, and policy reforms. Hyun et al. [19] proposed a supply chain model with an important scheduling mechanism for forming an optimal supply chain by means of negotiation and passing information along the supply chain. Inspired by the goals of scheduling optimal resources within a single entity, the mechanism was called the single machine earliness/tardiness (SET) model and its scheduling takes both early (earliness) and late (tardiness) production costs into consideration, along with the competitive relationships between multiple participants. The primary theoretical fundamental used by the SET model is Pareto optimality [20]. In line with the Pareto-optimal algorithm, each participant along the dynamic supply chain cannot suffer a loss, meaning that every participant gains from the jobs to varying extents. One potential drawback of the SET model is the relatively long time required for the transfer of cost information and negotiation as the result of the intertier connections. To address this, Hang et al. extended SET to create CSET [21], which has a central agent to coordinate the negotiation agents on each tier of the supply mesh. Using this double-agent architecture increases efficiency because the amount of information flow is reduced between each pair of tiers. More importantly, the CSET model functions as an overall scheduler where just-in-time (JIT) mechanisms can be implemented to globally optimize the overall performance of the supply chains.

The well-known JIT principle of supply chain management was initially developed in Japan [22]. JIT is a production process approach that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time so that the ROI improves as a result of reduced inventory levels and delivery lead times. The performance of a zero inventory simulation model for a JIT manufacturing and production system was studied and proven. Menberu Lulu [23] modified a directly linked process structure to include one accumulator with one unit of float between each individual process that eliminates these adverse effects. The main benefits of JIT, such as inventory reduction, quality improvement, and quick delivery, are well known [24–27]. Therefore, it makes perfect sense to incorporate JIT principles into CSET to achieve optimal resource allocation and efficiency in dynamic supply chains. CSET lays out a suitable agent operational framework for dynamic supply chain formation. This paper aims to validate this hypothesis via experimental simulations.

Furthermore, which resource allocation schemes are chosen has significance for a supply chain's efficiency. For example, Lau and Zhang [28] proposed a two-level framework for coalition formation. This framework used a centralized optimization model on the upper level and a distributed agent-negotiation model on the lower level similar to our CSET model, except that it only had two levels. Lau et al. proved that this two-level framework more effectively encouraged the agents to be partially cooperative rather than either being fully cooperative or self-interested during the operation of the supply chain. In their subsequent research [29], the open constraint optimization problem (OCOP) was solved using this two-level framework. The objective of the generalized OCOP was to find a solution with a low total cost and high overall satisfaction level for agents. On the one hand, their proposals were validated as a set of problem-driven mathematical equations that had not been referred to as a practical application, especially in tests conducted under supply chain management. Supply chain negotiation, however, is more complex than the OCOP problem because it involves special factors such as sequent times, meeting deadlines, penalties, and costs. The two-level framework only considered the cost and global satisfaction. On the other hand, every agent is seen as an autonomy that uses the specified local schemes to define satisfactions. Essentially, the agents on different tiers might have different schemes. Under the competitive condition, intelligent agents with the Pareto-optimal algorithm support negotiation by searching for an agreement that benefits every participant as much as possible; at the same time the central agent in CSET applies the JIT principle to improve the ROI for the whole supply chain. Our proposed automated negotiation model integrates these two methods [30, 31]. For this reason, our model is able to shorten the scheduling and waiting time so that the dynamic formation of supply chains in a supply mesh can be made more efficient and the overall ROI can be improved.

3. CSET Model for Optimizing Supply Chain Formation

3.1. CSET Model Framework. The collaborative single machine earliness/tardiness (CSET) model is an extension of the SET model [19]. It is designed as a methodology for finding an optimal supply chain formation that ensures that every entity in a supply mesh has a job. First, the participating companies that are connected to an e-marketplace would have to join a supply mesh—a logical group of companies that are willing to take part in supply chain collaboration. The CSET model then functions as a multiagent system governing the supply mesh. This multiagent system is mainly composed of two functional agents: the Pareto agent (PA) and the JIT collaborative agent (JIT-CA). As shown in Figure 3, between every two tiers in a supply mesh there is one PA, which runs Pareto-optimal computations to optimize the satisfaction of all the participants between the two tiers. All of the PAs work under the JIT-CA, which acts as a central authority. The JIT-CA is then responsible for optimizing the whole supply chain by synchronizing the job allocations. It is assumed that all participants are electronically connected to each other within the e-marketplace and that they are members of a common supply mesh that has one JIT-CA overseeing the supply chain flows.

In the CSET model, when a job is initialized by the clients who are usually retailers in the supply mesh, it is first sent to the JIT-CA who works as an inquisitor to validate the feasibility of the job. Consideration factors include, but are not limited to, participant availability within the supply mesh, profit margins, technical requirements, and economic and political issues. The JIT-CA serves as a gate-keeper and administrator of the supply mesh. Once the jobs have been checked and are deemed worthy, they will be represented as job requests and will naturally descend all the way down to the upstream of the supply chain where the raw material suppliers are. The PA serves as the mediator in each layer (section of the supply chain), deciding who gets which shares of each job. In the CSET model, the decision would be made collaboratively between the JIT-CA and the PAs. The JIT-CA monitors the conditions and the well-being of each participant, and because it has all the information about the whole supply chains and the supply mesh, the JIT-CA is in a position to derive a global optimal decision based on an overall view. In this scenario it is assumed that the participating businesses in the supply mesh trust the JIT-CA and actively delegate to them all decisions about whether job orders are accepted. Hence, the JIT-CA has the overriding authority to decide the arrangements over the PAs. The JIT-CA's main task is to collaborate with all the PAs. Each PA is tasked with submitting information to the JIT-CA, at which point the PA is instructed to adjust its local Pareto decision regarding the job allocations.

The old SET model propagates job information through tiers of PAs, but it lacks a global decision-maker to optimize final decisions. In addition, because the SET model is lacking this common channel to the central agent, the amount of information flowing between the PAs and participants is greater. In the CSET model, the sum of the information that flows between the participants can be expressed as follows:

$$\text{infoFlow\#}_{\text{total}} = \sum_{i=1}^{n-1} m_i + \sum_{j=2}^{n} m_j + n - 1, \qquad (1)$$

where n is the number of tiers, $n \geq 0$, and m_j is the number of m participants in tier $j, m \geq 0$ and $2 \leq j \leq n$.

3.2. Operation of the CSET Model. CSET is the pioneer model that adopted the JIT principle and extended the framework of SET into a collaborative environment where a central agent maintains an efficient workflow and the fairness of job allocation. The CSET model achieves an efficient flow of supply chains by operating tasks in synchronization and reducing the waiting time of the messages as they pass from tier to tier. That means that a pipelining mechanism is facilitated in CSET to ensure that the companies downstream start receiving jobs as soon as the previous job requests have been sent upstream.

While staying in communication with each PA, the JIT-CA is able to monitor the overall conditions and remain informed of all happenings in real-time along the supply chains. The JIT-CA is responsible for reconstructing common requests into sequent requests, namely, equilibrium request units by sequence time with job requests being given a time rule. The SET model works within "tardiness" and "earliness" time principles. That means the completion of the goods/jobs must be done within a given period of time. Too early or too soon will incur a cost penalty. Combining the PAs and the JIT-CA makes the overall Pareto-optimal efficiency higher than when using PAs alone.

CSET is designed to work with a generic number of multiple midtiers in a supply mesh. For the sake of simple illustration, we use a three-tiered supply mesh. The three tiers are clients' orders (downstream), manufacturers (midstream) and suppliers (upstream). Figure 4 explains the operation of the CSET framework with a flow chart that represents a simple three-tier supply chain formation. There are n units of orders to be allocated to m number of manufacturers and the manufacturers require supplies from x number of suppliers. The operational flows between the PAs and the JIT-CA are synchronous because they operate as if under a single entity. The other operations involving companies that are members of the supply mesh connected via the e-marketplace are asynchronous. However, they are given deadlines to respond to requests. In general, the workflow can be partitioned into 9 steps. The works within any step are atomic and the steps may take place in a sequential order.

Step 1. Orders from downstream arise and clients initiate requests to form potential supply chains for producing products. The orders are sent to PA_1 for estimation.

Step 2. PA_1 passes the order requests to the JIT-CA for consideration; the orders are assessed by attempting to reconstruct them into JIT requests.

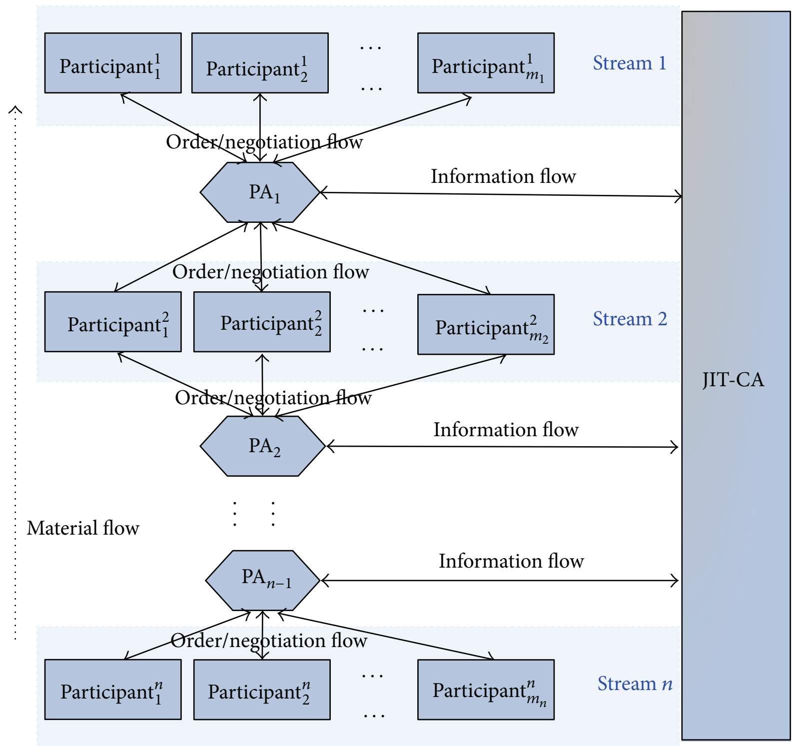


Figure 3: CSET model framework.

