

## Business Intelligence using Software Agents

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*This paper presents some ideas about business intelligence today and the importance of developing real time business solutions. The authors make an exploration of links between business intelligence and artificial intelligence and focuses specifically on the implementation of software agents-based systems in business intelligence. There are briefly presented some of the few solutions proposed so far that use software agents properties for the benefit of business intelligence. The authors then propose some basic ideas for developing real-time agent-based software system for business intelligence in supply chain management, using Case Base Reasoning Agents.*

**Keywords:** Business intelligence, Agent-Based Systems, Supply Chain Management, Case-Base Reasoning

### **1 Business intelligent nowadays. Real-time business intelligence**

Business intelligence applications are not a new trend any more, but they have become a must during the last decade as a basic tool used by the modern management. Business intelligence is the result of the natural evolution in time of decision support systems and expert systems, systems that aimed at replacing humans in the decision making process or, at least, at offering solutions to the issues they are concerned of. Gartner's definition [Gartner, 1989] introduces business intelligence as an umbrella term that includes humans, processes and applications/tools used or information management, access and analysis in order to improve decisions and increase business performances.

In fact, business intelligence software solutions are applications that help organizations to know themselves and better understand themselves. The main objectives of a business intelligence system are:

- Accessing and integrating data from various data sources and

storing it, usually into a data warehouse,

- Analyzing data in order to transform it into information, and then into knowledge;
- Presenting information using an easy to understand and use graphic interface.

Our day's business intelligence applications focus on the way they can ensure the useful, correct and in-time information, usually taken from disparate data sources of the organization. The main concern is that of crossing the « information gap » between huge amounts of data available to the decision factor and the useful information, presented in a suggestive manner, that should support the decision making process. So, they insist very much on data collection stage and on presenting information in a friendly way, in form of reports and charts in order to give an image as clear as possible on the current organization state and they are less a real decision tool.

On the other side, most of BI platforms/applications need a specialist to run statistical reports or data mining process and to make the setup for the reports that are

accessed by various business users. Business users usually do not have real time access to data, as they work on a historical data warehouse, so they have no control and cannot choose between the various available data sources having different quality that are integrated and loaded into data warehouse through the ETL process (Extract, Transform and Load).

As business environment is continuously changing, the use of historical data stored in data warehouses can lead to results that are not any more applicable to the new situation, and the delay between the moment of the analysis and the moment of moving decision into action can decisively affect the opportunity and the effectiveness of the resulted actions. This is the reason why companies speak more and more about real time business intelligence or even real time enterprise.

Real time business intelligence makes a comparison between present business events and historical patterns in order to automatically detect problems and opportunities. The result should be the initiation of corrective actions or the adjusting of business rules for process optimization. When talking about business intelligence there are three types of latency: data latency (for data collecting and storage), analysis latency (for analyzing data and obtaining actionable information) and action latency (for reacting to changes and get action to change the business processes). The latest two are not considered by traditional business intelligence as they are dominated by manual processes. [15] Business intelligence in real time is event-driven and uses event stream processing techniques in order to allow event analysis without being transformed and stored in the database first. These in-memory techniques present the advantage of quick monitoring many events and data latency is reduced to milliseconds.

Here are some examples of domains that really need real time business

intelligence, as have various latency levels and data persistence requirements:

- supply chain optimization;
- call center management;
- quality management in manufacturing;
- global shipment and delivery monitoring;
- fraud detection in financial companies;
- real time marketing etc.

It is supposed that modern companies have achieved the transition to a performing management style, to an entrepreneurial culture that incorporates business intelligence elements. The next step is the usage of business intelligence system that can offer solutions to problems and can make decisions starting from the existing information. An organization can include intelligent behavior in its base functions by using business intelligence. And the current method to add intelligent behavior is to include artificial intelligence methods and techniques.

So, we can conclude that most of today business intelligence systems are passive systems. The main problems can be structured on three levels [1]:

**a. Analytics level** – most business intelligence solutions need an expert or an analyst to run or to setup them, and that fragments the information flow and leads to important delays.

