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Intelligent Business Activity Management – Sense and Respond Value Net Optimization

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Intelligent Business Performance Management – Sense and Respond Value Net Optimization*

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Abstract

Today's business environment is changing at a rapid pace. Enterprises need to transform themselves to adapt with speed and intelligence, using real time information, advanced technology, and intelligent decision making to gain a competitive edge. The Sense-and-Respond paradigm is a new customer-centered management approach that provides real-time responsiveness necessary for organizations to proactively manage and use distributed networks of resources in rapidly changing environments. It uses advanced technologies to support business agility and intelligence to achieve a competitive advantage. In this paper, we describe a Sense and Respond Value Net Optimization framework that continuously recognizes and transforms events of business processes, generates and provides access to current business performance indicators, and immediately triggers appropriate actions across the entire enterprise and beyond. We discuss two pilot engagements where the Sense-and-Respond framework was applied. In a pilot with IBM's Personal Computing Division, we describe how to use order trends to provide an early warning of constraints and excesses to make demand conditioning more effective.

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In another pilot with the IBM Microelectronics Division, we built a system that supports event-driven management of inventory and customer order fulfillment.

1 Introduction

Today's market and business environments are inherently complex, dynamic and global. Customers are becoming more informed and demanding. To stay competitive, enterprises must improve their flexibility, efficiency and responsiveness by transforming their business and operational models.

During the past 20 years, supply chain management has evolved from the internal efficiency improvement and cost cutting focus of the 80's, to the limited information sharing of the extended supply chains and the ERP implementation for transaction efficiency of the 90's. However, a major issue with the ERP system is its lack of flexibility and speed to support decision making throughout the internal and extended supply chain to meet changing business requirements. By the mid 90's, Advanced Planning and Scheduling (APS) tools, implemented with legacy and ERP systems, allowed "what-if" analysis and optimization of supply chains during planning and execution cycles. In the late 90's, the development of packaged applications, e-Commerce and e-Business offered Internet connectivity and limited capability for supply chain collaboration and near real-time information sharing and decision making.

However, despite the implementation of the supply chain management tools and the Internet connectivity, enterprises still found that they often sub-optimize their operations. Furthermore, the ROI of supply chain management package implementations is constantly being questioned. Forrester reported (based on interviews of 25 firms) that companies overspent on supply chain optimization packages and got diminished returns: 80% of the companies spent more time than expected; and, on the average, companies spent 74% over budget to implement supply chain optimization tools [7].

In fast changing business environments, business and technical problems can occur anytime, and at every level. Lack of information visibility across internal and external supply chains, insufficient customer collaboration, inability to leverage knowledge and manage uncertainty, overly rigid business processes, and lack of infrastructure

flexibility can all cause major business disruptions and inefficiencies. Local supply chain optimization based on incomplete information under rigid top-down planning models can not only result in sub-optimization, but can also cause adverse effects.

The key to a successful adaptive organization is ensuring continued focus on responsiveness and agility. New business models enabled by real-time business process management are evolving. They present new opportunities that enterprises hope to embrace to enhance their competitiveness. At the same time, converging social and technological trends are changing the nature of decision-making. The Internet has caused an explosion of information availability. Pervasive computing and wireless technology have added to the information pile by drawing from formerly isolated sources of data. Improvements in network bandwidth and processor technology have reduced information latencies, and enabled businesses to place large numbers of sensors. Flexible interconnect technologies such as Web Services have made it easier for one network to pass information onto another network. However, an abundance of information, and the ability to respond rapidly to events do not guarantee success.

The successful supply chain optimization of enterprises also depends on their ability to streamline operations, while being able to process information intelligently and holistically, so they can respond proactively and effectively. This includes fully understanding the needs of customers and business partners, and the capabilities of employees, as well as analyzing risks and opportunities in a changing environment.

After the IBM Extended Supply Chain R&D group successfully helped IBM Personal System Group and other divisions transform their supply chains from Make-to-Plan to Configure-to-Order [10], the group started to explore more flexible and responsive models. In doing so, they included lessons learned from a number of supply chain transformation efforts both within IBM internal groups and their partners. The Sense and Respond Value Net effort was initiated in 1999 at IBM Research to build an open and adaptive framework, using intelligent decision making and IT technology for business optimization [11, 12]. This effort departed from the traditional extended supply chain models. Traditional extended supply chain management systems are based on static, structured information within a rigid planning cycle, while a Sense and Respond Value Net orchestrates dynamic, structured and unstructured information within a continuous, adaptive event-based planning process. Traditional

extended supply chain management focuses on supply chain planning and execution. A Sense and Respond Value Net not only performs supply chain planning, but also determines business rules and policies and orchestrates among the value partners to achieve better overall performance. Traditional value chain management responds to environmental changes reactively, while a Sense and Respond Value Net utilizes a real-time, predictive and proactive modeling capability to address potential issues.

The rest of the chapter is organized as follows. We start with an overview of related work in section 2. The four key requirements for an enterprise to become more adaptive are discussed in section 3. In section 4, we introduce two core aspects of the Sense and Respond Value Net framework: a model-driven capability design and an architectural framework of loosely coupled components for adaptive business management. In section 5, we describe two pilot implementations where the Sense and Respond Value Net framework was applied. In the pilot with IBM's Personal Computing Division, we describe how to use order trends to provide early warnings of constraints and excesses of PC components; in the second pilot with IBM's Microelectronics Division, we describe how to use an end-to-end supply chain model to support event-driven management of inventory and customer order fulfillment. We conclude the chapter with a summary in section 6.

2 Related Work

The first reference to the term "Sense and Respond Organization" we found was in the book entitled "Sense and Respond: Capturing Value in the Network Era" [2]. This book focuses on two components of value creation: electronically sensing customers' needs in real time and using the electronic connection and shared infrastructures to respond to those needs.

In his 1999 book entitled, "Adaptive Enterprise: Creating and Leading Sense-and-Respond Organizations", Stephan Haeckel of IBM defined the Sense-and-Respond business organizational change model [4]. He describes the transformation from a Make-and-Sell organization to a Sense-and-Respond organization and advocates a new form of strategic transformation based on roles and responsibilities. In his view, organizational hierarchy is replaced by a dynamically configured network of modular

capabilities. Governance is performed on the basis of context and coordination by people in roles accountable for outcomes rather than by command and control.

