CHAPTER 5

MAS BASED SCM SYSTEM

In the situation of unmanaged supply chain, the supply chain performance is critically affected by various factors and constraints. These factors and constraints generate the worst effect in the supply chain. One of the major problems faced due to this unmanaged supply chain management system is the bullwhip effect. In SCM, the bullwhip effect generates a lot of problems such as low product quality, high product price, unavailability of desired product at needed time period and high customer dissatisfaction. Hence main roles and responsibilities of the supply chain orchestrator are described to reduce the causes of the BWE occurring in the supply chain system. For this purpose, it requires the efficient information sharing and coordination between the supply chain entities. The new technologies and architectures have emerged to provide a platform for maintaining the efficient information flow and coordination. The service-oriented architecture is a significant innovative paradigm which is capable of supporting the modularized implementation of the supply chain activities. Hence we are going to apply the multi-agent system along with service oriented architecture in the supply chain management.

5.1 EXISTING MAS BASED SUPPLY CHAIN SYSTEM

In Artificial Intelligence, there exist multiple technologies and mechanisms that can be utilized to implement the efficient communication and ordination between various entities. The intelligent agent is one of the emerging fields of AI. The intelligent agent is automatic; cooperative and own knowledge base. The groups of the intelligent agents build the multi-agent system.

The MAS technology guarantees proper communication, coordination and information flow among a mixture of functions in the supply chain. The MAS based supply chain is included with a model management system (MMS) which includes Case Based reasoning
(CBR), Data Mining Systems and several mathematical models. This system will minimize the causes of the bullwhip effect to a great extent. The SCM processes recognize the organization goals, their objectives, outlining policies, strategies and controls for its effectiveness and well-organized implementations. The SCM should be energized to congregate any newfangled challenges from numerous instructions including suppliers, customers and supplementary exterior and interior factors. For this purpose, the strong modeling technologies are required to maintain the complexity involved in SCM. Also business changes fast, collaboration and coordination are vital in SCM, the combination of SOA and MAS is the perfect solution for the organization to meet its objective. The supply chain management system consists multiple entities for managing the customer requirements and fulfilling the organization goals. As simple view, the SCM may be considered following elements as given below:

- **Fundamental elements**
  These elements define the overall basic configuration for the completing the supply chain operations. There are mainly emphasized on the productions and transport decisions.

- **Strategic elements**
  These elements manipulate the decisions involved in whole supply chain activities such as information flow, inventory control, and demand forecasting and product delivery.

Let’s discuss the all these SCM elements in details required to complete the processes needed to preserve its reliability.

### 5.2 FUNDAMENTAL ELEMENTS

These elements are not being modified so easily. So the process of selecting these elements is the complex phenomena. The SCM consist mainly two Fundamental elements as given as below:

- **Production**
  It is a core element of the supply chain activities. It retrieves the information from the control elements for managing the inventory, supply and product flow. It also utilizes information control elements for forecasting the product demand. For
fulfilling the customer requirements, the desired products should be manufactured at timely manner for product availability. The production contains the following elements as given below:

- **Supplier**
  It is the entity of the SCM which model the external suppliers for the purpose of providing the raw materials required for manufacturing the desired products. The reliability of these external suppliers defines the cost and quality of the product. It supplies the raw materials to the manufacturing plants.

- **Manufacturer**
  After receiving the raw material from the external suppliers, the manufacturer produces the desired products with the aim of achieving preferred quality for maintaining customers’ satisfactions. It pursues the production policies and strategies for properly managing the customers’ orders.

- **Distributor**
  After manufacturing the desired products, they should be distributed to different locations for the purpose of delivering the products to the customers. It works the decoupling point between the pull and push activities. The distributor may store the products or send the goods to the retailers. The main concern of this entity is to reduce the inventory required during the whole downstream activities.

- **Retailer**
  It sells the products to the customers with the aim of reducing the cycle time for delivery of the products to the needed customers. It generates the availability of products at nearby their living places though the sale points likes shops and shopping malls. There exist multiple retailing policies which may be applied during the retailing operations. To apply the accurate the retailing policy regarding the particular situation is one of the major responsibilities of the retailer.
All these entities come under the upstream activities of the supply chain system. These activities initialize from the selecting the external suppliers ending with delivery of the products to the retailers for easy availability of the goods to the customers.

- **Transportation**
  The transportation delivers the manufactured products from one location to other locations physically. Proper transport scheduling is being required to deliver the products for reliable and timely for achieving the customer satisfactions. This entity finalizes the vehicles for product delivery and route followed. The main aim of this entity is to deliver the goods with reliability and cost effective targets.

These elements are the core of the supply chain management system. The production system defines the whole performance of the supply chain system. The transportation carries the manufactured goods to the all distributors and retailers to deliver the goods.

### 5.3 STRATEGIC ELEMENTS

These elements are being modifies easily regarding the customer’s viewpoint. The decisions of selecting these elements make directly impact on the performance of the supply chain. There are following Strategic elements of the SCM as given below:

- **Demand control**
  The demand should be forecasted before the production of the goods. This process is known as the demand forecasting. This control element manipulates actual customers’ requirements for fulfilling it timely. There exist various demand forecasting techniques. It may be quantitative, qualitative, time series methods, and casual methods for demand manipulation of existing products. To lunch new product, the marketing is done for judging the response from the customers for production scheduling.

