AML Modeling of Trust in Supply Chain Management

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ABSTRACT: *Agent Modeling Language (AML) is a semiformal visual modeling language for specifying, modeling and documenting systems in terms of concepts drawn from Multi Agent Modeling (MAS) theory. Supply chain management (SCM) is the management of network of interconnected business which spans all movements of services and goods from the point of origin to the point of consumption. In SCM, Trust modeling is an important and crucial aspect from the perspective of sustainability of the supply chain and efficient performance in business. In the supply chain, the more we trust, the more we exchange information on demand and on forecast of the last customer so as with the level of stock and on the forecast of the suppliers. In this work, we attempted to model the Trust in SCM using AML and proposed a MAS SCM model of trust in supply chain management. The proposed model is implemented using JADE and the simulation results demonstrated the impact of trust in supply chain along with the evolution of trust.*

KEYWORDS: *AML, SCM, MAS, Trust Model, JADE*

1 INTRODUCTION

With the globalization of markets, rapid development of technology, and the shortening life cycle of products, the importance of supply chain management has become more and more pronounced and goal centric. In a broad sense, a supply chain is a value-creating network consisting of suppliers, warehouses, manufacturers, wholesalers, and retailers through which material and products are acquired, transformed, and delivered to consumers in markets. In this entire scenario, the most difficult but critical issue is to improve the efficiency of supply chains in the perspective of the whole supply chain, not in the perspective of individual companies.

In order to sustain the supply chain in virtual organization form, trust has been identified as one of the ingredient. The general finding suggest that trust act as a buffer to facilitate the agreement and execution of transactions in the context of the virtual organization in the supply chain scenario. Trust fosters the willingness to cooperate and reduce the transaction costs, which in turn increase the value from virtual organization form (Kasper *et al.*, 2001). Trust is also a vital component contributing to conflict resolution, global goal setting, and creation of shared values (Jarvenpaa *et al.*, 2000). Trust involves within the interdisciplinary fields, including philosophy, computer science, economics and organizational behavior (Kasper *et al.*, 2001). Incorporating trust into the supply chain requires synthesis of human science representation of trust in the computation model.

For the simulation of the supply chain based business model, multi-agent technology is increasingly regarded as a good solution. The features of multi-agent technology such as autonomy, distributed collaboration, and intelligence naturally fit well with the characteristics of supply chain management where geographically dispersed companies should collaborate with each other without central control. Besides, the agent systems possess the ability to form flexible collaboration networks through contract or negotiation which is helpful for dynamic supply chain configuration.

On the other hand, Agent Modeling Language (AML) is a new approach to model systems comprised of interacting autonomous agents. AML promises to have far-reaching effects on the modeling of multi agent system and thereafter implementation.

This research work is a joint effort of social and computer sciences toward the understanding of trust in supply chains. More precisely, we aim to understand the strengthening or weakening of trust as well as the effect on the performance of SC. The goal of this paper is to propose an AML model for modeling and simulation of trust in supply chains through transformation of trust model in MAS. Specifically, this paper uses Java agent development environment (JADE) which has been the most successful foundation for intelligent physical agents (FIPA)-compliant multi-agent platform for research and commercial purposes. The system is implemented using JADE and tested for different levels of trust in supply chain and performance along with the evolution of trust has been experimented.

This paper is organized as follows: Section 2 reviews related research on the issues of supply chain management and trust. Section 3 introduces AML modeling and MAS. Section 4 presents the proposed AML trust model of supply chain and prototype implementation and simulation experiments are illustrated in Section 5. Section 6 gives discussion and conclusion.

2 SUPPLY CHAIN MANAGEMENT AND TRUST

Supply chain is a composition of network of suppliers, factories, warehouses, distribution centers, and retailers which synthesizes and integrates the movement of goods between suppliers, manufacturers, distributors, retailers and customers (Nagurney et al., 2003) and through which raw materials are acquired, transformed, and delivered to customers (Fox *et al.*, 2000), (Nefaoui *et al.*, 2008). This entirely covers the full range of activities from the earliest level of incoming raw materials through the internal processes in an industry and on to the outgoing products through the distribution and marketing channels. As a consequence, supply chain is the planned continuous improvement of processes and relationships that exists to support the movement of these products and services to enable the chain to evolve.

