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A COLLABORATIVE MODEL FOR LOGISTICS PROCESS MANAGEMENT

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In this work we present a collaborative model for logistics process management addressing the problem of the integration of activities of a 3rd party logistics (3PL) operator. The scope of a 3PL operator is to achieve a balance between the warehouse and transportation costs and customer service level. In our model we define a collaborative network in which the 3PL operator interacts with subcontractors such as manpower suppliers and transporters, and the relationships are governed by contracts. The model supports a negotiation mechanism among partners and a cooperation system among macro modules in order to find optimal combined logistics and distribution plans. The architecture of the collaborative model is organized in operational modules and elements to support a chain's dynamic execution.

1. INTRODUCTION

Collaborative networks that connect customers and suppliers are creating value by making trading more efficient and possibly even more effective than traditional method. The term collaborative network (CN) was used in (Camarinha-Matos, and Afsarmanesh, 2004) to refer to the complex systems emerging in many forms in different application domains, and consisting of many facets whose proper understanding requires the contribution from multiple disciplines.

Companies focus on their core business and outsource secondary activities to other organizations. The coordination of processes by the customer's organization is difficult because part of the work is executed outside the company's boundaries. Indeed, the outsourced service can be considered as a sub-part of a process initiated in the customer's organization. Thus, the whole process spans the customer and the supplier of the service and could be considered as an inter-organizational workflow that should be defined and managed in order to ensure that it produces the desired level of quality (Stricker et al, 2000).

The traditional workflow approach to business process management involves describing the entire process from a centralised perspective (Jennings et al, 2000).

In order to co-ordinate the relationships among supply chain actors it is important to have integrating techniques at tactical level used in conjunction with

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integration tools at operation level (Perona and Saccani, 2004).

Supply Chain components can provide intelligence and flexibility to supply chain architectures. In (Verwijmeren, 2004) a software component architecture to provide intelligence and flexibility to supply chains is proposed. Supply chain engines are built on top of ERP, WMS and TMS to provide a global inventory management engine. For implementation issues Java Enterprise, CORBA and web service technologies are used.

(Mason et al, 2003) make use of a discrete event simulation model to examine the total cost benefits that can be achieved by suppliers and warehouses, through the increased global visibility provided by an integrated system. Global visibility can be considered as enabler for cost and service efficiency.

Our approach considers a set of agents to perform activities associated with logistics management providing more flexibility than the traditional methods. The agents provide an open system with loosely coupled components and perform common tasks of a 3rd party logistics (3PL) operator such as storage, replenishment, order picking, packing, shipment, etc. Some tasks are outsourced to the collaborative partners (i.e shipping to transporters) or scheduled on basis of availability of manpower supplied by the collaborative partners. The advantages of employing agents include the facilitation of inter and intra organizational cooperation and flexibility in controlling process parameters.

In some situations, it is not always possible to predict in advance all the parameters that may be important for the overall processes. This gives rise to the need of adaptive systems. (Piramuthu, 2005) presents a theoretical framework for dynamic formation and reconfiguration of supply chains.

In this work we present a collaborative model for logistics management addressing the problem of the integration of activities of a 3PL operator. The goal of a 3PL operator is to achieve a balance between the warehouse and transportation costs and customer service level.

In our model we define a collaborative network in which the 3PL operator interacts with manpower suppliers and transporters. The model supports cooperation between Warehouse Management System (WMS) and Transportation Management System (TMS) in order to find optimal combined logistics and distribution plans. The benefit of using this approach can be that better coordinated inter-organizational processes would cost less while decreasing inefficiencies and improve overall quality. The internal (flow of works among WMS and TMS) and external (flow of works with manpower suppliers and transporters) costs can be reduced and the quality of the services provided can be increased due a better planning.

The paper is organized as follows. In Section 2 we describe the logistics scenario, and the relationships among the existing partners. In Section 3 the proposed multiagent model is overviewed. In Section 4, we suggest how the actors should collaborate in order to reduce the logistics activities inefficiencies. Finally in Section 5 conclusions and future work is discussed.