Step 3. JIT-CA returns the results of the order reconstruction (sequent request) to PA$_1$ if okay, negative acknowledgement to PA$_1$ otherwise.

Step 4. PA$_1$ distributes those sequent requests to midstream factories.

Step 5. According to the orders' sequent requests, every factory makes a new request for estimation through PA$_2$.

Step 6. PA$_2$ sends factories' requests to the JIT-CA for JIT request validation and reconstruction.

Step 7. JIT-CA reconstructs factories' requests and returns the sequent requests to PA$_2$; meanwhile, the factories, requests are sent to PA$_1$ by the JIT-CA.

Step 8. PA$_2$ sends the factories' sequent requests to all the upstream raw material suppliers and the suppliers propose their scheduling plans and return them to PA$_2$; meanwhile, PA$_1$ makes the Pareto-optimal resource allocation between orders and factories.

Step 9. PA$_2$ makes a Pareto-optimal resource allocation between factories and orders.

The JIT function will try to shorten the time difference between job requests as much as possible with the aim of pipelining the supply chain's entire production flow.

3.3. System Architecture. A supply mesh of the three-tier architecture can be technically implemented as illustrated in Figure 5. The agents, as described in the CSET model, are running on secure servers connected through an extranet over a VPN. The participating companies, proxied by their agents, interface with the PAs over the network. Logical supply chains as scheduled workflows operate over these systems. Developing a CSET model designed with this technical structure has two main benefits: extensibility and security. Each PA connects and works with a group of agents residing among the companies. The Pareto computation, in addition to messaging, will generate certain traffic flow and workloads on the agents' application server allowing the network to expand outward like a hierarchy. Having the root on top, namely, the JIT-CA tasked with making centralized decisions, puts the PAs on the lower level to perform tasks pertaining to their tiers. If the tiers increase, more PAs are added. If the number of participants is increasing horizontally on any tier, multiple servers can be clustered to share the workload among the participants on a particular tier.

The security perimeter is clearly marked. The PAs and JIT-CA are grouped in the same security zone, leaving the participants outside the firewalls. Thus, the intra activities among intelligent agents are transparent to the participants. Regarding privacy, sensitive information that identifies a participant can be masked during the information exchange between PAs and participants. The job tasks are subsequently converted into JIT task requests that effectively anonymize the identification data. Participants receive orders and job

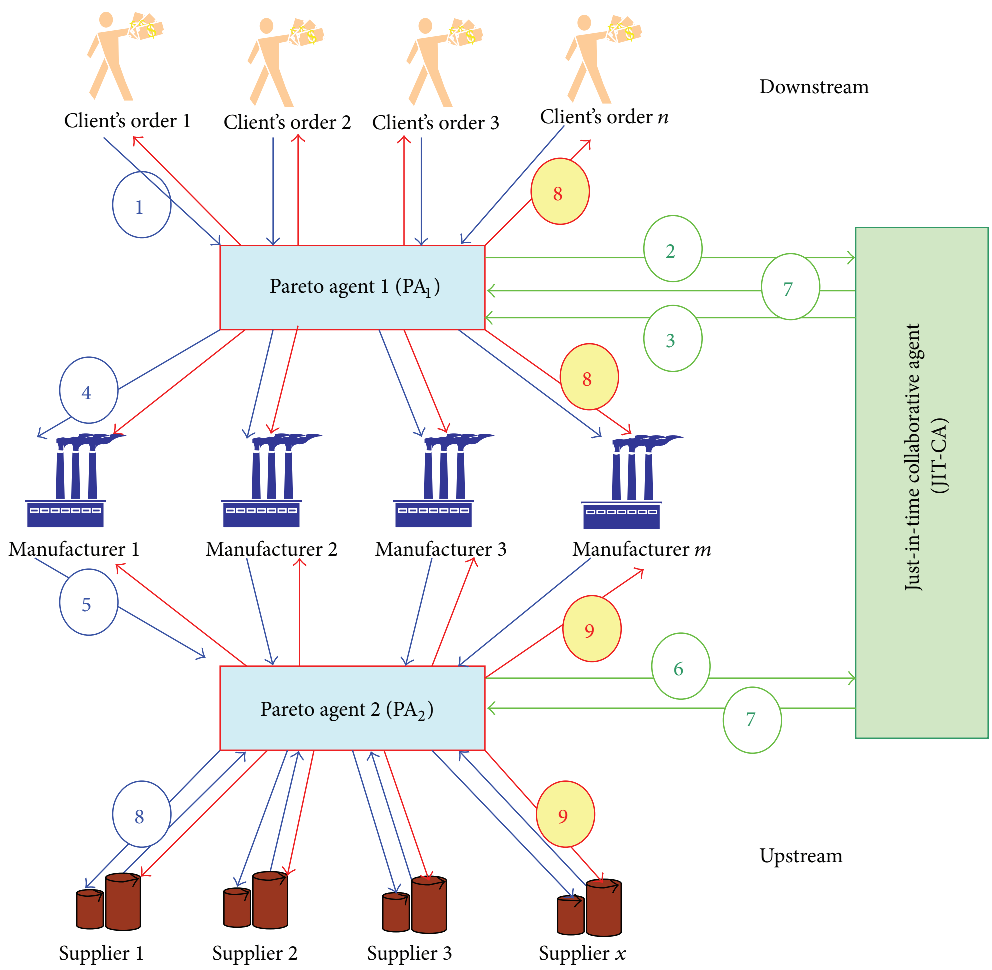


Figure 4: An example of workflow for dynamic supply chain formation in the CSET model.

requests from PAs without knowing the true identity of the job initiators on the upper tier.

3.4. Participants' Input Parameters. There are four types of participants in a CSET system and each of them has specified parameters data that must be inputted into the agents for computation to obtain an optimal resource allocation. These input parameters are summarized in Figure 6 and briefly described as follows.

Clients are the order request senders. The data package of job requests sent from the client includes the following information.

Amount. This is the quantity of the final product that the client proposes to purchase.

Location. This is the client's location and is used to calculate 3PL delivery costs.

Anticipant Delivery Time. This is the expected due-date when the final product will be delivered. Before this date, the client refuses to receive the goods from upstream because early delivery may imply unnecessary storage costs.

Latest Acceptable Time. This is the latest due-date at which the client is willing to accept the goods. However, if the delivery comes later than the anticipant delivery time the manufacturer pays the penalty. In other words, the delivery date between the anticipant delivery time and the latest acceptable time is the available zone; otherwise, the delivery is rejected. If so, the manufacturer suffers the loss on its own.

Daily Penalty. This is the per-day penalty for late delivery.

Price. This is the final product procurement price.

Manufacturer is the factory that implements the manufacturing work. It is midstream between the downstream clients and upstream suppliers. The data package sent from the factory includes the following information.

Final Product Amount. This is the amount of the outbound final product that the factory is able to provide.

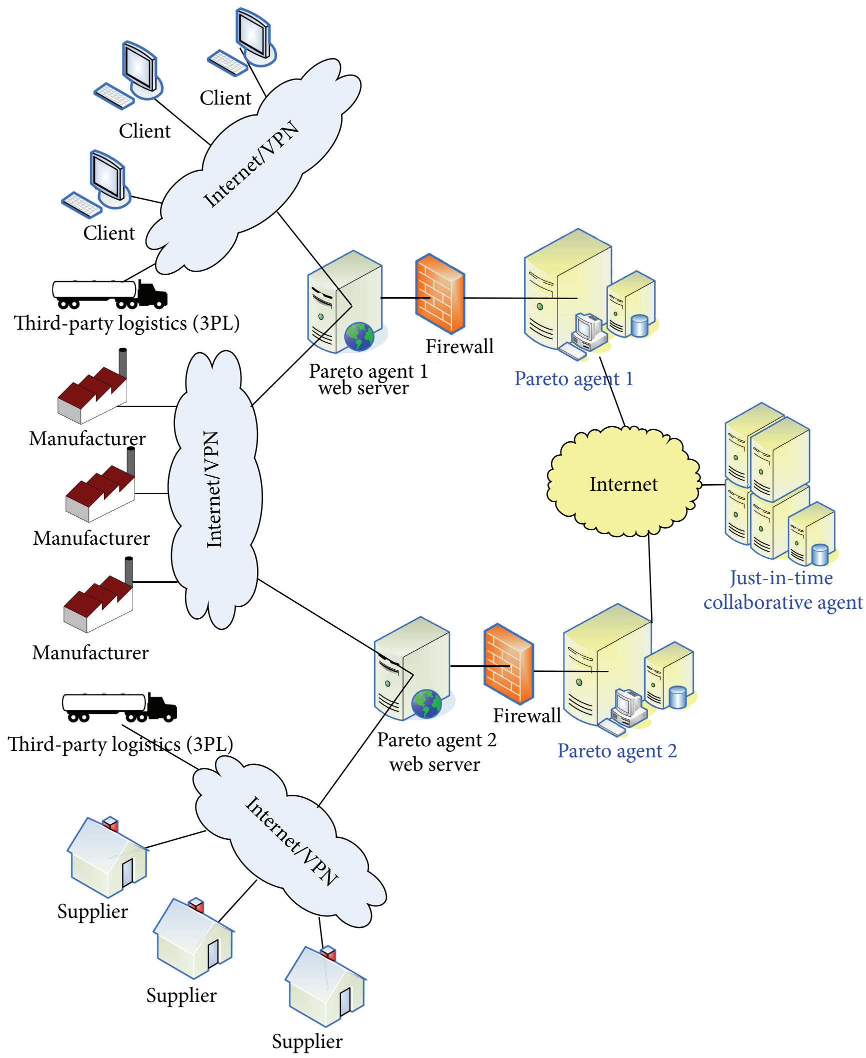


Figure 5: CSET system architecture.

Raw Material Amount. This is the amount of the inbound raw material that the factory needs to fulfill manufacturing.

Manufacturing Ratio. This is the ratio of final products and raw materials' amounts. For example, one unit amount of the final product is manufactured from two units of raw material A and one unit of raw material B for a manufacturing ratio of final product : raw material A : raw material B = 1 : 2 : 1.

Location. This is the location of the factory and is used to calculate 3PL delivery costs.

Working Duration. This is the period of work time spent in manufacturing.

Daily Manufacturing Cost. This is the per-day manufacturing cost that a factory must pay.

