Major Project

On

Automated order processing and inventory management using multi agent system in Supply Chain Management

By

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Ahmedabad 382481
May 2008

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Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Computer Science & Engineering

By

Shah Bhumi S.
(06MCE022)

Under Guidance of

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Ahmedabad 382481
May 2008

This is to certify that Dissertation entitled

Automated Order processing and inventory management using multi agent system in Supply Chain Management

Submitted by

Bhumi Shah

has been accepted toward fulfillment of the requirement

for the degree of

Master of Technology in Computer Science & Engineering

Dr. S. N. Pradhan	**Prof. D. J. Patel**
Professor	**Head of the Department**

Prof. A. B. Patel

Director, Institute of Technology

CERTIFICATE

This is to certify that the work presented here by **Ms. Bhumi Shah** entitled "Automated order processing and inventory management using multi agent system in Supply Chain Management**"** has been carried out at **Institute of Technology, Nirma University** during the period **September 2007 – May 2008** is the bonafide record of the research carried out by her under my guidance and supervision and is up to the standard in respect of the content and presentation for being referred to the examiner. I further certify that the work done by her is her original work and has not been submitted for award of any other diploma or degree.

Dr. Dilip P. Ahalpara
Scientist SF,
Institute of plasma research,
Gandhinagar.

Date:

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The successful completion of a project is generally not an individual effort. It is an outcome of the cumulative efforts of a number of persons, each having own importance to the objective. This session is a vote of thanks and gratitude towards all those persons who have directly or indirectly contributed in their own specials way towards the completion of this project.

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ABSTRACT

Supply Chain exists in both service and manufacturing organizations, although the complexity of each enterprise may vary greatly from industry to industry.

In many situations, real-time operation is required in a supply chain, where it is desirable to optimize the schedules each time a new order is submitted. Order will be successfully executed and will be shipped to customer after passing through different phases. Each phase requires human interaction with system. This human interaction may be error prone and it costs to company in terms of facilities provided like training, communication cost etc. for personnel. Supply Chain Management (SCM) is a modular and decentralized application. If user interaction can be reduced at all stages where it can be applicable, then whole process can be automated and is less error prone. In order to achieve such automation we require a software system which can be modular and can work intelligently and provide continuous support for whole SCM cycle in efficient and effective way. Considering this as a base, industrial research work has been carried out and by considering electronics manufacturing industry's SCM cycle an effort has been made to automate whole SCM cycle using agents and making multi agent system.

Agents are best suited for applications that are modular, decentralized, changeable, ill-structured and complex. As different agents will be created for different tasks and thus multi agent system will be created for whole CSM cycle. Optimization has been done at the stages where it is required and automated order processing and inventory management is the main concern. The system is implemented in a decentralized form and by submitting different orders, different aspects of the system has been tested.

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LIST OF ABBREVIATIONS

SCM	**Supply Chain Management**
EDS	**Estimate Date of Shipping**
KA	**Knowledge Agent**
ADA	**Autonomous Data Analysis**
PMO	**Proactive Monitoring of Orders**
SCN	**Supply Chain Network**
DA	**Dispatch Agent**
SMA	**Simple Moving Average**
WMA	**Weighted Moving Average**
MAS	**Multi Agent System**

1. INTRODUCTION

This chapter presents how multiagent systems are used to manage supply chains. Here the concept of supply chain is introduced as a solution to some industrial issues. Such industrial issues are first outlined next.

1.1 Industrial Problem in general

First, companies face a huge number of problems, such as how to make decisions concerning production planning, inventory management and vehicle routing. These three decisions are managed separately in most organizations because making each individual decision is very difficult, since many constraints have to be satisfied [1] (production, shipping and inventory capacities, precedence order of activities, legal obligations, etc.).

Secondly, the problem is yet harder in reality because the decisions concerning production planning, inventory management and vehicle routing are interdependent. Hence, these three decisions should be taken together, which makes the planning problem harder.

Third, companies are not isolated, but impact on and are impacted by their partners. As a result, when a company maximizes its profits, it may disturb other companies, which may result in globally under optimal decisions, because organizations may have different conflicting objectives. The best solution would be to make the decisions together concerning production planning, inventory management and vehicle routing for several companies. As this planning problem is hard for a single company, synchronizing all companies' decisions together is very hard [2].

The concept of supply chains was proposed to address these problems and minimization of total supply chain cost, while meeting fixed and given demand by points-of-sale.

1.2 Challenges for Supply Chain Management

There are four major areas in supply chain management.

1) **Location**
2) **Production**
3) **Inventory**
4) **Transportation (distribution)**

There are both strategic and operational elements in each of these decision areas. As a solution to such problems, number of Enterprise Resource Planning (ERP) systems has been introduced in the market. But again this system requires personnel training for users and synchronization among all modules so it is a centralized system. Again cost which one has to pay to buy such systems are very high, even though they are coming in modules, cost of all required modules go high. Successive activities in the current system require frequent human interaction which makes it a slow process. The current system is planned to take care of this problem by providing a solution that is automated at each stage of the Supply Chain. This makes the whole process quite fast and efficient.

To overcome such problems work presented here aims making such SCM system automated so that user interaction required will be very less. System will work intelligently to take decisions.

SCM is a decentralized system. It is very complex and modular. It usually keeps changing quite frequently, for such systems agent can be very useful to make system automated and less error prone.

As a solution current work aims at use of agents for making system automated.

Agents are best suited for applications that are modular, decentralized, changeable, ill-structured and complex.

Some arguments in favor of using agent systems in supply chain management can be found in the literature. In industry of concurrent engineering, collaborative engineering, design, manufacturing enterprise integration, supply chain management, manufacturing, planning, scheduling and control, material handling has been already applied multi agent system.

1.3 Agents in Supply chain management

Supply chains are made up of heterogeneous production subsystems gathered in vast dynamic and virtual coalitions. Intelligent distributed systems, e.g. multiagent systems, enable increased autonomy of each member in the supply chain. Each partner (or production subsystem) pursues individual goals while satisfying both local and external constraints. Therefore, one or several agents can be used to represent each partner in the supply chain (plant, workshop, etc.). Moreover, the agent paradigm is a natural metaphor for network organizations, since companies prefer maximizing their own profit than the profit of the supply chain.

In fact, the distributed manufacturing units have the same characteristics as agents are having [3] as follow.

a. **Autonomy: a company carries out tasks by itself without external intervention and has some kind of control over its action and internal state.**

b. **Social ability: a company in the supply chain interacts with other companies, e.g. by placing orders for products or services.**

c. **Reactivity: a company perceives its environment, i.e., the market and the other companies, and responds in a timely fashion to changes that occur in it. In particular, each firm modifies its behavior to adapt to market and competition evolutions.**

d. **Pro-activeness: a company not only simply acts in response to its environment; it can also initiate new activities, e.g. launching new products on the market.**

Moreover, multiagent systems offer a way to elaborate production systems that are decentralized rather than centralized, emergent rather than planned, and concurrent rather than sequential. Therefore, they allow relaxing the constraints of centralized, planned, sequential control.

Agent: software specialized on one or more tasks which operate in cooperation with other agents.

Agent-system: the total of all agents that operate for one organizational unit, e.g. a company and/or an agency of a firm.

Multi-agent-system: the total of all Agent-systems which operate together in the whole application domain.

1.3.1 Multi Agent System

Multi-Agent systems correspond to some systems containing interacting agents. The agent interactions [4, 5, 6] are essentially based on communications between them. Communications are here seen as interactions processes. The detection and management of organizations inside multi-agent systems is an actual topic of numerous scientific publications, the correlated notions of self-organization and emergence are also a thrilling topics for some AI researchers. The study of multi-agent systems (MAS) focuses on systems in which many intelligent agents interact with each other. The agents are considered to be autonomous entities, such as software programs or robots. Their interactions can be either cooperative or selfish. That is, the agents can share a common goal (e.g. an ant colony), or they can pursue their own interests (as in the free market economy).The probability of agent accomplishing a task collaboratively is fully autonomous by decision making of each agent.

Following are some areas of Multi Agent System applications

a. **Supply Chain Management**
b. **Computer-Aided Design**
c. **Electronic Commerce**
d. **Manufacturing Systems**
e. **Network Monitoring**
f. **Office and Home Automation**
g. **Robotics Control**

To implement agents in Supply Chain Management industrial research study has been carried out as follow.

1.3.2 Industrial Research Study

Two months of study has been carried out to see what the modules in SCM of electronics manufacturing company are where agents can be best suited.

Company

Sunrom Technologies, Offices in Finland, Mumbai & Ahmedabad (Head Office). URL: http://www.sunrom.com

About Company

Manufacturer of embedded system products provides latest technological evaluation kits for system level design & development. Marketing of products is done by various methods like online shop, distributors, dealers, direct marketing & government tenders.

Method of Business

Takes new development technologies from semiconductor manufacturer and provides evaluation technologies for those semiconductor products. Constantly gets feedback from customer for next possible range of products. Due to feedback from customers, products are constantly revised and upgraded.

Structure of Company

a. **100+ Suppliers providing raw material**
b. **4 Production Facilities**
c. **4 Inventory Stores**
d. **1 Central Head office / R&D Office**

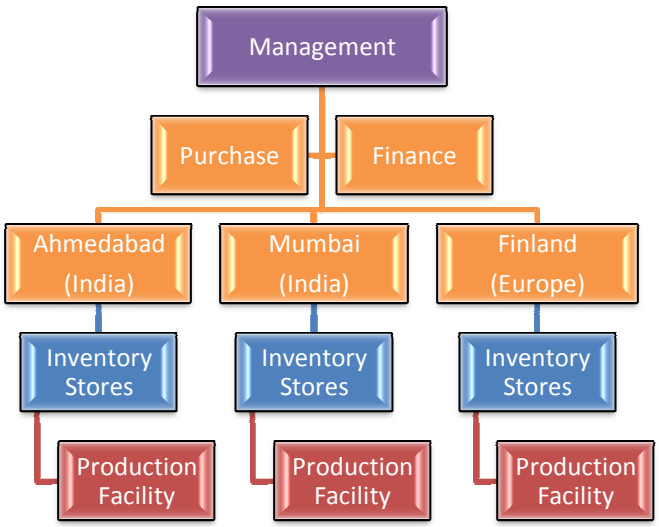

Figure 1.1 Structure of the company

Made to Order as per demand

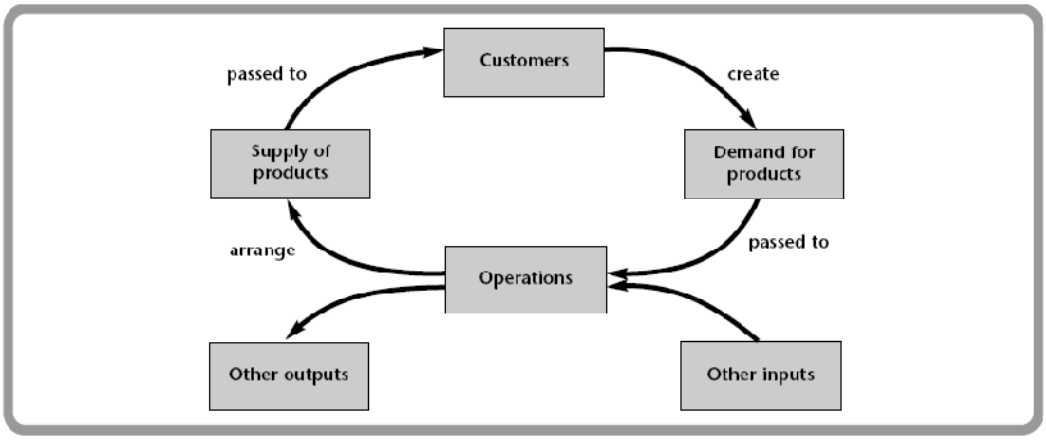

Figure 1.2 SCM strategy for Sunrom [7]

Factors for selecting made to order strategy,

1. **Lower Inventory Cost**
2. **Fluctuating demand**
3. **Products getting outdated soon**
4. **Constant process of changes to products**
5. **Non-Steady requirements of material used in production**
6. **Multiple Factories for different production line**

1.4 Problem Statement

In Sunrom, a considerable number of information & material flow for the import and export of products is carried out. Every year some thousands of products are processed in the production factory facilities. In recent years, the businesses were strongly affected by the globalization trend being observed in the technological industry. In this regard, technological manufactures like Sunrom focus more on flow of information and products.

Consequently, the rise of the production as well as the relocation of production all over the world lead to an increasing demand for smooth information and material flow for decision making process. Following are the key areas requirement for business process at Sunrom.

Requirements

a. **The first requirement regarding the process concerns activities of gathering information. They have to be fulfilled proactively and in a timely manner to provide a data basis for the next process steps.**

b. **Since Sunrom's purchases from a single point and supply to factories and inventory stores. Information communicated from network partners regarding orders needs to follow supply networks.**

c. **In the distribution process order relationships determine potentially affected network partners that have to be informed proactively.**

d. **The set of data gathered from internal and external sources regarding the status of an order and its customers has to be interpreted.**

e. **Necessary rules have to be editable to provide easy integration of new knowledge (e.g. new rules for interpretation) as it becomes available.**

1.5 Scope of work

a. **Implement Supply chain management system using Multi agent system which can fulfill above requirements and can remedy for following hidden cost.**

b. **Expecting hidden costs: Consultancy for implementation can be a major part of costs. Apart from the consultancy and cost of software and hardware, the implementation will involve some other costs like training employees across enterprise. Loss of productivity in the first few months after you install ERP is also to be expected. Annual maintenance costs and annual costs can also be hefty.**

2. PROPOSED SOLUTION

2.1 Existing Order Processing System for Sunrom Technologies

Before the multi agent based proposed solution is presented a brief description of the current SCM based system adopted by Sunrom technologies is presented here with a view to highlight the aspects which are improved in the current system.

Current Scenario for Sunrom Technologies

Sunrom is doing most its business through their website having following features:

a. **Front End: For the customers (viewers) to browse through all items and placing an order.**

b. **Back End: This part contains Administrator panel from which allows various options to edit forms in front end. Main work of Order processing and Order shipping is done from backend. Sequences of steps are followed from the place where customer places an order and till order gets shipped.**

In the following, series of screenshots are presented to show that their system requires human interaction at each step hence it is quite cumbersome to use.