On the other hand, trust component is considered as outcome of information sharing in the supply chain network. The information sharing has always been considered to be beneficial in a supply chain since this helps the management of flawless chain activities. Lee and colleagues (Larzelere *et al.*, 1980) were the first to identify that the information asymmetry is the main reason for the amplification of the demand signal and fluctuation of inventory level along a supply chain. This phenomenon which is called the “bullwhip effect” has been extensively analyzed (Cachon *et al.*, 2004) to comprehend on the research issues. Besides, the information sharing can also yield to other advantages such as reducing costs, improving service levels, and reducing lead times and stock outs (Anderson *et al.*, 1992). The quantity of data exchanged in the supply chain is not as important as the quality to generate the highest benefits and performance in the supply chain (Premkumar, 2000).

There are many scales which exist for measuring trust in the management literature as pointed out by Morgan and Hunt (Morgan and Hunt, 1994), by Larzerele and Huston (Larzelere *et al.*, 1980), Swan, Trawick and Silva (Swan *et al.,* 1985), Swan, Trawick, Rink and Roberts (Swan *et al.*, 1988), and Shurr and Ozanne (Schurr *et al.*, 1985). As per the above scales, the "trust" refers to the reliability and belief in something and that "trust" means the trust and honesty to an individual. In another reference Guibert (Guibert, 1996) which adapts its precise scales in the French context, and extracts information on honesty and loyalty, confidence and trust in your relationship with your supplier based on proposed scales.

2.1 The Proposed Trust Model

Based on a critical review of literatures and on a qualitative survey of supply chain management, we figured out different criteria of the trust as: 1 - Honesty (ex: the supplier's compliance with contract); 2 - Credibility (ex: the supplier always keeps its commitments); 3 - Experience (ex: the supplier is aware of good practices and has the knowledge necessary to meet my needs); 4 - Jurisdiction (ex: the advice we give our partner we are useful.); 5 - Sincerity (ex: the supplier is frank and honest); 6 - Predictability (ex: the supplier has no opportunistic behavior); 7 -Transparency (ex: what we shared provider of comprehensive information on its processes); 8 - Goodwill (ex: the supplier is prepared to take extraordinary measures to respond as appropriate to our needs); 9 - Commitment (ex: the supplier invests in the relationship); 10 - Respect the confidentiality of information exchanged (ex: the provider respects the confidentiality of information that I provide it); 11 -Communication skills (ex: the supplier meets our needs through effective communication); 12 - Shared values (ex: suppliers that share the same moral values as us);13 - Similarity (ex: the supplier and we belong to the same network); 14 -Sharing working methods (ex: the supplier and we agreed on all processes that are common or individual); 15 - Influence in the network (ex: the supplier is recognized in the work network); 16 -Sharing information, type of information shared

The trust behaviour is calculated based on weighted average of all the defining criteria as shown in equation 1.

$$Cc = (\alpha.Ho + \beta.Cr + \gamma.Ex + \delta.Co + \varepsilon.S + \zeta.Pr + \eta.T + \theta.Bv + \iota.En + \kappa.Rp + \lambda.Ha + \mu.Pv + \nu.Rs + \xi.Pt + o.I) / (\alpha + \beta + \gamma + \delta + \varepsilon + \zeta + \eta + \theta + \iota + \kappa + \lambda + \mu + \nu + \xi + o) \quad (1)$$

where Cc = Trust Behavior; Ho = Honesty; Cr = Credibility; Ex = Experiment; Co = Competence; S = Sincerity; Pr = Predictability; T = Transparency; Bv = Goodwill; In = Commitment; Rs = Respect the confidentiality of information exchanged; Ha Communication skills; Pv = shared values; Rs = Resemblance; Pt = Sharing working methods; I = Influence in the network. In this research we considered for simplicity all the coefficients are identical and equal to 1.

The calculation of trust behaviour Cc is associated with the level of trust in three different levels. The value of Cc between 0 and 0.5 is classified as ‘Non-Trust’, between 05. and 1.5 is classified ‘Moderate’ and between 1.5 and 2.0 is classified ‘Trust’. Since the trust behaviour within the supply chain network is influenced by multiple-party engagements and thereafter the evolution of trust naturally requires modelling using multi agent systems to represent these multi-party engagements.