Daily Inventory Cost. This is the per-day cost of inventory that the factory has to pay to store the final product.

The *Supplier* is accountable for providing raw materials to the manufacturing factories. The data package sent from the supplier includes the following information.

Max Supply Amount. This is the maximum amount of raw materials supply to be provided to the manufacturer.

Supply Time. This is the date on which the supplier is able to provide the supplement.

Location. This is the supplier's location and is used to calculate 3PL delivery costs.

Price. This is the price of raw material supply.

The Third Party Logistics (3PL) Provider is accountable for providing the freight among clients, factories, and suppliers. The data package sent from the 3PL provider includes the following information.

Delivery Price (per unit weight plus unit distance). This is the delivery price calculated using the distance and weights of the goods.

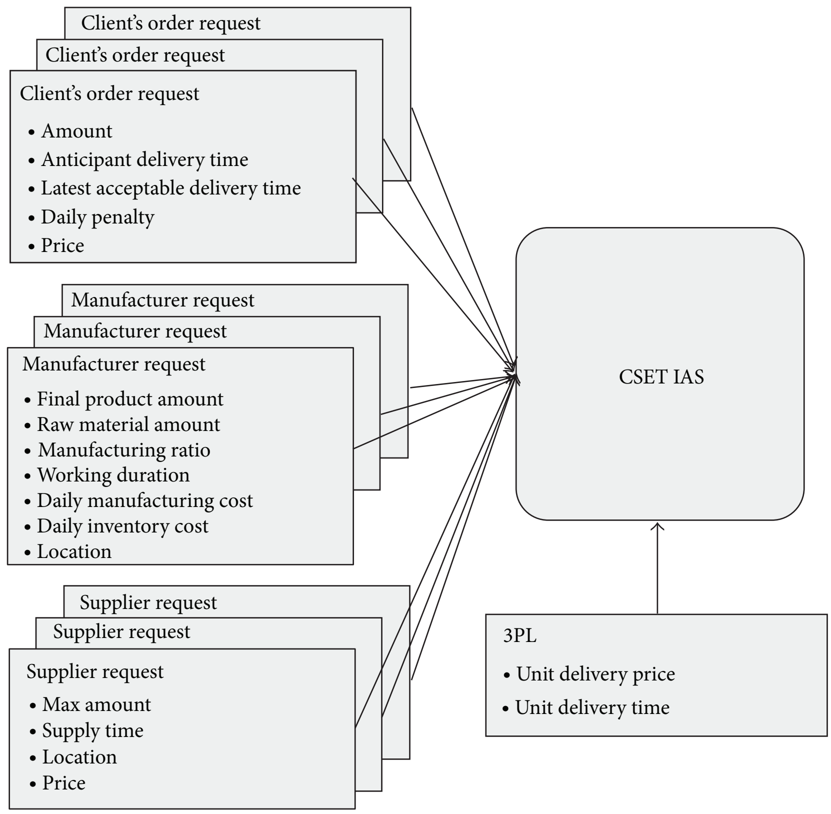


Figure 6: Parameter inputs.

Delivery Time (per unit distance). This is the delivery time calculated using the distance between the starting point and the destination.

4. Agent Design

There are two types of intelligent agents used in the CSET model as shown in Figure 7. Both the JIT-CA and the PAs have their own different functional modules.

4.1. Pareto Agent Design. The *Info Inquiry Module* is used to solicit responses from the participants. The procedure contains two activities: inquiring after a manufacturing reply from midstream (manufacturers) and inquiring after a raw materials supplying reply from upstream (suppliers).

The *Response Collection Module* is responsible for collecting information that contains different details from clients, manufactures, and suppliers.

The *Pareto Calculation Module* is used to run the Pareto-optimal algorithm so that an optimal allocation can be found.

The *Reply Distribution Module* is responsible for dispatching the reply to downstream participants. It plays an important role as a solution distributing filter for the PAs and contains the following activities:

(1) the allocation of the suppliers' replies to the manufacturers;

(2) the allocation of the manufacturers' replies to the customers.

4.2. Just-in-Time Collaborative Agent (JIT-CA) Design. The *JIT Request Validation Module* is responsible for validating job requests. The validation process compares the supply chain productivity with the order request. If productivity is not less than what the order requires, it passes the validation; otherwise, it fails to pass validation and a negative acknowledgement is returned to participants.

The *Request Reconstruction Module* is responsible for running the job requests validation. This process is shown in Figure 8. After finishing with this process, the system obtains a set of sequential requests with minimum manufacture waiting time.

The *Seq_Req Distribution Module* is responsible for allocating sequential requests to the next participants in the stream.

4.3. Agent Interactions. There are inter- and intraagent interactions between the PAs and the JIT-CA. The CSET model's information stream and agent processes are specified into four phases presented in the following steps.

Phase One: Orders to Manufacturers (Figure 9)

(1) Requests are sent to PA_1.

(2) PA_1 collects the request information through the Response Collection Module and sends them to JIT-CA.

(3) Requests are validated by the JIT.Req Validation Module; if available, they are sent to the next module;

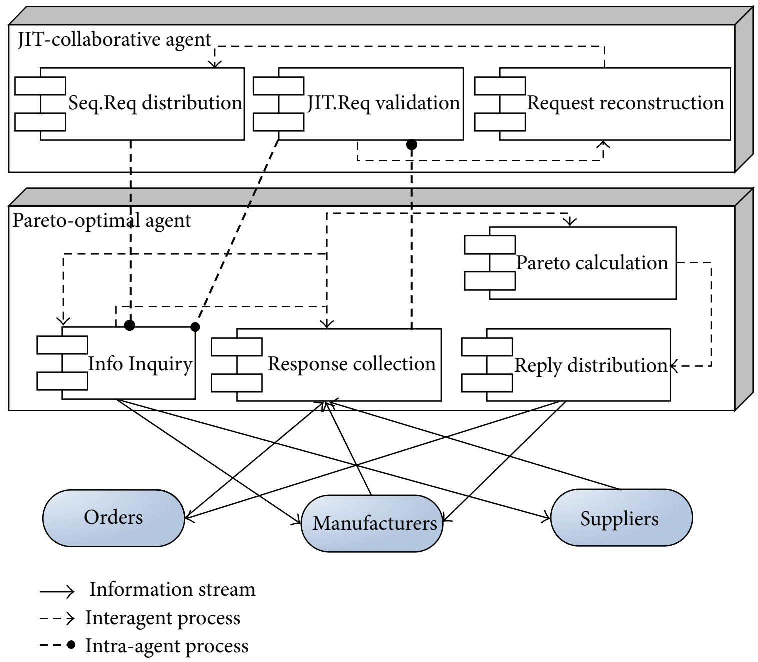


Figure 7: Agent design in a CSET model.

if not available the requests are returned to the sender via the Info Inquiry Module.

(4) Validated requests are reconstructed into new sequent requests by the Request Reconstruction Module and transferred to PA_1 in terms of time sequence by the Seq.Req Distribution Module.

(5) The Info Inquiry Module receives Seq.Req and allocates them to the manufacturers.

Phase Two: Manufacturers to Suppliers (Figure 10)

(1) When Seq_Req is received, the manufacturers estimate their own manufacturing conditions and send the raw materials supplying request to PA_2.

(2) PA_2 collects the manufacturers' requests through the Response Collection Module and inquires to the supplier through the Info Inquiry Module.

Phase Three: Suppliers to Manufacturers (Figure 11)

(1) In terms of self conditions, the suppliers reply to the supplying requests of PA_2.

(2) In line with phase one (steps 3 and 4), requests are converted into new Seq_Req by JIT-CA.

(3) Depending on the information transferred by the Response Collection Module, PA_2 computes the optimal suppliers and replies to the distribution solution through the Pareto Calculation Module.

(4) The suppliers' new Seq_Req is allocated to each manufacturer by the Reply Distribution Module.

Phase Four: Manufacturers to Orders (Figure 12). After considering self-conditions, the manufacturers return job request confirmations to PA_1. PA_1 calculates the Pareto-optimal allocation, selecting the best distribution proposal with the minimum cost, and distributes it to the orders.

Once these four agent interaction phases are complete, the information from each participant along the supply chain is able to pass through the double-agent architecture system. Furthermore, the CSET model can compute the Pareto-optimal solution with the JIT principle.

4.4. Formulation for CSET Model. The CSET model aims to balance the utility and welfare of all of the participants in a supply mesh to establish an optimal supply chain formation. The utility is reflected by the due-date, amount, and profit for different types of participants. Welfare is represented by the cost of forming a supply chain.

The JIT-CA is responsible for shortening the waiting time in the supply chain, minimizing the time difference between one order and the next in the sequence, including the customer's final product order and the supplier's raw material supply order. For this reason, the following formula is used to calculate the waiting time between effective and expired times in customers' and suppliers' orders:

$$\mathrm{WT} = \sum_{c=1}^{C-1} \sum_{s=1}^{S-1} \left(\mathrm{ET}_c + \mathrm{ET}_s - \mathrm{ST}_{c+1} - \mathrm{ST}_{s+1} \right). \tag{2}$$

The final product delivery time (DT) of a supply chain is determined by when the raw materials are delivered to

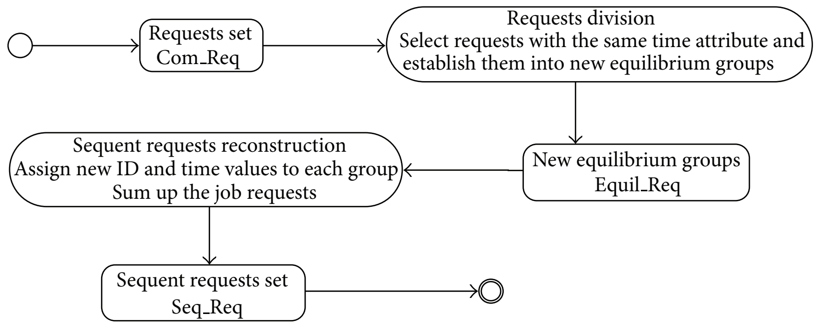


Figure 8: Workflow of request reconstruction module.

