

# Effect of Trust Model in Supply Chain Management

Hossain. Syed Akhter and Ouzrout. Yacine

**Abstract**— Effect of trust in supply chain management (SCM) plays crucial role since the management of network having interconnected business nodes which spans all movements of services and goods from the point of origin to the point of consumption through chaining the services within the network. On the other hand Trust modeling is an important and crucial aspect from the perspective of sustainability of the supply chain and to gain efficient performance of the network. 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 experiment the effect of trust through a proposed trust model for SCM using Agent Modeling Language (AML) and implemented using Multi Agent System (MAS). The proposed model is implemented using Java Agent Development Environment (JADE) and the simulation results demonstrated the effect of trust in supply chain along with the evolution of trust.

**Keywords**— Supply Chain, SCM, MAS, Trust Model, JADE

## I. INTRODUCTION

THE globalization of markets, rapid development of technology, and the shortening life cycle of products with the importance of supply chain management has become more and more pronounced and goal centric. 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 a 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 [1]. Trust is also a vital component contributing to conflict resolution, global goal setting, and

creation of shared values [2]. Trust involves within the interdisciplinary fields, including philosophy, computer science, economics and organizational behavior [1]. 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. This research 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 II reviews related research on the issues of supply chain management and trust. Section III introduces AML modeling and MAS. Section IV presents the proposed AML trust model of supply chain and prototype implementation and simulation experiments are illustrated in Section V. Section VI gives discussion and conclusion.

## II. SUPPLY CHAIN MANAGEMENT AND TRUST

A supply chain is defined as a network of suppliers, factories, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed, and delivered to customers [3], [4]. The supply chain covers the full range of activities from the earliest level of incoming raw

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materials through the internal processes in an industry and on to the outgoing products through the distribution and marketing channels. Therefore, supply chain is the planned continuous improvement of processes and relationships that exist to support the movement of these products and services through the supply chain.

Trust is considered as a necessary antecedent of information sharing in a supply chain. Information sharing has always been considered to be beneficial in a supply chain. Lee and colleagues [5] were the first to identify information asymmetry as the main reason for the amplification of the demand signal and fluctuation of inventory level along a supply chain. This phenomenon, called the “bullwhip effect” has been extensively analyzed [6]. Information sharing can also yield to other advantages such as reducing costs, improving service levels, and reducing lead times and stock outs [7]. However, it not the quantity of data exchanged in the supply chain that is most important but its quality to generate the highest benefits and performance in the supply chain [8].

Many scales exist for measuring trust in the management literature. Morgan and Hunt [9] for example, use the scale dyadic Larzerele and Huston [10] scale that includes the major facets of trust (reliability, integrity, strong belief). Swan, Trawick and Silva [11], Swan, Trawick, Rink and Roberts [12], and Shurr and Ozanne [13] also established scales, designed primarily to measure the trust of the Purchasing Manager to the seller. These scales are mainly Anglo-Saxon with a difference made between "trust" and "trust". It is possible to write that "trust" refers to the reliability and belief in something and that "trust" means the trust and honesty to an individual. Guibert [14] and adapts its precise scales in the French context, and obtains information on honesty and loyalty, confidence and trust in the relationship with the supplier.

A. Proposed Trust Model

Based on the literature survey and from a critical review of literatures of a qualitative survey of supply chain management, we figured out different variables (or criteria) of the trust as the following:

- 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 is provided);
- 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) -Sharing information, type of information shared.

The trust is a weighted average of all the defining criteria as shown in equation (1).

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

However, mobilized the literature does not attempt to define precisely the weights of each criterion. It is true, a priori, each individual or entity has its own scale of values against the various criteria components of trust, i.e, the weight each set of weights for each criterion. In this research we consider that overall (alpha omicron) is a priori identical and equal to 1. In our present research behaviour representing the trust is expressed as follows:

$$C_c = (Ho + Cr + Ex + Co + S + Pr + T + Bv + En + Rp + Ha + Pv + Rs + Pt + I) / 15 \quad (2)$$

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

Based on the calculation of trust behaviour Cc, the level of trust is classified in the proposed scale as shown in the Fig. 1 and relate to a phenomenon of sharing information.

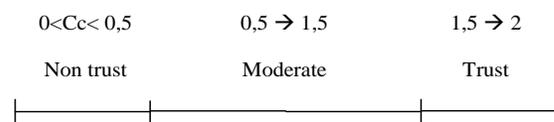


Fig.1. Classification of Trust Level

As seen from the figure, the trust behaviour between 0 and 0.5 is the behaviour of non-trust of the actor, between 0.5 and 1.5 is the behaviour of moderate trust and between 1.5 and 2.0 is for the trust. The trust behaviour within the supply chain network is influenced by multiple-party engaged in the chain and the evolution of trust naturally requires modelling using multi agent systems.