- **Inventory control**
  This element of the supply chain system decides the quantity of the products stored by the retailers and wholesalers to avail the goods at needed period. The inventory may be found in the centralized or decentralized depending the locations or places. There exist multiple inventory control strategies like base-stock, MRP-ordering policy and echelon based inventory control policy.
• **Information control**
  The SCM entities require the information flow between them to know the status of the whole operation with the aim of fulfilling the organization goals and customers’ requirements. This Strategic element defines the mechanism of passing the information among all the SCM entities. The information flow may be passed in real time or periodically depending on the different situations.

• **Order processing control**
  It manages the information related to the delivery of the final products on basis of the order placed by the customers. It also defines the terms and conditions when the order of the products is being placed. These terms and conditions are being kept in the contracts. These contracts may be differ on the basis of the suppliers.

• **Flow control**
  It organizes the transfer of the products from the production panel to the transport system. It handles two different control processes such as loading and routing process. The loading control elements manage the mechanism in which transportations elements are being laden and unloaded. Another Strategic element manipulates the routing of the transportation.

These elements contain the strategic decisions on various activities happened in the supply chain system. Hence for the purpose of implementing the supply chain management system, each element of the SCM is being represented by particular intelligent agents. The intelligent agents perform the particular task regarding the particular elements. The group of such intelligent agents is known as the multi-agent system. This system contains following intelligent agents as given below:

• Supplier Agent
• Manufacturer Agent
• Distributor Agent
• Retailer Agent
• Production Agent
• Transport Agent
• Demand Agent
• Inventory Agent
• Order Processing Agent
• Flow Control Agent
• Information Agent
• Manager Agent
• External Agent

These intelligent agents are being named regarding their role and responsibility. These intelligent agents are being designed using BDI architecture. Various supply chain entities work in systematic ways as shown in the figure 5.1 as given below:

![Figure 5.1 Various SCM entities](image)

The role and responsibilities of these entities are being handled through the particular intelligent agents in the multi-agent based supply chain management system.

5.4 ORGANIZATION OF AGENTS IN EXISTING MAS BASED SCM

In the multi-agent system, multiple intelligent agents are conscious about their role and responsibilities. In the BDI architecture, the intelligent agents are being designed as the goal oriented. The goal of each agent is specified to achieve their responsibilities. During
the operation, these agents communicate with each other and pass the information between them. Let’s know the details about these intelligent agents and type of the information passed to other agents as given below:

5.4.1 Production agent

This agent has the responsibility of organizing the upstream activities. It communicates with Demand Agent and receives the forecasted amount of the product and passes these values to the Manufacturer Agent. On the basis on this forecasted value, it communicates with the Supplier Agent for purchasing the raw materials required for manufacturing the needed products. It communicates with Inventory Agent for taking the decisions regarding the inventory control strategies. The production agent takes the following inputs as given below:

- List of Suppliers RFQs
- Product demand forecasted values
- Pending orders
- Orders due dates
- Quality standards

The major task of the production agent is to handle the production activities in the supply chain management system. The main goals of the production agents are being described as below:

- It is being designed to prepare the production schedules for delivering all orders including the delayed orders.
- A major responsibility of this agent is to maintain the product quality with the aim of maintaining the customers’ satisfactions.
- It is also designed to run the production activities in the cost effective manners.
- To implement the production quality standards is another goal of this agent in the supply chain management system.

5.4.2 Supplier agent

This agent has the responsibility of providing the raw materials required for production of the goods. The final products are made of the various individual components. These components are provided by multiple supplier so these suppliers can be classified as the
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Tier-1 supplier, Tier-2 supplier and etc depending on the role of providing the raw materials. There are following inputs for intelligent agent as given below:

- Product brand
- Cost of desired product
- Quantity of required raw materials
- Delivery time of raw materials

To avail the raw materials required for manufacturing the needed product is the major task of the supplier agent in the supply chain management system. The main goals of the supplier agents are being described as below:

- To avail the raw materials timely is the major goal of the supplier agent in the supply chain management system.
- It is being developed to select the reliable supplier for reliable raw material delivery for timely manufacturing process.
- It is majorly designed for reliable raw material delivery for maintaining the product quality.

5.4.3 Manufacturer agent

This agent performs the task of assembling the raw materials to manufacture the final products at desired product quality. It is more responsible for maintaining the customer satisfaction through low price and good product quality. There are following inputs for the manufacturer agent as given below:

- Order quantity
- Machinery strength
- Labor capacity
- Delivery time of product order
- Order priority

The manufacturer agent is being developed with aiming of manufacturing needed products for completing the customers’ needs with maximized customer satisfaction with preferred product quality. The main goals of the manufacturer agent are being described as below:
• The main goal of this agent is to manufacture the goods timely to avail the goods to customers at needed time period.
• To maintain the customer quality is the one of the major goals of the manufacturer agent.
• It is directed to gain the customer satisfaction through the improved product quality.
• It is majorly designed for manufacturing the best quality products for attracting more customers.