1. **Customer places an order. To place an order customer creates account on website www.sunrom.com and creating an account.**
2. **After placing an order customer will confirm his order and will make payment.**
3. **User has to go to admin panel and manually it has to change its status as shown in below figure 2.1:**

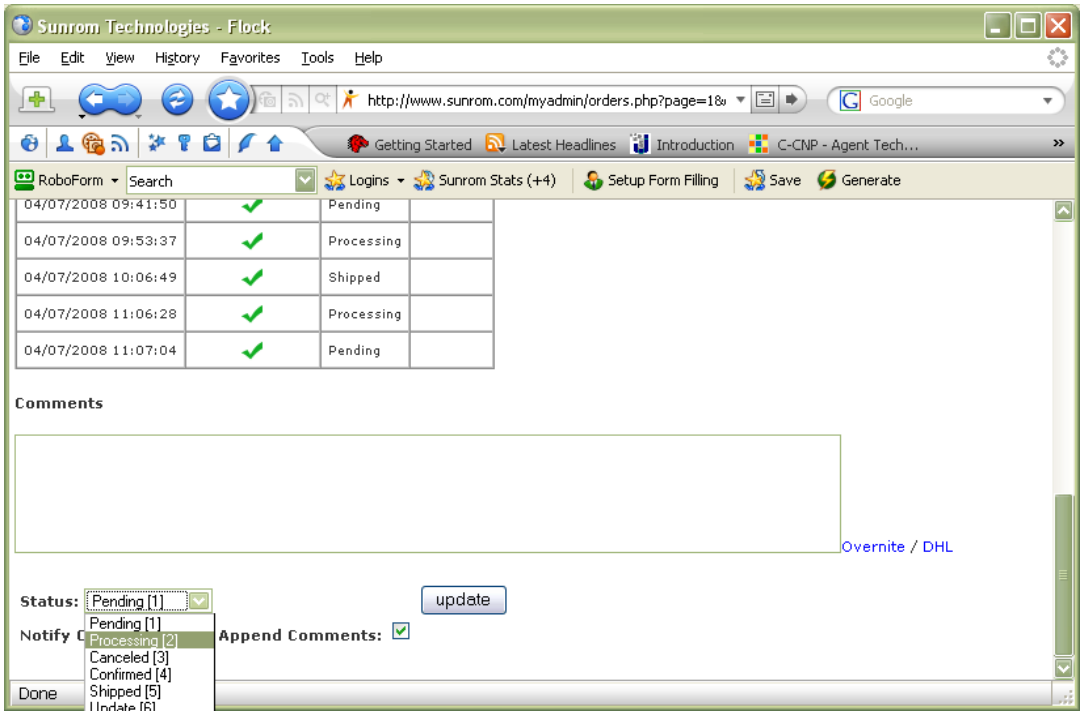

Figure 2.1 Form of Sunrom website that allows manual entry for changing order status

4. **User will check for inventory and if not enough material to fulfill the order he will manually order from supplier by listing each item.**

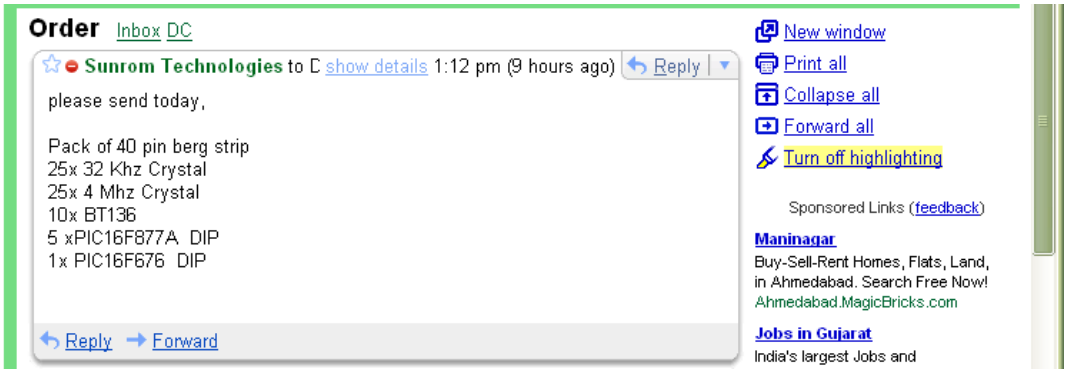

Figure 2.2 Manual ordering for material

5. **After receiving material again manually will have to see list of pending order and modify its status as shown in figure 2.1.**

Thus by following above procedure user has to interact with the system and complete the order processing. Here this procedure is time consuming, error prone and required personnel training. Such parameters are affecting and so

automation of system through agents can be one of solution to minimize above parameters.

2.2 Proposed Solution

From above steps it is evident that in each and every step human interaction is required. So a possible solution for this problem is to avoid or minimize user interaction as far as possible. As mentioned earlier these problems arise because the system is modular, decentralized, changeable, ill-structured and complex. So we can apply multi agent system to make it automated.

Consider following scenario.

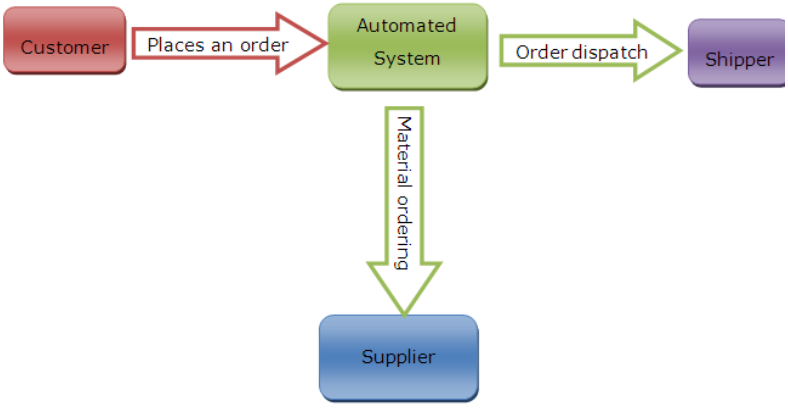

Figure 2.3 Modules involved in proposed solution

Different agents are created and each agent is assigned a particular task. An agent focuses on its assigned work and it communicates with other agents. For sake of simplicity consider that on all agents are residing on one system and every agent will have access to their local database. To retrieve data of another location there will be a communication between agents. So it is not an issue if we allow agents to access to only their local database. By considering whole scenario following agents are to be created.

2.3 Types of Agents

a. **KA (Knowledge Agent)**
b. **PMO Agent (Proactive Monitoring of Orders)**
c. **SCN Agent (Interdependencies in Supply Chain Network)**
d. **ADA Agent (Autonomous Data Analysis)**
e. **DA (Dispatch Agent)**

Brief introduction and responsibility assigned to each agent is as follow.

KA (Knowledge Agent)

This agent will provide view for all other agents. Whenever system initializes itself this agent will start first and all other agents will first inform to KA for their existence on the system. So we can also monitor which agents are currently working and which are not through this agent.

PMO Agent (Proactive Monitoring of Orders)

Traditional methods are user driven, that is only carried out with consent of end user. There is no reliable method by which real time analysis and decisions are carried out.

Agents carry out real time analysis and act in a timely manner for completions of the process. Agent carries out real time analysis by identification of orders with a high probability of encountering disruptive events. With this knowledge a more focused proactive monitoring has to be realized.

Agents uses past knowledge in carrying out analysis to solve the occurrence of failure events. Therefore Proactive Monitoring of Orders can only be satisfied via agents and not by traditional method.

SCN Agent (Interdependencies in Supply Chain Networks)

As soon as order status is received from PMO agent it will start looking for inventory and if it is not sufficient then it will order the inventory to supplier through email. This agent is also responsible for analyzing inventory and according that result it will place an order for he required inventory. So here user interaction is avoided for material checking in database and manually order inventory. Automation of system will be done through agents and user interaction will be reduced.

ADA Agent (Autonomous Data Analysis)

This agent provides view of database, i.e. mainly order status and ordered material status. User will not have direct access to database; instead agent will have access to database and will allow the user to see the above status. User can not modify this view.

DA (Dispatch Agent)

This agent is responsible for dispatching the order. It will monitor for pending orders as well as pending material which as been ordered. If material is arrived then it will start processing the order which has been pending. If order is ready it will email to Courier Company to pick up the courier.

Overview for sequences of task arrived and executed when agents will take place can be shown in following way.

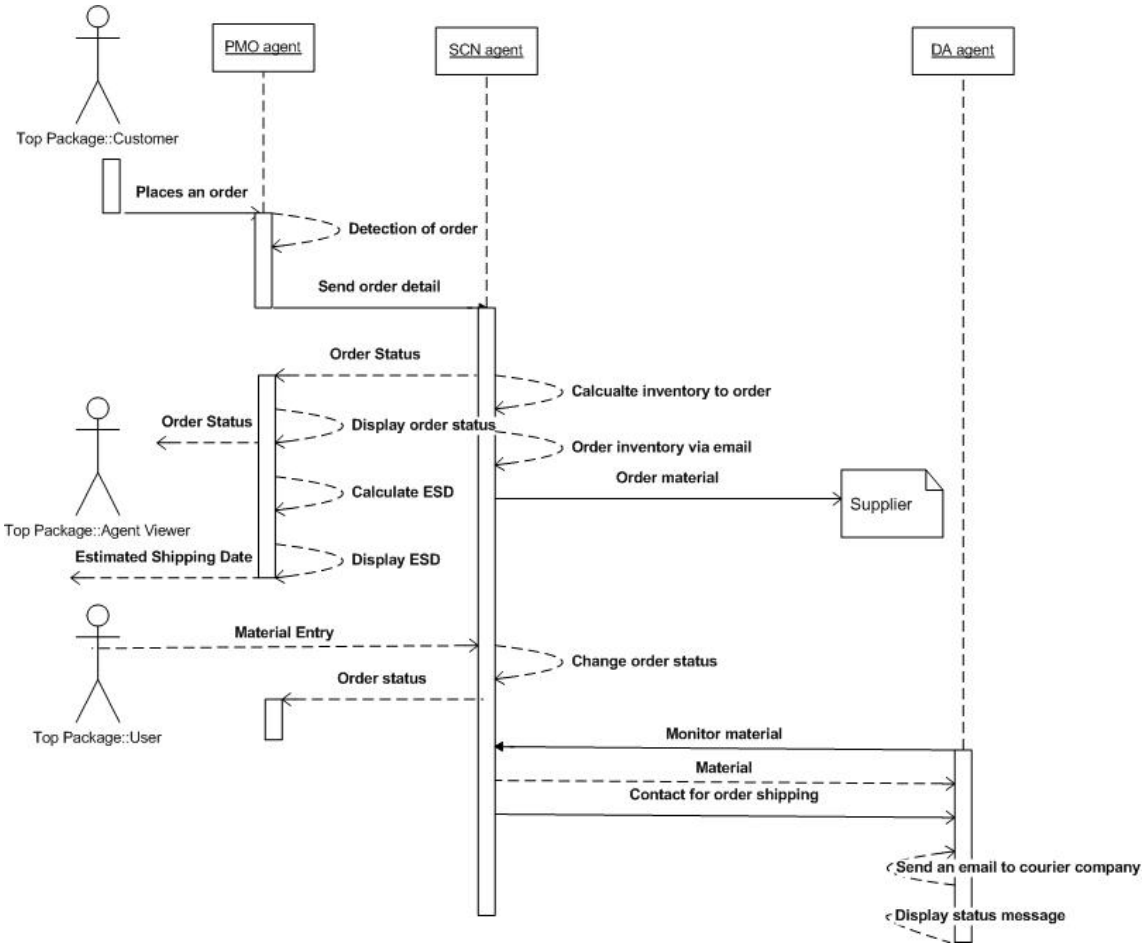

Figure 2.4 Sequence diagram for SCM including agents

Now we will see the structure for agents.

2.4 Common Structure of all Agents

a. **Implemented in VC++, specific task assigned to each agent**
b. **TCP/IP Communication capability of behaving as both client and server**
c. **XML data sending and receiving capability**

d. **Each Agent occupy two ports of TCP/IP – One port for listening and another for sending data**
e. **Agent opens sockets and communicates XML data**
f. **Agent can establish communication between following ways**
    i. **Between agent of same company**
    ii. **Between agents of another unit company**
    iii. **Between management agents for reporting and notification**
g. **Each agent can access database for monitoring and processing**

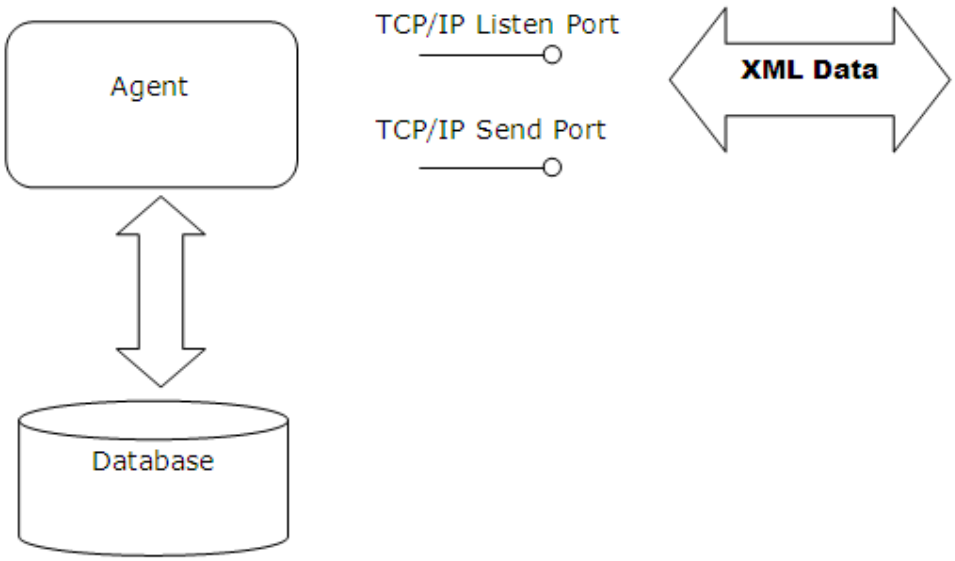

Figure 2.5 Common structure for all agents

2.5 Development

Microsoft Visual Studio 2005, VC++, Version 8.0.50727.42

XML Communication

In the real world, computer systems and databases contain data in incompatible formats. XML data is stored in plain text format. This provides a software and hardware-independent way of storing data. Upgrading to new systems (hardware or software platforms), is always very time consuming. Large amounts of data must be converted and incompatible data is often lost.

XML data is stored in a structured text format. This makes it easier to expand or upgrade to new operating systems, new applications, or new browsers, without losing data.

This makes it much easier to create data that different applications can share.XML was created to structure, store, and transport information. XML is about carrying information. XML is nothing special. It is just plain text. Software that can handle plain text can also handle XML.

However, XML aware applications can handle the XML tags specially. The functional meaning of the tags depends on the nature of the application. Its primary purpose is to facilitate the sharing of structured data across different information systems, particularly via the internet and it is used both to encode documents and to serialize data.

Database

Microsoft Access97 is used as backend for data storage. It contains template database called Northwind.

Northwind Sample Database

The Northwind Traders sample database contains the sales data for a fictitious company called Northwind Traders, which imports and exports specialty foods from around the world. The Northwind sample database (Northwind.mdb) is included with all versions of Access. It provides data you can experiment with and database objects that demonstrate features you might want to implement in your own databases. Using Northwind, you can become familiar with how a relational database is structured and how the database objects work together to help you enter, store, manipulate, and print your data.

