Supply Chain Business Intelligence: Technologies, Issues and Trends

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Abstract Supply chains are complex systems with silos of information that are very difficult to integrate and analyze. The best way to effectively analyze these disparate systems is the use of Business Intelligence (BI). The ability to make and then to process the right decision at the right time in collaboration with the right partners is the definition of the successful use of BI. This chapter discusses the need for Supply Chain Business Intelligence, introduces driving forces for its adoption and describes the supply chain BI architecture. The global supply chain performance measurement system based on the process reference model is described. The main cutting-edge technologies such as service-oriented architecture (SOA), business activity monitoring (BAM), web portals, data mining, and their role in BI systems are also discussed. Finally, key BI trends and technologies that will influence future systems are described.

1. Introduction – Supply Chain

Competing in today's business environment precipitates the need for successful integration and collaboration strategies among supply chain partners. The global environment is influenced by increased globalization and outsourcing, mergers, new technologies, and e-business. Shorter time-to-market, reduced product lifecycle, built-to-order strategies, pull systems and uncertainty force organizations to adopt new ways of doing business.

There was a lot of pressure on companies to increase profit, decrease cycle times, reduce inventories, improve service and adapt to forthcoming changes. Supply chain management (SCM) as a new management philosophy followed. Supply Chain Management (SCM) was seen as a tool for gaining competitive advantage through real-time collaboration with trading partners, and offered a new

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way to rapidly plan, organize, manage, measure and deliver new products or services.

Many companies are beginning their search for a solution to implementing an electronically oriented supply chain management system that provides connection to customers and to suppliers. This integrated supply chain may be based on new software solutions or based on enhanced communication capabilities. The ultimate objective is to create a “seamless system interface” that provides the capability to review and analyze varying elements of information. The objectives for analysis of this information are to create a more efficient supply chain characterized by [1]:

- Increased customer service levels;
- Decreased transaction costs;
- More efficient inventory investments;
- Reduced expenses for manufacturing;
- Increased responsiveness to customer demands;
- The ability to fulfill customer requirements more profitably;
- The ability to deliver high quality products in the shortest time;
- The ability to deliver products at the lowest cost;
- The ability to penetrate smaller, fragmented markets cost effectively;
- Greater linkages with key suppliers;
- Demand driven logistics;
- Capacity planning across the supply chain;
- Sharing of information with key suppliers thus reducing supplier costs.

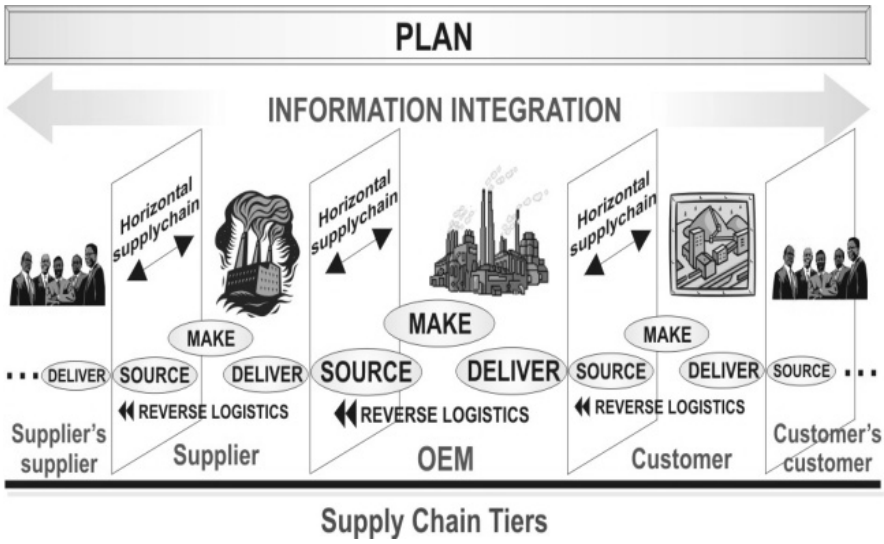

Fig. 1. The Supply Chain

In today's fast-changing global market organizations need to compete as supply chains, not as single business entities [2]. Additionally, an organization can participate in many supply chains, thus creating a complex supply network of interconnected processes (see Figure 1).

Pushed by globalization and competitive forces, the classic linear supply chain has evolved into a complex value network of partners participating in a common business (Figure 2). These networks are expanding to include additional services provided by an increasing number of partners: customers, the government, financial services organizations, and so forth. Investments in systems or applications need to take into account the requirements or opportunities enabled by this increasing interconnectedness.

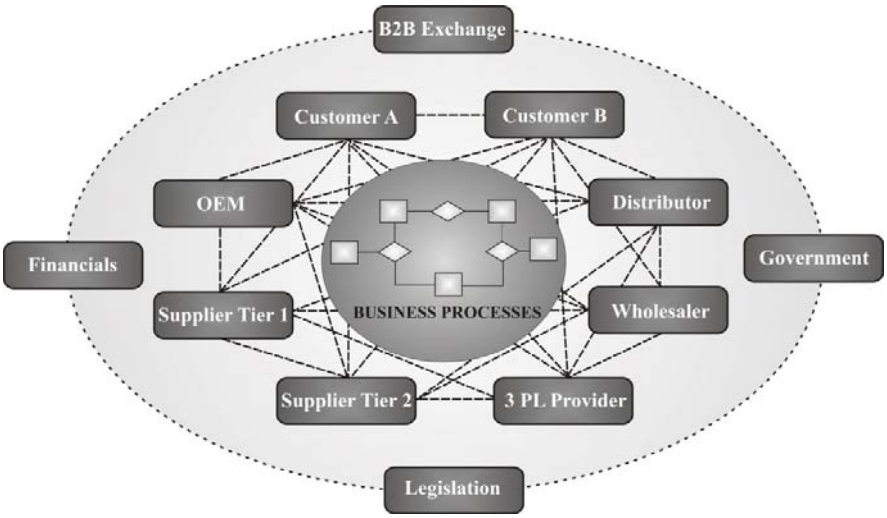

Fig. 2. The Supply Network

However, despite the huge investment in SCM software systems, they did not provide desired Return On Investment (ROI). The main reason is that these systems mostly provide only transaction-based functionality. They lack the sophisticated analytical capabilities required to provide an integrated view of the supply chain. This is where Business Intelligence (BI) tools like data warehousing, ETL (Extraction, Transformation, and Loading), data mining, and OLAP (On-Line Analytical Processing) can help adequately analyze operational effectiveness across the supply chain.

1.1 Supply Chain Performance Measurement

Supply Chain Performance Measurement (SCPM) is vital for a company to survive in today's competitive business environment. Performance measurement is one of the key aspects of management. If a company does not have a clear understanding of how well its supply chains are performing, it will be very hard to manage them successfully.

Until a few years ago, there were several reasons why most companies did not implement supply chain performance measurement systems [3]:

1. No clear established approach or set of measures was available
2. Software vendor products offered only a limited range of supply chain metrics
3. Companies were too busy with other more important initiatives.