5.4.4 Distributor agent

This agent receives the products from the manufacturers and performs the task of storing the products or sending directly to the retailers. The main responsibility of this agent is here to reduce the inventory carried and maximize throughput. Other responsibilities are to manage the customer orders in such way to maintain the availability of the products timely. There are following inputs for the manufacturer agent as given below:

• Stock status
• Stock buffer
• List of retailers
• Market scenario
• Order visibility

The distributor agent is being developed with aiming of availing the manufactured needed products to the retailers after receiving from the manufacturer agent. The main goals of this agent are being described as below:

• The main goal of this agent is to reduce the inventory cost related to storage of the manufactured goods for availing the goods timely.
• To avail the customers’ product within the required time period is the one of the major goals of the distributor agent.
• It is being designed with aim of maintaining the good response time for the customer requirement fulfillment process.
• It is majorly designed for maintaining the stock for managing the seasonal customers’ demands.
5.4.5 Retailer agent

This agent has the responsibilities to avail the products to the customers for buying the products at nearby their living places. It is one of these agents that interpret with the customers directly. It bargains with the customers for the product prices for achieving the profits. There are following inputs for the manufacturer agent as given below:

- Product demand
- Customer response
- Product pricing strategies
- Stock status
- Order priority

The retailer agent is being developed with aiming of selling the product to the customers needed products for completing the customers’ needs with maximized customer satisfaction with preferred product prices. The main goals of the manufacturer agent are being described as below:

- The main goal of this agent is to sell the goods along with maximized customer satisfaction.
- To sell the product at the reasonable prices for attracting the customers for long time periods is the one of the major goals of the retailer agent.
- It is directed to gain the profits through the bargaining process with customers.
- It is majorly designed for managing the seasonal pattern of the customers demand properly.
- To motivate the customers regarding the new upcoming products is another major goal of the retailer agent.

5.4.6 Transportation agent

This agent has the responsibilities to transfer the products from one location to the other locations physically. The main responsibility of this agent is to prepare the transportation scheduling for reliable and timely delivery with communication with Distributor Agent and Retailer Agent. This factor reduces the lateness rate for maintaining the customer satisfaction. There are following inputs for the transport agent as given below:

- Order quantity
• Delivery location
• Transport capacity
• Delivery time
• Order priority

The manufacturer agent is being developed with aiming of manufacturing needed products for completing the customers’ needs with maximized customer satisfaction with preferred product quality. The main goals of the transport agent are being described as below:

• The main goal of this agent is to deliver the goods in a given time period.
• It is being designed for preparing the optimized route for product delivery.
• To maintain the customer satisfaction is one of the major goals of the transport agent.
• It is directed to gain the customer satisfaction through the timely and reliable product delivery.
• It is majorly designed for optimizing the transportation facility for attracting more customers.
• To reduce the transportation cost is another major goal of this agent.

5.4.7 Inventory agent

This agent is designed with the responsibility of managing the flow of material during the whole SCM operation. It provides both centralized and decentralized inventory controls for raw material and finished products. It coordinates with Supply Agent and Production agent to know the actual status of the stocks. It passes the all details to the Information Agent for managing the market fluctuations. There are following inputs for the inventory agent as given below:

• Probability of Selling
• Number of batches
• Economic Order Quantity
• Bill of materials
• Annual cost of ordering and stocking
The inventory agent is being developed by controlling the inventory during the supply chain activities through applying the efficient inventory control policy. The main goals of the inventory agent are being described as below:

- The foremost objective of this agent is to minimize the total cost of inventory involved in the supply chain activities.
- To choose most efficient inventory policy quality is the one of the major goals of the manufacturer agent.
- It is directed to shun product overstock and outages by maintaining the Out-of-stock sheets.
- It is majorly designed for maintaining the Open-to-buy records to prevent ordering more than is needed to meet demand or to stay within a budget.

5.4.8 Demand agent

The main responsibility of the Demand Agent is to manipulate the customer demands for a particular product before making the manufacturing scheduling. By manipulating the customer requirement it helps in controlling the bullwhip effect considerably. It understands the market demand and helps the Supply Agent to clear the orders in time. It also helps in reducing the lead time. It shares all its activities with Information Agent.

There are following inputs for the Demand agent as given below:

- Historical Data Streams (Bookings, shipments, invoices and past forecasts etc.)
- Forecast Data Streams (Statistical Forecast, Annual Plan, Revenue Forecast, Sale Forecast, Customer Forecast, Manufacturing Forecast, Backlog / Future Orders)
- Causal Data Streams (Stock-Outs, Seasonality, State of Economy, Marketing Events / Promotional Activity, Weather, Labor Problems & Price Changes etc.)