3 MAS AND AML MODELING

The Multi-agent systems (MAS) bring the real life essence of models in decision making while several decision makers interact in a particular business process. An agent may be defined as an autonomous program which is reactive, proactive and has social abilities (Wooldridge, 2002) from the characteristics point of view. The important characteristic is the social abilities of agents having beliefs about other agents and thus trusts as the end results. As a reality, an important ingredient for multi-agent systems interaction is trust. As per the review of Ramchurn and colleagues (Ramchurn *et al.*, 2004) on trust in multi-agent systems show that the purpose of trust is to minimise the uncertainty in interactions.

On the other hand, intelligent agents and MAS are an evolving paradigm of software system development. These are applied in a broad and increasing variety of applications (Chaib-draa *et al.*, 2001), (Chaib-draa, 1995) and in many different combinations. The term "agent" denotes a hardware or more usually software-based intelligent computer system, that has the following characteristics (Wooldridge *et al.*, 1995):

Autonomy: agents operate without the direct intervention of humans or others, and has some kind of control over its actions and internal state; *Social ability*: agents interact with other agents (and possibly humans) via some kind of agent-communication language; *Reactivity*: agents perceive their environment, (which may be the physical world, a user, a collection of other agents, the Internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it; *Proactiveness*: agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking the initiative. Jennings (Jennings, 2000) pointed out in his research that the flexible, high-level interactions of agents make the engineering of complex systems easier. This author indicates that complex systems are always distributed, and from this point of view, agent decomposition is very important to manage complexity.

During the past several years, methodologies and graphical modeling languages have been widely used by the designers in order to design systems, software and components. UML (Booch *et al.*, 1999) is certainly the best known graphical modeling language amongst. During these years, multiagent system designers have the same possibility with some modeling languages like Agent UML (Odell *et al.*, 2000), (Bauer *et al.*, 2000). Agent UML is based on UML and now particularly known as AML. As Odell and Bauer quoted it, it is not possible to directly use UML since several differences exist between agents and objects like the autonomy or the ability to cooperate (Jennings *et al.*, 2000). Even though, it seems to be important to capitalize on the skills of designers. Multiagent system designers are often software engineers who use UML (FIPA, 2005).

At the same time, software agents have some core and additional characteristics such as autonomy, proactivity, situatedness, interactivity, adaptability, learning, reasoning and mobility (Garcia *et al.*, 2004) as outlined in this section earlier. The most well-represented characteristic is interactivity because AUML emphasizes too much Interaction Protocols. Adaptability and situatedness can be noticed while looking at Statecharts and Activity Diagrams: an agent may realize and change its plans if another delivered a message that affects the "environment state". On the other hand, concurrent threads of interaction in Sequence Diagrams may represent that an agent is able to choose an action, showing a certain level of reasoning.

4 PROPOSED AML MODEL OF TRUST

This section presents an issue for modelling the dynamic behaviour of the proposed SC Trust model. Our aim is to design an efficient tool of simulation which can be applied to evaluate the global performance of the chain based on the trust behaviours of its actors. The link between trust and performance will be obtained via the level and the quality of the information sharing. For that, we first implemented within the agents the trust variables and behaviours, and then we defined some strategic policies to simulate different relationships between the actors of the SC.

We introduced the Trust agent and used this agent in multi-agent systems to model SC in which trust impacts and is impacted by the performance of the companies. The trust agent with cyclic behaviour interacted with different agents within the proposed model. To shift from the proposed trust model to an agents-based model we started with the modelling of each actor of the supply chain (central company, customers and suppliers). To represent the three main functions of the company (source, make and deliver) and consider the control processes in the supply chain and its environment, each actor is modelled by different agents in line with the trust model as outlined in the section 2.1. The TrustModelAgent implements the trust criteria with all the trust parameters and a cyclic behaviour for the collaboration with other agents to determine the level of the behaviour trust. All these agents are implemented using a JADE framework.