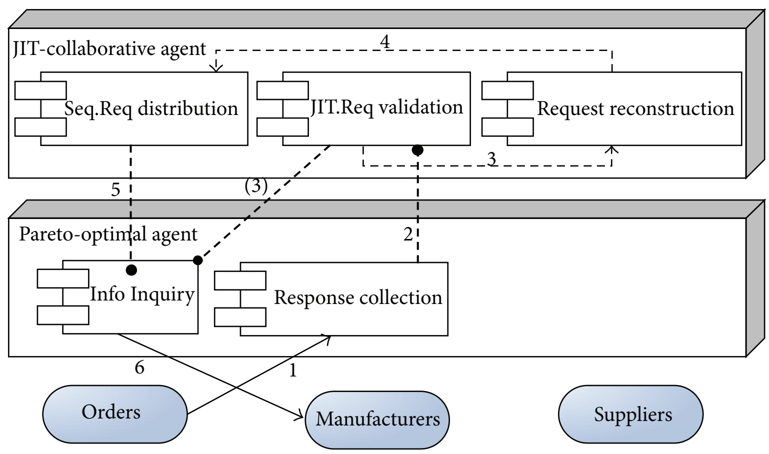


Figure 9: Phase one of agent interactions.

the manufacturer, when the manufacturer starts and finishes the manufacturing, and how much time is spent on transportation. For this reason, the following formula gives the delivery time of goods to customer c as manufactured by manufacturer m with the raw material from supplier s; it is calculated using transportation time (from supplier to manufacturer and from manufacturer to customer) and manufacturing duration:

$$\mathrm{DT}_c^{sm} = \mathrm{FrT}_{sm} + \frac{Q_c}{P_m} + \mathrm{FrT}_{mc}. \quad (3)$$

The CSET model considers the fixed cost in a supply chain to be the cost for the manufacturer to purchase raw materials from the supplier. This fixed cost is determined in the following formula by price and amount:

$$\mathrm{FC}_m^s = p_{sm} \times Q_{sm}. \quad (4)$$

The total cost of a supply chain relates to all entities including upstream suppliers, midstream manufacturers, and downstream customers. This cost, as shown in the following formula, consists of five aspects: the fixed cost of raw material procurement, the penalty cost of late delivery, the inventory cost of temporal storage, the manufacturing cost of resource consumption, and the cost of transportation:

$$C = \mathrm{FC}_m^s + \left(\mathrm{ST}_c - \mathrm{DT}_c^{sm}\right) \times \mu \times \mathrm{IC}_m + \sum_{m=1}^{M}\sum_{c=1}^{C}\sum_{s=1}^{S}\left(\mathrm{DT}_c^{sm} - \mathrm{ET}_c\right) \times \eta \times \mathrm{PC}_c + \frac{Q_c}{P_m} \times \mathrm{MC} + \mathrm{FrC}_{sm} + \mathrm{FrC}_{mc}. \quad (5)$$

The CSET model considers the utility of an allocation solution to be the aspects from cost, time, quantity, and price for all entities. The following formula finds the value of utility for a supply chain formation by calculating the profit margin and the delivery time; for each supply chain formation, the utility value is from 0 to 1:

$$U = \sum_{m=1}^{M}\sum_{c=1}^{C}\sum_{s=1}^{S}\left(\frac{\left(1 - C_m\right)/\left(p_{mc} \times Q_{mc}\right)}{2} + \frac{\left(\mathrm{ET}_c - \mathrm{DT}_c^{sm}\right)/\left(\mathrm{ET}_c - \mathrm{ST}_c\right)}{2}\right) \times 100. \quad (6)$$

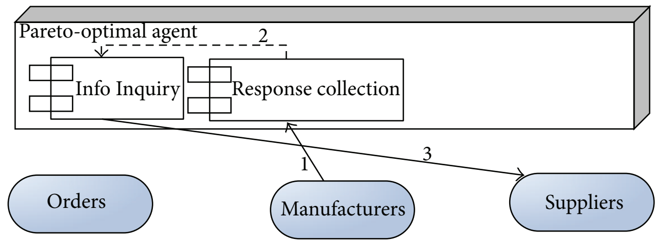


Figure 10: Phase two of agent interactions.

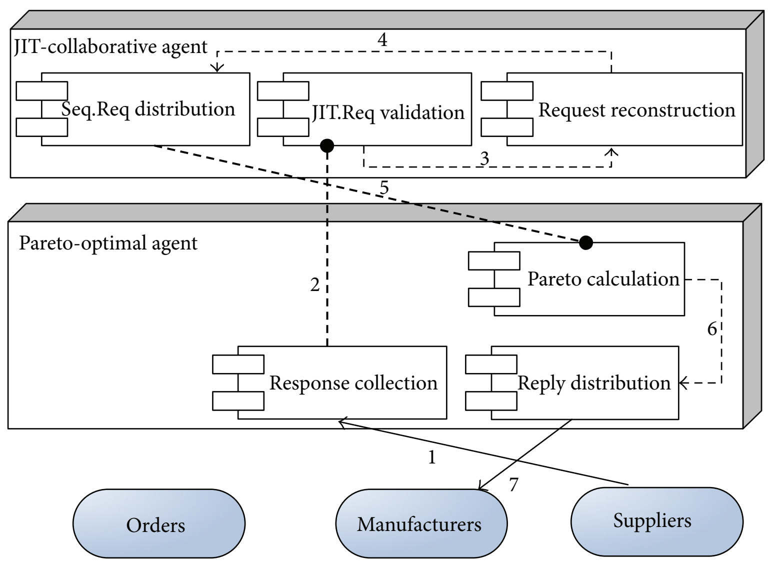


Figure 11: Phase three of agent interactions.

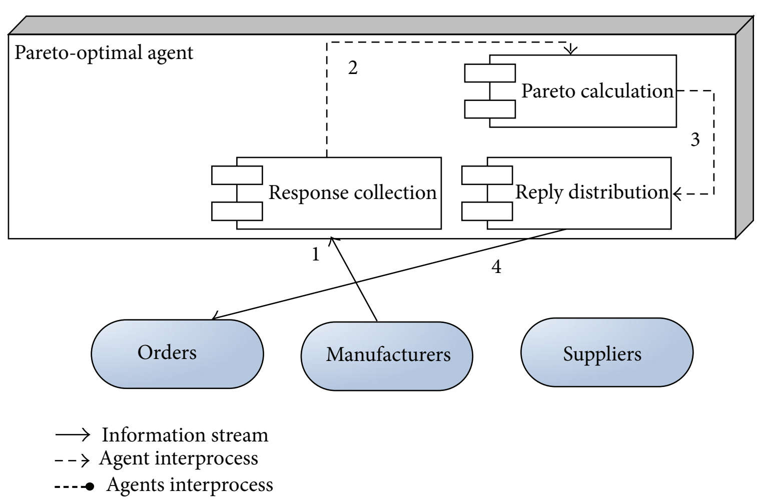


Figure 12: Phase four of agent interactions.

CSET Model Process

minimize WT;

maximize U;

minimize C.

The objective of the CSET model is to choose a suitable supply chain formation in the supply mesh. The term "suitable" in this objective can be defined as follows: (1) having the shortest waiting time for the customers' and suppliers' orders to optimize manufacturing; (2) delivering a good profit

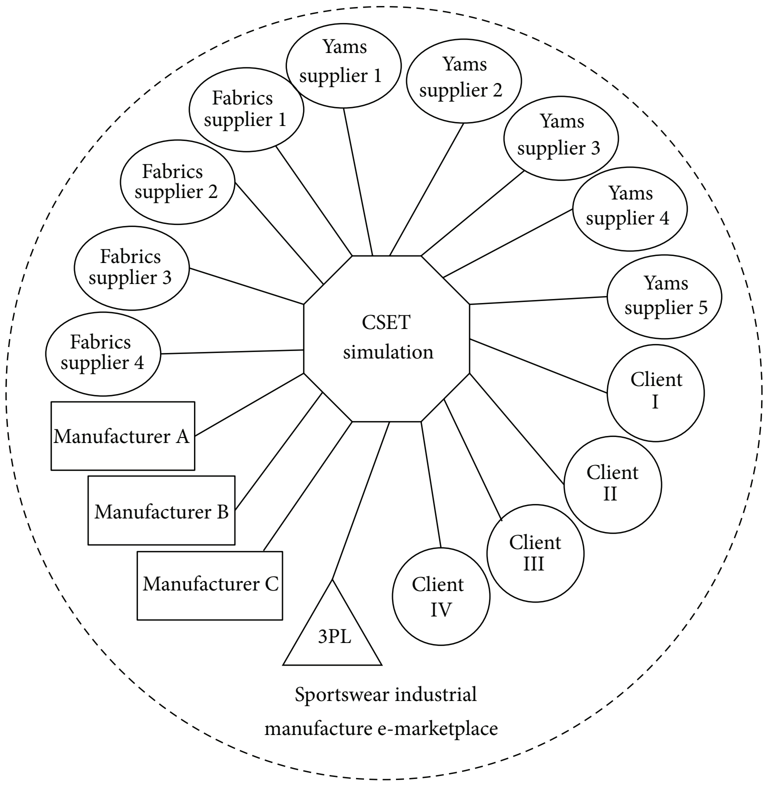


Figure 13: A supply mesh example used in our CSET simulation based on a sportswear scenario.

Table 1: Clients' order parameters.

ID	Amount (KG)	Anticipant DT (day)	Latest accept DT (day)	Location (KM)	Penalty (MOP/day)
1	3000	20	24	100	3000
2	4500	22	24	150	3300
3	2000	20	24	100	3000
4	6000	25	27	200	3500

Table 2: Fabric suppliers' supply request parameters.

ID	Max supply amt	Supply time	Location
1	3000	12	100
2	6000	13	150
3	7000	10	120
4	5000	12	100

Table 3: Yam suppliers' supply request parameters.

ID	Max supply amt	Supply time	Location
1	5000	12	100
2	10000	13	120
3	7000	12	100
4	11000	11	130
5	6000	13	120

margin and on-time arrivals, and (3) producing the lowest total cost. The JIT-CA is responsible for minimizing the waiting time by incorporating the JIT mechanism. The PAs maximize utilities and minimize costs by allocating jobs to different participants in various ways. Ideally, both types of agents collaborate to find the best group of participants with which to form a supply chain as a way of assigning jobs.