AMR Research defines Supply Chain Event Management, or SCEM, as a class of supply-chain-management software that allows companies to respond to unplanned events on an exception basis [1,13]. SCEM comprises integrated software functionality supporting the five business processes Monitor, Notify, Simulate, Control and Measure.

Business Activity Monitoring, or BAM, defined in 2002 by Gartner Group is a class of software that provides real-time access to critical business performance indicators to improve the speed and effectiveness of business operations [3,9]. It focuses on the IT aspect of the adaptive enterprise.

Lee and Amaral [8] describe Supply Chain Performance Management (SCPM) as a cycle consisting of identifying supply chain problem areas, understanding root causes, responding to problems with corrective actions, and continuously validating data, processes and actions. The authors describe how the approach was used by two large electronics manufacturers to improve the velocity of their extended supply chain.

The Sense and Respond Value Net addresses the full spectrum of SCEM and takes it several steps further. It enhances the global visibility by focusing on the collaborative interactions based on the degree of trust on data, people, and organization. The model integrates supply chain planning with a dynamic sense-and-respond control model, utilizing an agent-based framework that supports different business and execution models. It allows enterprises to adaptively use the most effective model to address their value chain needs. It enhances the event-based management by marrying real time decision support with end-to-end performance and risk management. Further, it helps realize operational business designs through business process integration, automation technology and Web services, and helps partners to integrate their processes and optimize supply chain collaboration and enables intelligent decision-making on events and prediction of future value net performance.

3 Sense and Respond Value Net Roadmap

An adaptive business senses changes in the environment and in the needs of customers, employees and business partners. Adaptive businesses focus on core competencies and support an open and integrated operating environment to collaborate with customers and suppliers. Being adaptive means being able to sense changing business conditions and customers' needs and respond with speed and intelligence.

The adaptive business approach provides promising solutions to many of the challenges that companies face throughout the value chains. As in any major business transformation, becoming an adaptive e-business requires establishing a strategy and a roadmap [14]. To become adaptive, enterprises need the following capabilities:

- *Automation.* Proactively developing a better understanding of transactional data representing customers' needs while also monitoring environmental factors.
- *Visibility.* Integrating data and applications within the enterprise as well as with business partners, suppliers and customers to increase visibility and operational efficiency.
- *Control.* Creating an IT infrastructure that fully supports business goals and has the intelligence to help transform ways to do business so that enterprises can react with agility to the changing environment.
- *Adaptiveness.* Developing competitive advantages through adaptive optimization supported by dynamic tradeoff analysis and cross functional collaborations.

The Sense and Respond Value Net addresses the full spectrum of all of the above concepts. It integrates value chain planning with a dynamic Sense-and-Respond control model, utilizing an agent-based framework that supports different business and execution models. It allows enterprises to adaptively use the most effective model to address their value chain needs. Further, it helps realize operational business designs through business process integration, automation technology, and Web Services, and helps partners to integrate their processes and optimize supply chain collaboration.

3.1 Automation

A key requirement to an optimized execution of the extended value chain is the ability to collect, maintain and manage information linked to business partners, customers and suppliers. Information such as customer profiles, supplier status, customer demand, product information, planning data, current inventory, capacity, pricing, and product and process cost must be accurate and timely. Transactional data comes from business applications and is usually process-related. Derived data may be obtained from data services, partners, internal sensors and post-analysis of historical data. Intelligent decision-making is only possible when up-to-date and accurate information is available.

In today's business environment, data is often stored in a variety of formats using various tools and may be quite fragmented. Data integrity problems come from different sources: fragmentation, incompleteness, data unavailability, data latency (delays in data arrival), nonstandard data models and lack of trust in sharing data among business partners. Techniques to ensure good data quality include data cleansing, measurements, information integration and analytic processing.

The Sense and Respond Value Net architecture leverages J2EE-compliant application servers to acquire data, analyze data to detect events, and invoke actions in response to events. It enables monitoring of data within and outside the enterprise such as data from databases, JMS message queues, ftp repositories, and web services. Advanced analytics leverage the transactional data to predict critical events and invoke responses when such events occur, which ultimately enables the development of contingency plans before events impact the value chain.

3.2 Visibility

Visibility across the enterprise requires real-time information, rationalization, aggregation, performance analysis capability, workflow technology and dashboard technology. Limited visibility can prevent organizations from optimizing their value chain or internal operations, and may be a direct cause of excess inventory. It can

lead to bad decisions with costly results. On the other hand, excessive information from data warehouses, automatic sensors, partners, portals, etc. can be overwhelming and make it difficult to identify the important data from the mundane data.

Companies that can understand their data needs, proactively collect useful data, analyze and manage data utilizing filtering and data aggregation techniques, and use data to derive intelligent information will have significant competitive advantage.

Dashboards and portals help to aggregate and synchronize enterprise information and enable workflow-based information display for users based on their roles. They support the presentation of performance and supporting information in standard formats for aggregation and analysis. Transactional visibility and dashboard displays of information can be enhanced with well-defined business logic. Alerts can be generated for timely decision support. Most importantly, workflows with exception-based business logic and rules can identify where critical points in the supply chain processes may require immediate intervention (e.g. potentially late or missed shipment, supplier quantities received not equal to ordered quantities). All too often when individual value chain components are measured independently, functional performance meets or exceeds thresholds but in the aggregate, the entire supply chain remains sub-optimal due to lack of visibility, synchronization and control.

3.3 Control

A control is a closed-loop feedback mechanism that drives a business process towards performance goals. A control utilizes available data, business logic, and analytics to determine whether actions are required in response to disturbances in the business environment and recommend actions. A significant fluctuation in demand, for example may initiate a response that the production schedule be re-optimized and then send the appropriate information to the appropriate party. That same fluctuation may also send collaborative messages and even correcting transactions to trading partners, such as logistics service providers and suppliers. An example might be a shipment request, or a purchase order change.

Potential control actions can be simulated based on historical responses, business rules, business analytics, what-if-analysis, risk analysis or predictive modeling. The

effectiveness of a control depends upon the latency and accuracy of available data, the completeness of the data, and the sophistication of the business logic and analytics. Because the environment is constantly changing, a control must allow its business logic to be updated dynamically without programming interruption.

To achieve optimal business performance in a dynamically changing environment, enterprises need to exercise control at all levels (strategic, tactical and operational) to determine the best short-term and long-term course for their value chain. Adaptiveness implies that the organization and its processes are "adaptive", responsive and agile. Multiple functional controls and cross-functional demand and supply signals are integrated at all levels within the organization to collaboratively optimize strategy, business policies and operational decisions.