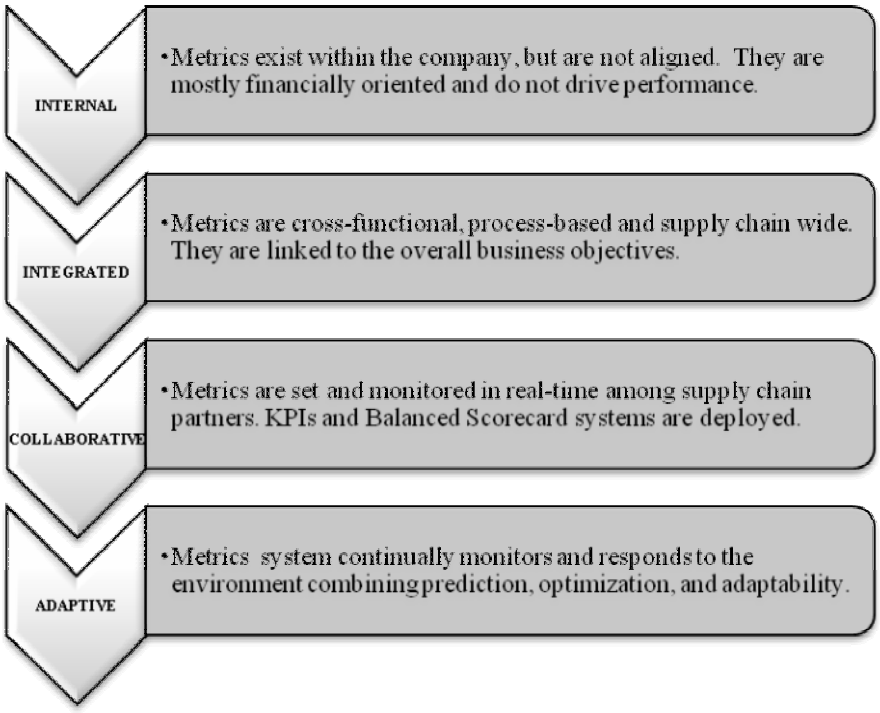

Fig. 3. A Supply Chain Performance Measurement Maturity Model

Measurement is important, as it affects behaviour that impacts supply chain performance [4]. As such, performance measurement provides the means by which a company can assess whether its supply chain has improved or degraded.

Only a few leading-edge companies are currently using true extended SCPM systems (either developed in-house or implemented SCPM software applications) that not only measure the performance of their enterprise but also that of their extended enterprise activities. Most companies are still in the Internal or Integrated stage of the maturity model (as shown in Figure 3) where they focus on the performance of their own enterprise and measure their supply chain performance with financially-oriented metrics.

In response to some of these deficiencies in traditional accounting methods for measuring supply chain performance, a variety of measurement approaches have been developed, including the following: The Balanced Scorecard, The Supply Chain Council's SCOR Model, The Logistics Scoreboard, Activity-Based Costing (ABC), Economic Value Analysis (EVA), etc.

1.2 SCOR Model

SCOR model represents a universal approach to supply chain management that can be applied in diverse business domains [5]. SCOR combines business process engineering, benchmarking and best practices into a single framework. This standardization movement facilitates the deliverance of business content for the supply chain simulation model.

A standardized operations reference model provides significant benefits. Standardized models provide companies' maps toward business process engineering, establish benchmarking for performance comparison and uncover best business practices for gaining a competitive advantage. By standardizing supply chain operations and metrics for managing such operations, companies cannot only compare their results against others, but they are able to gain visibility of operations over a supply chain that may cross corporate borders. Partners in a supply chain can communicate more unambiguously and can collaboratively measure, manage and control their processes. Greater visibility over complicated orchestration of supply chain activities lets you fine-tune targeted problem areas and identify the cause-and-effect relationships in a supply chain network.

The process reference model contains:

- Standard descriptions of management processes
- A framework of relationships among the standard processes
- Standard metrics to measure process performance
- Management practices that produce best-in-class performance

According to SCOR, supply chain management consists of the following integrated processes: Plan (P), Source (S), Make (M), Deliver (D) and Return (R) — from the suppliers' supplier to the customers' customer, and all aligned with a company's operational strategy, material, work and information flows [6].

Additionally, SCOR includes a series of Enable (E) elements for each of the processes. Enable elements focus on information policy and relationships to enable the planning and execution of supply chain activities.

SCOR contains three levels of process detail. The top level consists of the aforementioned processes (plan, source, make, deliver and return) further subdivided into process types of planning, execution and enable (Figure 4).

The second SCOR level defines the configuration of planning and execution processes in material flow, using standard process categories such as make-to-order, engineer-to-order, or make-to-stock categories.

The third level consists of the actual process elements and their process flows. This bottom level of the SCOR model is most significant to analytics. It consists of process element definitions, inputs and outputs, relationships, performance metrics and best practices where applicable.

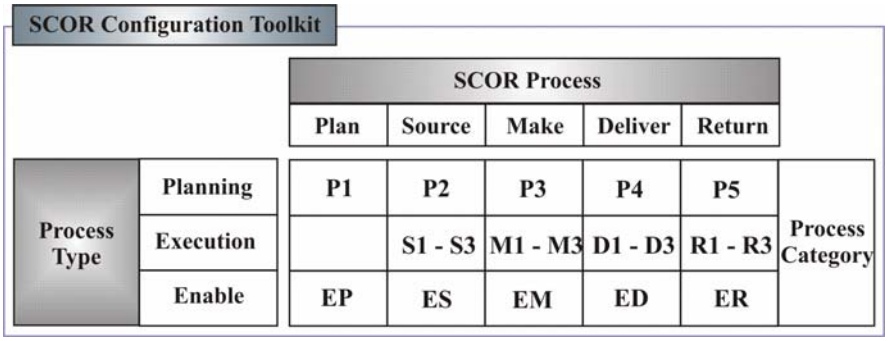

Fig. 4. SCOR Process Categories

Metrics enable measurement and benchmarking of supply-chain performance. All process metrics are aspects of a performance attribute. The performance attributes for any given process are characterized as either customer-facing (reliability, responsiveness and flexibility) or internal-facing (cost and assets) metrics as shown in Table 1. Level 1 Metrics are primary, high level measures that may cross multiple SCOR processes.

Table 1. SCOR Performance Attributes and Level 1 Metrics

Performance Attributes					
Level 1 Metrics	Customer-Facing		Internal-Facing		
	Reliability	Responsiveness	Flexibility	Costs	Assets
Perfect Order Fulfillment	X				
Order Fulfillment		X			

Cycle Time					
Upside Supply Chain Flexibility			X		
Upside Supply Chain Adaptability			X		
Downside Supply Chain Adaptability			X		
Supply Chain Management Cost				X	
Cost of Goods Sold				X	
Cash-To-Cash Cycle Time					X
Return on Supply Chain Fixed Assets					X

Performance metrics equate to the BI key performance indicators (KPI). Each Level 1 metric can be decomposed to the lower Level 2 and Level 3 metrics, thus providing standardized performance measurement at the operational, tactical and strategic level across the supply chain.

2. Business Intelligence

For decades, corporate executives have made strategic business decisions based on information deduced from multiple reports that IT compiled by summarizing sets of frequently conflicting data.

Business intelligence systems promise to change that by, among other things, pulling data from all internal systems plus external sources to present a single version of the truth. This truth can then be delivered to decision-makers in the form of answers to highly strategic questions

Gartner, an information technology research firm, coined the term “business intelligence” during the 1990s. Business intelligence generally refers to the process of transforming the raw data companies collect from their various operations into usable information [7]. Since data in its raw form is of fairly limited use, companies are increasingly electing to use business intelligence software to realize their data’s full potential. BI software comprises specialized computer software that allows an enterprise easily to aggregate, manipulate and

display data as actionable information, or information that can be acted upon in making informed decisions.