Agent Modeling Language (AML) class diagram is used to depict the relationships between different agents and the TrustAgent which carries attributes, operations, roles, protocols, etc for the simulation of trust in supply chain as shown in Figure 1.

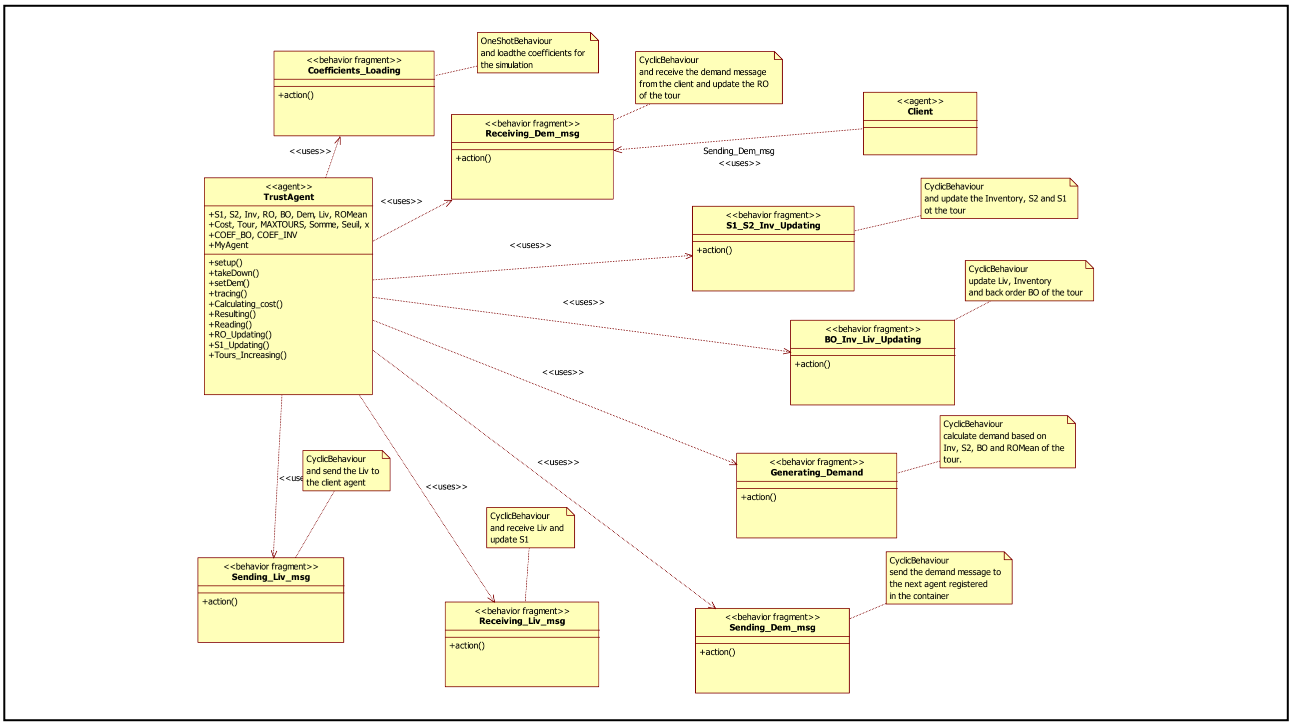

Figure 1: The AML State diagram of TrustAgent with the different agents

As seen from the Figure 1, in the AML state diagram, the TrustAgent is interacting with agents for coefficient loading which implements one shot behaviour and creates the initial environment for the simulation to run. Among the cyclic behaviour, the agents that directly interact with the TrustAgents are: Receiving_Dem_Msg which receives the demand message and do the necessary update of the return order of the tour; S1_S2_Inv_Updating which updates the inventory and stocks during the simulation; BO_Inv_Liv_Updating which updates the inventory as well as the back order based on the demand pictures in successive runs; Generating_Demand which calculates demand based on the inventory, stock, backorder and average return order scenario of simulation runs.

Besides the other cyclic behaviours are: Sending_Dem_Msg which send the demand message based on the trust values; Sending_Liv_msg which send the ultimate order and Receiving_Liv_msg which receive the delivered order and update the stock.

