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A Review of Supply Chain Management using Multi-Agent System

Vivek Kumar[1] and Dr. S. Srinivasan[2]

[1] Research Scholar, Department of computer Science & Engineering, Suresh Gyan Vihar, University
Jaipur, Rajasthan 302 004, India

[2]Professor & Head, Computer Science Department
PDM Engineering College,
Bhadurgarh, Haryana 124 507, India

Abstract

Supply chain consist of various components/ identities like supplier, manufacturer, factories, warehouses, distributions agents etc. These identities are involved for supplying raw materials, components which reassembles in factory to produce a finished product. With the increasing importance of computer-based communication technologies, communication networks are becoming crucial in supply chain management. Given the objectives of the supply chain: to have the right products in the right quantities, at the right place, at the right moment and at minimal cost, supply chain management is situated at the intersection of different professional sectors. This is particularly the case in construction, since building needs for its fabrication the incorporation of a number of industrial products. This paper focuses on an ongoing development and research activities of MAS (Multi Agent System) for supply chain management and provides a review of the main approaches to supply chain communications as used mainly in manufacturing industries.

KEYWORDS: Information exchanges, Multi Agent System, knowledge sharing and supply chain management

1. Introduction

Supply chain is a worldwide network of suppliers, factories, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed, and delivered to customers. In recent years, new software architecture for managing the supply chain at the tactical and operational levels has emerged. It views the supply chain as composed of a set of intelligent software agents, each responsible for one or more activities in the supply chain and each interacting with other agents in the planning and execution of their responsibilities. Supply Chain Management is the most effective approach to optimize working capital levels, streamline accounts receivable processes, and eliminate excess costs linked to payments.

2. Literature Survey

Analysts estimate that such efforts can improve working Capital levels, streamline accounts receivable processes, and eliminate excess costs linked to payments. Analysts estimate that such efforts can improve working capital levels by 25% [2]. Today, the best companies in a broad range of industries are implementing supply chain management solutions to improve business performance and free cash resources for growth and innovation. Supply Chain Management is about managing the physical flow of product and related flows of information from purchasing through production, distribution and Delivery of the finished product to the customer. This requires thinking beyond the established boundaries, strengthening the linkages between the supply chain functions and finding ways to pull them together. The result is an organization that provides a better service at a lower cost. MihaelaUlieru et al. give a approach based on the holonic enterprise model [10] with the Foundation for Intelligent Physical Agents (FIPA) Contract Net protocols applied within different levels of the supply chain. The negotiation on prices is made possible by the implementation of an XML rule-based system that is also flexible in terms of configuration. According to Pericles A., the system is viewed as an organization or collection of roles that relate to each other and form an interaction model. Roles in the system are descriptions of business entities, whose functions are modeled at an abstract level. Whole system is divided in Business Description, Product Description, and Order Management Holarchy, Manufacturing Holarchy.ole Modeling. Author has given the following System