**b. Data integration level** – data integration has critical importance. The stage of data preparation has a particular importance, even if the result presentation stage has bigger impact and impresses the beneficiary more. If some real time analysis is needed, then there are two possibilities: or the data warehouse is continuously fed from various real/time data sources, or the business intelligence system has direct access to operational data sources through a data integration layer. The data integration layer is a unified data layer that offers a common metadata structure and unifies data access by creating a unique virtual view.

**c. Operational level** – the information

flow is interrupted by annual interventions. This level has two main functions: business activity monitoring (by using dashboards and charts) and real-time process tuning and change

(implying that Bi tools should be automatically linked to business processes and they adjust and lead the process parameters).

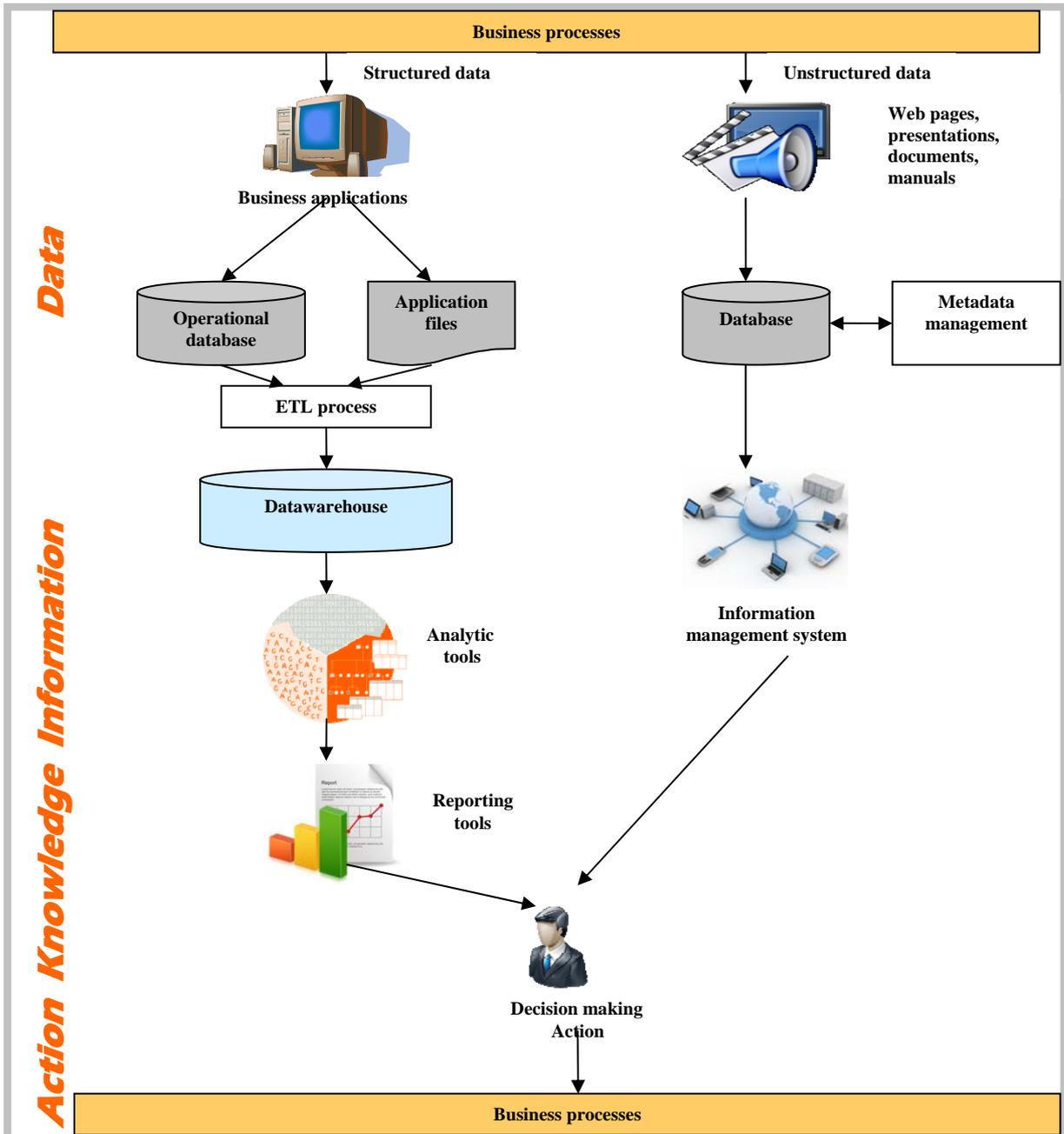


Figure 1. Business intelligence today

**2 Software agents and multi-agent systems**

Artificial intelligence has been used in economic applications since 80's, generating a lot of interest, but not imposing itself at that moment. During

the last years, artificial intelligence made fast progresses, and the success of neural networks and expert systems conducted to the final acceptance of artificial intelligence in the corporate environment. Neural networks, for example, are already

considered a dedicated method for pattern recognition, especially used for image data type and for complex data sources, being included as base technique by most of data mining tools on the market (e.g. The data mining solution offered by SAS, IBM, Oracle, SPSS all include neural nets as a modeling option).

Usually, artificial intelligence is used for solving complex problems or as a decision support tool (using neural networks or expert systems). For real-time business applications, artificial intelligence includes several techniques that could also be used for improving business intelligence applications:

- Data mining and automatic learning – using neural networks, decision trees, and support vector machines, random forests;
- Evolutionary computation – using genetic algorithms, evolutionary strategies, swarm intelligence;
- Other techniques, like software agents or fuzzy logic.

Our purpose is to investigate how multi-agent systems and software agents have been applied in BI and how can their potential be used for business intelligence systems improvement.