By providing an insight into vital information, BI enables companies to improve the way they do business. Companies are empowered with the ability to offer products and services at the lowest possible cost and with the greatest amount of efficiency and productivity possible – while returning the highest revenues and profits.

Some companies are finding that it is beneficial to share BI capabilities with business partners as well as with employees. To do that, they are building Web-based "BI networks" to deliver intelligence to suppliers, consultants and others.

Business intelligence was once the domain of statisticians and corporate analysts. Not anymore. BI capabilities are spreading to virtually all parts of the organization, as companies strive to put critical data into the hands of business users who need it to do their jobs. Users want the following from their business intelligence systems [8]:

- The ability to run ad hoc queries
- Access to multiple databases
- Scalability, affordability and reliability
- Ease of integration with back-office systems

Many surveys conducted by the leading market research firms show that BI becomes one of the CIO's top priorities. While other segments of the enterprise software sector are floundering, interest and adoption in business intelligence continues to rise. CIOs recently surveyed by the IT research firm Gartner identified BI as their number-two technology priority for the coming year, a significant jump from the number-10 spot in 2004. The market is also on the rise. Forrester Research predicted that the BI reporting and analysis tools and applications software segment could scale up to $7.3bn by 2008, from $5.5bn in 2005 [9]. BI and business performance management account for a full 30 percent of the technology profile of a successful solution [10]. In the next five years we will see a dramatic 40% increase in the number of end users who use business-intelligence tools, and at least 50% of the Fortune 500 will turn to outsourcing contractors that have the next-generation technology and necessary expertise [11].

2.1 BI Challenges

Organizations are now willing to invest heavily in data warehousing software, servers and other hardware because they expect a rich pay-off. They anticipate that data warehousing will make huge numbers of employees more productive and efficient and result in better business decisions. However, doing this in practice is very difficult and is confronted with many challenges such as:

- Organizational and cultural differences

Cultural and organizational issues can be attributed to the fact that supply chain processes are distributed among many internal and external organizational groups that tend to operate individually.

- Metrics

Existing metrics do not capture how the overall supply chain has performed because they are primarily internally focused financial metrics [12]. The supply chain paradigm requires new metrics. The central place in the metrics system is taken by the Key Performance Indicators (KPI).

- Data quality

One of the surveys showed that 75% of the organizations experienced financial pain from defective data [8]. Poor data quality costs them money in terms of lost productivity and faulty business decisions.

- Data security

Security is one of the main IT concerns, since the information BI provides is the organization's most valuable asset. Fine-grained authorization and authentication, along with encryption are the requirements.

- Plenitude of data sources

Most of the organizations have huge volumes of structured data housed in different data sources such as mainframes and databases, and also unstructured data sets. Providing the supply chain, integrating data from such a variety of sources is prerequisite for effective BI.

- Lack of expertise

Experts knowledgeable in both SCM and data warehousing/BI are rare. Also, training is required for the business analyst and information workers in order to yield most benefits from SCI systems.

- End-user access

The key to having a successful SCI system is having an interface that is simple to operate and offers personalization, customization, ad-hoc queries and collaboration through web portals.

2.1.1 BI project management

More than half of all Business Intelligence projects are either never completed or fail to deliver the features and benefits that are optimistically agreed on at their outset. While there are many reasons for this high failure rate. The biggest is that companies treat BI projects as just another IT project. It is, rather, a constantly evolving strategy, vision and architecture that continuously seeks to align an organization's operations and direction with its strategic business goals.

Organizations must understand and address these following challenges for BI success. BI projects fail because of [13]:

1. Failure to recognize BI projects as cross-organizational business initiatives, and to understand that as such they differ from typical standalone solutions.
2. Unengaged business sponsors (or sponsors who enjoy little or no authority in the enterprise).
3. Unavailable or unwilling business representatives.
4. Lack of skilled and available staff, or sub-optimal staff utilization.
5. No software release concept (no iterative development method).
6. No work breakdown structure (no methodology).
7. No business analysis or standardization activities.
8. No appreciation of the impact of dirty data on business profitability.
9. No understanding of the necessity for and the use of meta-data.
10. Too much reliance on disparate methods and tools.

2.1.2 BI benefits

Implementing a data warehouse and using business intelligence and data mining technology can provide a significant benefit. For example, use it to:

- Analyze the performance and quality of the resource, for example, by comparing the process activity duration times across different resources.
- Understand and predict exceptions. BI can be used to understand the real cause of problems and, hopefully, avoid them based on knowledge gained from past process behaviour.
- Optimize processes. With BI, you can discover conditions under which specific paths or sub-paths of the process are executed, so you can redefine the process.
- Improve process execution times. Analyze process execution times and quality testing configurations of the system, assignment of resources and dynamic adaptation of the process.

2.2 BI Architecture

As the organization's information infrastructure expands across the Internet to encompass the entire supply chain, so does BI. The Internet expands the information sources of the data warehouse. It reaches beyond what is contained within the organization's internal systems, across the Internet, to include partner, supplier and customer systems.

In order to collaborate effectively, organizations must coordinate their businesses. According to the latest surveys, they are willing to share data and invest in collaboration. Some organizations have established a BI Competency Centre [14]. Team members should be cross-functional, full-time individuals who

have the mission to identify and work with all BI-related initiatives within the enterprise. Building the BI system must begin with an understanding of the combined information needs of all users who might access the system.

The basic elements of a BI solution are: operational data store (ODS), data warehouse (with data and metadata), data mart (data warehouse that focuses on an individual subject area within the organization), ETL tools, OLAP engine, analytical tools (reporting, data mining, etc) and web portals. Combination of these elements forms a variety of possible scenarios which depend on the concrete organizational and informational structure of an organization and a supply chain.

Central to the BI system is a data warehouse. Generally, it can be centralized or distributed. It is important to make a distinction between the physical and the logical views. For example, a data warehouse can be centralized logically, but distributed physically thanks to distributed DBMS technology. The politics, the economics and the technology greatly favour a single centralized data warehouse [15].

A data warehouse system must:

- Make an organization's information easily accessible
- Present the organization's information consistently
- Be adaptive and resilient to change
- Be a secure bastion that protects information assets
- Serve as the foundation for improved decision making
- Have enterprise-wide support.

A data warehouse can be built using the top-down or the bottom-up approach [16]. Many organizations have built multi-tier warehouses (data warehouse with several data marts) using the bottom-up approach because of the lack of resources and the pressure to deliver solutions quickly. The top-down approach is better because it improves the consistency of information and reduces the number of extracts from operational systems. An organization can also choose the OLAP storage mode (Relational, Multidimensional, Hybrid) depending on the specific needs and priorities (real-time access, querying performance, storage, etc).

BI web portals are the ideal front-end because they utilize Internet technologies, offer personalization and customization, user-friendly, analytical tools and security mechanisms. The architecture of the supply chain BI system is shown in Figure 5 [17].