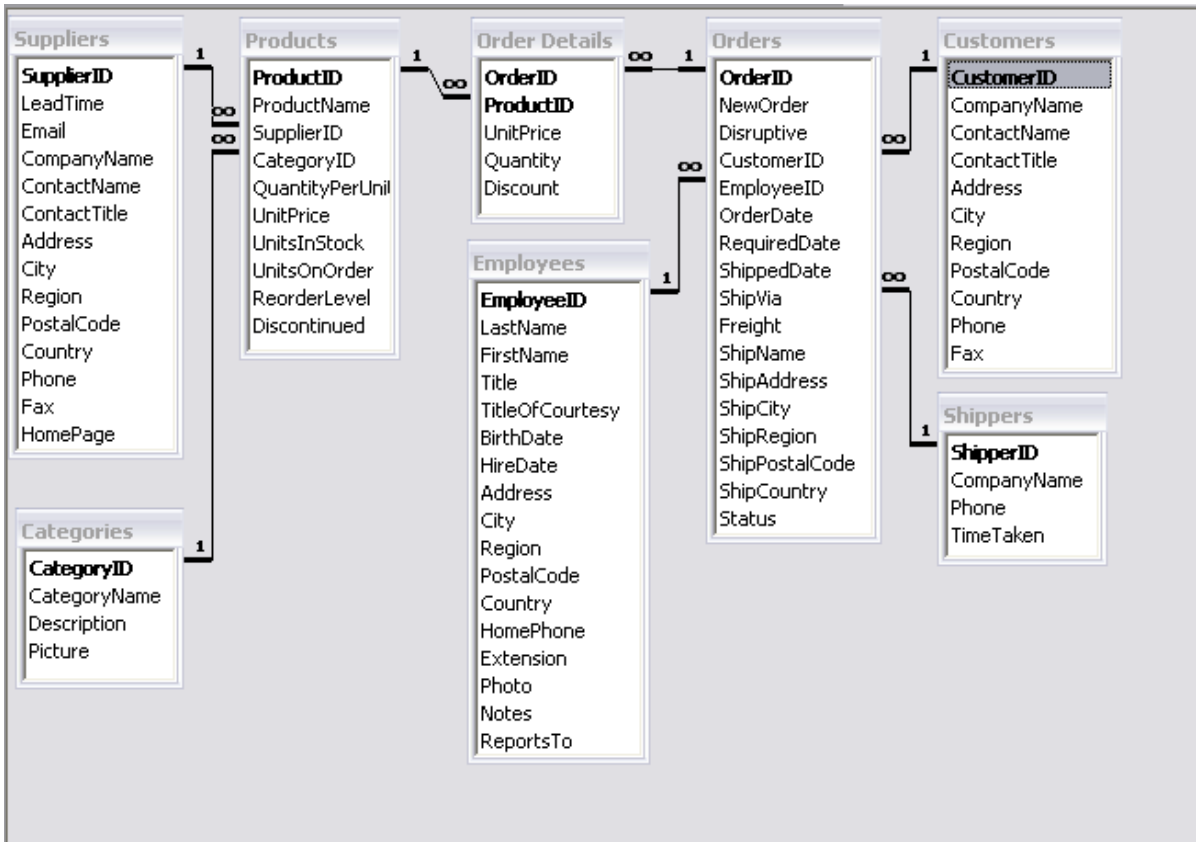

Figure 2.6 Relationship diagram for Database

3. ORDER MONITORING USING PMO AGENT

Supply Chain Management streamlines processes within organization and helps to meet business needs more efficiently and quickly. Here is a manufacturing company, and then SCM system comes into action from the point that sales representatives in different parts of the country or world, book orders, and feed them into the system. The system helps to track what inventory have of raw material and finished goods, how much more need, and how much time it will take to deliver. Customer service department can then use this to tell the customer when to expect his order. Manufacturing department uses the same information to set its production schedules, hire temporary staff, and so on. The packaging will gear up for shipping. Customers can track the shipping status online.

For proactively monitor the order design for agent which is called PMO (Proactive Monitoring of Orders) will be implemented with following functionality.

3.1 Proactive Monitoring of Orders (PMO agent)

Problem: The first requirement regarding the process concerns activities of gathering information. They have to be fulfilled proactively and in a timely manner to provide a data for the next process steps. Since Sunrom's purchases from a single point and supply to factories and inventory stores, information communicated from network partners regarding orders needs to follow supply networks. In the aggregation and interpretation process data from different network partners has to be aggregated and interpreted to evaluate effects of disruptive events that occurred in the network.

Solution: However, gathering information on monitored orders always incurs costs (e.g. communication costs, infrastructure costs, activity costs associated with personnel) that cannot be neglected. Therefore, identification of orders with a high probability of encountering failure possibilities is needed. With this knowledge a more focused proactive monitoring has to be realized with the result of an improvement of a proposed solution's efficiency regarding operational costs. Here as soon as order will be placed it will be detected and will send further for

processing. This agent is also responsible for calculating estimate date for customer to receive an order. As the problem for aggregate and transfer information across network incurs cost, by considering no network latency agent will only monitor the orders of local location only. It will only monitor and detect its local database rather than global one.

3.2 Process of PMO agent

Initially when PMO agent starts it will start monitoring for new orders. As soon as orders will be detected it will collect all information and will send to the next agent for processing.

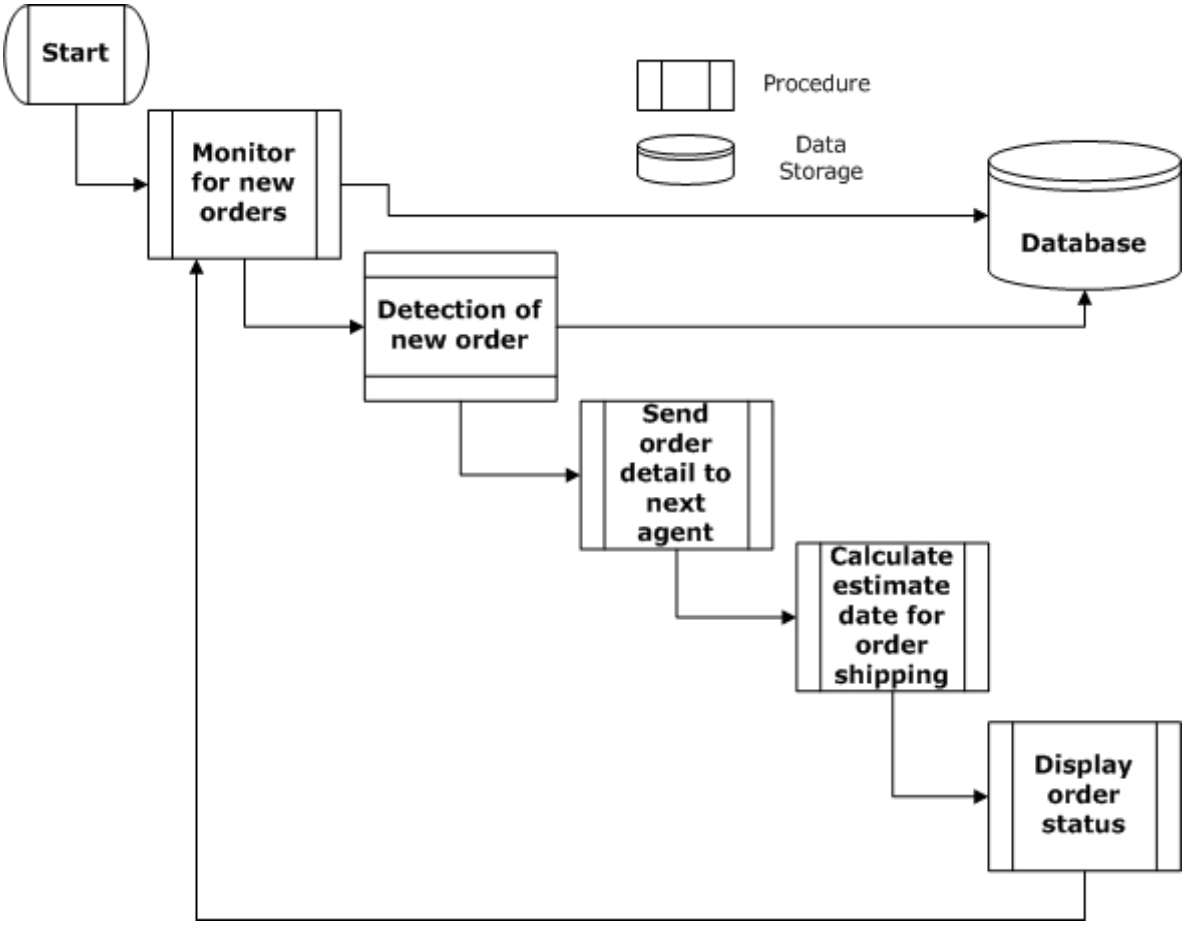

Figure 3.1 Activity flow for PMO agent

After sending detail it will calculate Estimate Date for Shipping (EDS) of newly arrived order. Algorithm and procedure used for EDS are described further. After calculation it will try to receive order status from next agent that, weather order is

pending due to insufficient material or it can be processed? And again it will in monitoring state.

3.3 Design of PMO agent

From the design of PMO agent shown previously it can be seen that communication between agents and with database is done by TCP/IP and XML. Paths are shown by dark line for XML communication and dotted line for TCP/IP communication.

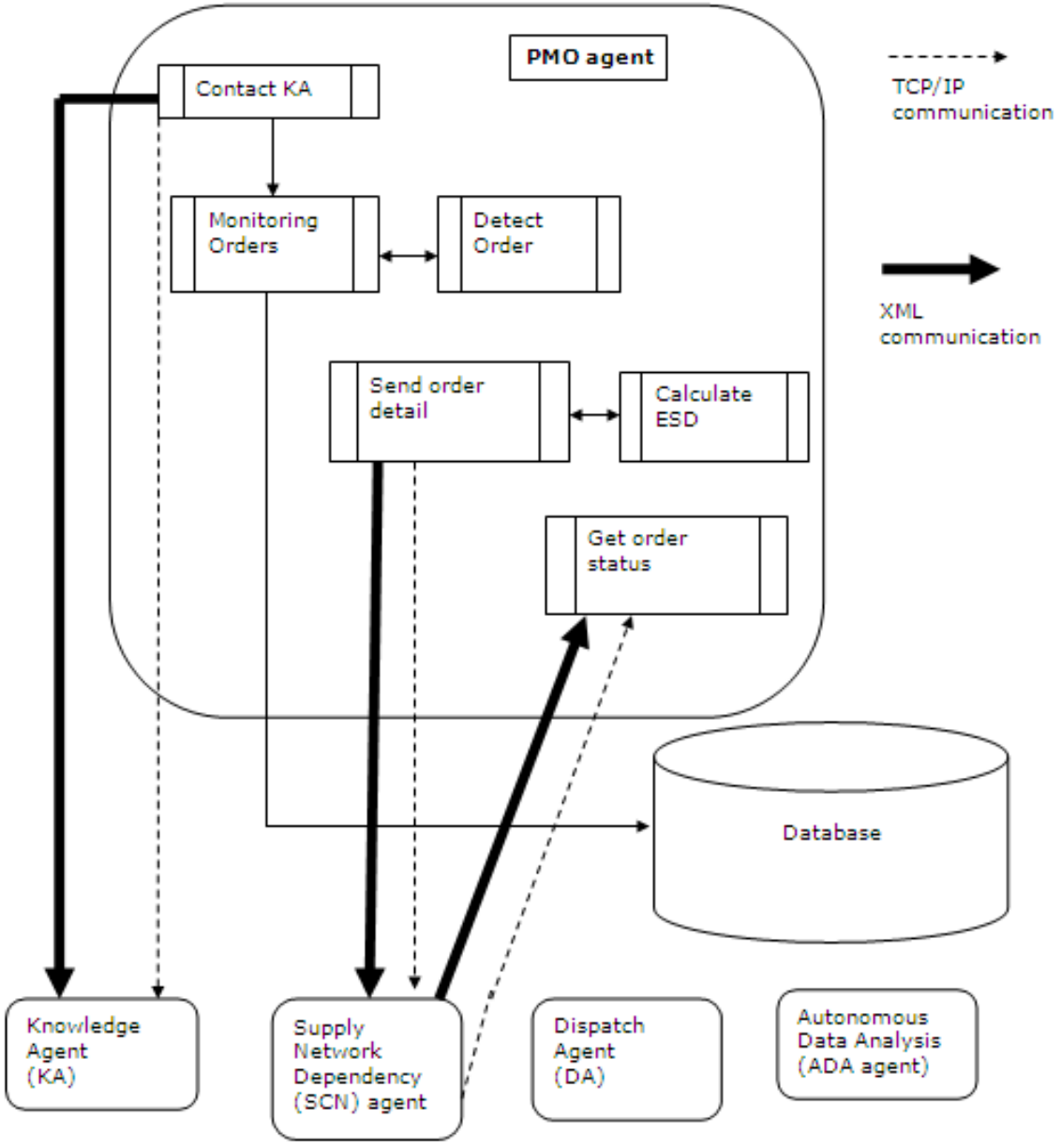

Figure 3.2 Communication to other agents of PMO agent

TCP / IP: Whenever agent send any information it will become server and when it will ask for any information it will be in client mode. Here ports are assigned for ach agent so communication will be done by identifying particular port number.

XML: Efficient electronic marketplaces require flexible languages such as XML to define the exchange of structured and unstructured information across electronic commerce applications. Software agents can enhance such marketplaces significantly. Therefore here agent technology has been integrated with XML.

Document Type Definition (DTD) for PMO agent:

Initially when PMO agent starts it will send message to KA for registration of its existence on network.

```
<?xml version=”1.0”?>
<INFO>
  <AGENT> </AGENT>
    <COMMAND> </COMMAND>
    <HOST> </HOST>
   <PORT> </PORT>
</INFO>
```

DTD for PMO agent when it sends an order detail to SCN agent

```
<?xml version=”1.0”?>
<ORDERS>
   <AGENT> </AGENT>
  <COMMAND> </COMMAND>
  <ID> </ID>
     <ITEM>
        <PRODUCTID> </PRODUCTID>
        <QTY> </QTY>
    </ITEM>
</ORDERS>
```

3.4 Classes for PMO agent

Here classes used by PMO agent are shown figure 3-3. Every class is supporting to activities done by PMO agent. Main classes are shown here which are most frequently used as shown in table 3-1.