3.4 Adaptiveness

Adaptiveness involves the use of predictive modeling and learning based on historical performance coupled with real-time information. Adaptiveness requires two feedback loops:

- A robust version of the basic control loop described in the previous section
- A loop that detects inaccuracies and weaknesses in the control model and adjusts the control model accordingly. Control model adjustments may be cascaded to strategy models and business process models.

Adaptiveness involves creative coupling of decision-making technology such as analytical models, simulation, and pattern recognition, data mining and learning algorithms. Visibility to relevant value chain data is critical. Advanced mining and forecasting techniques enable enterprises to sense trends for longer-term capability networks planning and events for short-term response optimization. Analytical techniques for strategic sourcing, inventory management, dynamic pricing and risk management enable intelligent decision-making and predictions of future supply chain performance. This enables enterprises to focus on core competencies and support an open and integrated operating environment to collaborate with customers and suppliers.

4 Sense and Respond Value Net Framework

Since the mid-1990's, IBM has been developing and refining software architectures and tools to support Sense-and-Respond business management. In this section we describe model-driven capability design, a core aspect of our Sense-and-Respond framework. We also discuss the monitoring framework that identifies the functional components necessary for real-time monitoring, analysis and optimization of business operations and the supporting IT infrastructure.

4.1 Model-Driven Architecture

The linkage of business and IT models in a multi-level model has the potential to greatly reduce the time-to-value of business transformation. This linkage is a significant step towards closing the business-IT gap by maintaining alignment between business design and IT solutions. This linkage also has the potential to provide real-time visibility of business operations which would enable the continual optimization of the business, guided by business-level optimizations and "what-if" analyses.

Model-driven capability design is a core aspect of the Sense and Respond Value Net framework. Instead of automating business processes using workflow management systems and enterprise application integration (EAI) techniques, the model-driven architecture approach is based on building solutions that have ability to respond to changing business conditions [6]. The modeling framework is shown in Figure 1.

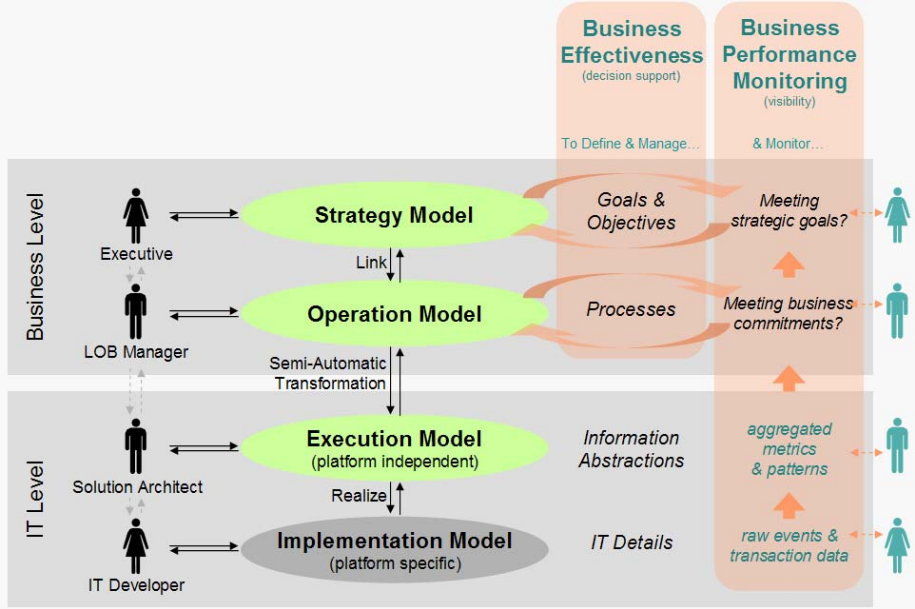

Figure 1: Modeling Framework for a Sense-and-Respond Enterprise.

The modeling framework consists of four modeling layers, two layers in the business domain and two layers in the IT domain. An adaptive change at any layer requires validation and verification with higher layers as well as semi-automated propagation of the change to lower layers.

- *Strategy Layer.* The strategy model specifies what the business wants to achieve. It models the business objectives in terms business leaders understand, for example, a description of strategic goals and business objectives in terms of a Balanced Scorecard [5].
- *Operation Layer.* The operation model describes what a business is doing to achieve the strategic objectives, and how will it measure progress towards them. It captures the business operations, commitments and key performance indicators (KPIs). The KPIs are directly linked to Balanced Scorecard goals.
- *Execution Layer.* The execution model describes processes and information flows that implement the operation model independent of a particular IT implementation. It is a platform-independent description of documents, flows and their connection to people, applications and data sources.
- *Implementation Layer.* The implementation model defines actual IT processes in a specific realization of the execution model. It is a platform-specific model

of the IT infrastructure, hardware, software, middleware and applications. Tools are used today to construct portions of the implementation model directly from the execution model much as a compiler translating a high-level language.

The four-layer modeling approach enables the linkage of strategic business objectives to the IT infrastructure. It increases the alignment of IT and business processes so that the entire enterprise can become performance-driven.

4.2 Monitoring Framework

Currently the implementation of many Sense-and-Respond systems in IBM is realized by the architectural framework of loosely coupled components shown in Figure 2. These components communicate with each other through an event bus. Each component has well-defined interfaces for receiving and publishing events on the event bus. A loosely-coupled framework gives a Sense-and-Respond designer the freedom to select from a variety of physical components.