III. MAS AND AML MODELING

Multi-agent systems (MAS) naturally models decision making when several decision makers interact. In fact, an agent may be defined as an autonomous program that is reactive, proactive and has social abilities [15]. The important feature in this definition is the social abilities of agents which provide them with beliefs about other agents, thus trust.

Consequently, trust is important for multi-agent systems. For instance, Ramchurn and colleagues [16] review the literature on trust in multi-agent systems and 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 [17-19] and in many different combinations. The term “agent” denotes a hardware or more usually software-based intelligent computer system.

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 modeling 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

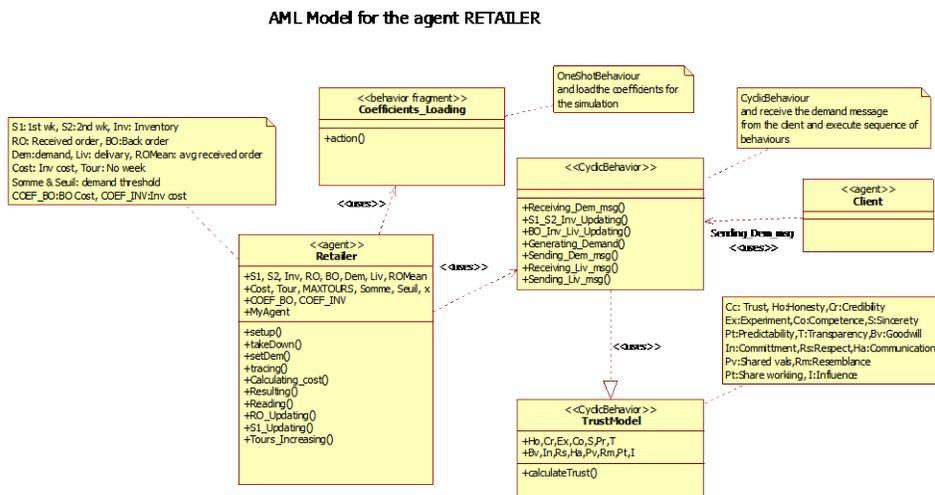


Fig.2. AML State Diagram of TrustAgent with the agent “Retailer”

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 [22] 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 [23], [24]. 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. Even though, it seems to be important to capitalize on the skills of designers. Multiagent system designers are often software engineers who use UML.

IV. 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

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 II. The TrustModelAgent implements the trust criteria with all the trust parameters and a cyclic behavior 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 for the simulation of trust in supply chain as shown in Fig. 2 which shows the conceptual level of the class diagram of an actor which illustrates, as an example, the implementation level for the agent Retailer along with the different behaviour and the TrustModel class. This TrustModel implemented the proposed human trust behavior formulation within the supply chain network and criteria for the trust level and calculation of the behaviour trust.

At every demand generation step in different agent, a cyclic call to calculateTrust() behavior of the agent TrustModel is made to ensure the level of trust and information sharing.

This interaction model shown in Fig. 3 demonstrates a situation while the level of trust is moderate and the information flows from different agents, based on the inventory and corresponding demand, is generated by the agents. At every demand generation step in different agent, a

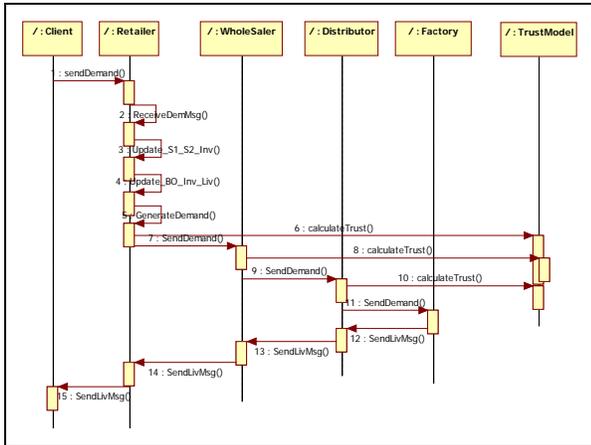


Fig.3. Dynamic model of TrustAgent collaboration with RetailerAgent when the level of trust is moderate

cyclic call to *calculateTrust()* behavior of the agent TrustModel is made to ensure the level of trust and information sharing.

V.EFFECT OF TRUST SIMULATION

In this Beer game scenario, each player in the supply chain decides on the demand generation based on inventory, virtual stock, backlog and the demand of the tour. The demand level is calculated based on week.

We conducted multiple rounds of experiments using our simulation model. In all the rounds, we tested supply chain performance under deterministic demand as set up in the Beer Game.

In the first round, we have a behaviour of non-trust between the companies, so there is no communication and information sharing between them, excepting the orders from the customers to their supplier.

In the second round, 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 (levels of stock are sent by the suppliers to their customers).