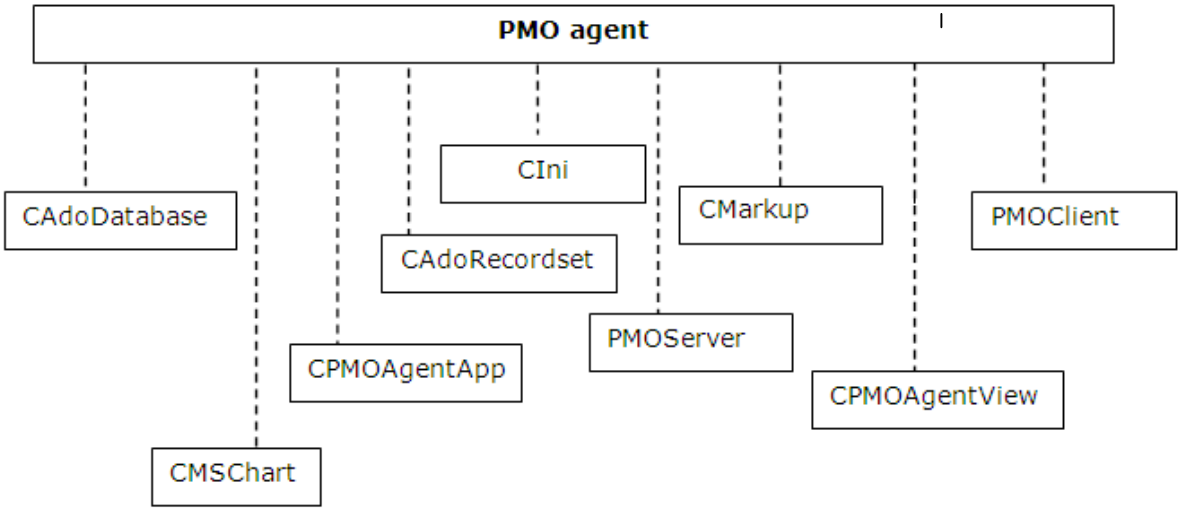

Figure 3.3 Classes used by PMO agent for its activities

Table for classes

CIni	**Read settings from file**
CAdoDatabase	**Database connection**
CAdoRecordset	**Fetch rows of data from table**
PMOServer	**Provides TCP/IP enabled server**
PMOClient	**Provides TCP/IP enabled client**
CMarkup	**Handles XML communication**
CPMOAgentApp	**Main application class**
CPMOAgentView	**Handles user interaction**

CMSChart	**Used to draw stacked bar graph**

Table 3-1 Brief summary of classes used by PMO agent for its activities

3.5 Calculation for Estimate order receipt date

PMO agent handles responsibility to give estimate date of order reception to the customer. This is calculated based on the past experience considering following parameters.

a. **Date of Order (P1)**
b. **Lead time supplier might take (P2)**
c. **Time taken by Production house (P3)**
d. **Time taken to deliver the goods (P4)**

So Estimate Date of Shipping (EDS) = P1+P2+P3+P4

Reasons for considering only these parameters are as follow:

1) **Date of Order to be consider will be very easy accessible and accurate.**
2) **After placing an order and in case if material is not available readily in store then we have to order it from supplier. So to process particular order we have to include time between we place the order for supplier and material received. This time duration is called lead time. This estimation can be known from the past knowledge of agent by monitoring how much time particular supplier has taken to dispatch the material and in how much time it has been received. This data is also about accurate as we are using past knowledge so this parameter is considered.**
3) **Time taken by production house is also strong candidate for calculation as we can have number of pending orders and processing orders in queue, so if particular order can be finished only when previous orders get fulfilled. So this can also be considered.**
4) **Time taken to deliver the goods is also as much dependent on time taken by shipping company as dependent on above three parameters. We are also considering time taken by shipping company takes to send material in particular company. So this can also not be neglected.**

Calculation of four parameters is shown below:

1. Date of order placed (P1)

To give estimation for the receipt of material first thing as to be considered is Date of order placed. This is no need to calculate as it can be directly accessible from database.

2. Lead time supplier might take (P2)

1) **Find out product and its quantity from order details**
2) **Loop through all the products of order**
3) **Get stock of that product and its supplier**
4) **If quantity required is more then stock then consider the lead time that will be taken to fulfill the order**
5) **If there are more then one product from different suppliers with different lead times consider the lead time of maximum value**

3. Estimate time of Production (P3)

Processing Time at production house (T1) = x hours
Current Load at production house (C2) = y orders

Time taken in production house = ((y * x) + x) /24 = z days

By applying this calculation we can get number of days (z) order will take to reach to customer.

4. Time taken to deliver the goods (P4)

Each method of shipping has different delivery times. Find out delivery time of the shipping method of particular order.

3.6 Screenshots of PMO agent

Here series of screen shots are provided with description of activities done by PMO agent at each step. As mentioned earlier PMO agent is used for monitoring of orders but proactively monitoring, so continuously it will monitor, detect and pass information to next agent.

1) Agent as started and monitoring for orders as shown in figure 3.4:

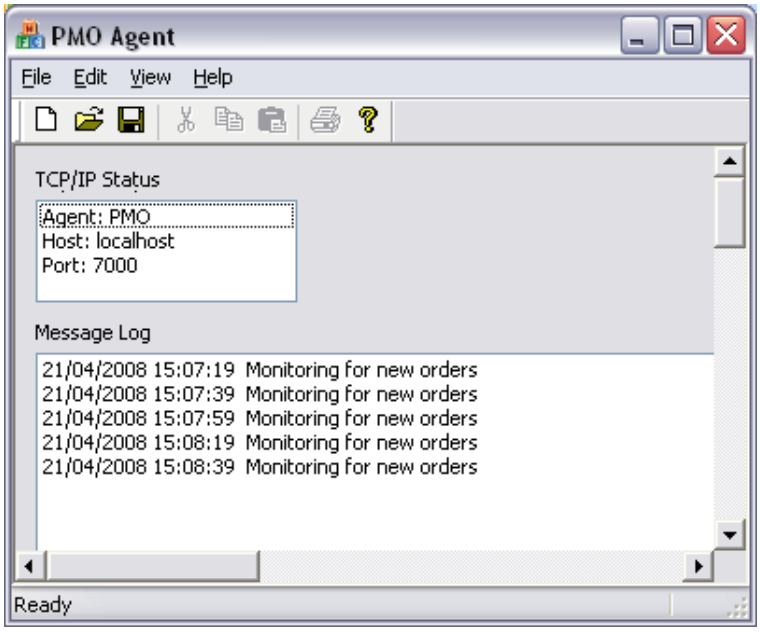

Figure 3.4 Initial state for PMO agent

2) Customer has placed order and it has been detected as shown in figure 3.5:

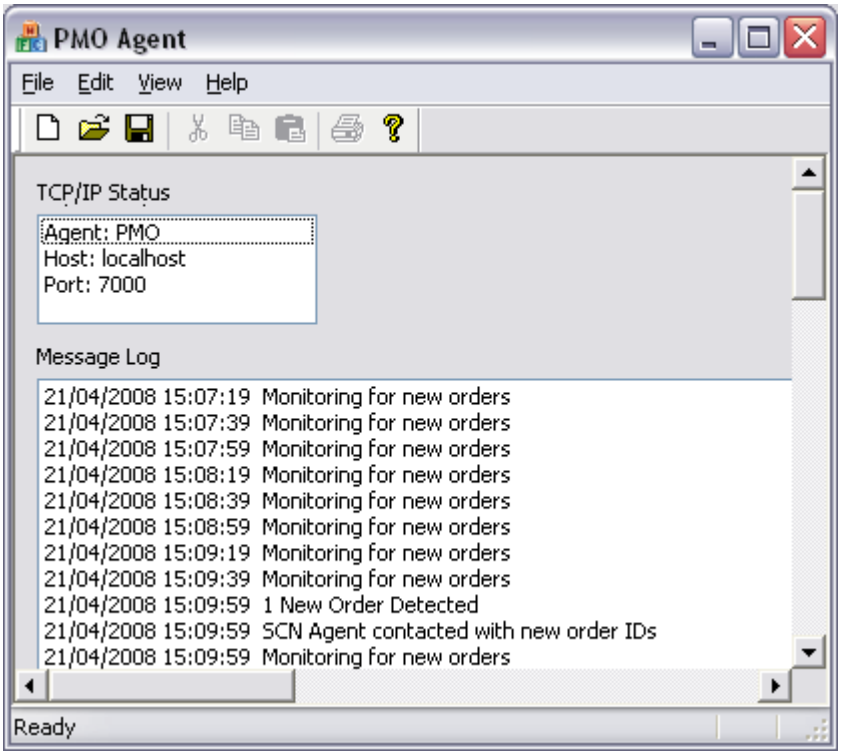

Figure 3.5 Order detection of PMO agent

3) It calculated Estimate Date for Shipping (EDS) and display as shown in figure3.6:

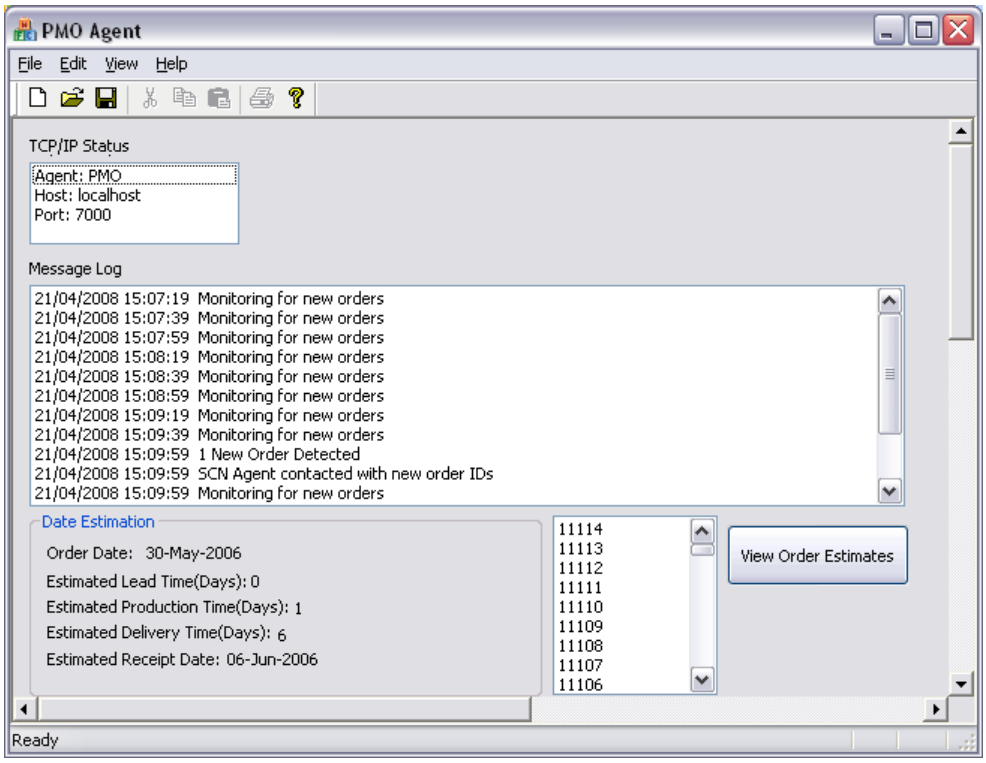

Figure 3.6 EDS result for new arrived order

4) Order analysis: calculate time taken by each phase and for each order and also calculate average of phase for particular range of orders as shown in figure 3.7:

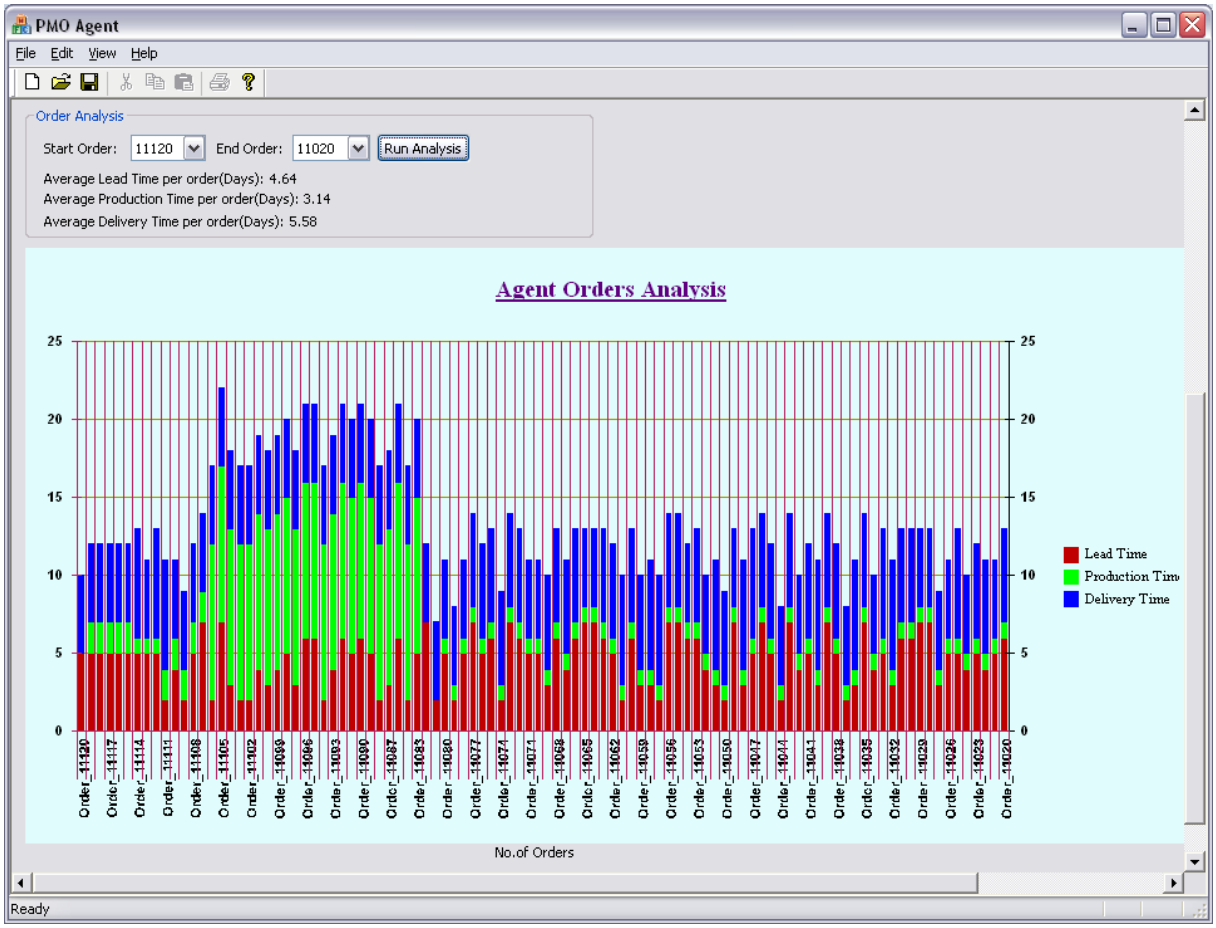

Figure 3.7 Analysis for different phases of order completion

3.7 Result

The specific actions undertaken by PMO agent are as follows:

a. **Orders are detected as soon as they are placed so there is no any pending orders**

b. **Contact next agent using order detail and get information about state of the order**

c. **Give estimate date of order shipping to customer**

d. **Down time maintenance**

4. SCN AGENT FOR INTERDEPENDENCY IN SUPPLY CHAIN NETWORK

For interdependency in supply chain network, Supply chain Network (SCN) agent has been developed.

Problem: In the distribution process order relationships determine potentially affected network partners that have to be informed proactively. Intensity of monitoring efforts has to be adapted to the likelihood of failure events. In dynamic supply networks error-prone order types may evolve over time into reliable ones that need not be monitored as closely as newly evolving critical types. A proactive solution autonomously adapts to such new conditions in its environment and gathers data accordingly. Material management must be includes having material monitoring and material ordering.

Solution: This agent will receive order detail information from PMO agent and will look forward for weather it can be fulfill or not. It will check for inventory. If inventory is sufficient it will make order processing and inform the status of order to PMO agent. And after order has been processed it will contact to dispatch agent for shipping.