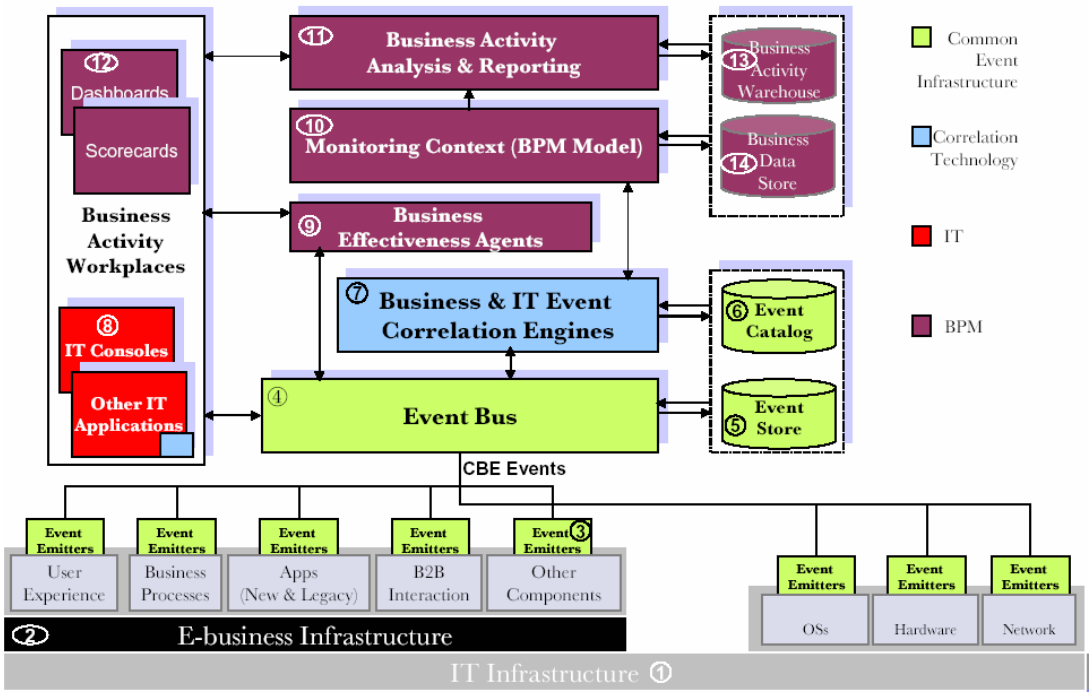

Figure 2: Architectural framework for Sense-and-Respond business management.

The logical components of the framework include:

- *Monitoring Context*. A model that configures and drives Sense-and-Respond activities.
- *Event Emitters*. Placed at appropriate points in the business process and responsible for sending signals and information into the Sense-and-Respond system. This is done by taking a snapshot of key business artifacts and placing a corresponding event on the Event Bus to be consumed by other components in the Sense-and-Respond system.
- *Event Bus*. The central component of the architecture. Other components publish events on the bus and consume events placed on the bus. Raw events published on the bus by Event Emitters are consumed by Business & IT Event Correlation Engines, which calculate KPIs and check for situations, which are either exceptions or noteworthy trends. Situations are published on the bus and consumed by Business Effectiveness Agents. Decisions made by Business Effectiveness Agents are published on the bus and communicated to users in Business Activity Workplaces.
- *Business & IT Event Correlation Engines.* Receive raw events published by Event Emitters. Correlation Engines parse each event, correlate multiple events, perform complex aggregations and recalculate KPI's from the data contained in events. KPIs are stored in the Business Data Store while events are stored in the Event Store. Correlation Engines evaluate new KPI values against predefined commitments (e.g. KPI thresholds) and publish situations if any commitments have been violated. Correlation Engines also try to detect important trends that could lead to violated commitments in the future.
- *Business Effectiveness Agents*. Receive situations published on the Event Bus and propose one or more actions. Actions can fall into a number of categories, including notifications to key business managers, changes to operational parameters or business rules, reallocation of resources, invocation of exception processes, improvement of ineffective processes and improvement of ineffective strategies.
- *Business Activity Analysis and Reporting*. Utilizes data in the Business Activity Warehouse to support trend analysis and root cause analysis. Standard OLAP (On

Line Analytic Processing) tools are provided for analysis, as well as advanced visualization graphics.

- *Business Activity Workplaces*. Receive information from the Event Bus and present it to business users in various formats. Provide visibility to current and historical KPI values as well as trend information. Support root cause analysis, in concert with Business Activity Analysis and Reporting. When situations arise, support decision making in concert with Business Effectiveness Agents.

5 Sense and Respond Pilots

Over the course of the last several years, we have built Sense and Respond systems and consulted customers in various industries and to help manage high-technology value chains, transportation management logistics, retail and service parts logistics, steel production, and banking operations. All these projects share the same reference architecture and solution patterns and components.

In the following, we describe two pilots to illustrate how the Sense and Respond Value Net framework was applied to each scenario. Analytics are the key to a successful Sense-and-Respond implementation, and we describe the analytical capabilities built for both systems.

5.1 Demand Conditioning for PC Manufacturing

The demand conditioning process at IBM's Personal Computing Division (PCD) began as part of an initiative to improve the on-time delivery of PCD products to customer orders, and to improve the ability to predict and respond to supply and demand imbalances. The goal of the pilot was to enhance supply chain visibility and proactively develop a better understanding of transactional data representing customers' needs. To support this process, we developed a web-based Sense and Respond system that identifies order events and available supply headlights across the order-to-delivery supply chain. The system monitors supply and demand imbalances for commodities, and indicates out-of-threshold situations on an enterprise dashboard. A key innovation in this pilot is a new algorithm that identifies potential gaps by

using historical information and future indicators to forecast ordering trends. The new algorithm has been coupled with improved data integration and a web-based management dashboard that provides a current view of key supply and demand metrics for each IBM PC component.

The principals of demand conditioning are threefold, involving the supply of commodities, the product offering and sales plan as shown in Figure 3. Each of these three areas provides unique capabilities to make the conditioning process work.

- *Procurement supply conditioning.* Focuses on working with suppliers to improve flexibility in supply to react to customer demand that is never totally predictable.
- *Offering conditioning.* Focuses on identifying alternative products or substituting PC components that can be provided to customers in reaction to supply imbalances. It is supported by a proactive product definition phase that provides more flexibility to define product configurations.
- *Demand conditioning*. Focuses on providing a dynamic sales plan in the sense that it can be changed in reaction to supply imbalances. It considers pricing actions and promotions to provide incentives to customers to choose alternatives.