Software agent technology was one of the fields that experienced the fastest development during the last years. The economic potential of agent based systems was identified at the beginning of 90's, so, nowadays there is an extraordinary explosion of agent-based applications or multi-agent based systems developed for a diversity of fields: e-commerce, supply chain management, resource allocation, intelligent production, industrial control, information finding and filtering, collaborative work, mobile commerce, decision support, simulations, production planning and control.

The researches that approach various aspects of software agent technology and its applications have registered very fast progresses and it promises to be only the

beginning. It is possible that in a close future every software application will include agents or agent communication capabilities. Software agents can play multiple roles in economic applications: taking over repetitive tasks, customizing interaction information, user notification when important events occur, user behavior learning, context-based user assistance, remote task execution etc. The obvious generated advantages of using software agents are: reducing the information overload and the amount of work by using software agents instead of humans, cutting down transactional costs, customized services, off-line work mode that is vital for distance working agents, restricted by technical limitations.

The definition of the agent term is very controversial, as it was used in many other computer branches besides artificial intelligence. In artificial intelligence we distinguish two main approaches: the first one is based on the agent notion as assigning of a behavioral identity to a software component, the second one is based on describing the attributes the agent possesses. A representative definition is given by Pattie Maes [7]: "autonomous agents are computational systems that can inhabit a complex, constantly changing environment, sense what is going on, and act independently to accomplish a specified set of tasks or achieve certain goals".

Intelligent agents are defined by IBM [14] as "software entities that carry out some set of operations on behalf of a user or another program, with some degree of independence or autonomy, and in so doing, employ some knowledge or representation of user's goals and desires". Wooldridge and Jennings [13] consider that an intelligent agent is a hardware or a software agent that has the following features:

- Autonomy – the agents operates as an independent process, with no direct human intervention and has control over its actions and internal state;
- Reactivity – the agent perceives his environment (physical world, Internet, a

collection of agents or even a user through a graphical interface) and promptly answers to the perceived environment changes.

- Pro-activity – the agent not only that reacts to its environment changes, but it is also capable of manifesting a goal oriented behavior, by taking the initiative.