For the problem of error prone orders we have to analyze them properly. Here case for error prone order is insufficient material. When order arrives and if inventory is insufficient then we have to order the material but we need analysis for how much material to order based on past usage and data. So this agent will do the analysis for order material.

4.1 Process of SCN agent

Figure 4-1 shows activities performed by SCN agent at each stage. Boxes present here activities done by agent and arrows shows data flow for activities.

Sequentially all activities are done by SCN agent and will continue monitoring PMO agent for getting order detail. SCN agent contacts to database for inventory

checking. SCN agent also contact supplier for material ordering and contact other agent for dispatching order.

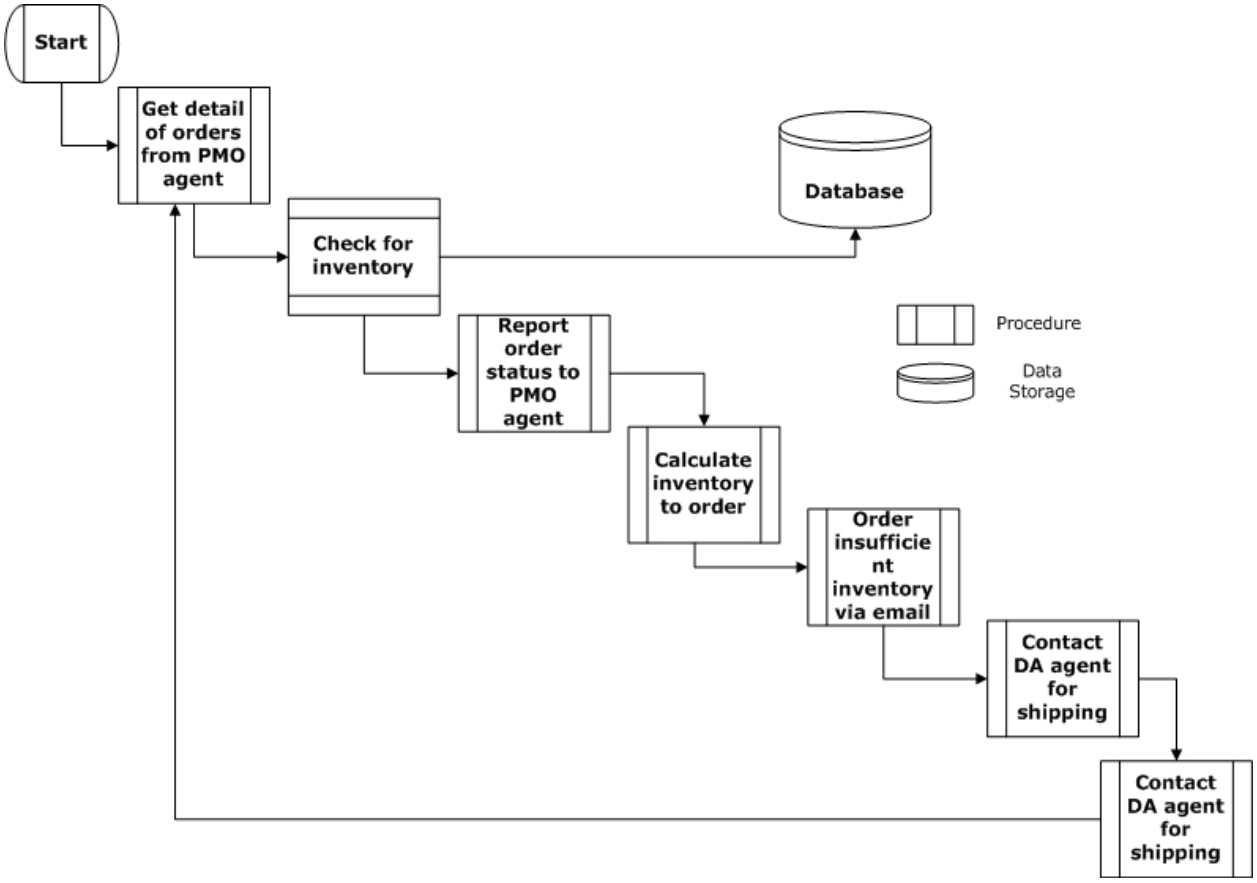

Figure 4.1 Activity flow for SCN agent

4.2 Design of SCN agent

Form the design of PMO agent it can be seen that it is doing assigned tasks by communicating with other agents. It also communicates with database for inventory monitoring and ordering. SCN agent will communicate to its environment using TCP/IP communication and XML communication. Messages passed across environment are shown in design.

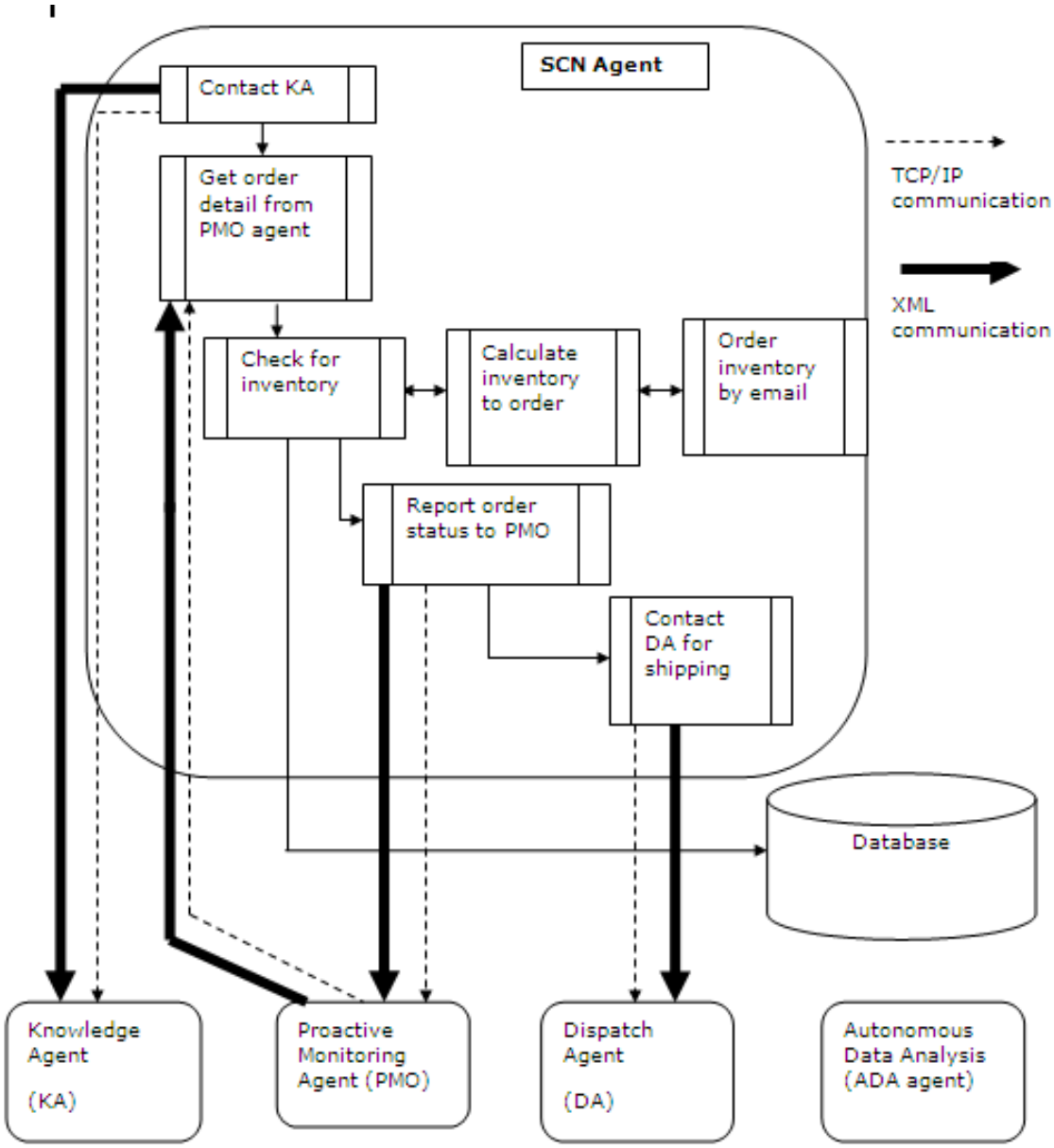

Figure 4.2 Communication of SCN agent to other agents

From the figure 4-2 it can be seen that communication between agents and communication is done by TCP/IP and XML.

TCP / IP: Whenever agent send any information it will become server and when it will ask for any information it will be in client mode. Here ports are assigned for ach agent so communication will be done by identifying particular port number.

XML: Efficient electronic marketplaces require flexible languages such as XML to define the exchange of structured and unstructured information across electronic commerce applications. Therefore here agent technology has been integrated with XML.

It has same XML DTD format as PMO agent.

4.3 Classes for SCN agent

Here classes used by SCN agent are shown in figure 4-3. Every class is supporting to activities done by SCN agent. Main classes are shown here which are most frequently used as in table 3-2.

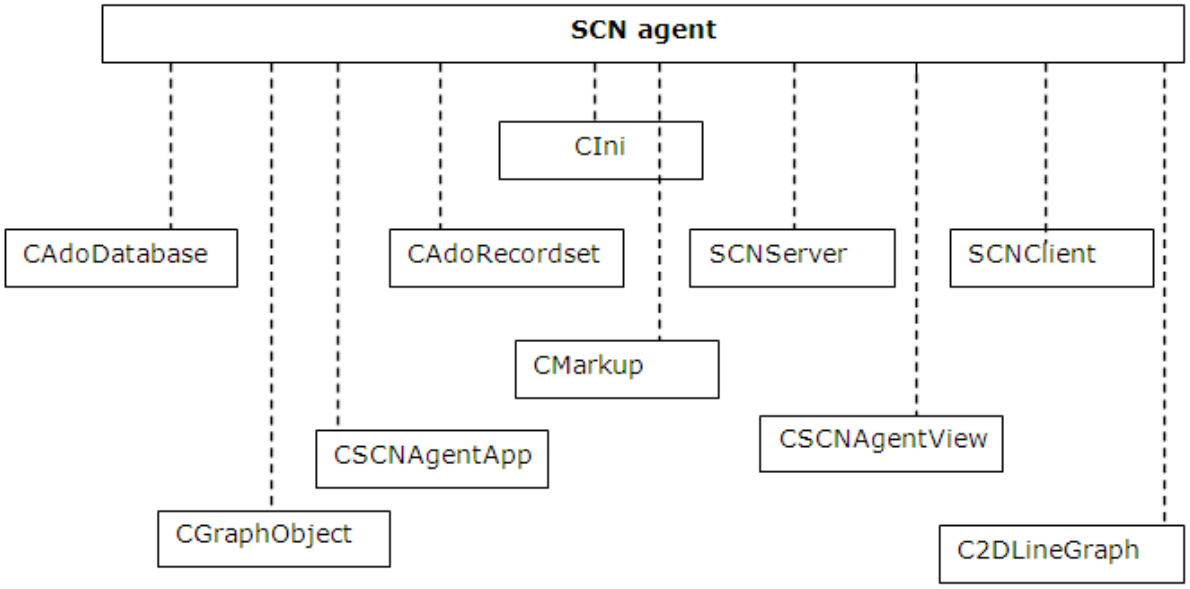

Figure 4.3 Classes used by SCN agent for performing assigned tasks

Table for classes

CIni	**Read settings from file**
CAdoDatabase	**Database connection**
CAdoRecordset	**Fetch rows of data from table**

SCNServer	**Provides TCP/IP enabled server**
SCNClient	**Provides TCP/IP enabled client**
CMarkup	**Handles XML communication**
CSCNAgentApp	**Main application class**
CSCNAgentView	**Handles user interaction**
CGraphObject	**Used for creation of graph**
C2DLineGraph	**Draws line on graph**

Table 4-1Brief summary for classes used by SCN agent for its activities

4.4 Calculation for order inventory

The agents are proactive in the sense they don't simply place the order as per the request. On the contrary SCN agent takes into consideration the past history (trend) of the usage of various items and there by places order well in advance. In other words fast moving items are preferred to placing order as compare to slow moving items. Following two algorithms are useful for identifying fast moving items and slow moving items.

1) **Moving Average Algorithm**
2) **Weighted Moving Algorithm**

First we look at the algorithms.

1) Average Moving Algorithm

A simple moving average (SMA) is the unweighted mean of the previous *n* data points. For example, a 10-day simple moving average of closing price is the mean of the previous 10 days' closing prices. If those prices are p_M, p_{M-1}... p_{M-9} then the formula is

$$SMA = \frac{p_M + p_{M-1} + \ldots\ldots + p_{M-9}}{10} \quad \ldots (4.1)$$

One characteristic of the SMA is that if the data have a periodic fluctuation, then applying an SMA of that period will eliminate that variation (the average always containing one complete cycle). But a perfectly regular cycle is rarely encountered in economics or finance.

Here this method will be applied on past data and for sake of comparison with other method; this will be implemented as follow:

```
// SMA
if(i > 10)    // we need 10 value to plot
    {
        int total = 0;
        for(int x=(i-10); x<i; x++) {
        total = total + _wtoi(sa.GetAt(x)); }
                total = total/10;
                m_pGraphObject1->Set2DLineGraphValue( i, 3, total );
}
```

2) Weighted Moving Average (WMA) Algorithm

A weighted average is any average that has multiplying factors to give different weights to different data points. But in technical analysis a Weighted Moving Average (WMA) has the specific meaning of weights which decrease arithmetically. In an *n*-day WMA the latest day has weight *n*, the second latest *n-1*, etc, down to zero.

$$WMA_M = \frac{np_M + (n-1)\,p_{M-1} + \ldots + 2p_{M-n+2} + p_{M-n+1}}{n + (n-1) + \ldots + 2 + 1} \quad \ldots (4.2)$$

The denominator is a triangle number, and can be easily computed as $\frac{n(n+1)}{2}$.

When calculating the WMA across successive values, it can be noted the difference between the numerators of WMA_{M+1} and WMA_M is $np_{M+1} - p_M - \cdots - p_{M-n+1}$. **If we denote the sum** $p_M + \cdots + p_{M-n+1}$ **by $Total_M$, then**

$$Total_{M+1} = Total_M + p_{M+1} - p_{M-n+1}$$

$$Numerator_{M+1} = Numerator_M + np_{M+1} - Total_M$$

$$WMA_{M+1} = \frac{Numerator_{M+1}}{n + (n-1) + \ldots + 2 + 1} \quad \ldots(4.3)$$

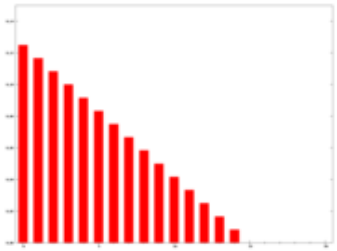

Figure 4.4 WMA weights n=15

The graph at the right shows how the weights decrease, from highest weight for the most recent data points, down to zero. It can be compared to the weights in the exponential moving average which follows.