2. THE LOGISTICS SCENARIO

The 3rd Party Logistics Operators (3PL) respond to the need of business operators (1st layer) and logistics operators (2nd layer operator – 2PL) to optimise the supply-chain performance by subcontracting operational tasks such as transport or warehousing to second-tier suppliers; screening, selecting and contracting the latter, and monitoring and evaluating their performance. A 3PL thus orchestrates supply chains.

To fulfil its role, the 3PL establish a business network driven by contracts and information systems. The most important information systems used by the 3PL are the Transportation Management System (TMS) and the Warehouse Management System (WMS). TMS is basically an Information System used to plan shipments. TMS solutions automate the entire shipping process of a company, from carrier selection to routing and scheduling. WMS is basically a software system to track and manage warehouse activities.

Once the logistics network is designed, the customer sends both shipping orders and storage orders to the 3PL. The 3PL forwards the orders to the *Warehouse Manager* and the *Transportation Manager* who build the operation plan outsourcing some activities to the 2PL operators (i.e. manpower and transportation suppliers). This step is fulfilled in two possible ways: by first solving the transportation problem, then by solving the warehousing operations problem or vice versa. Possible conflicts in the two plans are resolved mostly by phone.

We can now introduce the actors in our business model and explain their roles. Figure 1, illustrates the structure of the business model and the interactions among the actors. In particular, the 3PL operator can be represented as the *Contract Manager* (*CM*), the *Warehouse Manager* (*WM*), the *Transportation Manager* (*TM*), and the *Logistics Manager* (*LM*). The three decision makers interact with other partners of the logistics network and in particular with the *Transportation Suppliers*, the *Manpower Suppliers*, and the *Customer* (representing the 1st layer of the business model).

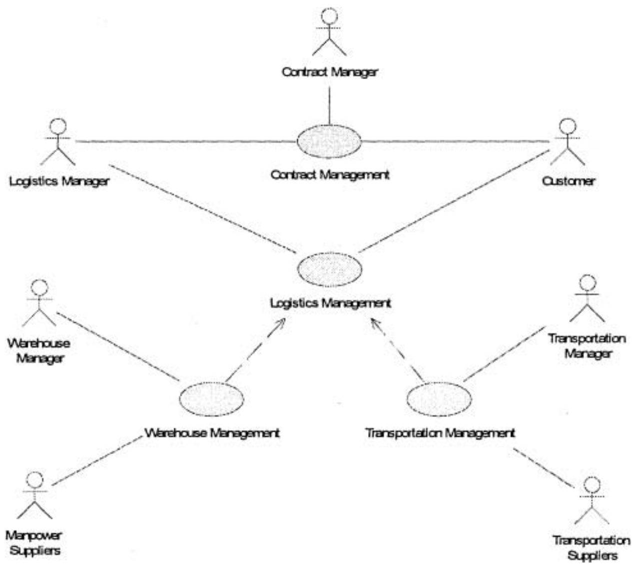

Figure 1 – The business model UML diagram

The actor interactions can be classified under three levels:

Strategic level. In this level the contract manager *CM* starts a contract with the customer, builds up the network and select the 2PL partners and internal resources to execute the business.

Planning level. At the planning level the actors interact defining their resources to fulfil orders. In this phase the WMS and the TMS are used in cascade. The interactions are mostly unidirectional. In this phase a planning flow can be individualised. At each step a subset of resources are booked and constraints are fixed for other resources.

Operation level. At operation level the interaction among actors is guided by process execution. The information and physical flows specify the sequence of interaction among partners.

3. THE MULTIAGENT COLLABORATIVE NETWORK

The mentioned interaction approach has some gaps. In particular one of the most important is the lack of flexibility in business planning and execution. The planning of resource allocation in cascade from WMS to TMS or from TMS to WMS in particular can result in inefficiency for the entire network. The research project PILOT-ICT (new integrated logistics framework based on ICT and distributed decision systems), partially founded by the Italian Ministry of Education University and Research - MIUR under the national law FAR n. 297/1999 - intends to undertake the development of a multiagent system for collaborative WMS and TMS integration.