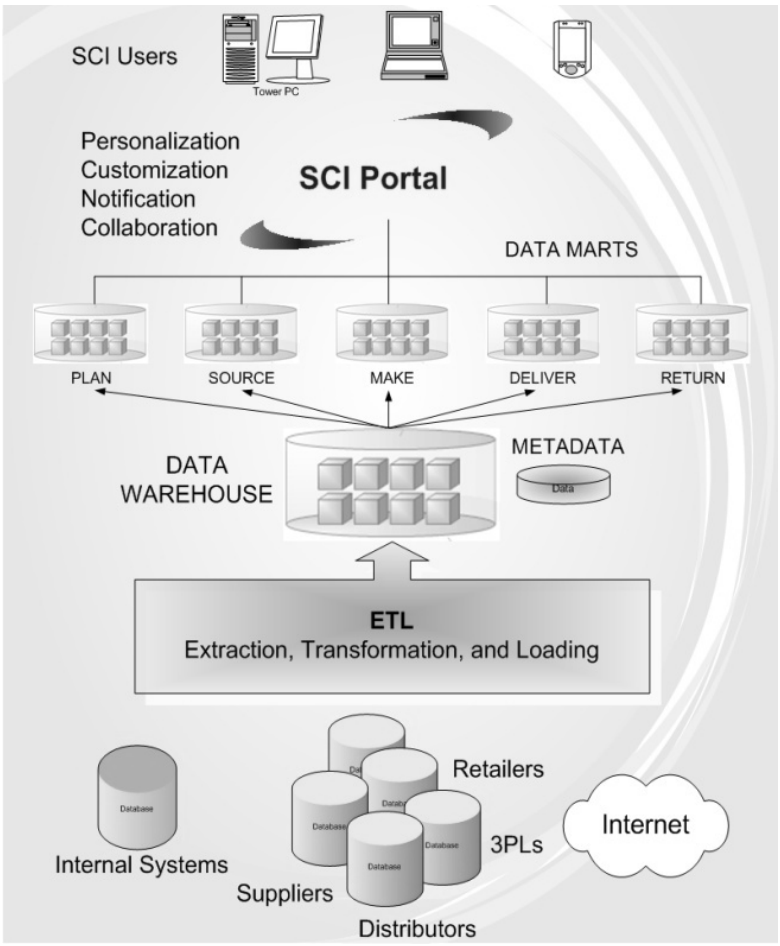

Fig. 5. Supply Chain BI Architecture

3. Supply Chain Intelligence

Supply Chain Intelligence (SCI) is a new initiative that provides the capability to reveal opportunities to cut costs, stimulate revenue and increase customer satisfaction by utilizing collaborative decision making [18]. SCI takes a broader, multidimensional view of the supply chain in which, using patterns and rules, meaningful information about the data can be discovered.

SCI technologies promise to extract and generate meaningful information for decision makers from the enormous amounts of data generated and captured by SCM systems.

The focus of SCM technologies primarily has been on providing operational and transactional efficiencies in the areas of sourcing, manufacturing, and distribution activities within a firm and across its supply chain. Applying the concepts of business intelligence to data from SCM systems, SCI technologies seek to provide strategic information to decision makers. Information categories range from what-if scenarios for reconfiguring key functions in sourcing, manufacturing and distribution to measuring the ability of a supply chain to produce cost-effective products.

The primary source systems for BI are the internal operational systems, while SCI integrates data from partner and supplier information systems. What truly differentiates SCI from BI is the ability to collect and aggregate data across the value chain. Data is then analyzed and the results distributed to all parties along that chain, regardless of location.

SCI complements supply chain planning because BI applications provide incremental benefits while a business lays the foundation for more sophisticated tools and related business process changes.

To reap some quick returns and support their supply chain projects, some companies are using BI tools to [19]:

- Improve data visibility so as to reduce inventory.
- Analyze customer service levels to identify specific problem areas.
- Better understand the sources of variability in customer demand to improve forecast accuracy.
- Analyze production variability to identify where corrective measures need to be taken.
- Analyze transport performance to reduce costs by using the most efficient transport providers.

By providing wider visibility to plans and supporting data, BI tools increase the return on existing SCP applications because they help companies understand where and how they deviate from their planned objectives. In addition, they provide shared data availability that encourages a global perspective on business performance. As a result, people are more likely to make decisions based on their global impact.

Organizations can apply BI in the following supply chain areas [20]:

- Plan Analytics — balancing supply chain resources with requirements.
- Source Analytics — improving inbound supply chain consolidation and optimization.
- Make Analytics — providing insight into the manufacturing process.

- Deliver Analytics — improving outbound supply efficiency and effectiveness.
- Return Analytics — managing the return of goods effectively and efficiently.

For example, demand forecasting is one of the key applications of data mining. Complex demand forecasting models can be created using a number of factors like sales figures, basic economic indicators, environmental conditions, etc. If correctly implemented, a data warehouse can significantly help in improving the retailer's relations with suppliers and can complement the existing SCM application.

SCI can have the following industrial applications in the area of supply chain management:

- Sales/Marketing. Providing analyses of customer-specific transaction data. Enabling retailers to know not only what's selling but who is buying it. Strengthening consumer 'pull'.
- Forecasting. Using scanning data to forecast demand and, based on the forecast, to define inventory requirements more accurately.
- Ordering and replenishment. Using information to make faster, more informed decisions about which items to order and optimum quantities.
- Purchasing/Vendor Analysis. Helping purchasing managers to understand the different cost and timeliness factors of each of their suppliers.
- Distribution and logistics. Helping distribution centres manage increased volumes. Can use advance shipment information to schedule and consolidate inbound and outbound freight.
- Transportation management. Developing optimal load consolidation plans and routing schedules.
- Inventory planning. Helping identify the inventory level needed, item by item, to ensure a given grade of service.
- Stock location planning. Helping warehouse planners assign products to locations so as to minimize distances, improve efficiency.
- Finished goods deployment. Balancing supply, demand, and capacity to determine how to allocate limited quantities of finished goods.

3.1 BI and Logistics

Increased impetus on core competence, globalization, and the emergence of the Internet has given rise to a new breed of e-Logistics companies called Third Party Logistics-3PL providers, which offer a spectrum of solutions [21]. They need to establish themselves as key business partners involved in the entire supply chain – right from logistics strategy formulation to its implementation. And they need to

effectively share information and knowledge with the customers using the BI tools. Business Intelligence can help the 3PLs in the following ways [22]:

- Service Improvement: Business Intelligence can improve the effectiveness of the logistics services by in-depth analysis and reports on various functions involved in these services.
- Provide Information Technology Based Services: With the help of BI, 3PLs can provide their clients with analysis and reports specific to their supply chain. These can significantly help the customers increase their responsiveness and time to market.
- Improve Organizational Support Functions: BI can significantly improve organizational support functions like HR and financial management by providing an integrated view of these functions and supporting their specific decision making requirements.

4. Service-Oriented Business Intelligence

As companies move from simply monitoring to proactively managing business performance, they need real-time visibility in market, customer and competitive conditions. This requires integration across IT systems and business processes in a cost-effective and flexible manner.

A service-oriented architecture (SOA) provides a standardized, flexible approach to enterprise business process integration and role-based access to process activities, information (including BI), business transactions and collaboration tools. A SOA makes it possible to separate processes from applications and to create on-demand and event driven information, application and collaborative services that can be invoked in an industry standard way. These services can then be rapidly assembled into composite applications associated with individual process activities in an industry standard way.