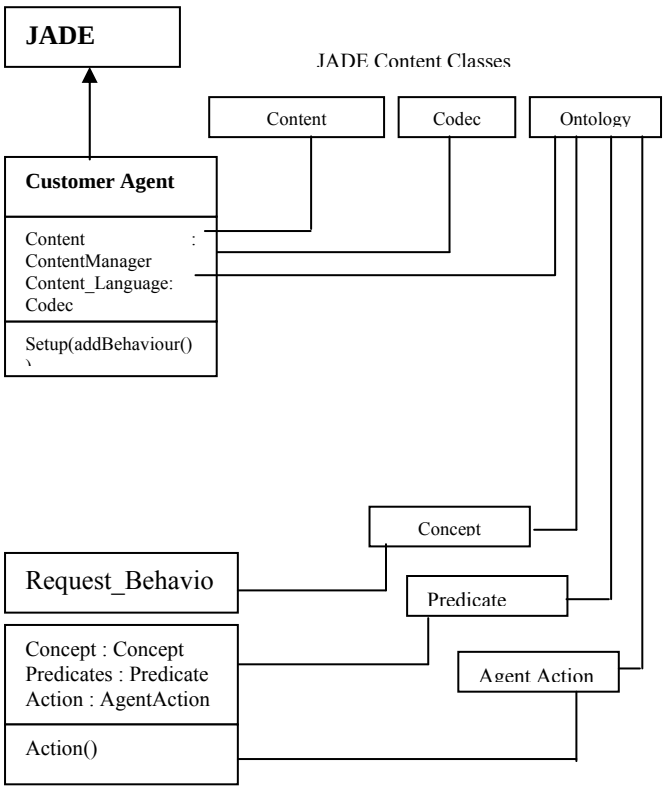

Fig. 1 Class Architecture for customer Agents

Yevgeniya Kovalchuk presented a way to manage the supply chain activities & try to automate their business processes [18]. In practice, all the activities are highly connected and interdependent. The project is mainly focused on the demand part of the supply chain. In particular, different methods for predicting customer offer prices that could result in customer orders are explored and compared in the system. RuiCarvalho et al. presented multi-agent technology as a sound alternative to classical optimization techniques that can contribute to solve hard problems. To prove this point , the MAS with the following functionalities designed : simulation of an almost infinite number of agents, heuristics for decision making, possibility to choose among alternative decision strategies and tactics, different evaluation criteria and evaluation functions, different message sequences, and stochastic or deterministic behavior.

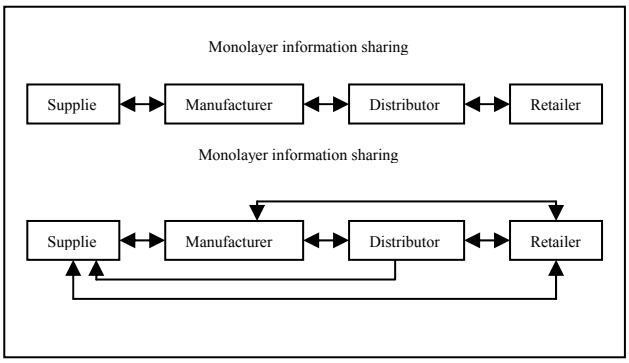

Fig. 2 Compartmentalization of operational information coordination

José Alberto R. P. Sardinha1 et al. presented a flexible architecture based on a distributed multi-agent architecture [15] of a dynamic supply chain. Intelligent agents tackle sub problems of a dynamic SCM. Authors present an implementation of this architecture by using international test bed for SCM solutions. The mail purpose of this work is to present a multi-agent architecture for a generic supply chain that uses a direct sales model, which links customers directly to a manufacturer through the Internet. Robert de Souza et al. addressed two main issues [6]: Can we chart the complex logistical dynamics of disk drive manufacturing? What are the critical success factors that impact the economics of hard disk drive manufacturing? The backdrop for this study is the (global) supply chain much in evidence in disk drive manufacture. Fu-ren Lin et al. analyzed the impact of various levels of information sharing including order, inventory, and demand information, which is based on transaction costs [14]. This study further examines the effects on supply chain performance in electronic commerce. Specifically, the multi agent simulation system Swarm is employed to simulate and analyze the buyer–seller correlation in sharing information among business partners in supply chains. Information sharing between firms helps to lower the total cost and increase the order fulfillment rate. In other words, information sharing may reduce the demand uncertainty that firms normally encounter. Onn Shehory et al. discussed suitability of agent modeling techniques [4] to agent-based systems development. In evaluating existing modeling techniques, addressed criteria from software engineering as well as characteristics of agent-based systems. Evaluation shows that some aspects of modeling techniques for agent-based systems may benefit from further enhancements. This technique tries to answer the following questions: (1) which agent-based system characteristics and software engineering principles are addressed within AOSE modeling techniques, and to what extent? (2) What should be the properties of the future agent-oriented modeling techniques? Rasoul Karimi et al. developed a new multi attributes procurement auction [11]. It is new because it has been defined for a special model of supply chain, in that customer has a new scoring rule, and producers have new strategies for biding. Multi Attribute Procurement Auction is a good solution for Supply Chain problem which fits its requirements. The implementation of the Swarm simulation system incorporates multiple agents with the decision model to, in turn; determine the relationship with their trading partners. Fig. 3 demonstrates a purchasing agent's decision model to determine which supplier should issue the purchase order.