The Demand agent plays the role of forecasting the future product demand used for the production scheduling and planning required for carrying out the customers’ requirements with exploitation of the customer contentment. The main goals of the Demand agent are being described as below:

- To forecast the future product demand accurately is the most important task of the Demand Agent.
Another major goal of the Demand agent is to choose the most efficient and accurate

- It is being designed for avoiding the overstock and shortage of the seasonal for the product during highest product demand.
- It is majorly designed for forecasting the product demand accurately for inventory control and efficient production scheduling.

### 5.4.9 Order processing agent

This agent has the main responsibility of performing the delivery of the product according the terms and conditions on which the order of the product is being placed. The lead time is major constraints on the working of the Supply Agent. It supports flexibility for managing customer demand frustration. The supply contracts are made with the customers for order processing purpose. There are following inputs for the manufacturer agents as given below:

- Nature of the shipped manufactured goods
- Category of the orders
- Shipping expenditure
- Time limit for shipping order
- Worth of product shipped

The Order Processing agent is being developed with aiming of fulfilling the customers’ orders with maximized customer satisfaction. The main goals of this agent are being described as below:

- The main goal of this agent is to maximize the customer satisfaction with real-time order visibility and earlier delivery.
- To improve the order visibility by concerning the tracking numbers to sales orders, invoices and customer records is another goal of the order processing agent.
- It is required for easily adoption of any shipment, and mechanization of mass fulfillment processes to save time and money.
- It is being directed to gain the customer satisfaction through the timely delivery and order fulfillment.
• To diminish the transportation cost through the combination of the customers’ orders on the same or related places is another goal of the Order processing agent.

5.4.10 Flow control agent

This agent manages the transfer of the products between the Production Agent and Transport Agent. This agent manages major activities- Loading and routing with the collaboration of the two agents i.e. Production Agent and Transport Agent. It takes care of transportation problems. There are following inputs for the manufacturer agents as given below:

• Delivery date
• SKU level
• Lead time
• Purchase orders
• Transportation costs

The manufacturer agent is being developed with aiming of manufacturing needed products for completing the customers’ needs with maximized customer satisfaction with preferred product quality. The main goals of the manufacturer agent are being described as below:

• The main goal of this agent is to produce greater product availability.
• To maintain the lowest inventory is the one of the major goals of the manufacturer agent.
• It is being designed to avail goods at the right and shortest time.
• It is majorly designed for maintaining the highest customer service for attracting more customers.
• It is being designed to reduce the transportation time.

5.4.11 Information agent

This agent is considered as the heart of the Multi-agent system which implements the supply chain. It has the responsibility of coordinating with all agents in the supply chain. For managing the demand frustrations in the customer’s demands then it circulates the all updates regarding the stock status, inventory level, delivery status and customer demand
at any particular time period. There are following inputs for the Information agent as given below:

- Consumer transactions
- Buying patterns
- Customer demand
- Delivery time of product order
- Stock level
- Delayed orders

The Information agent is being developed with aiming of sharing the information between all SCM entities. The information sharing plays very important roles in SCM activities. The main goals of the Information agent are being described as below:

- The main goal of this agent is to establish the accurate and reliable information flow in the supply chain activities.
- To provide the right amount of relevant information to the right person at the right is the one of the major goals of the manufacturer agent.
- It is being designed to choose efficient information flow technology in the affordable cost.

5.4.12 Manager agent

It is a central agent which works as a key coordinator for various supply chain agents. It is the backbone of these supply chain activities. It supervises the complete activities of the supply chain. It corresponds with any supply chain problem especially demand-supply problem to control agent for an appropriate solution. The responsibility of this agent is to guarantee that all the agents are working within their limits at the same time cooperation and collaboration among various agents are well established. There are following inputs for the Manager agent as given below:

- Customers’ orders
- Order due date
- Market status
- Price updating
- Inventory level
- List of suppliers
- Supplier RFQs

The Manager agent is being developed with aiming of managing all SCM activities for carrying out the customers’ needs timely with attaining the customer satisfaction. The main goals of the Manager agent are being described as below:

- It is being designed for making the efficient delivery timetable planning.
- It is being required to ensure stores having sufficient stock during the manufacturing process.
- To motivate the suppliers for consisting adequate stock to meet customers’ demand in timely pattern is another major goal of this agent.
- It is being designed to control the ordering and packaging process for timely delivery.
- It should work on the improvement of the supply chain activities for gaining the organization profits.

### 5.4.13 External agent

This agent enables the supply chain management system to connect with external modules like the database management system. According to the SCM requirements, this agent connects the supply chain system with some external resources to solve the problem and enhance the SCM performance. There are following inputs for the External agent as given below:

- SCM requirements
- External modules

The External agent is being developed by connecting the supply chain management system with external modules. The Model Management system consists of some external model base including Case-based Reasoning, Data Mining System, DBMS and various mathematical models and also a relevant model language for interaction with exact model for managing the bullwhip effects occurred in the supply chain system. The main goals of the External agent are being described as below:

- The main goal of this agent is to enhance the performance the supply chain management system.
To run the supply chain activities smoothly is the one of the major goals of the External agent.

It is being directed to select the reliable the external technologies for improved SCM system.