Multiagent Systems have a successful application in supply chain integration (Nissen, 2001). In (Ito and Abadi, 2002), multiagent systems are used for warehouse system management. In this paper we present the multiagent model as a collaborative model for supply chain partners. Collaboration is the most important form of cooperation in multiagent systems. Collaboration means that a group of agents work together on a common project or task (Shen, Norrie, and Barthès, 2001). In the ongoing project the multiagent approach intends to achieve the following goals:

Flexibility: The whole system and each agent of the system are adaptive. By means of negotiation they can share information about resource allocations, times and costs. Through adaptive behaviour the agents are able to modify dynamically the behaviour in function of unforeseen situations. To assure predictable behaviour to agents a constraints system has to be defined (Spears, 2006). We use a mechanism of upper and lower bounds to key performance indicators (KPI) is considered. During strategic interactions, bounds to KPI are fixed whilst during planning KPI levels are allocated to agents by negotiation. The agents keep track of the history of KPI levels..

Modularity: One of the gaps of the classical systems is that they are build up around a problem instance; the solutions to the problems are indeed very difficulty to apply to other systems. Often the 3PL has to build up information systems for each customer. The considered model is designed to be implemented around decision modules on which the system's agents are built up. These modules (for strategic planning, warehouse optimisation, distribution scheduling, and performance evaluation) will have a high degree of modularity. The need for flexibility and adaptability implies an important trade-off between modularity and integration (Lakatta et al, 2004).

Effectiveness: Agents have the ability to share a set of alternative plans. A strategic plan agent (the *Logistics Manager* agent) will build a general plan over the received plans, resolving the plan constraints violations by means of negotiations. Each partner of the logistics network can indeed propose a set of plan alternatives and it is not forced anymore to build up its plan based on fixed plans of other partners. This will result in a higher degree of performance for the entire supply chain. The KPI are a measure of Service Level, cost of the activities, time, and productivity for each sub process.

The actor interactions under the three levels can be reformulated as following:

Strategic level. During the contract management phase the *Contract Manager* agent interacts with the *Logistics Manager* agent and fixes the bounds for the KPI; in this phase the *Contract Manager* and the *Logistics Manager* also establish the correspondence among sets of KPI intervals (or bounds) and collaborative sub networks of 2PL operators able to meet those intervals.

Planning level. As explained in detail in the next section, the planning level is performed through the following steps: once the order details (related to outbound logistics or incoming logistics, e.g shipment or storage orders) are received from customers the logistics manager starts a collaborative negotiation asking alternative plans to *Warehouse Manager* and *Transportation Manager* agents. Using their knowledge base the two agents can fix upper an lower bounds of KPI that are able to respect for different plan alternatives (also interacting with the 2PL operators *Transportation Suppliers* and *Manpower Suppliers*). An iteration to resolve conflicts and ask for extra resources may be needed. After the resource allocation the agents, using optimization algorithms embedded in the information systems modules, compute the detailed operation plan and update their knowledge of resource allocation and performances. We assume that an agreement is always found.

Operation level. At the operation level the interaction among actors is guided by process execution. During the execution, agents adapt their knowledge about KPI parameters and resource allocation confronting foreseen plans with real performances.

4. THE PLANNING SCHEMA

Once the order details are received from the customer, the Logistics Manager Agent (LMA) groups orders using a selection method based on a function of the features of the order such as type, constraints, priority, etc. Then, for each order batch it selects the needed resources to execute the required activities. The LMA communicates with Warehouse Manager and Transportation Manager Agents (WMA and TMA respectively) so that they may produce consistent and feasible plans with maximum profit. To do so, the LMA provides case-base and contextual information to the WMA and TMA. In particular, on the basis of historical data, the LMA defines a set of bounds *BS* (e.g. time constraints, level service bounds, priority, etc) that WMA and TMA have to follow for each order.

The LMA sends the order batch details with the relative *BS* to WMA and TMA.

These manager agents select the needed activities to order batch fulfillment and define which of them outsource.

In the first step, the outsourcer (WMA and TMA) prepares the requests for the execution of the activities that he wants to outsource and define the searching criteria that needed to be used to find the convenient suppliers (manpower suppliers and transporters respectively). Given a list of supplier candidates, a preliminary screening is carried out to determine which potential supplier appears to be qualified to execute the required activities and/or services. The decision maker should take into account the degree of successes in past executions operated by the bidding suppliers to ensure quality in the outsourcing operation.