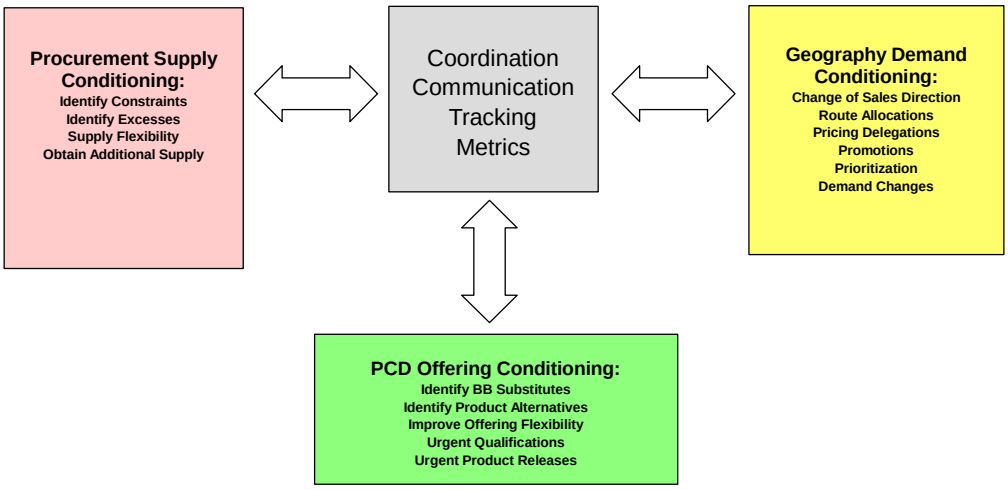

Figure 3: Principles of Demand and Supply Conditioning

The PCD Demand Conditioning Process illustrated in Figure 4 provides a management system with which to apply these three principals. The process involves

people in different organizations at locations worldwide. The execution of the process revolves around a weekly core team meeting led by PCD's Worldwide Fulfillment Organization (WWFO). The team consists of representatives from the PCD Brand, Operations, Procurement, Finance and Product Development. This team identifies supply imbalances, creates a conditioning plan in partnership with the geography sales organizations, and manages the execution of the conditioning plan. As the solution is executed, the actions taken in the three principals are being tracked to ensure that the solution is being executed properly. Finally, metrics involving customer orders must also be tracked to make sure that the solution is being effective. This process was begun in August 2003, and since that time several supply imbalances have been successfully conditioned.

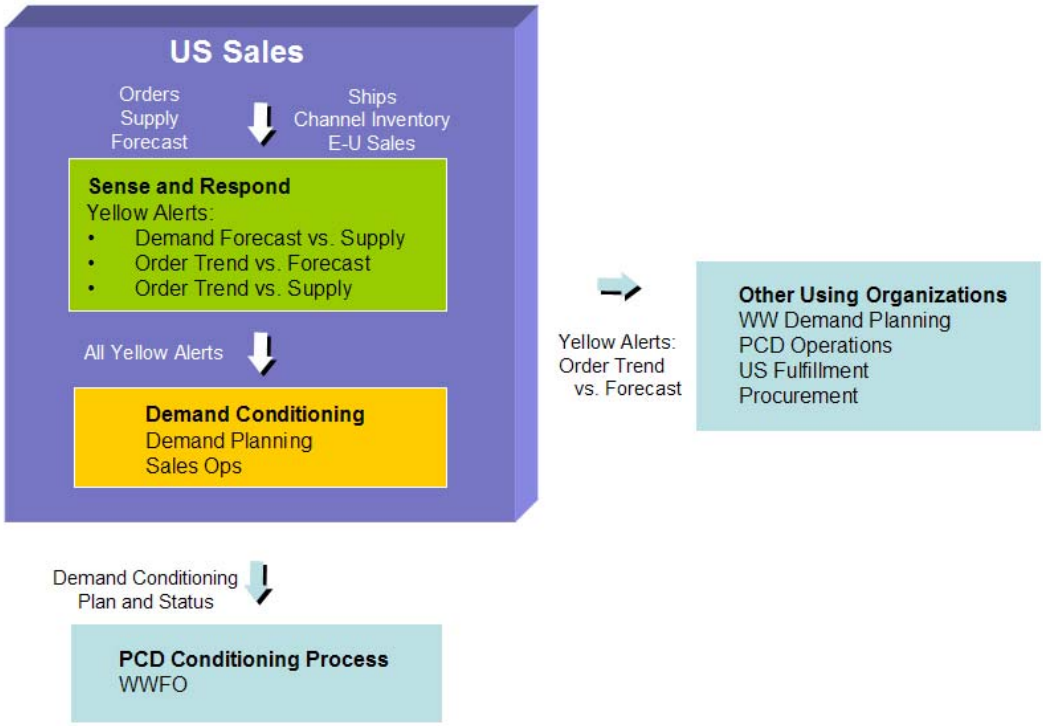

Figure 4: PCD Demand Conditioning Process

The Sense and Respond system directly supports the conditioning process by providing an earlier, proactive identification of supply imbalances that makes it possible to develop effective conditioning plans. The system receives daily order loads, shipments, supply commits and demand forecasts from PCD enterprise planning systems, correlates and analyzes the information, alerts the appropriate business users and recommends corrective actions.

Action tracking capabilities are provided which record a snapshot of the data at the time the alert was generated and compares it to the current over a pre-determined time horizon. This provides benefits in two respects:

- Providing a capability to track the performance of the actions which were invoked in response to a business exception.
- Building a rich history of actions in the data warehouse over which intelligent mining operations can be performed to learn and recommend actions in the future.

A key innovation in this pilot is a predictive analysis of orders that aims at developing short-term visibility (typically 4-6 weeks) into customer ordering behavior as an early indicator of supply imbalances. The order trend analysis is utilized to compare trends to the demand forecast as a lead indicator of future supply imbalances. Part of the weekly review is to select technologies where this indicator shows a potential issue and review the forecast with the US planning team.

Unlike long-range forecasting techniques, the order trend analysis identifies repetitive historical patterns of orders, and obtains accurate short-term predictions of order rates through increased consideration of data available in order execution systems. Coupled with improved data integration and the web-based management dashboard, the order trend analysis enables a current view of key supply and demand metrics for each IBM PC component.

The order trend analysis is based on a model that utilizes historical and future demand-related indicators such as actual demand and customer order inflow. The model estimates the effects of seasonality, order skew within a quarter, product life cycles, and repetitive order trends from historical data. It also provides point estimates, percentiles and confidence intervals for risk management. The order trend analysis combines traditional statistical forecasting techniques with demand-related indicators visible in the current time period that can serve as headlights for future demand to improve baseline forecasts. The order trends are operational forecasts that provide a more accurate picture of demand for the next 4-6 weeks which is the most critical time for deployment.

The three indicators that were integrated into the analysis are:

- *Total order load.* The current amount of unfilled customer orders with a customer requested shipment date some time in the future.
- *Order coverage.* The current amount of supply-committed customer orders with a confirmed future shipment date.
- *Channel inventory.* The current amount of inventory stocked at a business partner's warehouses to fill future customer demand.