5. Experiment

This experiment simulates the formation of a supply chain using a set of sample data taken from a real-life source. The data are taken from a textile-apparel supply chain example that is used as a study case. In this supply chain example, borrowed from Bruce and Daly [32] study, a company is sourcing for a group of manufacturers both domestically and globally to form a dynamic supply chain. The garment products are to be quickly and efficiently produced to capture a share of the sportswear market. The production has to be fast enough to allow the company to catch the trend, but the production does not need to be long-term because the products will fall out of seasonal fashion fairly quickly.

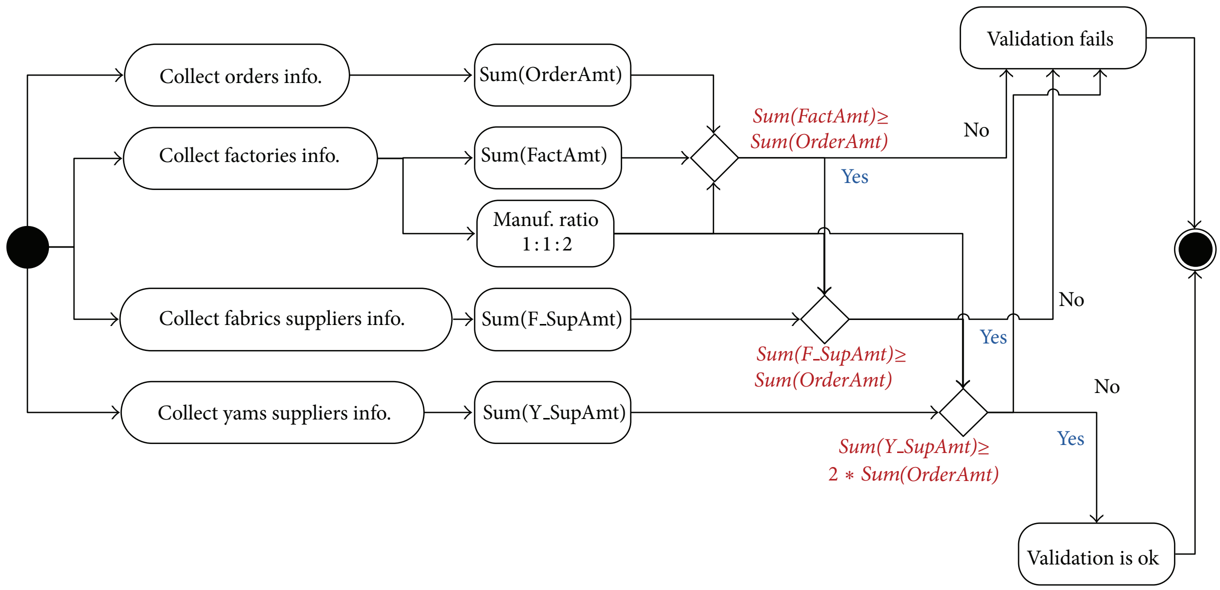


Figure 14: Simulation request validation activity diagram.

Table 4: Manufacturer's factory job request parameters.

ID	Max final product amt	Manuf. ratio fabric : yam	Work days	Manuf. cost (MOP/day)	Storage cost (MOP/day)	Loc
1	6000	1 : 1 : 2	8	1100	1800	100
2	8000	1 : 1 : 2	10	1200	1850	120
3	10000	1 : 1 : 2	13	1350	1780	110

In this simulation, the company opts to use the CSET model to form a virtual supply chain within an e-marketplace. First, the company joins a supply mesh where they find a list of potential manufacturers, suppliers, and clients to solicit as business partners. We assume that the supply mesh has four clients, three manufacturers, four fabric suppliers, and five yams suppliers in addition to one 3PL provider. All of these supply mesh members are able to connect with each other in the CSET model by using intelligent agents. Security and privacy, however, are assumed to be beyond the scope of this work at the moment. A sample of the supply mesh used in our simulation is shown in Figure 13. Our simulation is based on the input parameters whose values are derived from the example in [33] for forming suitable dynamic supply chains over the supply mesh.

5.1. Simulation Setup. To verify our CSET model, we programmed the simulator using JavaBeans + JSP to develop a set of experiments. The development platform is a PC with a 2.2 GHz CPU, 2048 MB of RAM, Windows Vista (32 bit), and Apache + Tomcat 5.5 for the web server. In this simulation, the JIT-CA's and PA's functions are integrated into the same JAVA program. The experimental results are saved in a MS-Access database. The results are then visualized in MatLab.

We used the data in Tables 1, 2, 3, 4, and 5, which contain the values for the parameters of various participants in the supply mesh to run the experiments.

5.2. Implementing JIT. To implement JIT for the JIT-CA agent in the simulation program, two main functions are used: request validation and request reconstruction. The former function determines whether the participant has the capacity to accept the jobs. The latter function reformats the requests, inserts timestamps for deadlines, and synchronizes them to impose them on the participants' operations. The request validation function is programmed using a JavaBeans package (Java Package: Bean.DataProcess.checkAssembleAmt()). The logic of this function is represented by the activity diagram in Figure 14. In a particular sample from our experimental data, a validation process and its result are shown in Figure 15 to illustrate how the requests must be validated before JIT processing. It is clear that a manufacturing ratio determined by the JIT-CA for synchronization would be injected into the assessment to ensure each participant's capacity for meeting or exceeding the hypothetical requirements tuned up by the ratio.

The step following validation is the process of requests division and reconstruction. A sample workflow extracted from our simulation is shown in Figure 16. The experimental clients' and suppliers' requests are reconstructed into sequent requests so that the sportswear supply chain's general formation is simplified and the flow can be synchronized. After this reconstruction process, the function redistributes the jobs in a Seq_Req format and composes a new supply chain formation as shown in Figure 17. The Seq_Reqs are

Table 5: Other negotiating parameters.

Product price (MOP/KG)	800	Fabrics price	150	Yams price	40
3PL price (MOP/KG∗KM)	2	3PL time (day/1000 KM)	1		

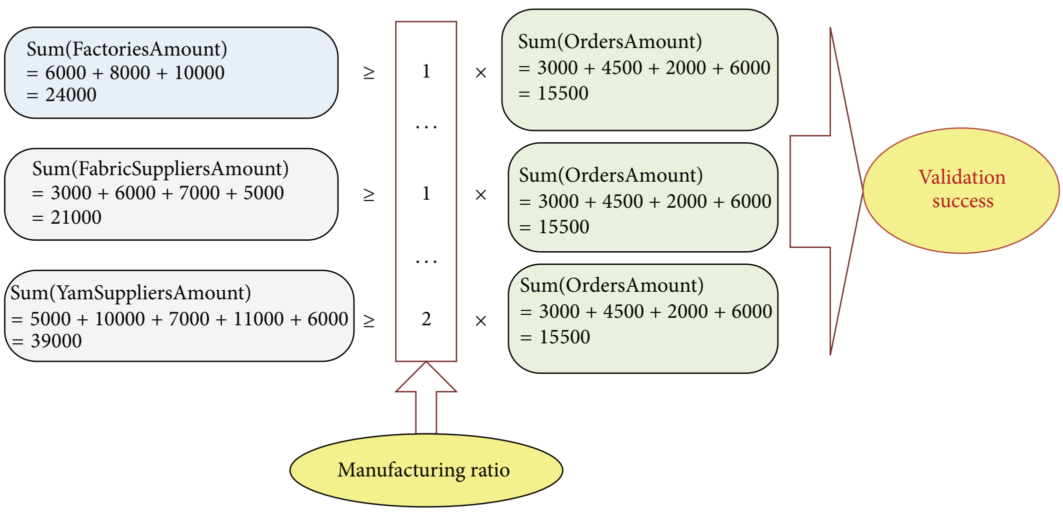


Figure 15: Experimental data request validation.

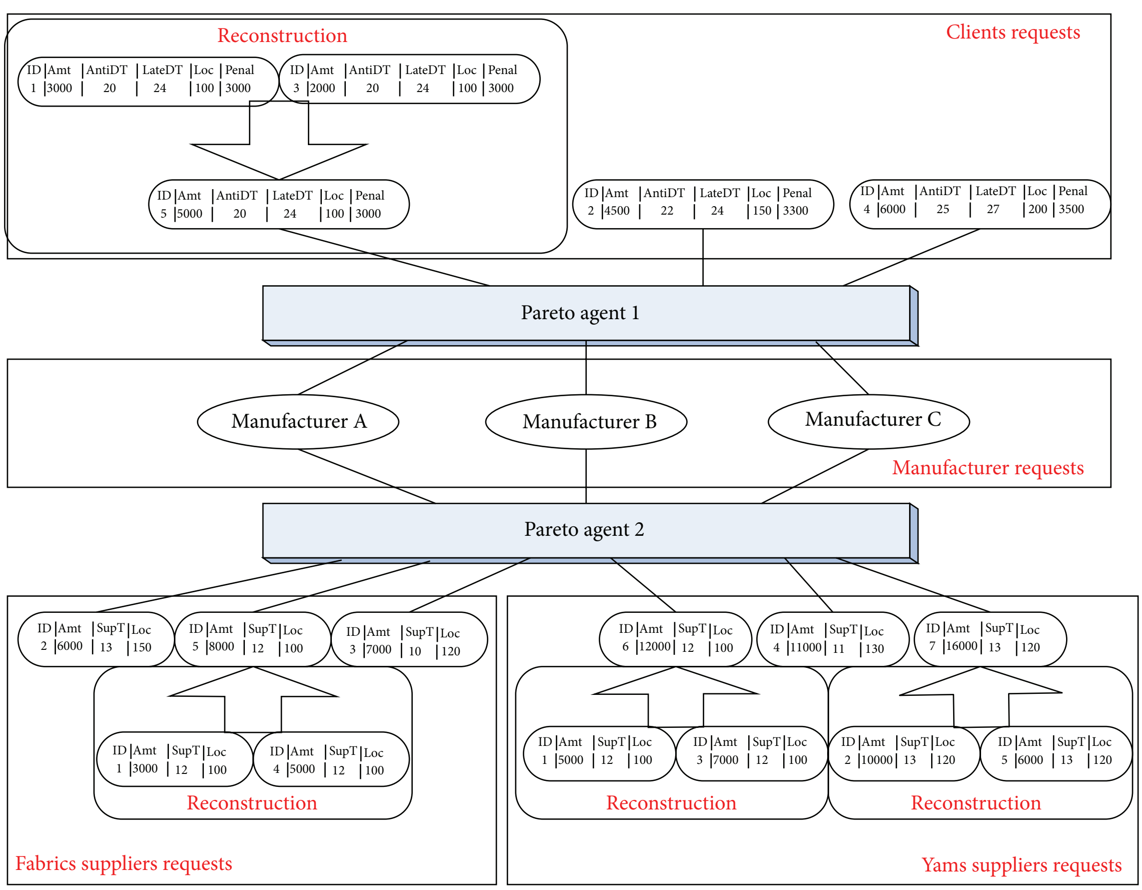


Figure 16: Experimental data request reconstruction.