In order to diminish the bullwhip effects occurred in the supply chain, every agent carries out the precise function of the SCM organization and contributes the information to the Information Agent. The MAS based supply chain is capable of performing the whole SCM activities. The intelligent agents are capable of taking the decisions on the basis of the knowledge base. They are autonomous and dynamic in managing the customer demand fluctuations besides controlling the demand-supply problem. In this research work the MAS technology is being applied to reduce the bull whip effect problem in the supply chain. It also leads to intense research activities in the supply chain management. These agents are being designed on the basis of the BDI architecture for handling the SCM activities.

5.5 PROBLEM FACED IN EXISTING MAS BASED SCM

In the process of implementing the SCM, the MAS technology builds and creates multiple intelligent agents. These intelligent agents are being designed with predefined roles and responsibilities. With specific roles and responsibilities, these intelligent agents are being directed to achieve their own goals. It is possible in single intelligent agent application environment. But in case of the multi-agent system, there is a system goal but having no global overview. For achieving the system goal there must be coordination between these intelligent agents in the multi-agent system.

5.5.1 Coordination problem

The problem of coordination in multi-agent systems is of critical importance in implementing the SCM phenomena. In the SCM system, one type of intelligent agent is stimulating with accomplishment of various objectives. In another case, the actions to being performed by one agent depend on that action performed by another. Hence the failure of one agent to coordinate its outcome with others could be major terrible. If the Demand Agent fails to coordinate the forecasting values to the Production Agent, the Manufacturer Agent will not capable of preparing the production schedule and Inventory
Agent will not capable of making the decisions regarding the inventory control. There exits numerous reasons for facing the difficulties in achieving effective coordination in a multi-agent system.

In order to make more informed control decisions, the agents have to acquire a view of the task structures of other agents. For solving the problem of coordination in the multi-agent system, multiple coordination models are being developed for generating the cooperative distributed computing environment in which agents interrelate and assist to accomplish their own goals along with fulfilling the system goals of the community. In a cooperative computing environment, the agents have typically individual potentials that help in solving the entire problem.

There may be two ways of achieving the coordination between these intelligent agents. In the first model, the agents are working with *collectively motivated* or *collectively interested mode* by nature as they are aimed to work in such way to achieve a common goal along with its predefined roles and responsibilities. This model is totally oriented on the concept of the cooperation between the agent groups. This model is found suitable only for the closed connected systems where the agent groups are designed with the priori along with interaction protocol and the strategy for each agent. There exists another possible model in which the agents are *self motivated* or *self interested* agents by nature because every agent has its individual goals and perform the tasks in competition with the other agents for achieving these goals. This model is totally oriented on the concept of the competition. The competition may be defined in terms of the resource allocation or awareness of convincing tasks.

This model requires the agents to coordinate their specific actions with other agents for the purpose of ensuring their consistent behavior. This model is found suitable for open systems that allow designing the agents for dissimilar entities for different working status. These issues are not specified and known at design phase. For achieving the coordination of the activities occurred in MAS, and then inconsistency may occur due to the occurrence of the multiple activities by different intelligent agents at the same time.

There is one of the fundamental approaches to crack these conflicts may be known as the negotiation. The negotiation may be defined as the process of identifying interactions based on communication and reasoning concerning about the circumstances and
intentions of other agents. In MAS based SCM, both models are found inefficient in implementing the coordination between the various activities performed by various intelligent agents during achieving common goals. Hence we require some better technology for achieving the coordination of SCM activities.

5.5.2 Incapability of learning

All the intelligent agents in existing MAS based SCM system are incapable of learning from the working environment. These agents are not capable of gaining the experience from the past solving problems during its operations. They take the decisions using the rule-based reasoning approaches. In the rule-based reasoning approaches, there exist the rules for determining the next actions to be taken for completing the SCM operation. The wastage of the past experience of problem solving is main drawback of this approach. This approach is not able to utilize the past experience of problem solving. This approach is not looked like the human reasoning approach. The human reasoning utilizes the past experience of problem solving during past time periods. Hence to implement the human decision-taking process in the supply chain activities so the BDI architecture should be modified for building the intelligent agent in the MAS based SCM system.

5.6 PROPOSED SOLUTION FOR PROBLEM FACED IN MAS BASED SCM

In last section we have discussed the problem faced in the existing the Multi-agent based supply chain management system. These problems formulate the worst impact on the performance of the supply chain management system. Such system is not capable of tackling the bullwhip effect efficiently. Without controlling the bullwhip effect, the SCM system will be not capable of fulfilling the customer requirements timely with achieving the organization goals. There may be following solutions of these problems given below:

5.6.1 CBR-BDI architecture

With the support of their reasoning capability & autonomous features, the intelligent agents are capable of resolving the complex problem faced in the real time world. They are built into BDI architecture. They have predefined goals, action plan for taking the step during the operation of solving the problem. Unfortunately the intelligent agents are
not capable to learn from the environment. In MAS based SCM system, the intelligent agents can’t learn from the existing surroundings. But it is needed to aware of the current status and gain knowledge of the outside surrounding in global market competition stage. As the human nature, all decision makers utilize its knowledge which is learnt from the market conditions and keeps the existing solution in their memory. The case-based reasoning is being found as the most suitable approach that enables users to learn from the existing environment.