Implementation for this is as follow.

```
// WMA

if(i > 10) // we need 10 value to plot
  {
    int total = 0, w=1, wt = 0;
    for(int x=(i-10); x<i; x++)
       {
          total = total + (_wtoi(sa.GetAt(x)) * w);
w++;
          wt = wt + w; // total weight
       }
total = total/wt;
m_pGraphObject1->Set2DLineGraphValue( i, 4, total );
returnval = total;
}
```

After such calculation SCN agent orders the required material via email. After order is processed it will contact Dispatch Agent (DA) for order shipping.

4.5 Screen Shots of SCN agent

Here series of screenshots of SCN agent are provided for showing different activities assigned to it.

1) **SCN agent has started as shown in figure4.5**

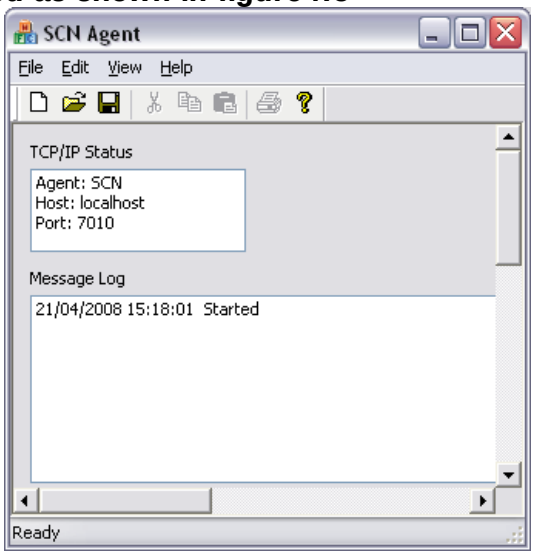

Figure 4.5 Initial status of SCN agent

2) **When new order detected PMO sends order detail through XML. And will make it processing. And contact Dispatch Agent for order shipping as shown in figure 4.6**

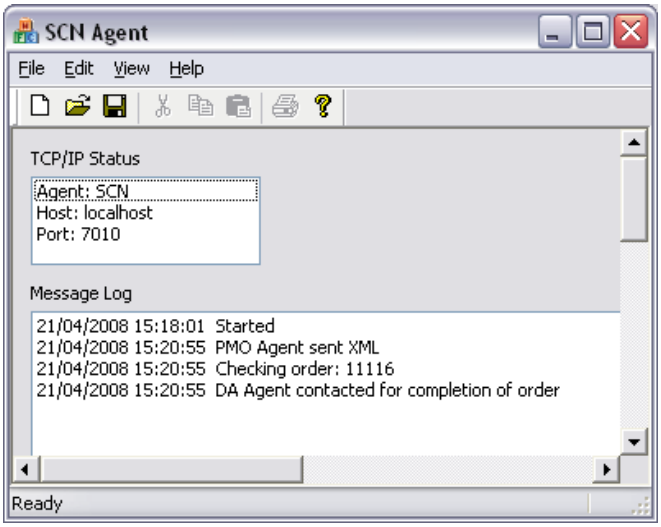

Figure 4.6 SCN checking for order feasibility

3) Shipping company notified for pickup by email as shown in figure 4.7

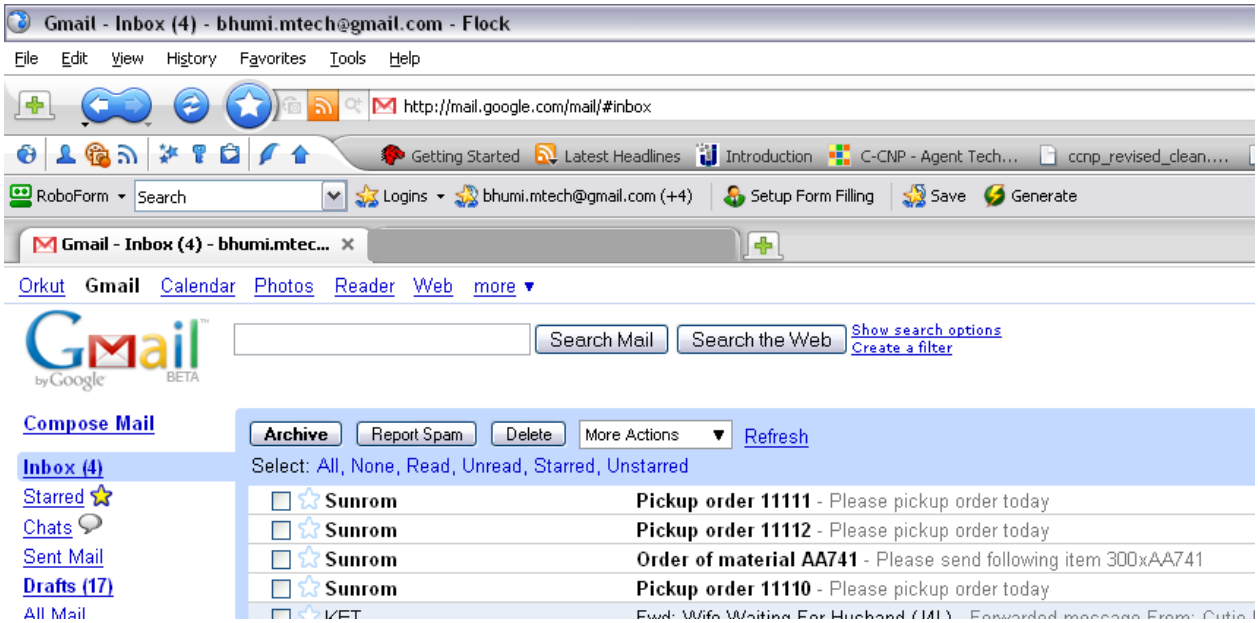

Figure 4.7 Automated email sending by SCN agent

4.6 Result

The specific actions undertaken by PMO agent are as follows:

a. **Receive order detail**
b. **Check inventory**
c. **Report status of order to PMO agent**
d. **Analyze for amount of inventory to order**
e. **Contact DA for shipping**
f. **Order insufficient inventory via email**
g. **If Sufficient inventory contact Dispatch Agent(DA) for shipping**

5. ORDER DISPATCHING USING DA AGENT

Problem: Every time when order will be ready one person has to look up and give call to shipping agent and Courier Company will pick the order. After that system has to be updated with shipped orders. Here main problem to be solved is to reduce Personnel intervention which is required. And it should be reduced as much as possible.

Solution: Agent called Dispatch Agent will be implemented having functionality that it will monitor ADA agent for orders in processing and as soon as they finished ADA will send them in queue were order has to be shipped. It will take that order and will send email to Courier Company to pick the order with order id. And order will be marked as shipped.

5.1 Process of Dispatch Agent

Responsibility of dispatching order is assigned to this agent. Dispatch agent will monitor ADA agent for order shipping as well as monitor database for pending inventory. As inventory received it will make order processing and after completion of order it will email to the courier company for shipping. Process is shown in figure 5.1:

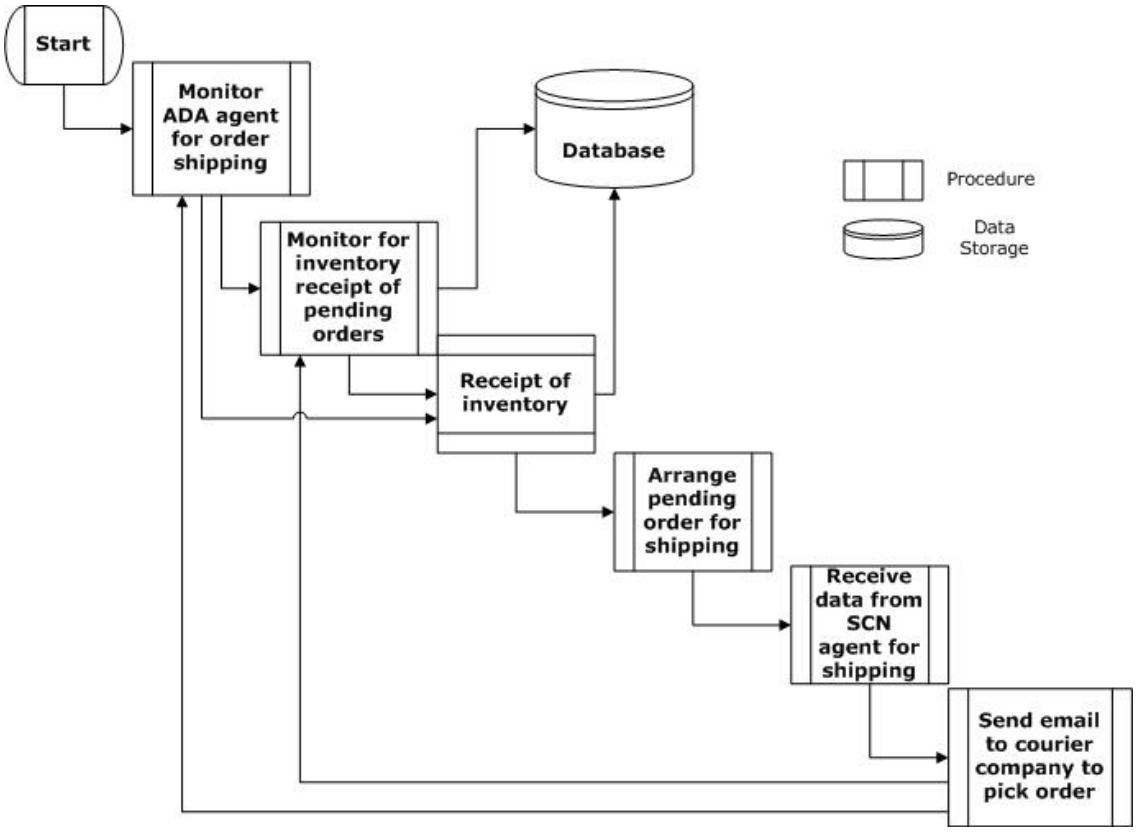

Figure 5.1 Activity Flow for DA agent

5.2 Classes for Dispatch Agent (DA)

Along with MFC classes some more classes which are specific to DA agent which are used by agent for its assigned tasks are shown in figure 5.2:

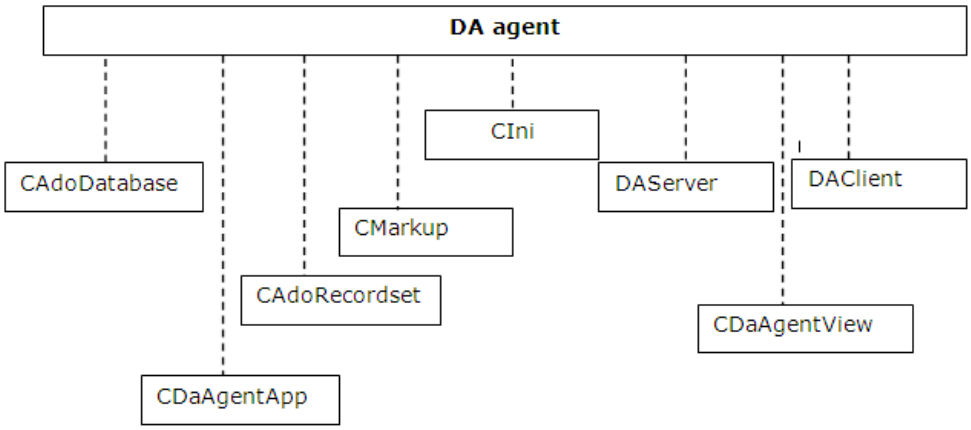

Figure 5.2 Classes used by DA agent for its assigned tasks

Table for classes

CIni	**Read settings from file**
CAdoDatabase	**Database connection**
CAdoRecordset	**Fetch rows of data from table**
DAServer	**Provides TCP/IP enabled server**
DAClient	**Provides TCP/IP enabled client**
CMarkup	**Handles XML communication**
CDaAgentApp	**Main application class**
CDaAgentView	**Handles user interaction**

Table 5-1 Brief introduction of classes used by DA agent for its assigned task

5.3 Screen Shots of DA agent

Here in figure 5-3 it can be seen that DA has received order detail from SCN agent and for dispatchin that order it will email to shipping company and order will be marked as shipped. All steps can be viewed by user.

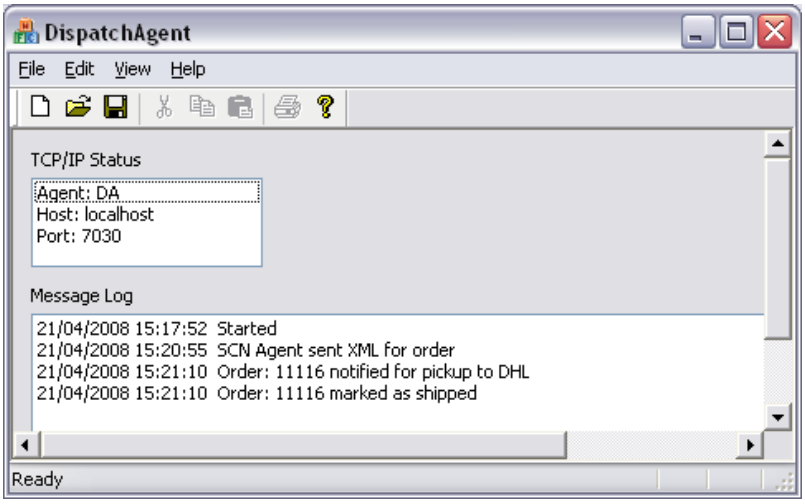

Figure 5.3 Activities done by Dispatch Agent

5.4 Result

The specific actions undertaken by PMO agent are as follows:

a. **Monitoring inventory receipt for pending orders**
b. **If sufficient inventory arrange the order for shipping**
c. **Receive data from SCN agent for shipping for order**

6. SYSTEM AGENTS (KA & ADA)

For the view of all agents and for the database view implementation of two agents called Knowledge Agent (KA) and Autonomous Data Analysis Agent (ADA).

6.1 Knowledge Agent (KA)

Knowledge Agent will keep log of all agents which are currently working and available on the system. Whenever any agent will start, it will first inform to Knowledge Agent for its existence and register with it. So KA all the time will show the view of all agents currently working.

6.1.1 Process of Knowledge Agent

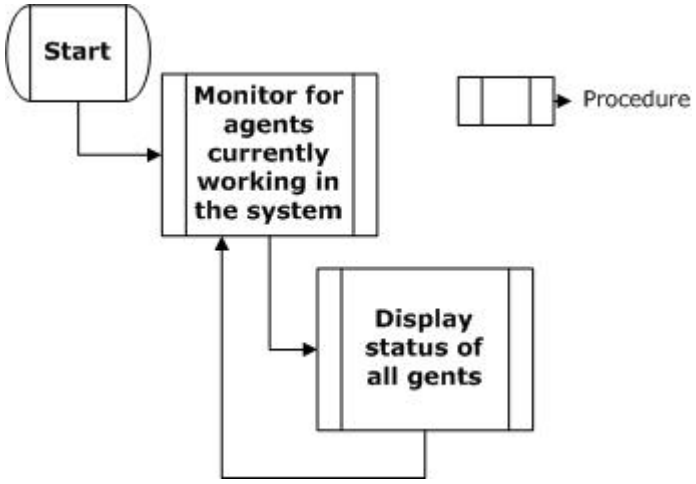

Figure 6.1 Activity flow for KA

Figure 6-1 shows main activities concerning with Knowledge Agent. As it only provides view of all active and running agent across SCN network for particular company.