There are many reasons why companies are investing in SOA initiatives at present. The obvious one is that a SOA reduces operational costs and increases efficiency, improves effectiveness and increases collaboration. Improving efficiency is typically achieved by standardizing on common business processes that have been separated from applications and then integrating and automating them by mapping process activities to applications within the enterprise and across businesses. A SOA can be used to improve effectiveness by leveraging business intelligence everywhere in order to guide employees during every performed activity so that everyone contributes to strategic objectives and executes on a common business strategy. It is also possible to monitor events to automatically detect/predict problems and opportunities for rapid response and business optimization. Improving collaboration allows employees, partners, customers and suppliers access to team workspaces where they can share information and services.

4.1 Web Services and BI

The kind of BI, performance management and data integration artefacts that can be developed and published as web services include [23]:

- Queries
- Reports
- OLAP slice services (MDX queries)
- Scoring and predictive models
- Alerts
- Scorecards
- Plans
- BAM agents
- Decisions (i.e., automated decision services)
- Data integration workflows and federated queries

Figure 6 shows the idea of composite SOA with BI services being accessible for portals, processes, operational applications, performance management scorecards, search engines and office applications all via an Enterprise Service Bus (ESB).

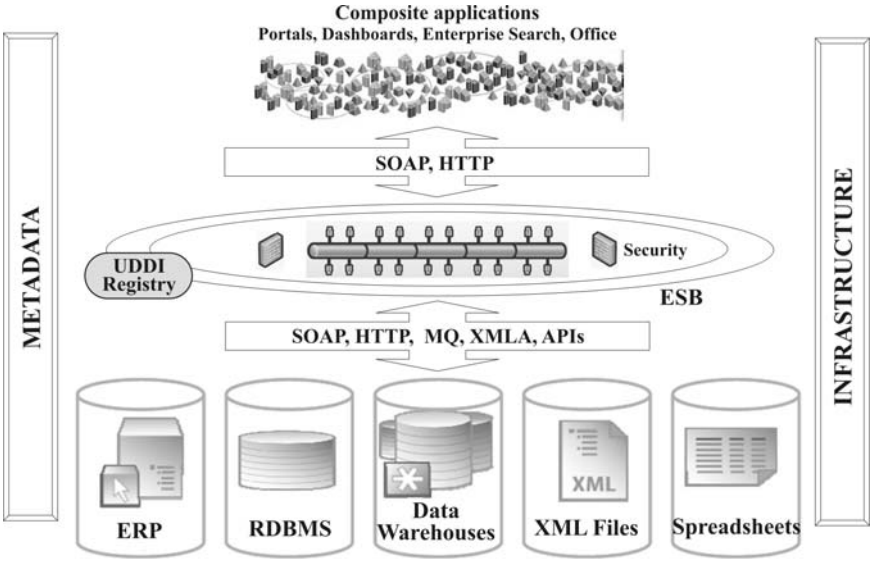

Fig. 6. BI SOA

A key point to note is that a SOA can interconnect resources that operate at the user interaction, application and data levels of an IT system. In a data warehousing environment, for example, a data validation service could be defined as a service provider and be called by a data integration application. Other examples of services providers include user authentication, search, data transformation, BI analysis, data mining models, legacy applications and business transactions.

The advantage of a SOA is that it enables common and shared interfaces to be defined and created for distributed resources. This eliminates the need to develop multiple proprietary point-to-point connections between resources, which reduces IT development and maintenance efforts and encourages service reuse [24].

One of the potential users of an ESB is a data integration service. In fact, several vendors have modified their data integration and ETL (extract, transform and load) tools to be event-driven so that they can consume event messages from an ESB. These events can carry information about source data changes, which can be used by the data integration service to incrementally update an operational data store (ODS) or data warehouse.

The Impact of Web Services on business intelligence systems can be seen at the following three levels [25]:

- Data Level

Web services will affect the access and delivery of BI data in several ways:

  - First, the input and output interfaces will evolve from proprietary API mechanisms to standard-based mechanisms, such as XML for Analysis, XBRL and JOLAP, that ease BI data integration.
  - Second, authentication tools, such as LDAP, NTLM and ADS, will help ensure authorization rights of users to data across applications.
  - Finally, encryption from Secured Socket Layers (SSLs) and Hypertext Transfer Protocol Secure (HTTPS) will help protect the integrity of a message during transit.

- Metadata Level

Web services will also have a significant impact on BI metadata. The functionality of defining dimensions, hierarchies, calculations, business rules and reporting formats and sharing them across BI tools and applications will be exposed as a Web service. In addition, the functionality of modifying metadata definitions, versioning the changes and synchronizing them across applications will be exposed as a Web service. And again, the import and export interfaces will evolve from proprietary mechanisms to XML-based mechanisms such as CWM in order to ease BI metadata integration.

- Process Level

Web services will be a major technology enabler for business activity monitoring and collaborative BI. By encapsulating application functionality and business rules within a Web service, companies will be able to create intelligent agents that monitor events in real-time, dynamically route information to targeted users or processes and automate analysis to improve

the speed and effectiveness of adapting business operations to changing conditions.

4.2 Service-Oriented Database Architecture

Service-Oriented Database Architecture (SODA) closely mirrors modern practice in application construction and allows for unlimited scalability by dividing database processing along service boundaries. Services can be scaled independently or partitioned into new services to handle additional load, availability, or business requirements. Each Service can be made highly available, and the overall application can be designed to provide continuous availability [26].

Unlike transparent scale-out, SODA avoids SQL-level cross-partition operations, and all the scalability limitations they bring, in favour of well-defined requests between database services. Additionally, unlike non-transparent scale-out, SODA integrates support for service interfaces and inter-service communications, and also routing directly into the database system, thus relieving the application development and maintenance burden.

The notion of a database service is central to SODA and its scalability model. At a logical level, a database service exposes a well-documented application level interface to data. This is not a general database interface for reading and writing data, but instead provides very specific application functionality. For example, an inventory database service might expose methods for checking inventory levels, reserving inventory, removing products from inventory, recording receipt of new shipments and managing back-ordered items.

The first difference between database services and traditional models is that access to data under the control of one database service is completely isolated from access to data under the control of a different database service.

The second difference is that requests to database services are not made over a database connection but, instead, the services are exposed as Web Services.

Database services encourage far more business logic to be managed by the database system than has classically been done. SODA supports the use of general purpose programming languages for creating business rules inside the database system.

With the SODA, databases are partitioned according to well-defined service boundaries that meet application requirements. These database services can then be hosted on a single server node, or multiple server nodes, to achieve the desired level of scalability.

5. Business Activity Monitoring

Most businesses are probably not using BI to continually and automatically monitor events in their operational business processes as their businesses operate to respond rapidly to detected problems or to predict whether problems lie ahead. In general, therefore, companies have no active real-time element to their BI systems. The consequences are that nothing is helping the business to automatically respond immediately when problems occur or opportunities arise. Also, there is no automatic notification or flagging of alerts to take action that may avoid unnecessary costs, business disruption, operational mistakes and unhappy customers in the future.

Business Activity Monitoring (BAM) is a collection of tools that allow you to manage aggregations, alerts, and profiles to monitor relevant business metrics (Key Performance Indicators - KPIs). It gives users end-to-end visibility into business processes, providing accurate information about the status and results of various operations, processes, and transactions so they can address problem areas and resolve issues within your business. BAM software products incorporate concepts from — and sometimes are built on — ERP, business intelligence, business process management and enterprise application integration (EAI) software.