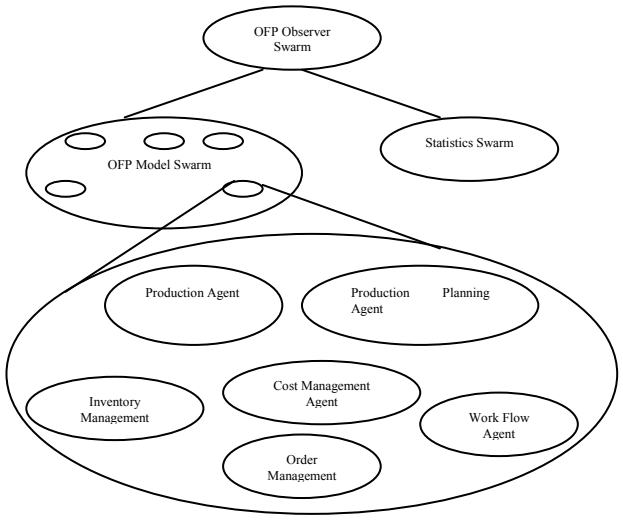

Fig. 3 Swarm implementation for modeling supply chains.

A trading partner contains several agents, including order management, inventory management, policy management, production, production planning, and purchasing. Among them, the purchasing agent proposes the decision model to determine from which supplier products should be purchased. The purchasing agent buys goods from suppliers that offer the lowest price. The price issued by a supplier is the outcome of weighing production cost and coordination cost. The final price is the one issued by a supplier. Yang Hang et al. proposed a CSET framework [13] for whole supply chain in collaborative manner by incorporating it with the Just-in-Time (JIT) principle, known as CSET. The core of the CSET model is based on intelligent agent technology. This paper defines such double-agent mechanisms in details, as well as demonstrating its merits via simulation study. The MAS proposed here was implemented using LISP and had as first source of inspiration the agent creation language named RUBA [Ventura97]. The system has as main blocks i) an environment agent, in charge of the meaningful functioning of the system and event execution simulation [Michael90], ii) client agents, with needs to be satisfied and iii) firm agents, that have also needs but are capable of product manufacturing. The system also includes a blackboard, where agents can post their messages, and a set of communication rules (a communication protocol inspired on the Contract Net protocol

[Smith80; Smith81]), common to all agents and that makes possible message exchange. KQML [Finin94], a standard message format, and KIF [Genesereth94], a message content specification, served as the basis for the communication protocol of our MAS [Huns99].The main elements of the system, agents, blackboard and a communication protocol, are essential for functioning. These agents are intelligent, because they are able to present successful behavior [Albus91]. Figure 4 shows the system behaviour. Fu-ren Lin et al. used multiagent simulation system, swarm, for simulating trust mechanism and analyzing the supply chain performance in four different market environments [19].Supply chain performance is evaluated by comparing the order fulfillment process of a mold industry both with and without trust mechanisms. From the experimental result ,