- Social abilities – the agent interacts with other agents (including humans) using an agent communication language.

In the context of intelligent agents, there are other two interesting properties to be mentioned:

- Self-analysis – the agent is capable of analyzing and explaining its behavior and of detecting its errors or its success;

- Learning, adaptation and improvement by interaction with its environment.

A multi-agent system can be defined as a loosely-coupled network of entities that work together to solve a problem that cannot be solved by an individual agent. These entities can show self-organization and complex behavior, even if the individual agent's strategies are simple.

The utility of the agent's special features depend on the way the agents are applied, as they are recommended for specific types and fields of applications. Contributory factors are:

- Complex real problems;
- Open, distributed system modeling;
- Limited capacity of a single agent to solve real-world problems;
- Data control and expertise distribution;
- Old software packages reuse and their integration into new systems;
- Agent-based application modeling by organizing the system environment as agent societies that cooperate and compete in solving problems;
- Need of reusing network distributed resources and expertise;

- Increase of system performance: calculation speed, extensibility, reliability, flexibility, maintenance, response quality.

### 3 Multi-agent systems applied in Business Intelligence

The specialty literature is not very generous when it comes to agent-based business intelligence applications.

Erik Thompson, specialist at Hyperion Solution Corporation defined in 2002 five potential impact fields for intelligent agent on traditional analytic systems [12]:

- i. Agents should contribute to BI solution evolution from application-oriented solution to process-centric solutions and to offering a single access point to distributed information. Agents-based systems must have access to a self-description of the individual modules and the user's personal agent can interrogate for specific information all library agents reasonable for various data sets.

- ii. There is necessary a software-user dialog so that it can learn what the user's wishes are and can anticipate his future desires. The active usage of agents gives BI solutions a more customization and intelligence besides the options and preferences offered by the application.

- iii. Intelligent agent can offer customized analytical assistance for high level business processes, observing them, learning about them and interacting with uses. Agent-based applications and a BPM (Business Process Management) platform could be involved in encoding horizontal analytic knowledge and domain specific knowledge.

- iv. For most Bi applications, the server side is very important because of the changes that occur in the loading patterns and it has a high number of physical settings. Intelligent agents for physical optimization can evaluate their own physical organization and, if necessary, interact with a system administrator before reorganizing data

In the following paragraphs we will shortly

present some of the rare approaches existing in the specialty literature.

In [8] it is presented a model of automatic reporting base on push agents as the next step in the evolution of reporting models, following the end-of-period reporting and the dynamic query reporting. The main characteristic of those three models are presented in Table 1:

Type of reporting	End of period	Dynamic query	Push/pull agents
Timeliness of data	Stale	Near real time	Near real time
Potential for managerial filtering	Yes	No	No
Delivery of choice	No	Not typically	Yes
Alerts	No	Not typically	Yes
Silo issues	No	Possibility	No

Table 1: A comparison of reporting models

In order to develop such a model, a company should define some key performance indicators (KPI) it wishes to monitor against to their planned level. When detecting changes in these indicators, software agents should automatically decide if they should make automatic recommendations/ warnings for corrective actions, sending messages to the appropriate manager through the chosen communication channel (email, voicemail, phone message etc). The main benefits underlined by the authors in using the proposed agent-based topology for business process modeling are:

- Prompt reporting;
- Automatic measurement of planned objectives;
- Unfiltered information;
- User preferences based delivery.

In [3], there are presented three potential domains for applying agent based systems in business intelligence and it is proposed an intelligent agent-based BI system for customer credit ranking in a bank. The three domains are:

1. Intelligent acquisition – for collecting unstructured data from internal distributed agents that are capable o recognizing information in semi-structured documents and autonomously search possible information sources.

2. Intelligent modeling – for creating simulation environment models in order to predict future model states, using agent-based systems, data manipulation and intelligent rules.