The BAM provides an easy, real-time, transaction-consistent way to monitor heterogeneous business applications and to present data for SQL queries and aggregated reports (OLAP). Through queries and aggregations BAM systems can include not only the data that is present during the running business process, but also the state and the dynamics of the running business process, independent of how the business is automated.

Figure 7 shows how data and messages flow within the BAM system.

BAM applies operational business intelligence and application integration technologies to automated processes to continually refine them based on feedback that comes directly from knowledge of operational events [27]. In addition to auditing business processes (and business process management systems), BAM can send event-driven alerts that can be used to alert decision makers to changes in the business that may require action.

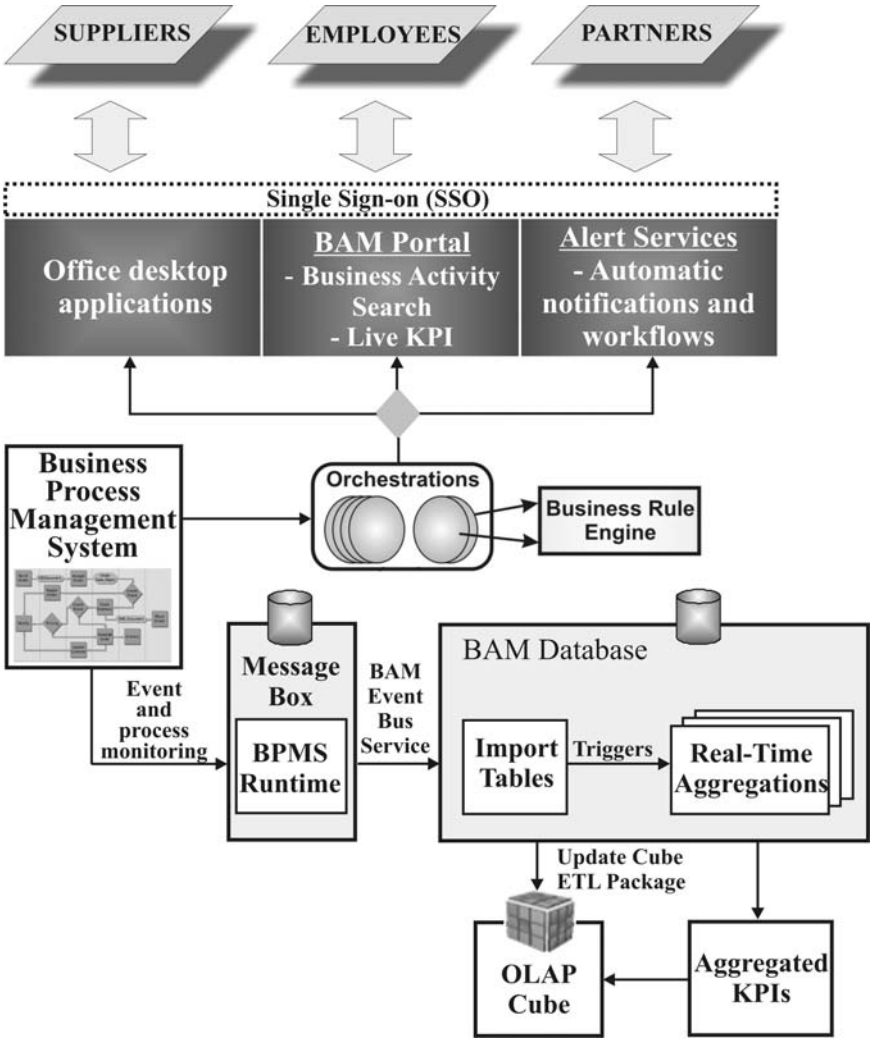

Fig. 7. BAM Architecture

Possible business reasons for the BAM system deployment are [28]:

- To detect any changes in orders (cancelled orders, large orders, orders from valuable customers) and, if need be, to alert the sales force and other people in operations when specific events have a business impact, e.g., to respond when cancelled orders occur.
- To check orders or predicted demand against inventory to optimize a supply chain by reordering/delaying/cancelling supply of inventory.

- To detect or predict bottlenecks in the package assembly activity.
- To detect or predict delays in shipments for valuable customers.
- To detect or predict cash flow problems because of late payments.

Business users use Business Activity Monitoring to gain a real-time holistic view of business processes that span heterogeneous applications, regardless of the infrastructure implementation.

BAM gives a different perspective on a business process. For example, a BAM system might provide graphical depictions of per-product sales trends or current inventory levels or other key performance indicators. The information might be updated every day, every hour, or more frequently.

BAM relies on one or more BAM activities. A BAM activity represents a specific business process, such as handling purchase orders or shipping a product, and each one has a defined set of milestones and business data. For example, a purchase order activity might have milestones such as Approved, Denied, and Delivered along with business data like Customer Name and Product.

One of the newest technology trends is toward the integration of BAM systems with web portals. Business end users can use the BAM portals to monitor KPIs, which measure progress toward a business goal, as well as other information about their business process.

The following list describes how business users can use BAM portal systems [29]:

- View a single activity instance such as a purchase order or loan (process) in real-time or as historical data.
- Show only the data relevant to the business process the knowledge worker is concerned with and hide complexity of the heterogeneous implementation.
- Search for activity instances based on their progress or business data. For example, you can search for loans that are waiting for customer signature and the dollar amount is greater than a given value.
- Browse aggregations (which are key performance indicators) around all the business activities that are currently being processed or have already happened. The aggregations can be done in real-time or can be based on a snapshot of the activities taken at a specific time.
- Navigate to the related activity instances such as shipments associated with a given purchase order, or the invoice in which it is included.

By combining business intelligence with different novel technologies such as SOA, business process management systems with business workflow capabilities and rule engines, and web portals, it is possible to create composite performance management systems in order to create the performance-aware intelligent enterprise.

6. Data Mining

As a fastest growing BI component, data mining allows us to comb through our data, notice patterns, devising rules, and making predictions about the future It can be defined as the analysis of (often large) observational data sets to find unsuspected relationships and to summarize the data in novel ways [30].

Data mining applies algorithms, such as decision trees, clustering, association, time series, and so on, to a dataset and analyzes its contents. This analysis produces patterns, which can be explored for valuable information. Depending on the underlying algorithm, these patterns can be in the form of trees, rules, clusters, or simply a set of mathematical formulas. The information found in the patterns can be used for reporting, as a guide to supply chain strategies, and, most importantly, for prediction [31].

Data mining can be applied to the following tasks [32]:

- Classification
- Estimation
- Segmentation
- Association
- Forecasting
- Text analysis

The main characteristics of data mining intelligent applications are:

- Make decisions without coding – Data mining algorithms learn business rules directly from the data, freeing you from trying to discover and code them yourselves.
- Customized for each client – Data mining learns the rules from the client's data resulting in logic that is automatically specialized for each individual client.
- Automatically update themselves – As client's business changes, so do the factors that impact their business. Data mining allows application logic to be automatically updated through simple processing steps. Applications do not need to be rewritten, recompiled or redeployed and are always online.

Data mining provides answers to three key business questions as shown in Figure 8.