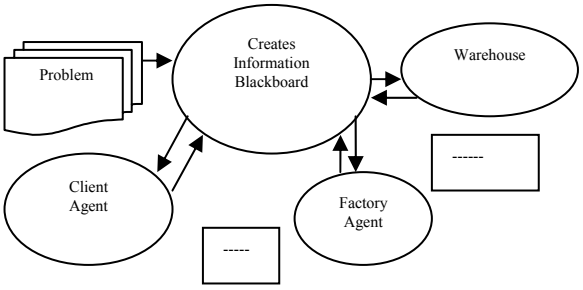

Fig 4. Environment Agent and Agent Behavior

they found that the trust mechanism reduced the average cycle time rate and raised the in-time order fulfillment rate as the premium paying for better quality and shorter cycle time. Charles M. Macal et al. gave a new approach [5] to modeling systems comprised of interacting autonomous agents. & described the foundations of ABMS, identifies ABMS toolkits and development methods illustrated through a supply chain example, and provides thoughts on the appropriate contexts for ABMS versus conventional modeling techniques. William E. Walsh et al. highlighted some issue that must be understood to make progress in modeling supply chain formation [3]. Described some difficulties that arise from resource contention. They suggested that market-based approaches can be effective in solving them. Mario Verdicchio et al. considered commitment as a concept [17] that underlies the whole multi-agent environment, that is, an inter-agent state, react a business relation between two companies that make themselves represented by software agents. Michael N. Huhns et al. found after this research that supply chain problems cost companies [8] between 9 to 20 percent of their value over a six month period. The problems range from part shortages to poorly utilized plant capacity. Qing Zhang et al. provide a review of coordination of operational information in supply chain [12] . Then the essentials for information coordination are indicated.Vivek Kumar et al. gave a solution for the construction, architecture, coordination and designing of agents. This paper integrates bilateral negotiation, Order monitoring system and Production Planning and Scheduling multiagent system. Ali Fuat- Guneri et al gave the concept of supply chain management process[16], in which the firm select best supplier , takes the competitive advantage to other companies. As supplier selection is an important issue and with the multiple criteria decision making approach, the supplier selection problem includes both tangible and intangible factors. The aim of this paper is to present an integrated fuzzy and linear programming approach to the problem. Firstly, linguistic values expressed in trapezoidal fuzzy numbers are applied to assess weights and ratings of supplier selection criteria. Then a hierarchy multiple model based on fuzzy set theory is expressed and fuzzy positive and negative ideal solutions are used to find each supplier's closeness coefficient. Finally, a linear programming model based on the coefficients of suppliers, buyer's budgeting, suppliers' quality and capacity constraints is developed and order quantities assigned to each supplier according to the linear programming model. Amor et al. presented Malaca [9], an agent architecture that combines the use of Component- based Software Engineering and Aspect-Oriented Software Development.

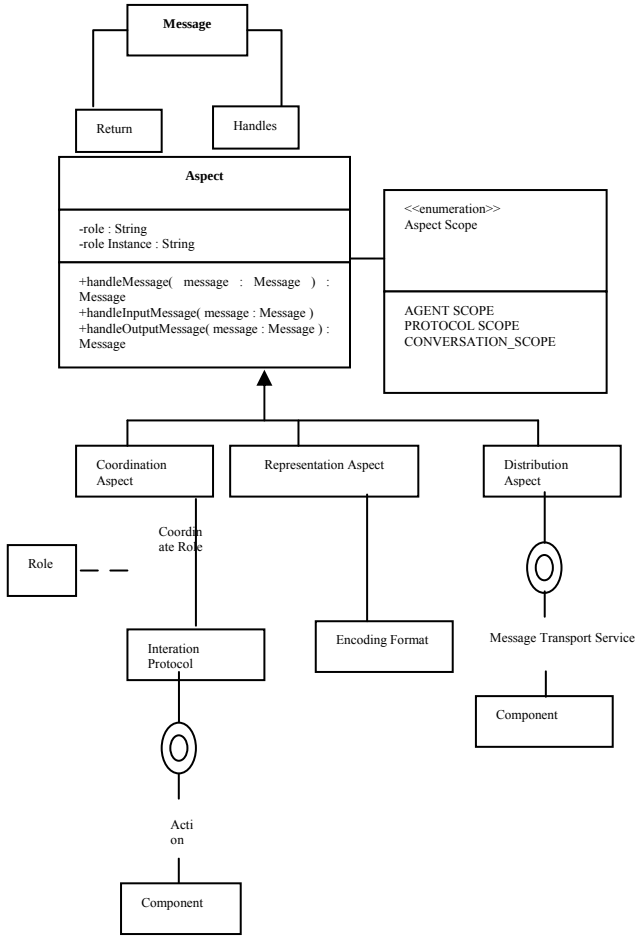

Fig. 5 Conceptualization of the aspect model in Malaca

Malaca supports the separate (re)use of the domain-specific functionality of an agent from other communication concerns, providing explicit support for the design and configuration of agent architectures and allows the development of agent-based software so that it is easy to understand, maintain and reuse. Ka-Chi Lam et al. investigated a selection model based on Fuzzy Principal Component Analysis (PCA) [7] for solving the material supplier selection problem from the perspective of property developers. First, the Triangular Fuzzy Numbers is used to quantify the decision makers' subjective judgments. Second, PCA is employed to compress the data of the selection criteria

and eliminating the multi-collinearity among them. Third, the linear combined score of PCA (SCOREPCA) is used to rank the Suppliers.