6.1.2 Design of Knowledge Agent

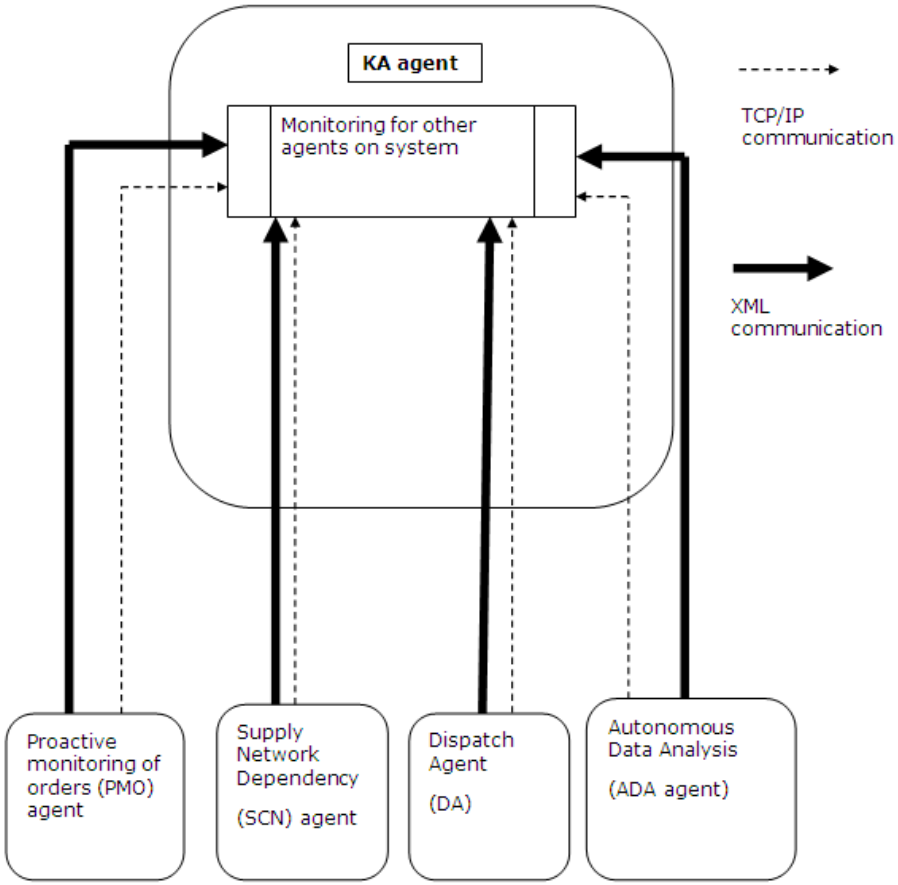

Figure 6.2 Communication done by KA agent to other agents

6.1.3 Classes for Knowledge Agent

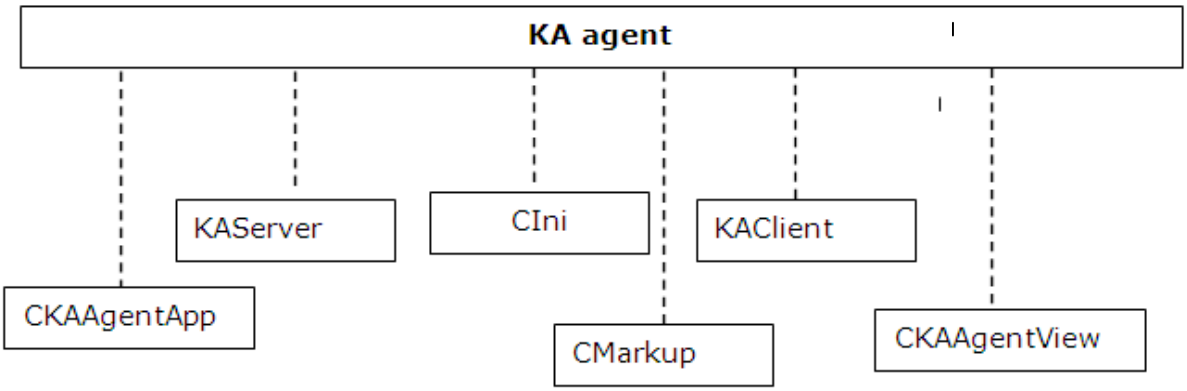

Figure 6.3 Classes used by KA for its assigned tasks

Figure 6-3 shows necessary developed classes used by KA along with MFC classes. Brief introduction of all classes used are given in table 6-1.

Table for classes

CIni	**Read settings from file**
KAServer	**Provides TCP/IP enabled server**
KAClient	**Provides TCP/IP enabled client**
CMarkup	**Handles XML communication**
CKAAgentApp	**Main application class**
CKAAgentView	**Handles user interaction**

Table 6-1 Brief introduction of classes used by KA for its assigned task

6.1.4 Screenshot of Knowledge Agent

As Ka provides only view for all running agents whenever all agents starts they first contact to KA for registration and view of KA is as shown in figure 6-4.

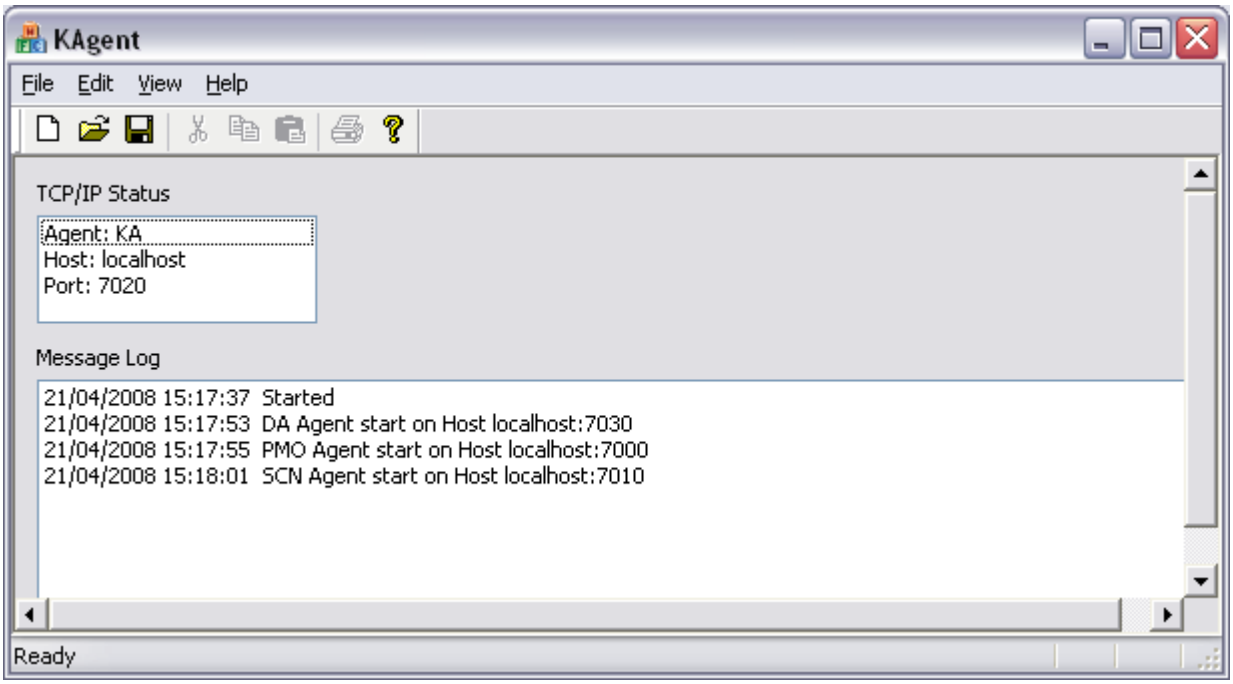

Figure 6.4 KA at its running state

6.2 Autonomous Data Analysis agent (ADA agent)

ADA agent will keep log of database view. It will show order details in three statuses called:

a. **Order pending**

b. Order processing
c. Order shipped

Along with this, it is also displaying

a. Material in Stock
b. Material in Order

As system is being automated so user will see what materials are in stock and what material has been ordered by system to supplier? This agent is only for view of orders' status and material as shown in figure 6-7.

6.2.1 Process of ADA Agent

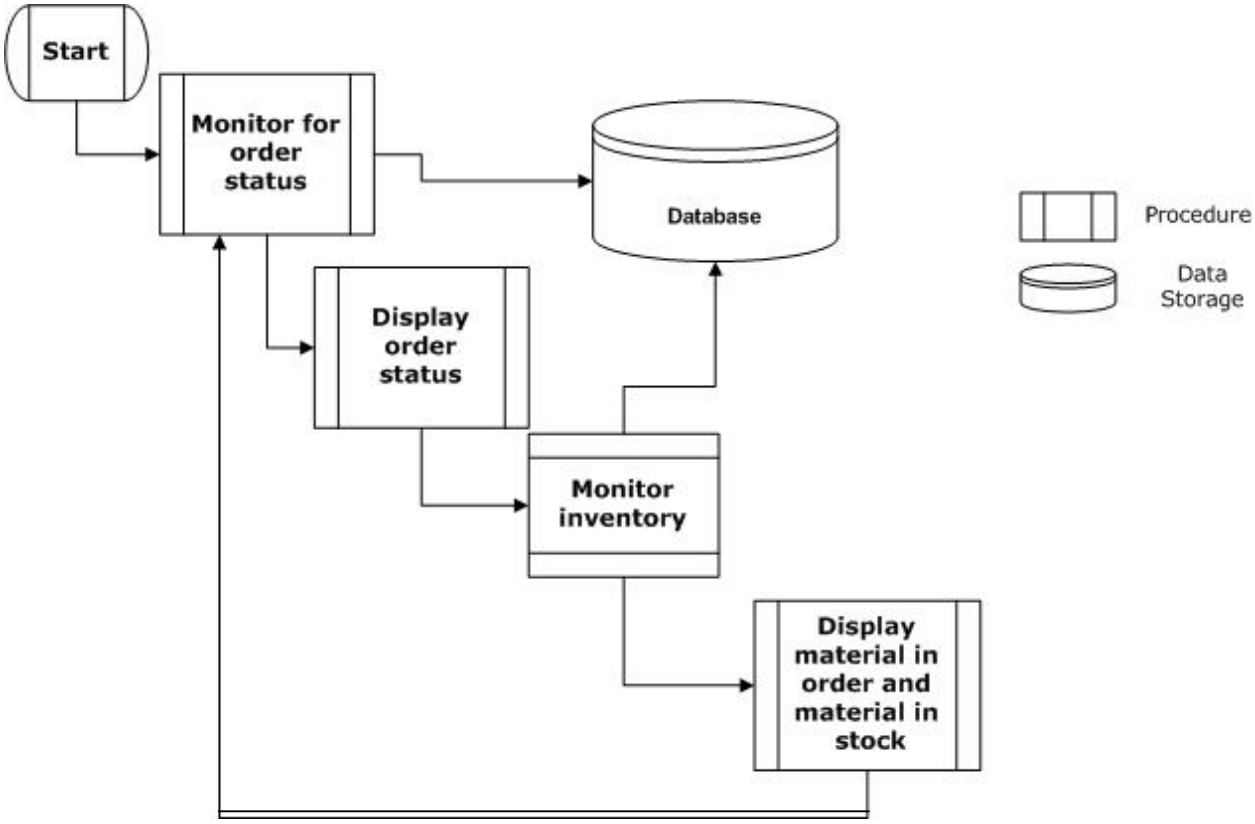

Figure 6.5 Activity flow for ADA agent

Different activities associated with ADA agent are shown in figure 6-5. As ADA agent is concern with database view at each step it is contacting to database and display information.

6.2.2 Classes for ADA agent

Different classes are used along with MFC classes for carrying out tasks assigned to ADA agent. Figure 6-6 shows such classes and table 6-2 provides brief introduction of these classes.

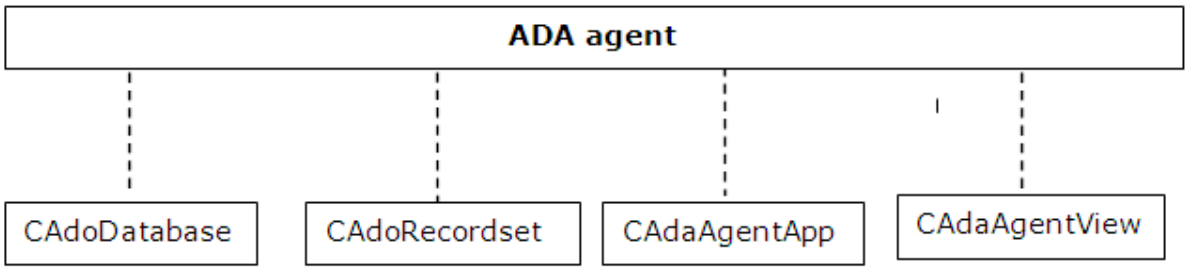

Figure 6.6 Classes used by ADA agent for assigned task

Table for classes

CAdoDatabase	**Database connection**
CAdoRecordset	**Provides TCP/IP enabled client**
CAdaAgentApp	**Main application class**
CAdaAgentView	**Handles user interaction**

Table 6-2 Brief introduction of classes used by ADA agent

6.2.3 Screenshots of ADA agent

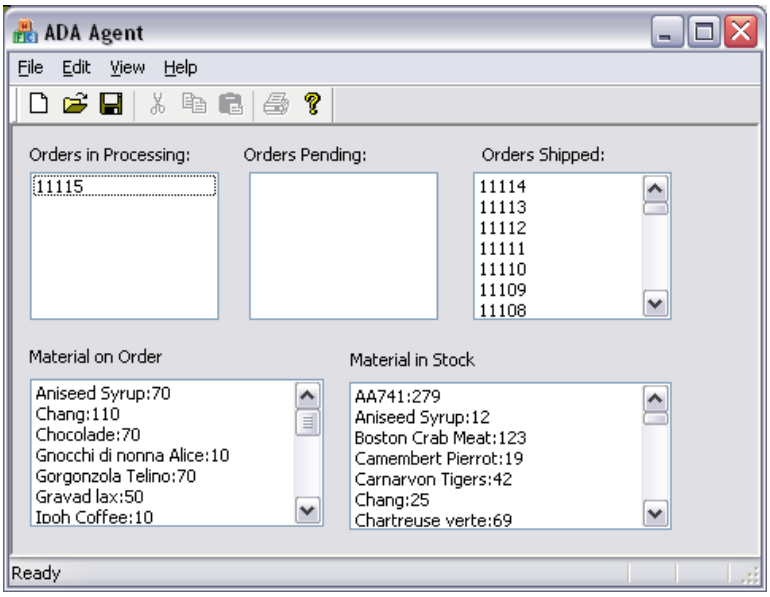

Figure 6.7 View provided by ADA agent

7. CONCLUSION AND FUTURE WORK

This chapter presents ongoing study on developing an agent-oriented and automated system for a Supply chain management (SCM) that provides less user interaction at each step starting form customer places an order till the order shipped. The objective is to develop an automated system for different modules of Supply chain management. Agents are best suited for applications that are modular, decentralized, changeable, ill-structured and complex. Supply chain management is modular system which has different modules involved for different activities. It can be decentralized. It is changeable and dynamic. It has lot of complexity so we can say agents are best suited for SCM.