3. Intelligent delivery – proactive information delivery of selected information using appropriate channels. There are used brokerage agents that identify information importance and correlation and autonomously decide on the delivery channel.

In [2] information software agents are proposed for collecting public data that are freely available on Web in order to support the decision-making process. Web information agent is capable of collecting information and organizes it as a local database, process that involves four steps: accessing data from real-time data sources or from historical data sources (achieved data that use an indexing system), collecting data, and verifying and correcting records consistency, preparing data and storing data locally. The steps are repeated iteratively until all the received data are stored. More than that, the agent ca monitor data changes and can update these changes daily. Such an agent was used for collecting data about stolen cars from the Croatian Ministry of Internal Affairs Web site. Insurance companies could benefit from the collected data in order to estimate risk more realistically.

In [4] a dynamic based infrastructure is developed. It is Java based, platform neutral, light-weight and extendable. It is Java based platform neutral, light-weight and extensible. It is different from other infrastructures and from the client-server model as it supports dynamic change of agent's behavior. Problem solving capabilities are obtained by dynamically loading java classes representing data,

knowledge and application programs. It was created for facilitating an easier design and implementation of autonomous, cooperative, adaptive and mobile software agents.

This infrastructure has been prototyped for developing event-driven BI applications and there were implemented several examples of such applications. The infrastructure has proved to be very efficient facilitating solution development, implementation and adoption.

#### **4 Business intelligence in Supply Chain Management using software agents**

Our approach is different from the other ones, as we intend to add real-time business intelligence features to an existing agent-based system for supply chain management. Supply chain management is one of the fields that have successfully applied agent technology, because its automation requires a distributed point-to-point architecture that must also have some special properties [5]: disintermediation – direct association between users and their software, dynamic composability and execution – the software infrastructure must enable resource discovery and composition at runtime, interaction – specific interaction patterns must be explicitly represented and reasoned with, as specific interactions might be unknown until runtime, error tolerance and exploitation – the system should be able to anticipate and compensate for errors.

Supply chain is a network of facilities for obtaining raw materials, conversion into intermediate goods and final products and then delivers the products customers through a distribution system [6].

Supply Chain Management aims at managing the flow of information, materials, services and money for an activity so as to maximize the efficiency of the process. Development of Internet and communication standards offers great

opportunities to connect the supply chain of suppliers and customers in a vast network, and thus optimize costs and opportunities for everyone involved.

In recent years there are many architectures for intelligent agents based on supply chain management, the set of activities efferent supply chain is modeled using agents that interact and communicate with each other and the environment to fulfill their individual tasks, but also considering the objectives of the entire system.

Activities like planning, programming, negotiation, multiple interactions make multi-agent system particularly appropriate for this area.

Some examples of complex activities, which usually involved several software agents as:

- Getting orders from customers, negotiating terms and conditions or other special requirements;
- Coordination of suppliers, production and distribution so as to obtain optimum results and maximum satisfaction of all parties involved.
- Planning and implementation of resource transport so as to avoid any delay and to minimize costs and transport times.
- Planning and re-planning activities considering the time of delivery, available resources, interdependencies between activities, delays and other specific criteria.
- Inventory management and material requirements planning starting from the expected demand or the planned production, etc.

For each of these activities, the need for real time decision is obvious. For example, agents should consider and decide the selection of suppliers need to review the activity of suppliers that has previously worked with the company, to analyze the frequency of delays or lacks of common stock, long-term trend of price increases, all that compared to other suppliers and making calls to the specific multidimensional operations (drill-down, roll up, slice / dice). Another example is the analysis of a specific

product sales activity compared to other products, taking into account various criteria (geographic, time, clients etc), tracking the trend for profits generated by it, and identify the causes that led to current situation. All these could help in accepting orders from customers, and negotiating with them and in deciding above the optimal production mix.

We propose a multi-agent system for managing supply chains based on Case Based Reasoning agents. Case Base Reasoning (CBR) solves new problems by retrieving previous solutions to similar or close problems that are stored in a database of cases. Therefore, CBR is based on previous experiences and patterns of previous experiences, similarly with human thinking. Each case

is described by a set of features or attribute-value pairs. Case retrieval algorithm is often a simple K-Nearest neighbor algorithm.