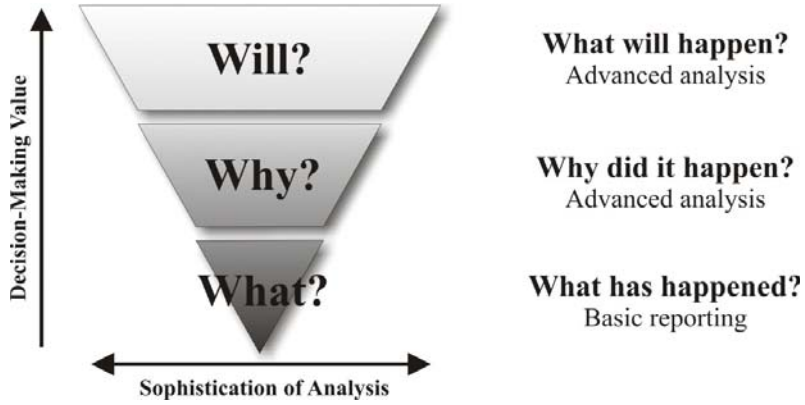

Fig. 8. Types of Analysis

Data mining techniques can be applied to many applications, answering various types of businesses questions, such as demand forecasting, inventory prediction, customer and product segmentation, risk management, etc.

Most of the data mining techniques existed, at least as academic algorithms, for years or decades. However, it is only in the last decade that commercial data mining has caught on in a big way. This is due to the convergence of several factors [33]:

- The data is being produced.
- The data is being warehoused.
- Computing power is affordable.
- Interest in customer relationship management is strong.
- Commercial data mining software products are readily available.

The business intelligence market has shifted its focus from the IT community to the broader line of business users, we can expect data mining to do the same.

Over the next few years, data mining technology should significantly grow, thanks to business applications and database software vendors.

Embedding data mining algorithms directly into business applications is a perfect conduit to reach them. As vendors create a closed loop between their data warehouses and their enterprise business processes, this will extend to areas like finance and the supply chain.

Market research groups expect the data mining market to expand 10% annually over the next few years [34].

7. Business Intelligence Web Portals

Technologies such as portals comprise a portfolio of collaboration and communication services that connect people, information, processes and systems both inside and outside the corporate firewall. These IT resources help to solve key information worker challenges, such as:

- Finding information more easily
- Working more productively in teams
- Connecting more effectively with others
- Collaborative planning and decision making
- Providing a consistent user experience.

Industry analysts predict that collaboration is rapidly becoming a strategic platform advantage, yet many organizations either already have or will implement such capabilities at the tactical level, purchasing and deploying collaboration technologies in a piecemeal fashion. The end result is likely to be expensive systems that are poorly integrated and costly to maintain.

Organizations usually view portals and business intelligence separately, but in the next few years, the two will become integrated. These technologies can shrink the amount of data that has to be analyzed to make a decision, in an era when people have less time and must focus on the decision criteria that truly make a difference [8].

The true value of the combination of BI tools and portal technology is that decision makers will have more complete information integrated on their screens from across their enterprise and their partners to make better decisions more quickly.

Portals provide the ideal framework for the integration of critical business intelligence information because portals support the delivery of a highly secure, unified access point through consistent interfaces to Web applications spanning a range of applications and systems [35].

Additionally, portals provide valuable functions like search, collaboration and workflow in a security-rich environment - as well as new capabilities that enable different kinds of analytics.

A BI web portal can be viewed as an integrated, web-based online analytical processing solution that enables employees throughout the entire supply chain to create and share reports, charts and pivot tables, perform ad-hoc analysis, based on online OLAP services, cube files, relational databases and web services.

Supply chain BI web portals combine modern technologies like portlets (web parts), content management, enterprise search and web services in order to provide better user experience for collaborative decision making.

In this way, it is possible to present different KPIs combined in a form of digital dashboard in order to provide a comprehensive view to the decision makers.

The BI web portal typically consists of many modules (web parts) with different functions. There can be web parts for organizing content structure, for creating views of data, for data analysis (querying, drill-down, cell colouring), for document exchange, etc.

Figure 9 shows a BI portal with two data views that introduce two reports for presenting data mining results. The reports are stored in a separate report server and integrated in the portal using standard XML web service and SOAP (Simple Object Access Protocol) technologies.

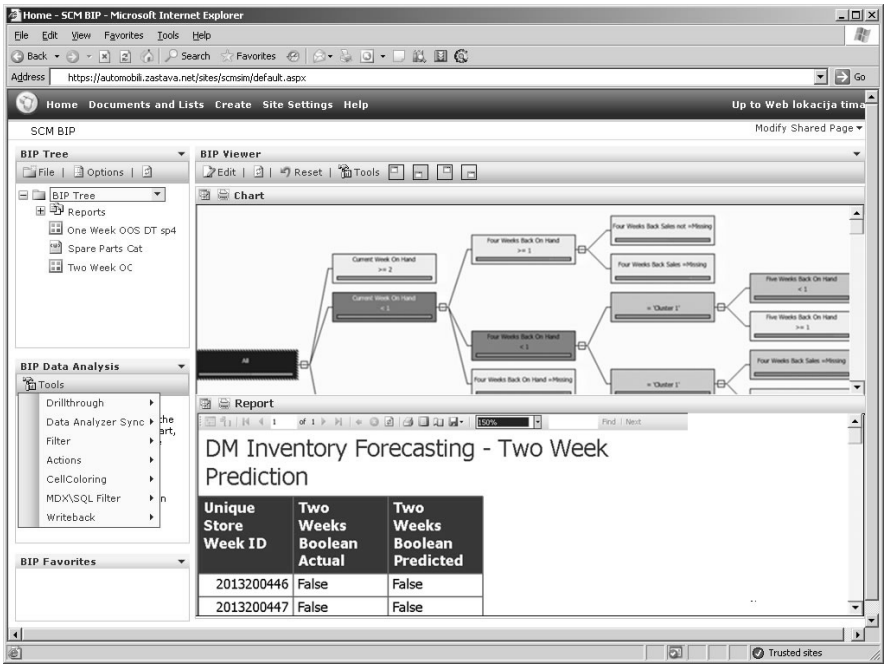

Fig. 9. Business Intelligence Portal

Another usage of web portals is related to the Balanced Scorecard (BSC) methodology. Web portals can bring visibility to the BSC process, ease a cultural transition, and enable participation by a wider audience. Many BI software vendors are adding BSC capabilities to their product line.

The main characteristics of the BI web portal are:

- Modularity – ability to compose web pages dynamically integrating content from different sources and using different technologies.
- Personalization – portal can be easily personalized to reflect users' needs and interests.
- Customization – Users can tailor a web portal to suit their particular needs.

- Self-service – Users can create new modules, site templates, share and reuse proven solutions, and get or access information on-demand.
- Fine-grained security mechanisms – role-based access control, authentication and authorization mechanisms and granular security.
- Easy user adoption – standardized and consistent browser-based interface enables users to access information using the familiar tools.

8. Business Intelligence Trends

As financial analysts have pointed out [36], the BI software segment is a bright spot in the software industry and continues to grow even in a tough economic climate. The BI segment is composed of firms specializing in BI and those offering BI as part of their product offerings such as ERP and database vendors.

There are three strong trends in the market today [37]:

- Solid market growth - Overall BI market growth is solid. At this point, however, the market is splitting into a group of haves and have-nots. Many smaller vendors are experiencing slowing growth rates and are bleeding money. This creates a vicious circle. Potential customers shy away from them because of their poor financial position, limited customer base, and concern about their longevity. Under these conditions, many BI firms and their customers are looking for an exit strategy with a larger firm acquiring them and incorporating their products into their offerings.
- Ripe for consolidation – A mature market like BI with many competitors is ripe for consolidation. Stronger players acquire smaller players for their customer base, technology and people. It is assumed that BI software companies need to reach $1 billion in sales to have sufficient depth to continue expanding and enhancing their products, support and services.
- Pressure from all sides - BI vendors are under pressure from ERP vendors at the high end and from open-source BI initiatives at the low end.