The contribution of this thesis is twofold: Firstly, the key challenges in today's SCM business were outlined. Secondly, it was investigated how agent technology can help tackling some of these challenges. Demonstration of possible approaches in using agent technology for SCM business solutions as well as main advantages in building agent based business systems is presented.

The conclusion shows that agent technology is well suited to develop highly dynamic, generic and intelligent integration frameworks for business based on standard services on top of existing standard platforms.

Agent-based solution: It is shown, that a group of agents is able to cooperate autonomously and provide benefits, not yet realized by common ERP system architectures. Interoperability is solved by using an ontology which is XML based and might e.g. be directly integrated into industry's applications in any language as along it can communicate in XML.

Decentralized Business Flow Management: This study is an example how decentralized lookup and routing functionality provided by peer-to-peer protocols in XML on TCP/IP enables a new class of robust, scalable, an self-organizing business applications with no need for central information or control instances. From an agent's perspective, observation is that, in contrast to the traditional custom programming related work resulting from multiagent systems research along to

create an impact in a very short time, due to fairly simple protocols with a clear, value creating functionality: the virtualization of resources. Yet, expectations of agent technology to contribute in making peer-to peer systems more flexible (e.g., by adding negotiation functionality) and situation-aware.

In this thesis work two SCM modules called order processing and inventory to order have been automated and analysis for Estimate Date of Shipping (EDS) and how much inventory to order considering investment and current stock using past data has been done.

Inventory ordering has been achieved via sending an email to supplier so agent will direct monitor inventory database as well as order, so that agent can calculate amount of inventory to order and will send email notification to supplier specifying item and its amount.

After order has been completed and ready to ship, agent will take care of informing Courier Company to pick up the order. This will be done by sending email to particular company providing information of order number.

7.1 Accomplishments

a. **Activities for gathering information have been achieved through PMO agent. Information has been fulfilled proactively and in a timely manner to provide a data basis for the next process steps.**
b. **As every agent is only concerned with its local database and each has assigned specific responsibility amount of information communicated regarding orders is very low.**
c. **As soon as order arrives Estimate Date will be calculated considering following parameters and adding them all together**

    i. **Date of Order**
    ii. **Lead time supplier might take**
    iii. **Time taken by Production house**
    iv. **Time taken to deliver the goods to particular location**

These parameters are most crucial and one has to consider as they are included in all types of SCM considering simple to very complex. These parameters are quite variable from order to order and by considering past data.

a. **Dispatch agent will monitor the order which has been completed and when they are ready to ship this agent will send an email to Courier Company for picking up the order.**
b. **Even if agents are down and under maintenance task assigned to them will be queued up and it will be executed when agent is alive again.**

7.2 Conclusion

Consider one item has to be ordered as shown in the figure 7.1:

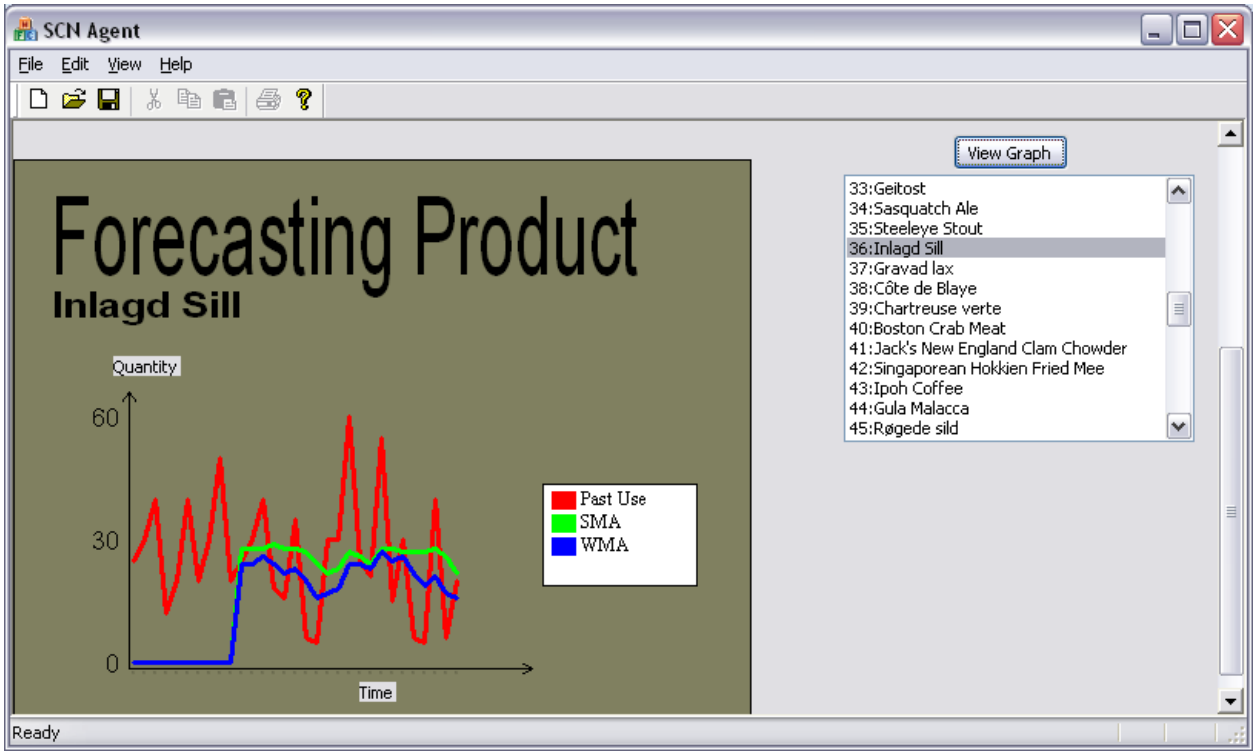

Figure 7.1 Forecasting for material to order

If we consider only past usage which is shown by RED LINE says around 25 items to order. Considering only simple moving average around 28 items are required to be order based on past usage. Using the method for Weighted Moving Average (WMA) around 19 items are required to be ordered based on past usage where the recent usage has given more importance then the past usage.

BEFORE use of AGENTS for ordering inventory

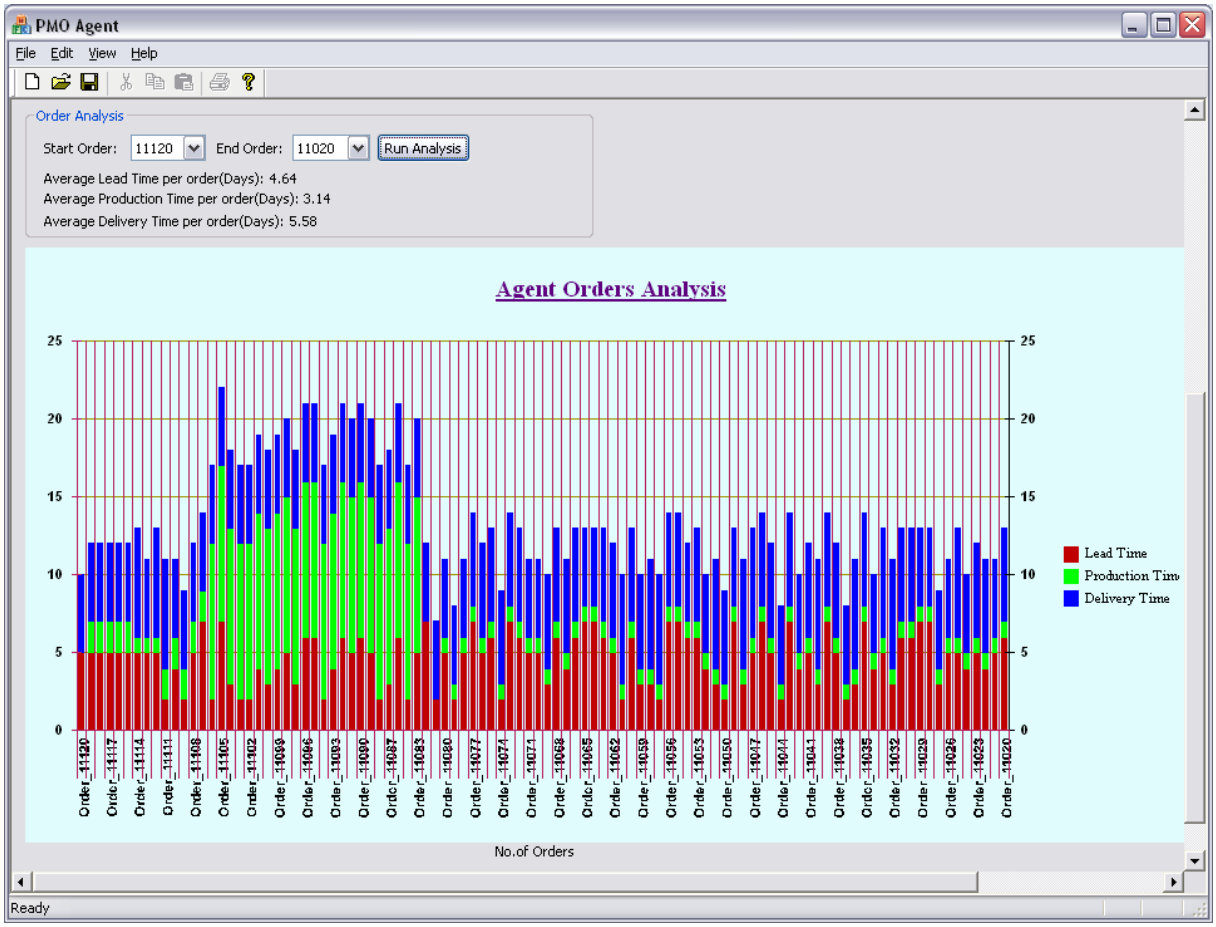

Figure 7.2 Inventory ordering before agent system applied

From the above figure can be seen that average lead time per order is around 4 days. If agents are not applied and manually considering fixed amount of days for particualr supplier then result is as shown in figure 7.2:

AFTER Ordering Inventory Using Agents

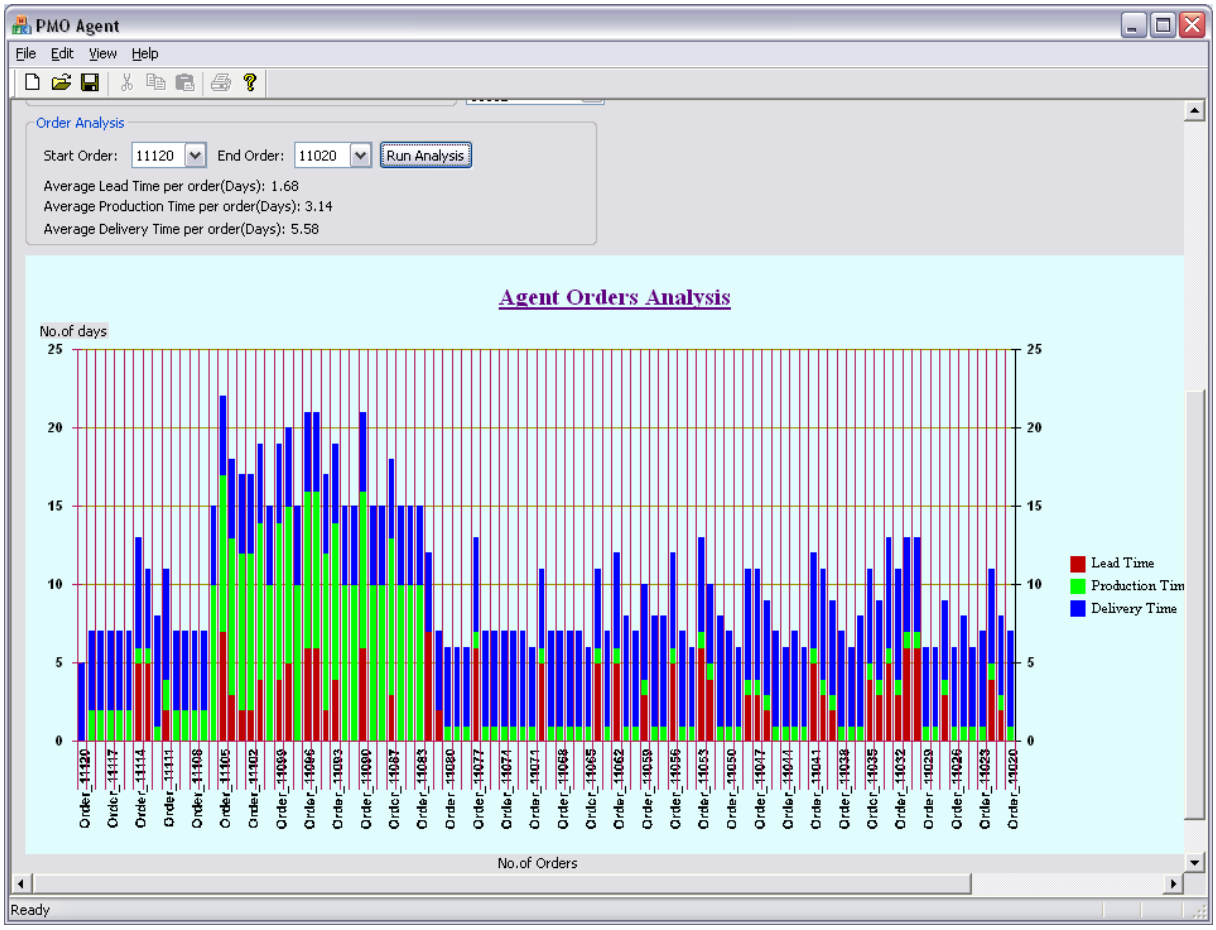

Figure 7.3 Inventory ordering estimation after agent system applied

From the figure 7.3 can been seen that lead time has been reduced to around one and half day.

Applying this testing procedure by placing different types of order achieved result is as follow.

At each point of ordering material to fulfill order agent also considers past trend of usage and orders accordingly so that future orders using that material will have reduction in lead time is 63.79%.

Calculation

	Ordering of inventory without agents as per current order requirement	After applying agents for predicting inventory ordering as per past usage trend
Average Lead Time per Order	**4.64 days**	**1.68 days**
Reduction for delivery (In %)	**((4.64 – 1.68)*100)/4.64 = 63.79%**	

Table 7-1 Result for reduction in delivery time after applying agents for analysis

7.3 Future Work

Currently, the objective is to demonstrate the feasibility and the effectiveness of the proposed architecture as a design and integration model for *using multi agent system* **for supply chain management. In continuing this work, the operational effectiveness of the architecture will be the main concern. Since the present work can be modularized that is application can be expanded and the implementations of different modules for each phase like order processing, inventory, quality check and finance etc. so in future whole system can me modularized and automated as per the new requirements.**

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