After this step, the outsourcer broadcasts its requests to every selected supplier. To increase the rate of successful contracts, each supplier determines a set of offers that maximizes own profit and presents it to the outsourcer. Until the best offer is selected, whole offers are stored in a working memory of the outsourcer.

The WMA and TMA select the optimal set of offers covering all orders and compose and schedule the workflow of the required activities feasibly with the available resources. They initiate a simulation of this workflow with the appropriate details to evaluate the performance and then produce operation plans (WP and TP respectively).

The LMA receives the plans from WMA and TMA and check their feasibility. If the plans are inconsistent the LMA starts a negotiating process.

Here is the logic outline for the negotiating algorithm of the LMA:

Get the order batch OB to fulfill
Set $i = 0$
Calculate BS_i *related to OB*
Repeat
    Broadcast OB and BS to the WMA and TMA
    Receive the plans WP and TP from WMA and TMA respectively
    Detect conflicts in WP and TP
    Redefine the BS to resolve detected conflicts
    $i = i + 1$
Until BS_i *is equal to* BS_{i-1}
Inform WMA and TMA that equilibrium has been reached.

After each iteration the BS is redefined and become more constricted allowing WMA and TMA to produce plans more convergent to reach an equilibrium.

Once the plans WP and TP are received, the LMA detects conflicts and ask new plans for a better convergence to WMA and TMA modifying the BS. Based on its own set of offers received by suppliers, WMA and TMA may send a new plan satisfying the new BS or not. If not WMA and TMA can restart the outsourcing phase. Once conflicts are resolved, the LMA closes the negotiation and validates the plans WP and TP.

4.1 Technological architecture

Architecturally, there are many styles and approaches to implement collaboration. The web has already become the communication infrastructure not only for people to people but also for application to application. The programmatic interfaces made available are referred to as Web services (Buhler, 2004). They are aimed at using XML to build distributed information processing systems that work across the Internet. Web services are now increasing in sophistication. Specifications for quality of service and service composition such as BPEL for Web Services (BPELWS) currently authored by IBM, Microsoft and BEA, WS-Coordination, WS-Transaction, WS-Security, WS-Reliable Messaging, and WS-Policy will allow for far richer, higher-level delivery of computing services via a web services management platform (WSMP).

While initial implementation of web services may be simple, over time business-to-business integrations will become complex. Business process integration may be aided by the increased adoption of BPEL or other standards such as business process management (BPM) for web services flow composition (Smith, et al, 2003).

We propose that the 3PL operator can make use of a composition of the Web Services. Each process to fulfilment of an order batch can be decomposed into a set of workflow managed by WMS and TMS. In the planning level required activities are defined and business objects are handled to compose the workflow. Then a workflow engine instantiates the workflow process specifications.

In this scenario also the outsourcing communication between WMA and TMA pass through Web Services. A two-level mechanism for selection of suppliers is used to configure a new business process that consists of a set of Web services. In order to narrow down the available suppliers list, at the first-level suppliers are selected by a Web Services discovery engine, whose search criteria are created automatically by the requirement document. In order to construct the best business process, at the second-level suppliers are selected in accordance with a global optimization algorithm.

Similarly for the negotiation phase it is possible to use the web service technology. In order to address these issues (Kim, 2003) proposed a framework for negotiation automation system. The framework leverages the scope of existing research on the negotiations and extends it to the level of complexity necessary for next generation eBusiness applications.

5. CONCLUSION

In this work we presented a multiagent model to undertake facilitation of inter and intra organizational cooperation, flexibility and effectiveness. In the proposed model the 3PL forwards orders received from customer to the Warehouse Manager and the Transportation Manager who build the operation plan outsourcing some activities to the 2PL operators. Furthermore we suggest how the actors should collaborate in order to reduce the logistics activities inefficiencies. Further developments will investigate the use of auction mechanisms to solve the planning problem. We have already implemented most of the optimisation modules and we are working on framework integration and on the simulation of the proposed collaborative multiagent model.

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