In this agent based decision-making process of the SCM, the different agents collaborate and decide on the demand generation based on level of behaviour trust. The demand generation strategy allowed the agent to choose the most appropriate demand based on the level of trust. As the communication language used by the agents to exchange their knowledge and information during the negotiation, the FIPA-ACL language is used in this application.

5 SIMULATION AND RESULTS

To validate the multi-agent trust simulation model, we proposed an interactive supply chain scenario (see figure 2). The MAS model of this scenario employs four supply chain specific agents: Retailer, Wholesaler, Distributor and Factory, and two other agents: Client and TrustAgent.

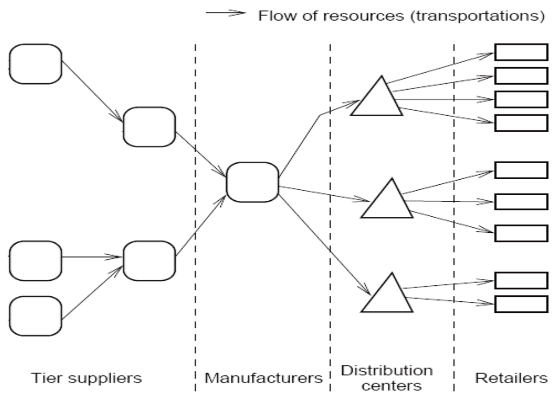

Figure 2: Experimental Supply Chain for Trust Simulation

The Figure 2 illustrates the simple supply chain which is implemented using SupplierAgent for the tier suppliers and manufacturers; the distribution center is represented by WholeSalerAgent and DistributorAgent along with the RetailerAgent.

In this simulated test scenario, each actor in the supply chain (other than the final customer) decides on the demand generation based on their respective inventory, virtual stock, backlog and the demand of the run. The demand level is based on the week and for effective demand level calculation, we compared the backlog of the successive weeks.

We conducted multiple rounds of experiments using our simulation model and in all the rounds, we tested supply chain performance under deterministic demand as set up in the proposed SC model based on the demand characteristics of the customer.

In the first round of experiment, we assign *a behaviour of non-trust* between the companies, and as a result, there is no communication and information sharing between them, excepting the orders from the customers to their supplier. In the second round of experiment, the "behaviour of trust" is moderate ($0.5 \leq Cc < 1.5$), which means that the companies share not only the orders, but also information about their stocks as the levels of stock are sent by the suppliers to their customers. In the third scenario of experiment, we assign a "behaviour of trust" between the participants ($1.5 \leq Cc < 2$); so in this case, the companies share the orders, the levels of stocks, and reduce the delay of information sharing e.g. from one week to real time by using integrated information systems as we simulate the fact that the companies connect their ERP's for example, so they have in real time the information about the orders sent by their customer.

Simulation Scenario 1: The goal of the first simulation scenario is to test the performance of SC in the worst case of collaboration; after calculation by the agents, the behaviour of trust in this case is "no-trust" between the companies involved in the supply chain. The results of the simulation as shown in Figure 3 demonstrate that the generated demand is increasing from the first agent to the last one, even if the demand of the final customer is not changing (average 7.657).

Agent	Avg Demand
Customer	7.657
Warehouse	7.914
Distributor	12.686
Retailer	17.029

Table 1: Scenario 1: average demand variation

The average demand generated by different agents after the first simulation scenario is shown in the Table 1. This table indicates the different demand variations across different agents within the simulation environment.

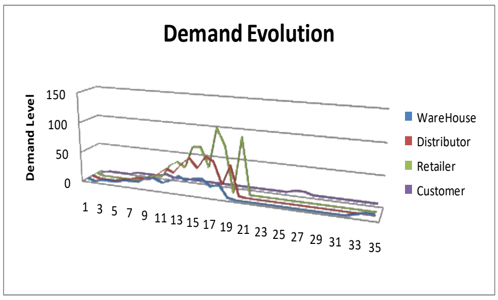

Figure 3: Scenario1: the generated demand evolution

This simulation scenario illustrates the proposed multi-agent simulation model for the non-trust behaviour.