TABLE I. OVERVIEW OF MAIN PARAMETERS OF EXPERIMENT

Scenario	Flow of Information		
	Information Shared	Information Flow	Physical Flow
1	Orders	Delay: 1 week	Delay: 2 weeks
2	Orders+Stock Level	Delay: 1 week	Delay: 2 weeks
3	Orders	Delay: Real Time	Delay: 2 weeks
4	Orders+Stock Level	Delay: Real Time	Delay: 2 weeks

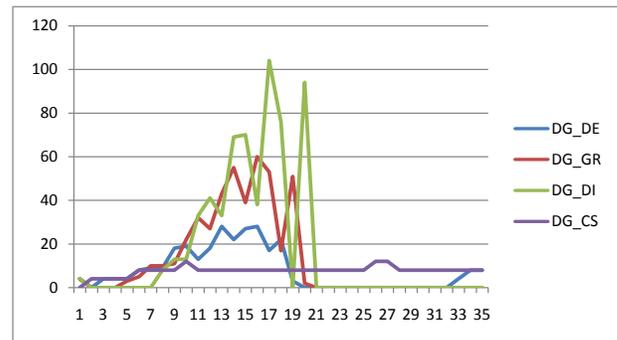
In the third and fourth scenarios, we have a “behaviour of trust” between the participants ( $1.5 \leq Cc < 2$ ); so in this case, the companies share the orders, the levels of stocks, and reduce the delay of information sharing. The Table I shows

the configuration of the four scenarios.

In the first scenario, the goal is to test the SC performance in the worst collaborative case; 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 Fig. 5 demonstrates that the generated demand is increasing from the first agent to the last one (the bullwhip effect), even if the demand of the final customer is not changing.

This scenario validates our multi-agent simulation model because, based on the non-trust behaviour, the global performance of the supply chain: inventory levels (Fig. 5) backlog levels are corresponding to that we have in the real Beer game.



(a) Generated Demand

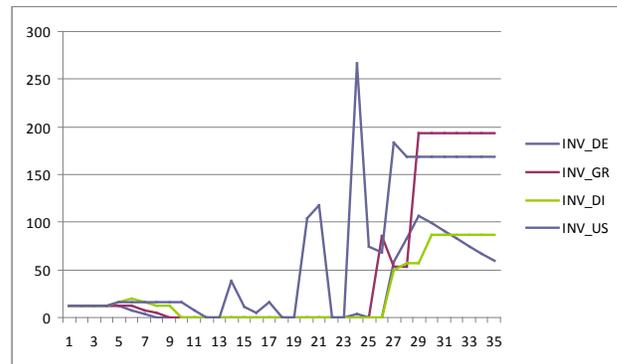
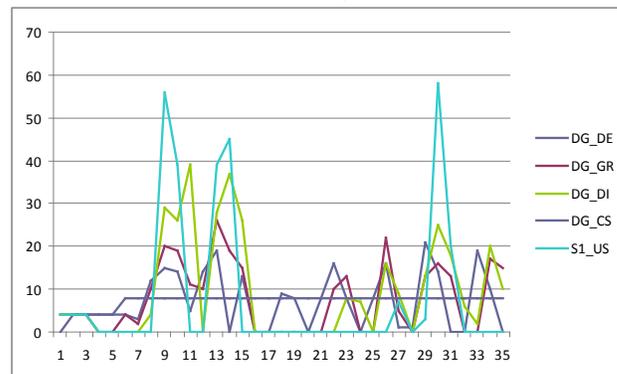


Fig.5. The generated demand (bullwhip effect) and Inventory level



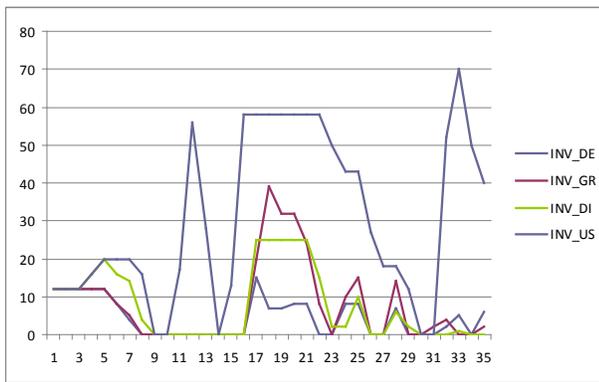


Fig. 6. The generated demand and Inventory level

The results demonstrated a real decreasing of the average level of backlogs and inventory (Table II.). These results illustrate the fact that a behaviour of trust between the partners.

TABLE II. OVERVIEW OF EXPERIMENTAL RESULTS

Scenario	Inventory		Backlog		Total Cost
	Avg	Max	Avg	Max	
1	45	284	18	174	2680
2	39	172	15	164	2230
3	15	68	6	45	1683
4	15	56	5	32	1498

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.

## VI. CONCLUSION

In this work, we have experimented the effect of trust with a proposed AML model of trust in supply chain. Through different trust scenario we have validated the trust simulation model on the case study, the Beer Game. We also have reported multiple rounds of 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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