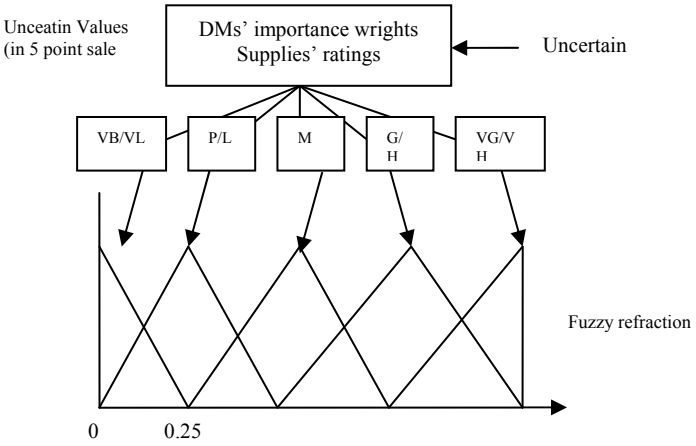

Fig. 6. Membership functions of DMs' importance weights and suppliers'ratings (modified from)

Four material purchases are used to validate the proposed selection model.The results show that the proposed model can be adopted in construction material supplier selection by the property developers.

Table 1: Summary

S.No.	***Title Name & Authors***	***Explanation & Conclusion***
1.	"supply Chain Models in Hard Disk Drive Manufacturing" Robert de Souza and Heng Poh Khong	This paper seeks to address two main issues: Can we chart the complex logistical dynamics of disk drive manufacturing? What are the critical success factors that impact the economics of hard disk drive manufacturing? The pressures in the disk drive industry are classic supply chain economics; value, timing, supply, demand and technology development that all play a part into price erosion patterns. To address such issues the authors' postulate that the five chains interact to give rise to complexities, static models cannot easily handle.
2.	Modeling supply chain Formation in Multiagent System William E. Walsh and Michael P. Wellman	In this paper the authors highlight some issues that must be understood to make progress in molding supply chain formation. Supply chain formation is an important problem in the commercial world and can be improved by greater automated support. The problem is salient to the MAS community and deserving of continued research.
3.	Evaluation of Modeling Techniques for Agent-Based Systems Onn Shehory and Arnon Sturm	Author discusses suitability of agent modeling techniques to agent-based systems development. In evaluating existing modeling techniques, and address criteria from software engineering as well as characteristics of agent-based systems. Based on these findings, we intend in future research, to address the needs of agent-based system developers. This should be done in order to find the required modeling techniques and components for building agent-based systems.
4.	Effects of Information Sharing on Supply Chain Performance in Electronic Commerce Fu-ren Lin, Sheng-hsiu Huang, and Sheng-cheng Lin	Findings indicate that the more detailed information shared between firms, the lower the total cost, the higher and the order fulfillment rate. And the shorter the order cycle time. In other words, information sharing may reduce the demand uncertainty that firms normally encounter. Firms that share information between trading partners tend to transact with a reduced suppliers. This work investigated the buyer–seller relationship in electronic commerce with an Extranet as the platform for sharing information. Using the Swarm simulation system, based on transaction costs, we have identified effects of sharing various levels of information between supply chain partners.