CBR is typically used when there isn't any model or method to match exactly to the problem requirements proposed by the user. The model or method is constructed by applying reasoning on similar cases. When a problem is solved, the solved case (scenario and solution) is retained by updating the case database. Therefore, CBR is not a special method of reasoning, but is also a paradigm of machine learning which allows the accumulation of lifelong learning through experience.[11].

Figure 2 represents a generalized CBR cycle, including four main steps: Retrieve, Reuse, Revise, and Retain.

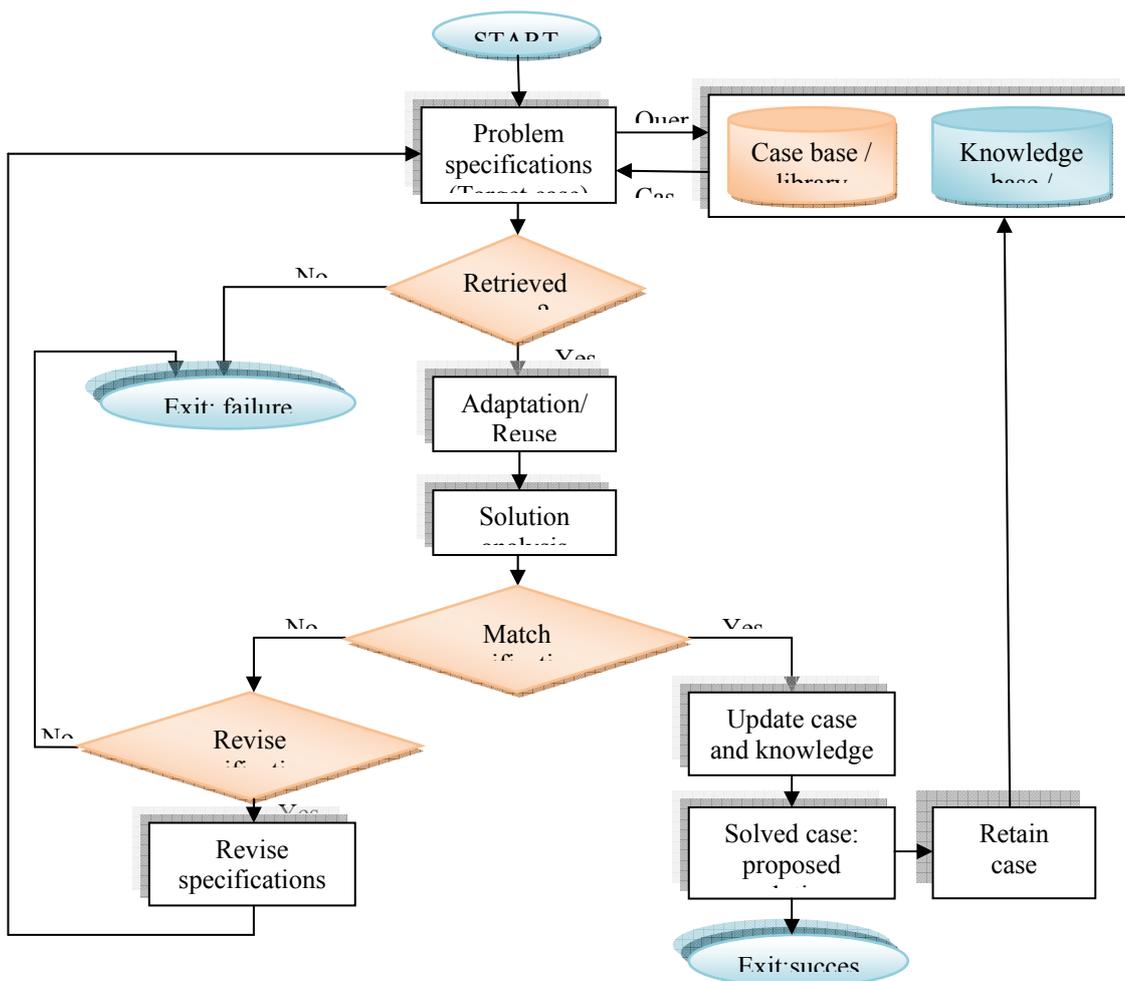


Figure 2. Case-based reasoning process

The proposed multi-agent system should be formed of three intelligent agent-based subsystems (Figure 3):