  High end In a effort to jumpstart their growth and capture more client dollars, ERP vendors like SAP, Oracle and Microsoft have expanded their reporting offering to include data warehousing, business intelligence, and analytics applications. Their attempts to win clients threaten the expansion of the pure BI vendors. Although some ERP vendors have included pure BI vendors' tools in their analytic offerings, this still jeopardizes the BI vendors.

  Low end From the low end of the marketplace, open-source products are going to be key competitors. Open source is gaining momentum and

there are significant amounts of money coming from the investment community into "open source" vendors. Open source approaches benefit both customers and vendors. For the customer, the benefit is lower software costs. The downside, however, can be higher development costs.

Business intelligence and data warehousing (DW) has reached a new level of maturity, as both a discipline and a technology market. Demand for BI/DW is stronger than ever and BI/DW are within the top ten CIO priorities. Most enterprises already have a BI/DW infrastructure in place and are now taking the lessons they have learned from previous efforts to remedy problem areas. At the same time, many enterprises are also moving towards the next steps in the evolution of BI/DW.

Besides the already discussed cutting-edge BI technologies and trends such as service-oriented architecture, business activity monitoring, predictive analytics and web portals, there are also some other important business intelligence trends that are shaping BI/DW today, as well as the new technologies and initiatives that are moving BI/DW forward.

- Infrastructure standardization and consolidation

  Enterprises tend to know what they are spending for ERP and other core systems, but not for BI/DW. That's because BI/DW efforts have largely been undertaken in silos, with each business domain creating its own solutions to the problem of obtaining and analyzing data. This siloed approach almost always results in duplication of effort, inefficiency and increased expense.

  Enterprises have come to recognize their disparate BI/DW solutions as a problem over the past couple of years. Their interest has been particularly piqued in these lean economic times, when eliminating duplicate BI tools or data marts might result in lower license costs and maintenance expense. Improved access to information, while more difficult to quantify, is also an important benefit of eliminating silos. However, standardizing and consolidating a BI/DW infrastructure is far easier said than done. It involves political and organizational issues that are just as challenging as the technology issues.

- Metadata and master data management

  Within every enterprise, there is a set of data that provides valuable information to identify and uniquely define core entities, such as customers, products, suppliers, etc.

  The proliferation of enterprise applications, combined with most organizations' siloed approach to BI/DW, has resulted in master data being scattered across the enterprise. The drive toward integrating and streamlining enterprise systems is getting more and more attention.

  Another increasingly important feature is metadata management, which enables information consistency. The Common Warehouse Metamodel (CWM) is an open industry standard defining a common metamodel and

XML-based interchange format for meta data in the data warehousing and business analysis domains [38].

- The rise of the BI application service providers

  Given the cost and difficulty of developing and implementing BI solutions, by 2010, at least 50% of the Fortune 500 will turn to outsourcing contractors that have the next-generation technology and database marketing expertise to do it [39].

  The worldwide software-as-a-service (SaaS) market reached $6.3 billion in 2006 and is forecast to grow to $19.3 billion by year-end 2011, according to Gartner [40]. SaaS is hosted software based on a single set of common code and data definitions that are consumed in a one-to-many model by all contracted customers, at any time, on a pay-for-use basis, or as a subscription based on usage metrics.

- Web 2.0 and BI 2.0

  Essentially, Web 2.0 is an umbrella term for a group of technologies that have advanced web usage and turned the web into a development platform for the enterprise. These technologies include: RSS and ATOM feeds, web services, JavaScript and AJAX, web scripting, mashups, programming frameworks (e.g., Adobe Flex, Ruby on Rails, and OpenLaszlo) and Wikis.

  Currently, we are about to enter a new era of Rich Internet Applications (RIA), when plain looking Web applications will gradually be replaced with RIA delivered over the Web [41]. RIA applications run in a virtual machine deliver over the Web and have a potential of becoming full featured desktop applications. This new approach will be part of a "Business Intelligence 2.0" revolution that makes any company's data more democratic [42].

- Adaptive Business Intelligence

  There is also a new trend emerging in the marketplace called Adaptive Business Intelligence. Adaptive Business Intelligence can be defined as the discipline of combining prediction, optimization and adaptability into a system capable of answering these two fundamental questions [43]: What is likely to happen in the future? and What is the best decision right now?

  This relatively new approach to business intelligence is capable of recommending the best course of action (based on past data), but it does so in a very special way: an Adaptive Business Intelligence system incorporates prediction and optimization modules to recommend near-optimal decisions and an “adaptability module” for improving future recommendations. Such systems can help business managers make decisions that increase efficiency, productivity, and competitiveness.

- Simulation and Business Intelligence

  Modelling and analysis of supply chains can be extremely challenging due to a complex network structure, process relationships, constraints and

especially uncertainty. Simulation can be a valuable tool for studying the behaviour of a supply network model under the most realistic business conditions.

The new approach to supply chain simulation allows process-based modelling of any supply chain configuration regardless of the number of supply chain nodes, process levels, process types, constraints, or business policies involved [44]. Also, the database-centric approach for supply chain simulation enables all the relevant data to be stored (models, processes, relationships, constrains, metrics, etc.).

The huge amount of data generated through simulation runs, now kept in the database, can be loaded into the data warehouse for further analysis and data mining. This way, different scenarios and business policies can be evaluated, KPIs can be monitored and predictions about the future can be made.

9. Conclusion

Market forces are driving the need for collaboration. Customers are expecting more and the economy is demanding greater cost efficiencies. Organizations working together as part of a collaborative supply chain have understood the need for better information exchange.

To succeed in a competitive marketplace, an agile supply chain requires business intelligence (BI) systems to quickly anticipate, adapt, and react to changing business conditions. BI systems provide sustainable success in a dynamic environment by empowering business users at all levels of the supply chain and enabling them to use actionable, real-time information.

Supply chain intelligence (SCI) reveals opportunities to reduce costs and stimulate revenue growth and it enables companies to understand the entire supply chain from the customer's perspective.

Many forward-thinking supply networks have realized that business intelligence networks are a first step to information consolidation and gaining visibility over the value chain. With BI networks, businesses can share information with customers, suppliers and partners.

Thanks to a new emerging set of Internet-based technologies such as web services and SOA, businesses are taking BI networks to the next level. These next-generation and loosely-coupled networks, built as BI web services, will enable collaborative, efficient, responsive and adaptive supply chains.

Furthermore, by combining business activity monitoring (BAM) in support of process management and event monitoring together with web portals for flexible, user-friendly and accessible information delivery, on top of the BI systems, it is possible to create a synergistic effect.

The way organizations gather, measure and analyze information often determines the ultimate supply chain success.

In this chapter, we discuss the latest supply chain management issues and the drivers for the implementation of business intelligence systems and performance measurement based on the process approach.

We also talk about BI challenges and benefits, as well as applications of BI technologies in the supply chain management domain.

Finally, the main BI trends and advanced IT technologies that will shape future BI systems are introduced.

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