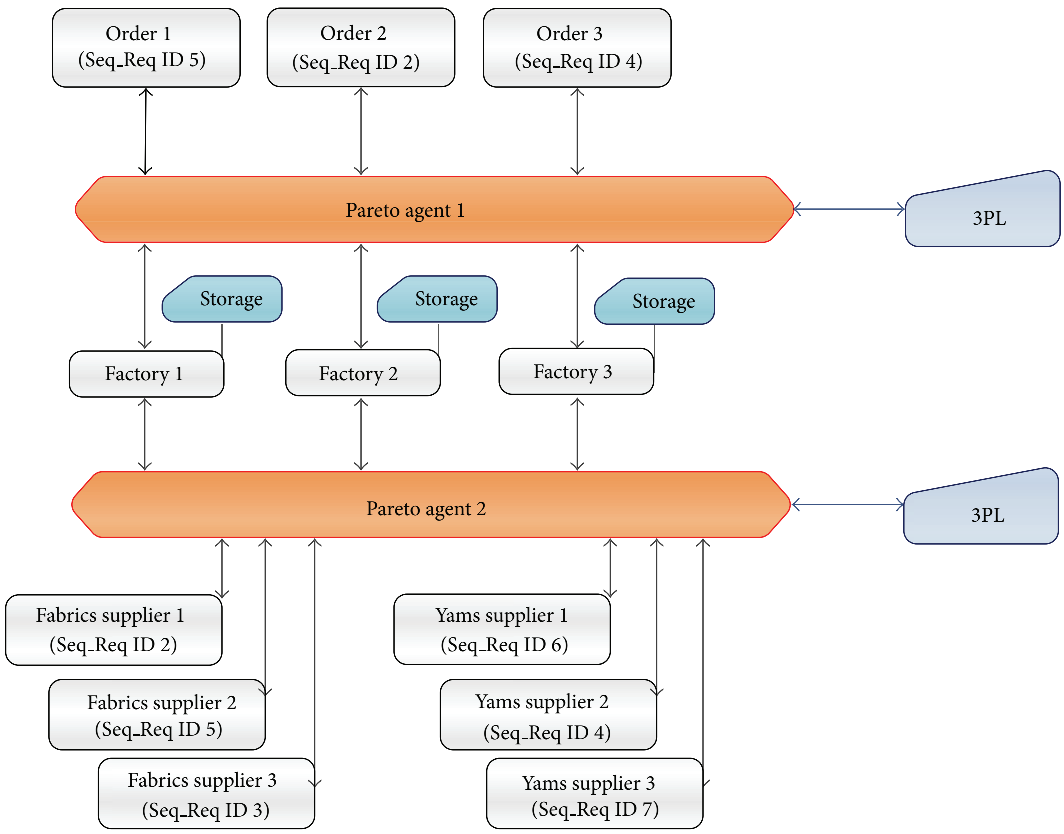


Figure 17: Seq_Req allocation.

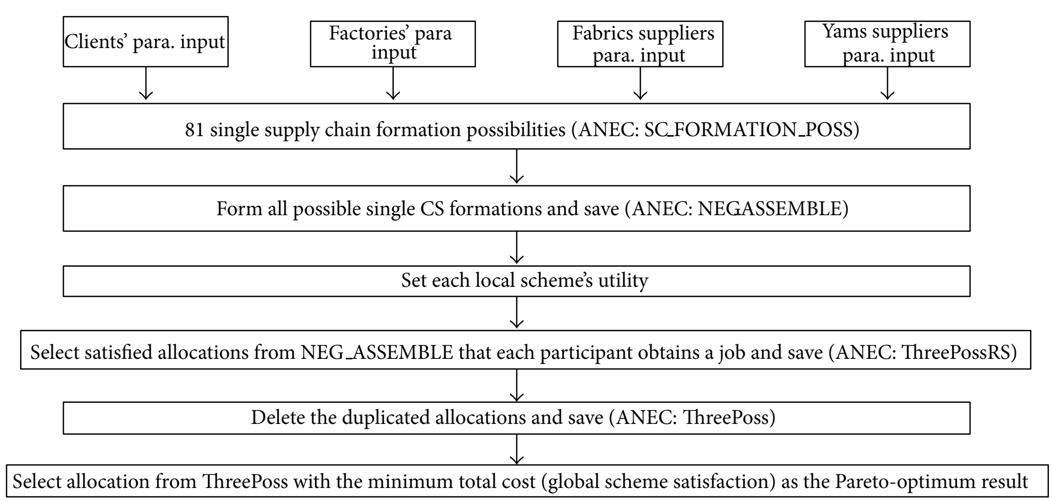


Figure 18: Pareto-optimal simulation flow chart.

then delivered to a Pareto agent for further processing by the Pareto-optimal algorithm, which computes allocation distributions to find an optimal resource allocation on its tier.

Normally, in a supply mesh, there are a large number of formation possibilities that meet the demand and supply requirements. Our simulation assumes a relation of orders that need to be produced by the factory, and the factory then relies on the fabric yam suppliers for material provision. A total of 1296 such potential supply chains can be arranged in this way.

5.3. Implementing Pareto-Optimal. Of all qualified candidates that could be arranged to form dynamic supply chains in a supply mesh, there must be some optimal allocations where participants are most fit to perform the jobs and most likely to benefit by incurring the lowest cost. From the global

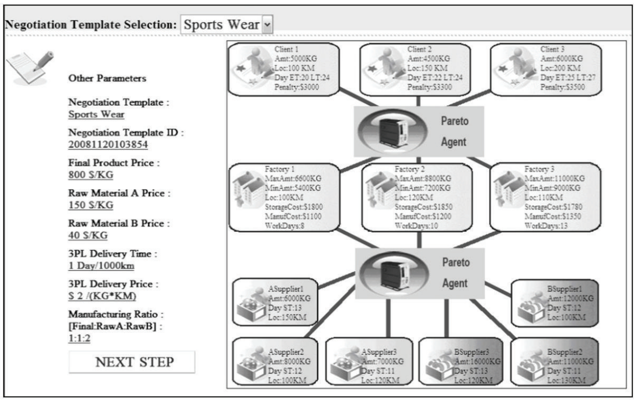
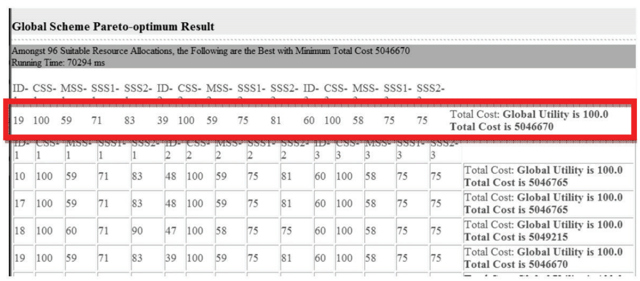


Figure 19: New supply chain formation after processing by JIT-CA and PAs.



Global Scheme Pareto-optimum Result

Amongst 96 Suitable Resource Allocations, the Following are the Best with Minimum Total Cost 5046670
Running Time: 70294 ms

ID-1	CSS-1	MSS-1	SSS1-1	SSS2-1	ID-2	CSS-2	MSS-2	SSS1-2	SSS2-2	ID-3	CSS-3	MSS-3	SSS1-3	SSS2-3	
19	100	59	71	83	39	100	59	75	81	60	100	58	75	75	Total Cost: **Global Utility is 100.0** **Total Cost is 5046670**
10	100	59	71	83	48	100	59	75	81	60	100	58	75	75	Total Cost: **Global Utility is 100.0** **Total Cost is 5046765**
17	100	59	71	83	48	100	59	75	81	60	100	58	75	75	Total Cost: **Global Utility is 100.0** **Total Cost is 5046765**
18	100	60	71	90	47	100	58	75	75	60	100	58	75	75	Total Cost: **Global Utility is 100.0** **Total Cost is 5049215**
19	100	59	71	83	39	100	59	75	81	60	100	58	75	75	Total Cost: **Global Utility is 100.0** **Total Cost is 5046670**

Figure 20: Snapshot of the Pareto-optimum result.

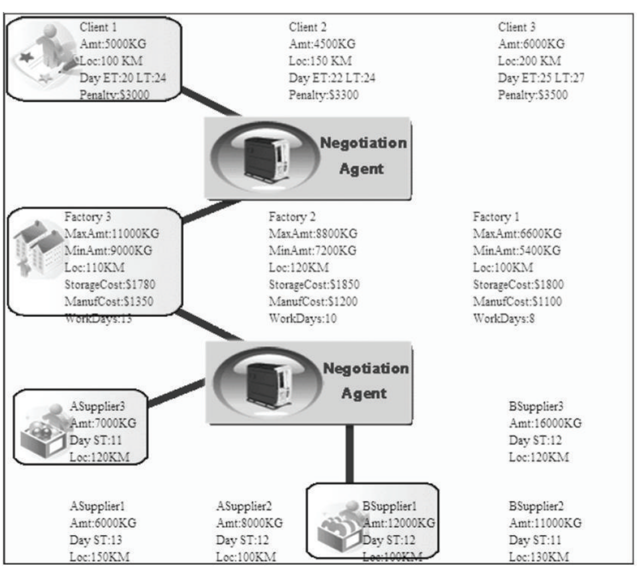


Figure 21: Visualization of the first supply chain ID19.