**a. Extracting and uploading data management sub-system** – It could be two parallel systems designed to ensure that decisions in short time: a classic one that actually store data in a traditional data warehouse and a second data virtualization system that accesses data directly from multiple data sources. This agent-based subsystem should decide which of the systems to be used and should implement specific mechanisms for extracting and loading data. The decision of adopting a virtualized solution should be carefully analyzed. BI projects usually involve complex multidimensional analysis and a great importance is given to data cleaning and consolidation. The number and dimension of data sources, the quality of the raw data and the analysis requirements should also be considered. In many cases, the best integration solution is a combination of virtual and physical approaches, keeping the physical data warehouse in order to benefit from its features and applying virtualization for cutting costs and getting quicker results for data source access, for data mart elimination, for prototyping new data marts or data warehouses, for federating multiple physical consolidated sources and so on.

**b. Data mining sub-system** – In SCM there are always discrepancies between supply and demand, and DM can help predict the degree of incertitude in the SCM. DM can thus be considered an essential tool in understanding the behavior of customers, in pricing, in promotion planning and product development. For example, for manufacturers, DM can make predictions of supply uncertainty, predictions of process uncertainty due machine failure, poor operation and maintenance plans, predictions of supply uncertainty using various criteria like article, distributor,

location, forecasting of future trends of supply, etc. [DM1]

As we know, DM techniques for complex environments should be very dynamic, because changes in the system can affect the overall system performance. Due to the need for data mining on distributed sources it appeared distributed data mining. MAS often solve complex applications that require distributed problem solving because they often have distributed and proactive and reactive properties that are very useful for these cases. On the other hand, in many applications, individual and collective agent behavior depends on observed data from distributed data sources. Therefore, combining distributed data mining with MAS data-driven applications is very attractive [9]. Agents can be taught through case base reasoning to automate the processes of data mining: to configure, set, test results and if results are unsatisfactory resume.

**c. Decision analysis sub-system** – This sub-system involves the use of agents that rely on CBR for each case stored in the cases database consisting of a set of analytical operations, aimed at finding a solution to a scenario of a problem. For the description of the scenario and solution to the problem there will be used some metrics or indicators such as KPI (key performance indicators). Some examples of KPI are: functional costs (storage, transportation etc), channel costs (institutional, retail, government, etc.). A KPI triggers a response that can be automated using CBR., seeking a match in the case base based on the KPI's similarity and retrieving those cases that are most similar to the current scenario. Any similar case will be a sequence of analytical operations. [1]

The results of the analysis would be presented by assistant agents to interested persons using appropriate communication channels. A second possibility would be automatic triggering of corrective actions in the chain of automated processes.

The analysis results could be transformed directly into action, if necessary. Software

agents could act directly on processes, but involves a good modeling and

automation of business processes, which is very rare, at this time.