5.	Commitments for Agent-Based Supply Chain Management Mario Verdicchio and Marco Colombetti	As there are several analogies between a company in a business network and an agent, the Multi-Agent System paradigm can be a valid approach for modeling supply chain networks. We consider commitment as a concept that underlies the whole multi-agent environment, that is, an inter-agent state, reacting a
6.	Building Holonic Supply Chain Management Systems: An e-Logistics Application for the Telephone Manufacturing Industry MihaelaUlieru and MirceaCobzaru	Approach is based on the holonic enterprise model with the Foundation for Intelligent Physical Agents (FIPA) Contract Net protocols applied within different levels of the supply chain holarchy. To accommodate differentiation of interests and provide an allocation of resources throughout the supply chain holarchy, we use nested protocols as interaction mechanisms among agents. Agents are interacting through a price system embedded into specific protocols. The negotiation on prices is made possible by the implementation of an XML rule-based system that is also flexible in terms of configuration and can provide portable data across networks. As the effectiveness of centralized command and control in SCM starts to be questioned, there is a critical need to organize supply chain systems in a decentralized and outsourced manner. Agent-based models can easily be distributed across a network due to their modular nature. Therefore, the distribution of decision-making and execution capabilities to achieve system decentralization is possible through models of operation with communication among them. The ontology structure of the JADE framework is, in our opinion, one of the best designed to address the issues of accessing and sharing information pertinent to a specific application.
7.	A Multiagent Systems Approach for Managing Supply-Chain Problems: new tools and results Rui Carvalho, Luís Custódio	It was modelled and implemented a MAS with the following functionalities: simulation of an almost infinite number of agents, heuristics for decision making, possibility to choose among alternative decision strategies and tactics, different evaluation criteria and evaluation functions, different message sequences, and stochastic or deterministic behavior. When we applied our MAS to a problem of SC management at HP, we obtained results with stock outs for every product of the bill of materials. On the contrary, some authors using mathematical tools only simulated the stock out of only one product of the bill of materials.
8.	A Multi-Agent Architecture for a Dynamic Supply Chain Management José Alberto R. P. Sardinha1, Marco S. Molinaro2, Patrick M. Paranhos2, Pedro M. Cunha2, Ruy L. Milidiú2, Carlos J. P. de Lucena2	This paper presents a flexible architecture for dealing with the next generation of SCM problems, based on a distributed multi-agent architecture of a dynamic supply chain. We define intelligent agent roles that tackle sub problems of a dynamic SCM. We also present an implementation of this architecture used in the international test bed for SCM solutions, the Trading Agent SCM competition, as well as some experimental results. A multi-agent design is used in the architecture, because we believe it facilitates the development of modular entities that are distributed and reusable. The design was also used to implement an agent entry for the Trading Agent Competition. This system competed against 32 entries, and was able to classify to the quarter-finals of the 2005 competition.
9.	How to Model With Agents Proceedings of the 2006 Winter Simulation Conference Charles M. Macal and Michael J. North	Agent-based modeling and simulation (ABMS) is a new approach to modeling systems comprised of interacting autonomous agents. ABMS promises to have far-reaching effects on the way that businesses use computers to support decision-making. Computational advances make possible a growing number of agent-based applications across

		many fields. Applications range from modeling agent behavior in the stock market and supply chains
10.	New Multi Attributes Procurement Auction for Agent- Based Supply Chain Formation Rasoul Karimi, Caro Lucas and Behzad Moshiri	In this article, this constraint has been relaxed and a new procurement auction is defined. In this auction, seller agents can take different strategies based on their risk attribute. These strategies is analyzed and compared mathematically. Authors define a new MAPA which is usable under the new model of supply chain. In this MAPA, the producer could have two different strategies based on its risk attribute. These two strategies are compared mathematically and also in a simulation.
11.	Multi-Agent Decision Support System for Supply Chain Management Yevgeniya Kovalchuk	The research approach followed is presented. The results achieved so far along with the plans for future work are given next. Various techniques for predicting bidding prices in the context of dynamic competitive environments are explored. Apart from the SCM, the solutions can be used in forecasting financial markets and participating in on-line auctions.
12.	Double-agent Architecture for Collaborative Supply Chain Formation Yang Hang and Simon Fong	The model is supported by double-agent architecture with each type of agents who makes provisional plans of order distribution by Pareto optimality and JIT coordination respectively As a result, pipelining manufacturing flow is achieved. This is significant to dynamic supply chain formation as it can help to optimize constraints and costs across production, distribution, inventory, and transportation.
13,	Essentials for Information Coordination in Supply Chain Systems Qing Zhang and Wuhan	Provide a review of coordination of operational information in supply chain which is classified into information types, their impact on supply chain performance, and the policy of information sharing Multi-agent computational environments are suitable for studying classes of coordination issues involving multiple autonomous or semi-autonomous optimizing agents where knowledge is distributed and agents communicate through messages.
14.	Effects of Trust Mechanisms on Supply Chain Performance Using Multi-agent Simulation and Analysis Fu-ren Lin ,Yu-wei Song and Yi-peng Lo	The multiagent simulation system Swarm is employed to simulate and analyze the buyer–seller correlation in sharing information among business partners in supply chains The deeper the information sharing level, the higher in-time order fulfillment rate and the shorter order cycle time, as information sharing may reduce the demand uncertainty that firms normally encounter. Finally, firms that share information between trading partners tend to transact with a reduced set of suppliers.
15.	A Multiagent Conceptualization For Supply-Chain Management Vivek kumar , Amit Kumar Goel , Prof. S.Srinivisan	Paper present solution for the construction, architecture, coordination and designing of agents. This paper integrates bilateral negotiation, Order monitoring system and Production Planning and Scheduling multiagent System. The wide adoption of the Internet as an open environment and the increasing popularity of machine independent programming languages, such as Java, make the widespread adoption of multi-agent technology a feasible goal
16.	An integrated fuzzy-lp approach for a supplier selection problem in supply chain management Ali Fuat Guneri,	A hierarchy multiple model based on fuzzy set theory is expressed and fuzzy positive and negative ideal solutions are used to find each supplier's closeness coefficient. Finally, a linear programming model based on the coefficients of suppliers, buyer's budgeting, suppliers' quality and capacity constraints is developed and order quantities assigned to