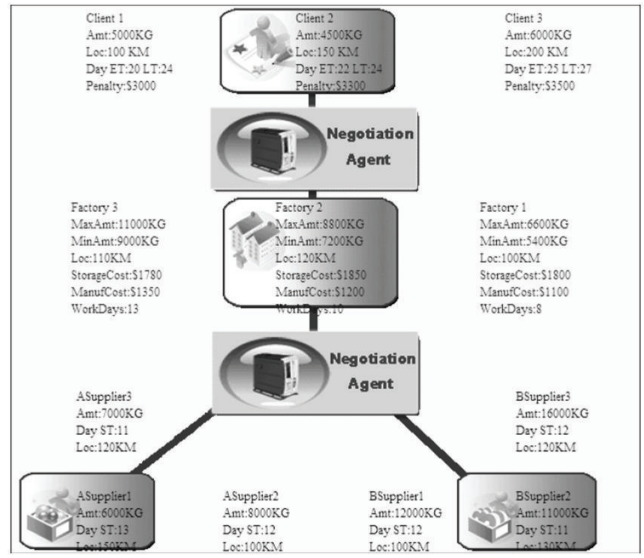


Figure 22: Visualization of the second supply chain ID39.

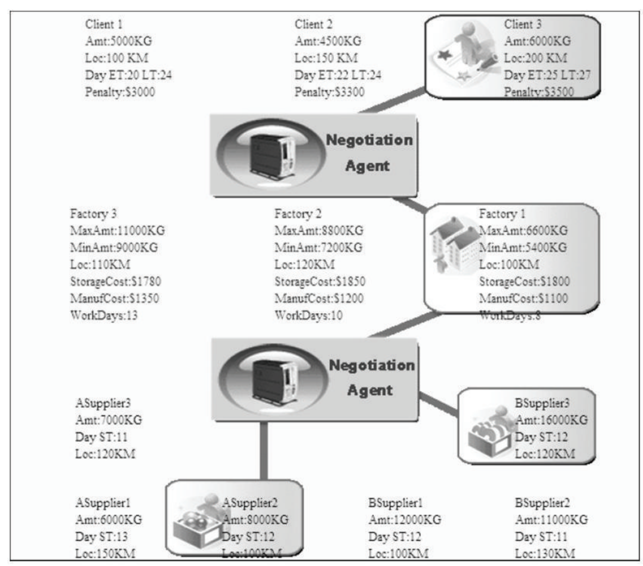


Figure 23: Visualization of the third supply chain ID60.

view of a supply mesh, the scheduling and formations of the supply chains should yield a global optimal in the form of the lowest total cost and maximum overall satisfaction of all the participants. The computation of such Pareto-optimal formations in supply chains takes into consideration all of the jobs and capabilities on hand, provided that they meet the JIT deadlines and follow the workflow as shown in Figure 18.

5.4. Simulation Results. The results from our simulation are computed by considering all of the parameters of all of the resource allocation choices in the simulation. There are a total of 81 choices of individual single resource allocations that represent single supply chain formations. Each result is computed from the relevant parameters such as freight, cost, time, and penalty. In our simulation scenario, the minimum local scheme satisfactions must be defined, namely, the thresholds for satisfaction of the clients, manufacturers, and suppliers of yams and fabric. These values are arbitrarily chosen as 90%, 50%, and 70%, respectively. From the 1296 choices that satisfied the JIT requirements, our simulation program narrowed them down to 96 single supply chain formations (about 7.41% of the total possibilities) that met the local scheme satisfaction requirements, specifically

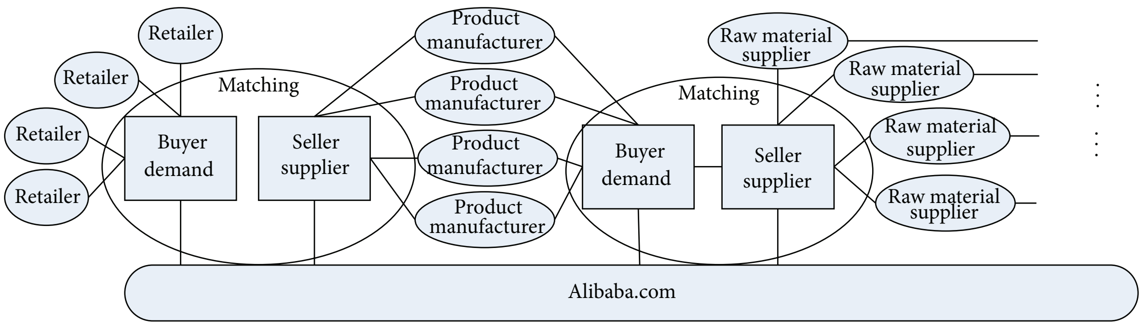


Figure 24: Loose buyer/seller relationship mediated by self-matching efforts.

the companies that were willing to accept the jobs based on their minimum satisfaction requirements. After the local optimization, the simulation system recomposed the suitable single supply chain formations for the global supply chain resource allocations to achieve global optimization and found the allocations with the minimum total cost as the Pareto optimum. As a result, only one can be found. Consequently, the one that is chosen is a new supply chain formation that is formed in the supply mesh and has satisfied all of the criteria, both locally and globally (see Figure 19).

A snapshot of the simulation run that shows the optimal combination is shown in Figure 20. The simulation run took 70,294 ms to calculate the optimal result by brute-force method. The minimum total cost of supply chain formation in terms of resource allocation was MOP5,046,670 (Patacas MOP8 = USD1). The resource allocation results recommend that we should form the following three supply chains on the supply mesh, given the following input parameters:

SC1 = ID19: Order 1 - Factory 3 - Fabric Supplier 3 & Yam Supplier 1

SC2 = ID39: Order 2 - Factory 2 - Fabric Supplier 1 & Yam Supplier 2

SC3 = ID60: Order 3 - Factory 1 - Fabric Supplier 2 & Yam Supplier 3.

Figures 21, 22, and 23 show the resultant supply chains that can be formed on a supply mesh to achieve the optimal results in terms of utilities and costs. The details associated with each participant can also be found in the visualization.

6. Discussion of Application Scenarios for CSET

There are many B2B e-marketplaces, including some such as http://www.Alibaba.com and http://www.globalsources.com, that are favored by many SMEs who signed up as users that do both buying and selling for their businesses. In this type of B2B e-marketplace, thousands of demand/supply relationships are formed (and dismissed) every day. The trading relationships are characterized by the procurement of goods through supply chains that the companies may not even be aware of. The majority of the time is spent in sourcing and browsing for suitable trading partners in the hope of finding the best matches. This type of supply chain formation scenario is loosely coupled; traders may usually be doing spot-buying instead of strategic procurement, and it lacks the grounds for cooperation let alone the optimization of an entire supply chain. Each company in the traditional e-marketplaces tends to be self-centered, operating individually and asynchronically.

Our proposed CSET model, however, can leverage an e-marketplace's potential to new heights, enabling collaboration among the companies that use it as a way to connect. Others have suggested that a supply mesh for a vertical market or some specific industry be created so that suitable candidates can be invited to join as members. Subsequently, agent technology could be deployed in such a supply mesh by implementing the PAs and JIT-CA as discussed in this paper. With all of the infrastructure and control mechanisms in place, the supply mesh administrator or the voting power of the participants can choose that the CSET model operates in any mode that is desired by the participants: pure cost-driven, fully Pareto, Pareto of a certain ratio, and with or without JIT operation.

CSET can effectively transform a pool of potential traders who were initially just concentrating on matching trading partners to fulfill their ad hoc buying/selling needs through integrated dynamic supply chains with all the merits collaboratively provided by CSET. This transformation can be seen in the evolution of the loosely coupled e-marketplace featured in Figure 24 into the properly connected system with collaborating agents shown in Figure 25.

One question that remains is how to apply the CSET model to a large B2B e-marketplace such as http://www.Alibaba.com. Conceptually we argue that it would be feasible to extend the current e-marketplace as a progressive evolution that incorporates CSET in the near future. As Figure 24 shows, the participants are basically doing businesses within the same layer from the perspective of the trading platform where every deal is a trade by itself without any context of supply chain activities. The participants on the same tier are pursuing a best profit for themselves. In Figure 25, however, with CSET the participants are trading as a part of the supply chain based on the cooperation between at least two tiers. Teamwork can be cultivated in the CSET scenario, where any failure in any company on any tier implies that some of the companies downstream will suffer, which will eventually have

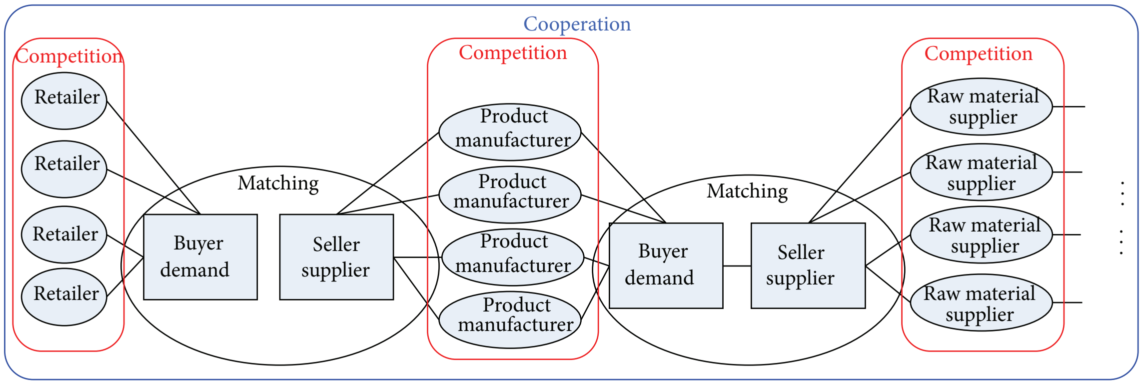


Figure 25: Integrated collaborative supply mesh with CSET features.

an effect on the global supply mesh and the rest of the participants (e.g., receiving fewer or no further orders/leads from a potential retailer if it closes down or leaves the supply mesh).

The CSET model provides an epitome scenario within a cooperative competition e-marketplace. Unlike destructive competition situations, every participant is able to gain a job and a fair level of satisfaction. Although the total cost to keep the fairness balance is not always the lowest, Pareto-optimal resource allocation plays a significant role when seeking a win-win situation. The CSET model is more suitable for forming dynamic supply chains that must keep the participant fellowship and their welfare balanced for certain duration.

The outcome of the CSET model places a stronger emphasis on a win-win situation than on a profit-driven solution. Because it is established at the top of a fairly acceptable satisfaction baseline for every participant, the CSET model's outcome seeks maximum acceptance with minimum total cost allocation. Everyone survived in terms of the allocation. Moreover, good cooperation was established among supply chain participants in long-term businesses.