For the purpose of utilizing the benefits of the case-based reasoning approach in the MAS based SCM system, the BDI architecture of intelligent agents is being modified with use of case-based reasoning approach. These types of the intelligent agents are known as the CBR-BDI intelligent agent. In other words, the CBR-BDI agent are the range of intelligent agents that exploits the features of case-based reasoning to facilitate the intelligent agents to gain knowledge of the surroundings & formulate the decisions by with the existing solutions.

The CBR-BDI intelligent agents are competent to react regarding the events occurring in their environment, capture the initiative regarding their goals, cooperate with other agents and utilize earlier period experiences to accomplish contemporary goals. In BDI model, the intelligent agents have rational approach of Beliefs, Desires and Intentions. The main advantage of this architecture is its competence to make a decision regarding the actions to be performed next and action plans for executing its operations according to their attitudes. Another advantage of BDI architecture is that it is perceptive and comparatively uncomplicated to recognize the procedure of decision-making and how to perform it. The concept of belief, desire and intention are unproblematic to recognize.

Its major negative aspect of this architecture exists in procedure of judgment the mechanism of its efficient implementation. Another problem of this architecture is inability to gain knowledge of its environment. The CBR-BDI intelligent agents have distinct structures of case containing all information about the current problem faced as given below:

Case: <Problem, Solution, Result>

Problem: initial_state

Solution: sequence of <action, [intermediate_state]>
Result: final_state
BDI agents are being designed with following parameters as given below:

Belief: state
Desire: set of <final_state>
Intention: sequence of <action>

On the conceptual level, the intelligent agents are being designed along with completion of the CBR approach at implementation level. The benefit of this approach in MAS based SCM is that the supply chain crisis can be easily conceptualized by the intelligent agents along with facility of utilizing past experiences in the appearance of the CBR approach. So once the beliefs, desires and intentions of an agent are being recognized, they can be plotted into a CBR system.

In a BDI agent, each state is considered as a belief; the objective to be reached may also be a belief. The intentions are plans of actions that the agent has to carry out in order to achieve its objectives, so an intention is an ordered set of actions; each change from state to state is made after carrying out an action (the agent remembers the action carried out in the past when it was in a specified state, and the subsequent result). A desire will be any of the final states reached in the past (if the agent has to deal with a situation, which is similar to a past one, it will try to achieve a similar result to the previously obtained result).

On the conceptual level, the intelligent agents are being designed along with completion of the CBR approach at implementation level. The agent’s knowledge base is the case base of the CBR system that stores the cases of past beliefs, desires and intentions. The working of the CBR-BDI intelligent agents is described as below:

- When the intelligent agent encounters new problem, it starts a new CBR reasoning cycle for acquiring the solution.
- The intelligent agent prepares their final strategy by retrieving the similar cases from the knowledge base; the selected cases are being reused and lastly revised it regarding the constraints of new problems.
- The agents work in dynamic environments and their knowledge-base has to be adapted and updated continuously by the retain stage of the CBR system.
The benefit of this approach in MAS based SCM is that the supply chain crisis can be easily conceptualized by the intelligent agents along with facility of utilizing past experiences in the appearance of the CBR approach. So once the beliefs, desires and intentions of an agent are being recognized, they can be plotted into a CBR system. Based on this relationship, agents (conceptual level) can be implemented using CBR systems (implementation level).

Based on this relationship, agents (conceptual level) can be implemented using CBR systems (implementation level). This means, a mapping of agents into CBR systems. The advantage of this approach is that a problem can be easily conceptualised in terms of agents and then implemented in the form of a CBR system. So once the beliefs, desires and intentions of an agent are identified, they can be mapped into a CBR system.

5.6.2 Supply chain orchestration

The orchestration may be defined as the mechanism for describing the automated arrangement, coordination, and management of the business processes in the complex computer systems. The concept of the orchestration is mainly applied in the perspective of service oriented architecture (SOA). The orchestration is being applied for supporting
the business request with the applications, associated data and infrastructure involved. It defines the policies and service levels with the help of automatic workflows with managing the changes occurred during the operation. The orchestration manages the resource pool centralized. The orchestration reduces the time in working with multiple instances of a single application. In the situation of need of more resources, the orchestration engine executes tasks operating on their entity pieces of the substantial heap. The multiple processes are involved in exchanging of information required for business activities with medium of web service interactions. The applications which perform the task of decoupling the orchestration layer from the service layer are called agile applications.

In the orchestration, the workflows and processes are being utilized in different type of the domains. At various levels the orchestration engine is capable of performing multiple types of tasks.

5.6.3 Distributed case base

In MAS based SCM system, whole activities are not occurring at a single physical location. The whole operation may be performed across a set of agents. In such system, each agent requires to store its own local case in its case base which is known as distributed case base. In the distributed case base, every intelligent agent maintains own case base for the purpose of storing the past experiences which are used for taking the decisions during their performing their tasks.