	Atakan Yucel , Gokhan Ayyildiz	each supplier according to the linear programming model. Fuzzy set theory approach helps to convert decision-makers' experience to meaningful results by applying linguistic values to assess each criterion and alternative suppliers.
17.	Malaca: A component and aspect-oriented agent architecture" Information and Software Technology Mercedes Amor *, Lidia Fuentes	An agent architecture that combines the use of Component-based Software Engineering and Aspect-Oriented Software Development Provided explicit support for the design and configuration of agent architectures and allows the development of agent-based software
18.	A material supplier selection model for property developers using Fuzzy Principal Component Analysis" Automation in Construction Ka-Chi Lam □, Ran Tao, Mike Chun-Kit Lam	Tthe Triangular Fuzzy Numbers is used to quantify the decision makers' subjective judgments. Second, PCA is employed to compress the data of the selection criteria and eliminating the multicollinearity among them. The model can efficiently eliminate the multicollinearity among the supplier's attributes and help to reduce the trade-offs and repeatability errors in the selection process.and the proposed selection model can also reduce the subjective errors on the sense that the weight assigned for each ζ is generated automatically.

3. Conclusion

Multi-agent system is a loosely coupled network of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each problem solver. The general goal of MAS is to create systems that interconnect separately developed agentsThus enabling the ensemble to function beyond the capabilities of any singular agent in the set-up in agent model. This research can demonstrate that agent technology is suitable to solve communication concerns for a distributed environment. Multi-agent systems try to solve the entire problem by collaboration with each other and result in preferable answer for complex problems. For further works, it is recommended for developing this model to have multi retailer and even multi distributor and apply the auction mechanism between them.

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Mr. Vivek Kumar has completed his M.Phil (Computer Science) in 2009. Apart from this, he did M.Tech. (Computer Science, 2005) & MIT in 2001. He has 10 years of teaching experience in various engineering Colleges. Presently he is working as faculty in Gurgaon Institute of Technology and Management, Gurgaon, Haryana, India. Under the guidance of Dr. Srinivasan, he is pursuing Ph.D. from Department of Computer Science and Engineering, S. Gyan Vihar University, Jaipur, India
He has published one international & two national (Conference Proceeding) papers on Supply Chain Management through Multi-Agent System.

Dr S Srinivasan obtained his M.Sc (1971), M.Phil(1973) and Ph.D. (1979) from Madurai University . He served as Lecturer for 7 years in National Institute of Tehnology in the Computer Applications Department . Later he joined Industry as IT Head for 18 years . Again he started his teaching career serving as Professor and Head of the Department of Computer Science, PDM College of Engineering , Haryana, India. He has published several papers in Multi-Agent Technology Systems and its applications . He is member of Computer Society of India. Attended various national and international seminars and conferences and presented papers on Artificial Intelligence and Multi-Agent Technology.