The CSET model may also suit enterprise business administrations or e-governments that have a number of associated agencies and trading partners. Some global enterprises fulfill their orders through internal departments or subcompanies that form a supply chain within the enterprise. When viewed from a global perspective, each department or subcompany within such enterprises is a component of the enterprise itself and their survival is its prime mission. For this reason, the CSET model may also extend its Pareto-optimal advantages into appropriate enterprise business administration scenarios.

7. Conclusion

This paper proposes a new B2B concept called CSET, which is essentially an agent-based supply chain management (SCM) system. CSET works by utilizing an intelligent agent system in a membership-based e-marketplace consortium known as a supply mesh. The most innovative feature of the proposed CSET model is the integration of the Pareto-optimal algorithm and the JIT principle into an SCM intelligent agent system. Its ability to find Pareto-optimal job allocations means that the resource allocation is preferred by all participants, leading to win-win solutions resulting from the formation of the right supply chains in the supply mesh. Incorporating the JIT principle means that the waiting and information transferring times are significantly shortened. This facilitates the faster and more effective flow of supply chains via pipelining. Furthermore, every company in a supply chain is able to get a job through the proper coordination exercised by the CSET agents.

When viewed from a supply chain evolution perspective, the CSET model is applicable for evolving existing e-marketplaces by equipping them with features that promote the formation of dynamic supply chains and ensure the common welfare of the participants. The optimization of resource allocation insures the costs and growth for both the individual companies in the supply mesh and the supply mesh as a community. No participants will suffer losses, thanks to the Pareto-optimal algorithm in CSET.

To verify the feasibility of the CSET model, a JavaBeans + Java Server Page (JSP) simulator was developed to simulate the supply chain resource allocation as a case study. By simulating different supply chain formation modes, be they cost-driven or Pareto (cooperative or otherwise), we can see that the CSET model does yield better resource allocations that are evidenced by the resultant costs and utilities. The output result shows that the supply chain formation is the most satisfactory for all participants at an acceptable total cost. In a cooperative competition scheme our results show that the CSET model participants have to spend a slightly higher total cost than those under destructive competition, but as long as all of the participants survive, this proves a win-win situation in the long-term. The CSET model is definitively able to obtain the desired balance between welfare and utility.

Abbreviation

$c \in C$: Customer identifier
$m \in M$: Manufacturer identifier
$s \in S$: Raw material supplier identifier.

Parameters

Q_{ij}: The quantity of an entity's order request offered by entity i to entity j

L: The standard location of entity
P: Manufacturer's daily productivity
p_i^j: The price offered by entity i to entity j
ST: The effective time when an order request starts
ET: The expired time when an order request ends
FrT_{ij}: The freight time from place i to place j
DT_c^{sm}: The delivery time of goods to customer c as manufactured by manufacturer m with the raw material from supplier s
WT: Total waiting time
FC: The fixed cost of the manufacturer
MC: The daily manufacture cost of the manufacturer
IC: The daily inventory cost for goods temporal storage
PC: The daily penalty cost of goods' late delivery
FrC_{ij}: The freight cost from place i to place j
C: Total cost
U: Utility of supply chain formation
$\mu \in \{0, 1\}$: If $(\mathrm{ST} - \mathrm{DT}) > 0$, $\mu = 1$; else, $\mu = 0$
$\eta \in \{0, 1\}$: If $(\mathrm{DT} - \mathrm{ET}) > 0$; $\eta = 1$; else, $\eta = 0$.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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References

[1] C. M. Harland, "Supply chain management: relationships, chains and networks," *British Journal of Management*, vol. 7, supplement 1, pp. S63–S80, 1996.

[2] M. Holweg and F. Pil, *The Second Century: Reconnecting Customer and Value Chain Through Build-to-Order*, The MIT Press, London, UK, 2004.

[3] G. Lo and G. E. Kersten, "Negotiation in electronic commerce: integrating negotiation support and software agent technologies," in *Proceedings of 5th Annual Canadian Operational Research Society Conference*, 1999.

[4] R. Buyya, D. Abramson, and J. Giddy, "An economy driven resource management architecture for global computational power grids," in *Proceeding of the International Conference on Parallel and Distributed Processing Techniques and Applications*, 2000.

[5] P. Kropotkin, *To Alter or to Abolish, Chapter 5: All Against All*, Darrell Anderson, New York, NY, USA, 2005.

[6] T. Bui and J. Lee, "Agent-based framework for building decision support systems," *Decision Support Systems*, vol. 25, no. 3, pp. 225–237, 1999.

[7] S. Banker, "The Global, Make-to-Order Supply Chain: Is it Time to Examine Alternative Models?" ARC 3 Allied Drive, Dedham, USA, ARCweb.com.

[8] C. Holsapple, H. Lai, and A. Whinston, "Analysis of negotiation support systems: roots, progress, and needs," *Journal of Computer Information Systems*, vol. 35, no. 3, pp. 2–11, 1995.

[9] C. W. Holsapple, H. Lai, and A. B. Whinston, "Implications of Negotiation Theory for Research and Development of Negotiation Support Systems," *Group Decision and Negotiation*, vol. 6, no. 3, pp. 255–274, 1997.

[10] A. Rangaswamy and G. R. Shell, "Using computers to realize joint gains in negotiations: toward an electronic bargaining table," *Management Science*, vol. 43, no. 8, pp. 1147–1163, 1997.

[11] L. Lim and I. Benbasat, "A theoretical perspective of negotiation support systems," *Journal of Management Information Systems*, vol. 8, no. 4, pp. 27–44, 1992.

[12] H. Li, D. Ahn, and P. C. K. Hung, "Algorithms for automated negotiations and their applications in information privacy," in *Proceedings of the IEEE International Conference on E-Commerce Technology*, pp. 255–262, July 2004.

[13] A. Chavez, P. Maes, and Kasbah, "An agent marketplace for buying and selling goods," in *Proceedings of the 1st International Conference on the Practical Application of Intelligent Agents and Multi-Agent Technology*, 1996.

[14] F. You and I. E. Grossmann, "Optimal design and operational planning of responsive process supply chains," in *Supply Chain Optimization*, 2007.

[15] I.-H. Nam, "Benefit of supply chain coordination," *Seoul Journal of Business*, vol. 9, no. 1, 2003.

[16] J. Tian, R. Foley, X. Yao, and H. Tianfield, "An extended contract net mechanism for dynamic supply chain formation and its application in China petroleum supply chain management," *Multiagent and Grid Systems*, vol. 2, pp. 183–207, 2006.

[17] C. Homburg and C. Schneeweiss, "Negotiations within supply chains," *Computational & Mathematical Organization Theory*, vol. 6, no. 1, pp. 47–59, 2000.

[18] W. Walker, *Supply Chain Flexibility*, vol. 6, Montgomery Research ASCET, London, UK, 2004.

[19] S. K. Hyun, H. C. Jae, R. C. Hyung, H. Soongoo, and H. K. Moo, "Optimal supply chain formation using agent negotiation in a SET model-based make-to-order," in *Proceedings of the 8th International Conference on Electronic Commerce*, pp. 579–583, August 2006.

[20] D. Fudenberg and J. Tirole, *Game Theory*, chapter 1, section 2.4, MIT Press, Cambridge, MA, 1991.

[21] Y. Hang, S. Fong, and Z. Yan, "CSET automated negotiation model for optimal supply chain formation," *World Review of Science, Technology and Sustainable Development*, vol. 7, no. 1-2, pp. 67–78, 2010.

[22] Y. Monden, "Adaptive kanban system helps Toyota maintain just-in-time production," *Industrial Engineering*, vol. 13, no. 5, pp. 11–46, 1981.

[23] J. T. Menberu Lulu, "Black snnual dimulation dymposium srchive," in *Proceedings of the 20th Annual Symposium on Simulation*, pp. 215–228, 1987.

[24] O. K. Hobbs Jr., "Application of JIT techniques in a discrete batch job shop," *Production and Inventory Management Journal*, vol. 35, no. 1, pp. 43–47, 1994.

[25] T. J. Billesbach, "A study of implementation of just-in-time in the United States," *Production and Inventory Management Journal*, vol. 32, no. 3, pp. 1–4, 1991.

[26] C. Temponi and S. Y. Pandya, "Implementation of two JIT elements in small-sized manufacturing firms," *Production and Inventory Management Journal*, vol. 36, no. 3, pp. 23–29, 1995.

[27] R. L. Cook and R. A. Rogowski, "Applying jit principles to continuous process manufacturing supply chains," *Production and Inventory Management Journal*, vol. 37, no. 1, pp. 12–16, 1996.

[28] H. C. Lau and L. Zhang, "A two-level framework for coalition formation via optimization and agent negotiation," in *Proceedings of the IEEE/WIC/ACM international Conference on Intelligent Agent Technology (IAT '04)*, pp. 441–445, IAT. IEEE Computer Society, September 2004.

[29] H. C. Lau, L. Zhang, and C. Liu, "Solving generalized open constraint optimization problem using two-level multi-agent framework," in *Proceedings of the IEEE/WIC/ACM international Conference on intelligent Agent Technology*, pp. 558–564, IAT. IEEE Computer Society, September 2005.

[30] Y. Hang, S. Fong, and Z. Yan, "A double agent-based framework of CSET negotiation model for optimal supply chain formation," in *Proceeding of the International Conference on Information Technology and Applications (ICITA '08)*, pp. 15–20, June 2008.

[31] Y. Hang, S. Fong, and Z. Yan, "Applying pareto-optimal and JIT techniques for supply chains," in *Proceeding of the 8th International Conference on Hybrid Intelligent Systems (HIS '08)*, pp. 308–313, September 2008.

[32] M. Bruce and L. Daly, "Challenges of fashion buying and merchandising," in *Fashion Marketing: Contemporary Issues*, T. Hines and M. Bruce, Eds., pp. 54–69, Elsevier Ltd, Oxford, UK, 2nd edition, 2007.

[33] M. Bruce, L. Daly, and N. Towers, "Lean or agile: a solution for supply chain management in the textiles and clothing industry?" *International Journal of Operations and Production Management*, vol. 24, no. 1-2, pp. 151–170, 2004.