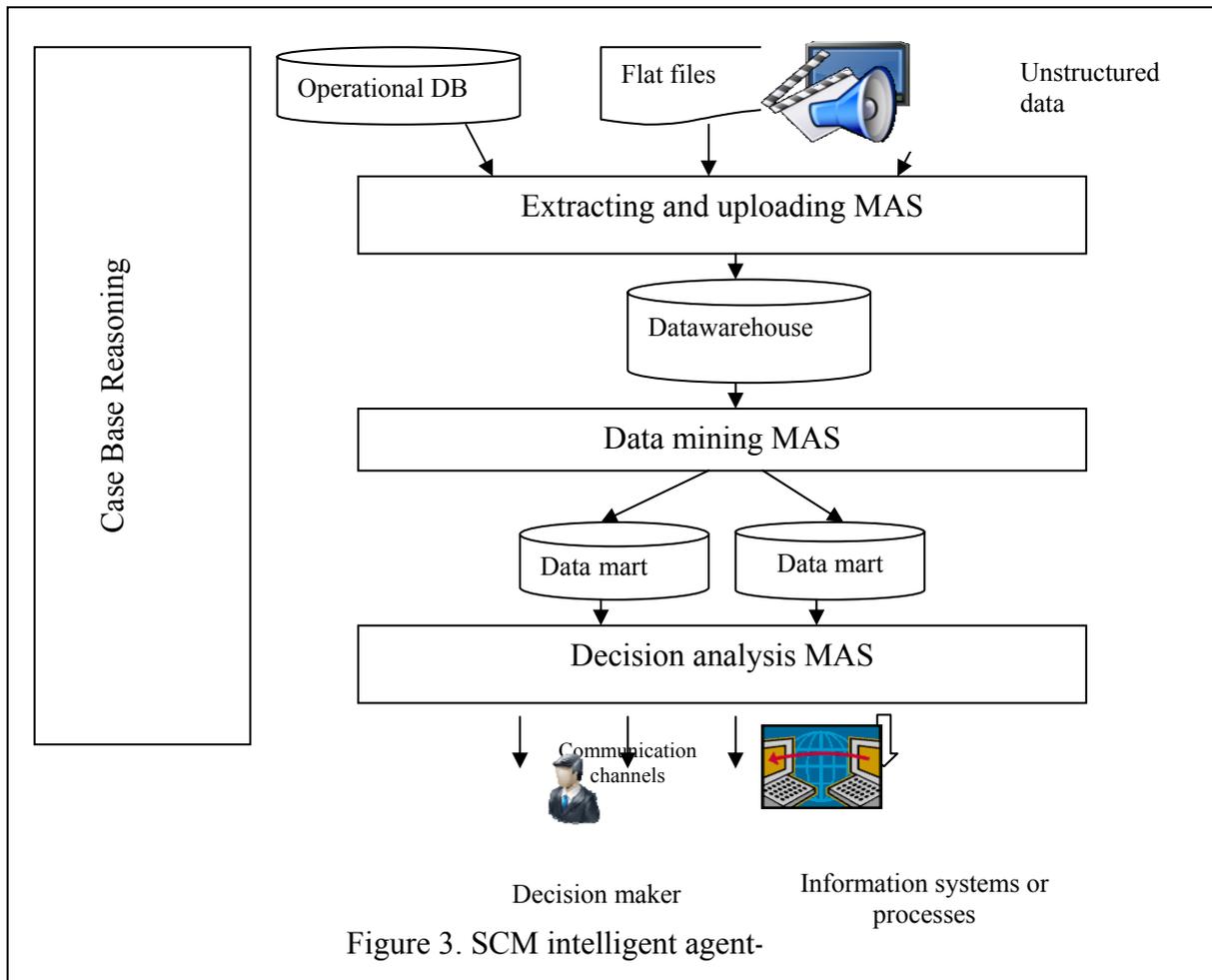


Figure 3. SCM intelligent agent-

## 5 Conclusions

The integration of business intelligence and software agents can provide solutions to some business intelligence problems. For example, business intelligence solutions often face difficulties when working on distributed data sources, possibly located in unstructured documents.

To highlight the potential of software agents we started from the specific case of using agents with very good results for Supply Chain Management. It was proposed a system based on software agents for implementation in real time (or as close to real time) of business intelligence in SCM, using CBR agents. It was proposed an intelligent agent-based solution based on three subsystems, emphasizing the benefits of

an agent- oriented solution.

It follows that in a future paper this architecture to be developed and detailed to the level of functional prototype.

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