The order trend analytics are executed on a daily basis in the Sense-and-Respond system to produce new order trends. During the initial deployment of the Sense-and-Respond technology, the algorithm has already proven to be much better at predicting actual future orders. Part of the weekly conditioning process is to select technologies where this indicator shows a potential issue, and review the forecast with the US geo planning team.

Figure 5 illustrates the linkages between the Sense-and-Respond system and PCD data sources and supply chain applications.

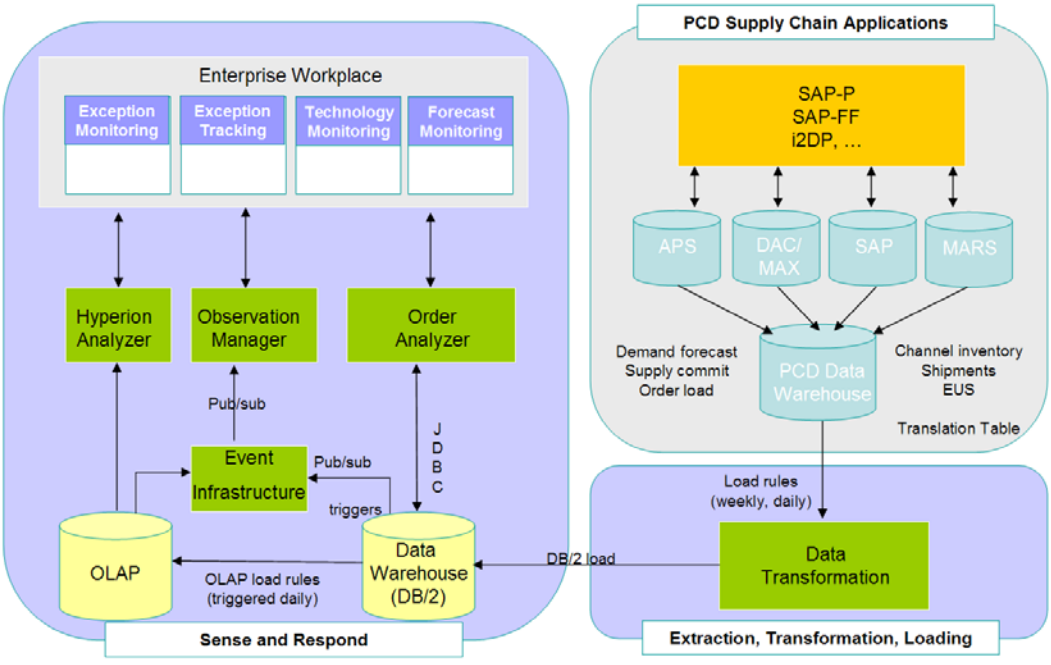

Figure 5: PCD Sense-and-Respond Architecture

The Data Extraction, Transformation, and Loading component (ETL) accesses transactional tables in PCD supply chain planning and execution systems. These contain demand forecasts, supply commits, order loads, order shipments, end-user

sales and business partner inventory. The load rules also explode the source data (provided at the fully configured system level) to the PC component level via a product-to-technology translation table which was a key requirement for the pilot.

The Observation Manager provides the functions for correlating and analyzing transactional data to detect business exceptions by comparing supply and demand indicators over a rolling time horizon. The business rules utilize cumulative differences between supply and demand which is the basis for detecting supply shortages or supply overages.

A relational Data Warehouse captures the order loads, shipments and planning data at a system level as well as component level. It is augmented by business intelligence that provides root-cause analysis by connecting an OLAP client to the dashboard.

The Enterprise Workplace provides an end-to-end view of the imbalances between supply and demand to enable successful conditioning. It allows for customization and administration by the different role players. It also recommends actions based on alerts generated and provides capabilities to track the actions thereby enabling business effectiveness. Figure 6 shows the main screen of the Enterprise Workplace.

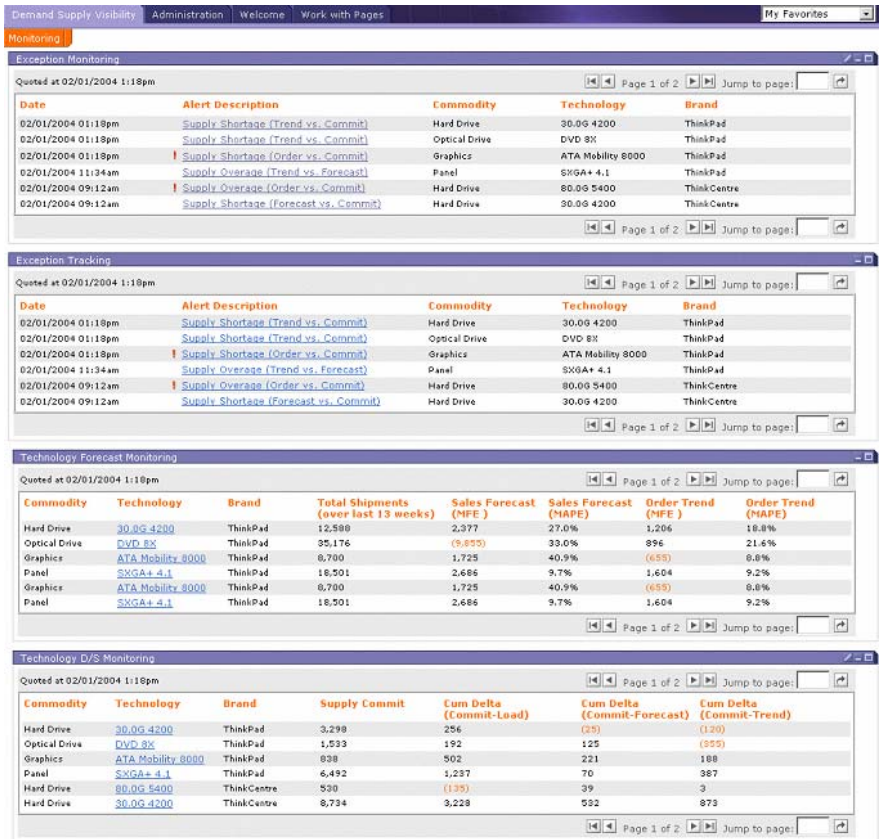

Figure 6: Top-Level View of the Sense and Respond Enterprise Workplace.