As shown in figure 5.3, each agent maintains its own case for storing the past experiences. This approach provides very important benefits during the operation of the whole system. Each intelligent agents have own separate case base. Hence it has capability to maintain the different case structure. There exist no such common attributes which are being involved in all intelligent agents working. For example, the attributes for the demanding agent is totally different from the attributes for delivery agents. Using this approach, each agent is capable to introduce the separate fields in their own case structure as their needs. But in case of single case base, there will be common structure for all intelligent agents.
There are following facts related to case structure in the distributed case base as given below:

- In MAS based SCM system, the individual agents consist the limited sight of the comprehensive problem solving situation so it have the interior background of a case structure.
- The individual agents may be designed independently having not any knowledge of whole system problem solving in which they are going to contribute.
- The goal of individual intelligent agents differs from the other agents. The constraints on their working differ due to these different goals.

These facts show the issues related to the case structures in distributed case base in MAS based SCM system. To resolve all these issues related to the case structure in MAS based SCM system, the distributed CBR is the most suitable option in implementing the CBR in this system.
These approaches can provide the solutions of the problems faced in the existing MAS based SCM system. They may strengthen the capabilities of the MAS based SCM system. The role of the supply chain orchestrator is being implemented by Orchestrator agent.

5.7 ORCHESTRATOR AGENT

This agent implements the role of supply chain orchestrator in the SCM activities. It organizes major actions transversely the supply chain. It supervises numerous tiers of their supply chain (e.g. their suppliers’ suppliers and further upstream suppliers) to guarantee supply continuity, societal acquiescence, and to expand competitive benefit. It manages the IT platform, selects suppliers, decides on locations, selects transportation providers, logistics, and other service providers, and mandates the performance requirements for all of the players. The responsibility of this agent is to coordinate functions across the supply chain. There are following inputs for the Orchestrator agent as given below:

- List of suppliers
- Detail of the order placed
- Delayed orders
- Inventory turn
- Market scenario
- Organization policies
- Organization goals

The Orchestrator agent is being developed with automating the supply chain activities for better coordination between the SCM activities. The main goals of the Orchestrator agent are being described as below:

- The main goal of this agent is to coordinate the supply chain activities efficiently for enhancing the SCM performance.
- To monitor the supply chain activities more accurately is the one of the major goals of the manufacturer agent.
- It is directed to reduce lead times and supply chain cost for growing the organization goals.
• It is majorly designed for improving the supply chain visibility during the supply chain activities.
• To reduce supply chain timelines to shun gaps of ‘dead-time’ is another goal of the Orchestrator agent.

These agents are used to perform the supply chain activities. The interconnections between these agents are shown in Figure 5.4 as below:

![Interconnection between MAS](image)

5.8 INTERNAL WORKING OF VARIOUS INTELLIGENT AGENTS

As the intelligent agent’s definition stated, it is the computation entity which precepts the inputs from the environment through the sensor and acts upon the working environment. It means that the working of the intelligent agents may be defined in terms of its inputs, its predefined goals and the actions taken for achieving the goals. The intelligent agents may be described with the help of following facts as given below:
• **Percepts**
  It may be defined as the parameters which specify the inputs for the intelligent agent such as customer demand, delivery time, ordering batch and inventory status etc. For every intelligent agent, there will be specific perceptions which may be retrieved from the environment.

• **Actions**
  These facts specify the sequence of events to be performed on depending on inputs provided by particular events such as the selection of suppliers, making production schedule and placing the orders etc.

• **Goals**
  It may be defined as the values of these parameters which are being targeted to achieve after completion of whole operation such as customer satisfaction, profit, flexibility and fulfillment of organizational goals etc.

• **Environment**
  It is the source of getting the information required for completing the specific operation such as upstream and downstream activities.

For every agent in MAS based supply chain system, the information is being spread through the supply chain activities. These activities are being classified into two categories- upstream and downstream activities. These activities generate the environment for working of the intelligent agents. Both types of the activities play a very important role in the process of the whole system. These agents are designed with aim of controlling the whole system working for fulfilling the system goals. There are various characteristics of this environment as given below:

• It is accessible by the nature. It means the information may be accessed easily and utilized in the decision-making process during the supply chain operations.

• It is dynamic by nature as the supply chain activities may face the market fluctuation due to the customer demand variance.

• It is deterministic by nature. The outputs of the current supply chain activity determine the next state of the current environment.

• It is continuous as there are not fixed sequence of the activities regarding the inputs of supply chain activities.
There are basic characteristics of the environment generated in the MAS based SCM system. Let’s discuss the percepts, actions and goals of these intelligent agents in this system. The table 5.1 consists all those intelligent agents oriented on the Fundamental elements of the supply chain management system.