Simulation Scenario 2: In the second case of simulation experiments, we worked with the case of a moderate "behaviour of trust"; the *TrustModel* Agent calculates the behaviours of trust based on the trust criteria, the results for the agents of the SC are in the interval: $0.5 \leq Cc < 1.5$; In this case, we simulate few information sharing; the companies share not only the orders, but also information about their stocks. The different agents collaborate and use this new information to generate the demand of the week knowing the exact level of the stock of their suppliers to optimize the value of the generated demand.

The results of the simulation are shown in Figure 4 and we observe that the performance is better than in the first scenario. The quantities are decreasing in this scenario (see table 2) because of the information sharing between the agents of the SC.

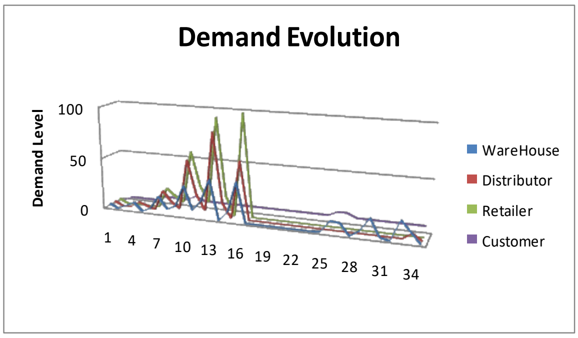

Figure 4: Scenario2*:* the generated demand evolution

Simulation Scenario 3: In the third round of experiments with a good behaviour of trust, the partners of the SC are allowed to collaborate. The companies share the orders and reduce the delay of information sharing as if they have in real time the information about the orders sent by their customers. The result of the simulation is shown in Figure 5.

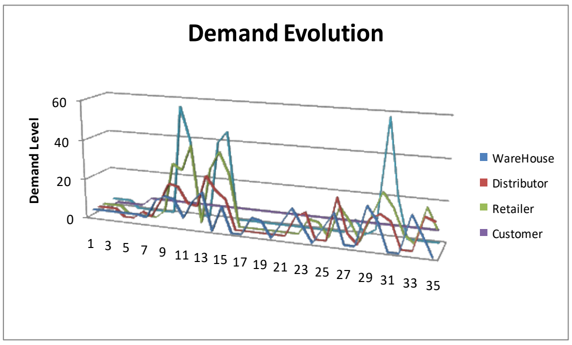

Figure 5: Scenario3: the generated demand evolution

Reducing the delay of the information flow let the agents to better react to the SC demand variation. As can be seen from the evolution of the demand characteristics based on the simulation experiments, the average demand level is decreasing while the maximum demand fulfilment is increasing at different actors for different scenarios of trust levels. These results illustrate the behaviour of trust between the partners. The summary of the results of the experiments are shown in Table 2.

	Warehouse			Distributor			Retailer			Customer		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Scenario 1	7.9	0.0	28.0	12.7	0.0	60.0	17.0	0.0	100.0	7.7	0.0	12.0
Scenario 2	7.8	0.0	39.0	8.1	0.0	82.0	10.1	0.0	101.0	7.7	0.0	12.0
Scenario 3	6.5	0.0	43.0	7.2	0.0	94.0	9.1	0.0	105.0	7.7	0.0	12.0

Table 2: Overview of experimental results for demand evolution

Based on the first analysis of these results, in this SC model case study, the different delays of the information and physical flows do not allow the partners of the supply chain to be reactive. In fact, anticipation of the ordering process does not really change the performance of their company because of the delay. We have observed that a reduction of the delay of the information flow (from 1 week to real time) increased the global performance of the chain. The level of trust impacted directly the level and the quality of information sharing, which improved the performance of the companies by reducing the delay and let them anticipate the variation of the market demands as well.

6 CONCLUSION

In this work, we have proposed an AML model of trust in supply chain. Through different trust scenario we have validated the trust simulation model on the case study which is an example of supply chain management from the point of view of academic research. We also have reported multiple rounds of simulation experiments conducted using this simulation model. We tested different scenarios, focusing on the “behaviours of trust” of the agents in the supply chain; the first analysis of the results is that, in a supply chain, the level of trust impact directly the level and the quality of information sharing, which improve the performance of the companies by reducing the delay and let the companies anticipate the variation of the market demands.

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