The top-level screen consists of four sections. The Exception Monitoring Portlet displays all current alerts for potential overages and underage situations, for example when the order trend is significantly departing from the demand forecast. The Exception Tracking Portlet allows business users to record conditioning actions and monitor the impact and effectiveness of executing recommended actions. The Forecast Monitoring Portlet shows the historical accuracy of the planned demand forecast and the order trend as measured by the mean forecast error (MFE) and the mean absolute percentage error (MAPE). Finally, the Technology Monitoring Portlet shows the latest demand and supply status of key PC components.

Figure 7 shows a sample detail view of a supply shortage alert, in this example for a hard drive component. The order trend is displayed for the future thirteen weeks in the form of weekly point forecasts and their confidence intervals. The order trend is compared to the latest supply projection, and a cumulative difference is calculated to track the amount of the projected imbalance over time.

Figure 7: Detail View of a Supply Shortage Alert.

The Sense and Respond system was successfully piloted in early 2004 and the tool is in use by the PCD Conditioning Team. The pilot provided business performance benefits, enabling sales teams to adjust selling tactics and supply teams to rebalance supply more quickly and effectively. A number of functional enhancements are currently under way. First, we are enhancing the order trending model to provide improved volume predictions for new product introductions and end-of-life situations based on technology transitions maps. Second, we are developing capabilities to record the actions the conditioning team is taking to resolve supply imbalances to form a knowledge base for data mining that will be used to assist decision making for future supply imbalances. And third, we are building advanced analytics that will go beyond the data and analysis associated with demand planning, extending into lower tier suppliers and optimizing inventory hubs and buffers for a more responsive supply

pipeline. The analytics will facilitate the monitoring of fulfillment activities and provide metrics and alerts that focus attention on serviceability issues.

5.2 Inventory Management in a Technology Supply Chain

The next pilot was developed to support an automated inventory management process at IBM's Microelectronics Division (IMD). This pilot utilizes Sense-and-Respond capabilities to improve internal business processes via KPIs such as inventory turns, on-time delivery, and forecast accuracy. The system enables monitoring of key supply chain events that help manage the supply chain's performance and to achieve customer service requirements with the minimum possible inventory. We piloted the tool successfully with the IMD inventory planning team at the end of 2003.

A key ingredient of the system is the analytical model that optimizes inventory positioning in the IMD semiconductor supply chain. The analytics complement existing planning applications by leveraging transactional data from enterprise business applications. Through this technology, business managers at IMD are able to make adjustments to optimize inventory, based on monitored performance and to reduce the response time by using decision analysis support.

IMD business managers had been looking for ways to improve operational performance and reduce expenses associated with inaccurate Original Equipment Manufacturer (OEM) forecasts, inefficient order flow, expedited shipments and obsolete inventory. Like many other organizations, IMD is faced with the challenge of responding and adjusting to supply chain events in a synchronized, timely, and intelligent fashion. They recognized that the key was to have a continuous process of performance measurements that would identify problem areas in the end-to-end supply chain on a timely basis.

Within the IMD end-to-end supply chain there were two key processes requiring response:

- *Supply management* - focusing on changes or modifications in work-in-process or production parameters such as yields and cycle times. Sense-and-Respond monitors supply versus demand and capacity utilization to provide key reports when demand is in jeopardy and help understand the impact of the

tardiness. This information enables analysts to gauge anticipated supply against demand by demand class, immediate identification of demands in jeopardy, identify assets supporting this demand, and full profile of anticipated capacity utilization.

- *Inventory management* - focusing on changes in a business policy such as inventory days of supply which is also impacted by changes in manufacturing practice such a shorter cycle times. The inventory management process controls the manufacturing of wafers, devices, and modules based on inventory reorder points.

To improve the above management processes, we first developed an analytical supply chain model that optimizes target inventory levels at different stages of manufacturing. The model helps to identify potential shortages of finished goods and avoid obsolescence and delinquent customer deliveries. This analytical capability was the key to proactive business management. The model improved IMD's inventory management process by diagnosing supply shortfalls, backlog accumulation, and inadequate inventory levels at strategic stocking points.

The analytical supply chain model was then combined with Sense-and-Respond performance management applications to enables pro-active exception detection by monitoring customer demand, inventory and shipments relative to predefined objectives. When performance metrics go outside of acceptable limits, the applications automatically alert inventory planners so they can investigate the issue.

A relational data warehouse that contains up-to-date profiles of business metrics for event engine processing serves as the primary data repository for event trails from enterprise applications and advanced planning systems. The data warehouse also contains operational manufacturing parameters such as bills of materials, lead times, process yields, demand forecasts, and supply commits that are used as inputs to the inventory optimization module. The Sense-and-Respond system retrieves transactions and planning data from enterprise planning and execution systems. The transactional data is organized and stored in a data warehouse from which metrics and KPIs are calculated.

The inventory optimization module provides business intelligence and analytics to improve the performance of the enterprise. It adopts existing business processes and

cost structures, and recommends optimized operational inventory policies that drive business performance to higher levels of operational and financial efficiency. The recommendations allow business process owners to see the expected impact of planning decisions, assess the profit risk and rewards of proposed actions, and evaluate alternative options. The optimization model consists of a three-echelon structure with an additional assembly node, including wafer fabrication, wafer test, substrates and bond-assembly and test. The objective is to minimize inventory subject to a service requirement measured as on-time delivery to customers within an allowed lead time window. Figure 8 is a graphical illustration of the model and the solution approach.