<table>
<thead>
<tr>
<th>Name</th>
<th>Percepts</th>
<th>Actions</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier Agent</td>
<td>Product Quantity, Product type, Cost</td>
<td>Selection of Supplier, Place the order,</td>
<td>Raw Material availability, Reliable Delivery, Incoming Quality</td>
</tr>
<tr>
<td>Manufacturer Agent</td>
<td>Order Quantity, Due date, Order priority, Capacity, Manpower, Pending order</td>
<td>Manufacture product, Deliver the product, Prepare manufacturing schedule, Modify existing schedule</td>
<td>On time delivery, Satisfy customer, Improve customer retention, Maintain product quality</td>
</tr>
<tr>
<td>Distributor Agent</td>
<td>Response Time, Product Variety, Order Visibility,</td>
<td>Make &amp; ship to stock, Assemble to order, Purchase &amp; make to order</td>
<td>Minimized Inventory cost, Good response time, Product Availability</td>
</tr>
<tr>
<td>Retailer Agent</td>
<td>Customer demand, Price updating, Stock status, Customer response</td>
<td>Selling product, Grading product, Packing, Ordering, Conducting Transaction</td>
<td>Engaging Customer, Educating Customer, Sale Promotions,</td>
</tr>
<tr>
<td>Production Agent</td>
<td>Product demand, Pending orders, Dues dates, Production Policies, Quality standards</td>
<td>Overseeing production process, Drawing up production schedule, Estimating costs, Setting quality standards,</td>
<td>Maintaining quality standards, Implementing production policies, Cost effective,</td>
</tr>
<tr>
<td>Transport Agent</td>
<td>Deliver time, Order size, Transporting Costs, Labor Cost</td>
<td>Selecting Carriers, Deciding transport costs, Loading products,</td>
<td>Reliable delivery, On time delivery, Cost effective,</td>
</tr>
</tbody>
</table>

Table 5.1 Fundamental Elements based intelligent agents
The table 5.2 consists all those intelligent agents oriented on the Strategic elements of the supply chain management system. These agents play a critical role in managing customer requirements.

<table>
<thead>
<tr>
<th>Name</th>
<th>Percepts</th>
<th>Actions</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Agent</td>
<td>Product response, History Basis, Customer demand, Market Conditions, Forecasting method</td>
<td>Forecast product demands, Feedback from customers, Maintain demand history,</td>
<td>Accurate product demand forecasting, Inventory Utilization, Product Availability,</td>
</tr>
<tr>
<td>Inventory Agent</td>
<td>Inventory items, Inventory status, Pending Orders, Product demand, Product sale, Inventory Cost, Stock Threshold</td>
<td>Inventory Planning, Establish order cycles, Balance Inventory Levels, Review Stocks, Follow-up and Control</td>
<td>Reduce inventory cost, Narrow gap between sale &amp; stock replacement, Efficient scheduling, Satisfying customers, Quickening Inv. Flow</td>
</tr>
<tr>
<td>Delivery Agent</td>
<td>Products price, Contract length, Product Volume, Penalty Defaulting, deliver time flexibility</td>
<td>Update demand, Transfer pricing mechanism</td>
<td>Reliable Delivery, Minimum Cost, Customer Satisfaction, Efficient, Maximum order flexibility</td>
</tr>
<tr>
<td>Flow Agent</td>
<td>Type of production element, Distribution Center, Destination of Products, Route</td>
<td>Loading goods, Unloading goods, Deciding routes</td>
<td>Reliable, Efficient routing, Cost effective</td>
</tr>
<tr>
<td>Information Agent</td>
<td>Inventory levels, Machines breakdowns, Capacity allocation, price updating</td>
<td>Pass information to different entities, Update the status</td>
<td>Efficient message passing, Efficient Information updating</td>
</tr>
</tbody>
</table>

Table 5.2 Strategic Elements based intelligent agents
The table 5.3 consists all those intelligent agents oriented on the purpose of controlling whole system operations in MAS based supply chain management system.

<table>
<thead>
<tr>
<th>Name</th>
<th>Percepts</th>
<th>Actions</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manager Agent</td>
<td>Customer Order, Suppliers lists, Customer RFQs, Supplier RFQs, Customer demand, Market Conditions, Customer RFPs, Supplier RFPs</td>
<td>Select supplier, Utilize control elements, Purchase raw material, Concern Manufacturers, Analyze customer RFQs, Analyze Customer RFPs, Analyze supplier RFQs, Analyze supplier RFPs</td>
<td>Efficient production, Inventory Utilization, Cost effective transport, Effective scrutiny of customer RFQs, Effective scrutiny of customer RFPs, Effective scrutiny of supplier RFQs, Effective scrutiny of suppliers RFPs</td>
</tr>
<tr>
<td>External Agent</td>
<td>External models, User requirement, External tech</td>
<td>Establish connection with external models, Monitoring whole system, Passing message to other entities</td>
<td>Compatibility, Flexibility, Efficient working, Optimized system performance</td>
</tr>
<tr>
<td>Orchestrator Agent</td>
<td>Multi-tier Supplier, brand partners, product supply seller, buyers</td>
<td>Share the information, Switch tasks, Contact other entities</td>
<td>Coordination and management of SCM activities</td>
</tr>
</tbody>
</table>

Table 5.3 System Managing related intelligent agents

All these 3 tables contain the precepts, actions performed and goals for various intelligent agents in MAS based SCM.