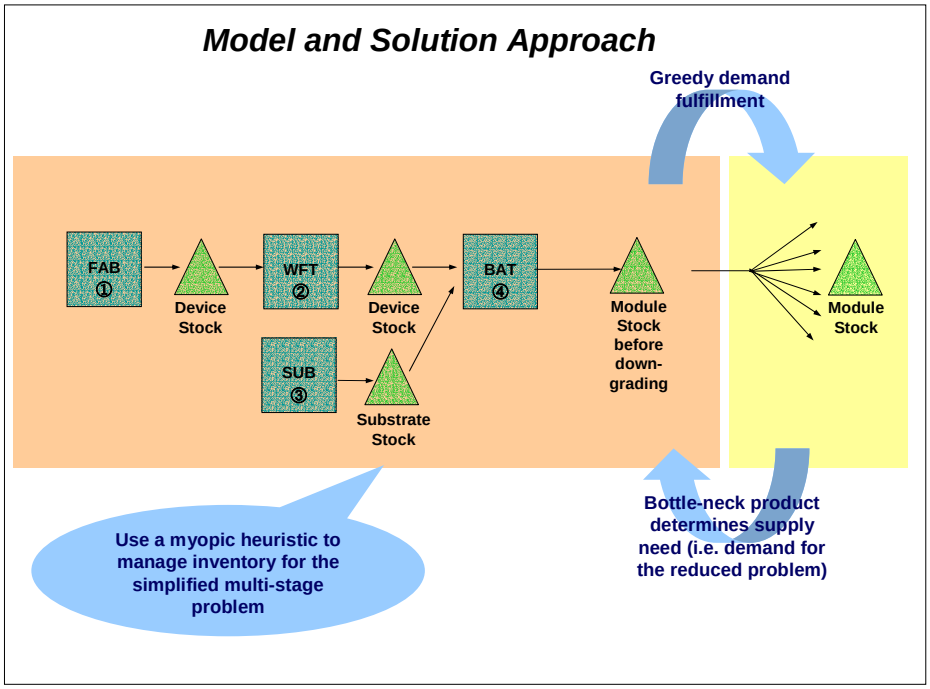

Figure 8: High-Level Illustration of the Analytical Inventory Model.

The model utilizes demand forecasts, manufacturing cycle times, yields, costs, lot sizes, inventory policies, contractual buffers, customer service targets, product prices, and the rates of change in prices and costs. Based on all these input parameters, it calculates and reports operational and financial performance for business managers and inventory planners. The performance reports comprise numerous financial and operational performance metrics as illustrated in Figure 9. These metrics are projected for several weeks or months into the future. The analytical model also determines

optimal operational days of supply policies at strategic stocking locations in wafer fabrication and module assembly and testing plants.

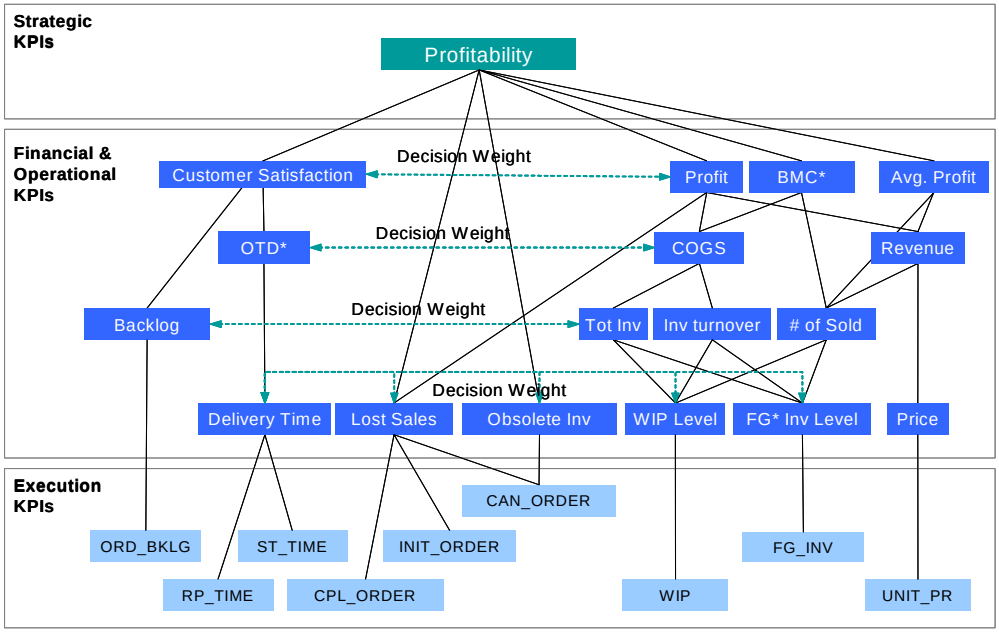

Figure 9: Financial and Operational Metrics Reported by the Inventory Model.

The Sense and Respond Enterprise Workplace provides a dashboard view of the overall health of the business. The dashboard is role-based with distinct portal views for inventory analysts, product line managers, supply chain executives, and financial executives. Figure 10 illustrates the visibility screen detailing the inventory status, customer delivery performance and order fulfillment related metrics.

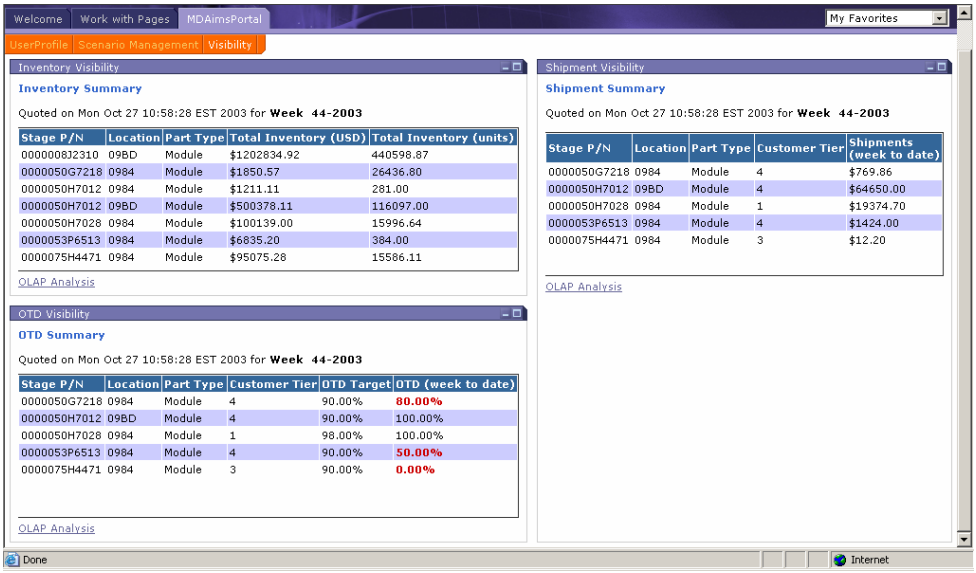

Figure 10: Visibility Portlet View for Inventory and Order Fulfillment Performance.

The Enterprise Workplace also supports what-if analyses to evaluate the impact of various manufacturing and demand characteristics on inventory turns and customer service levels. Users can view demand forecasts, manufacturing cycle times, yields, costs, lot sizes, inventory policies, contractual buffers, customer service targets, product prices, and the rates of change in prices and costs. Figure 11 shows the what-if analysis view of the scenario management portlet.

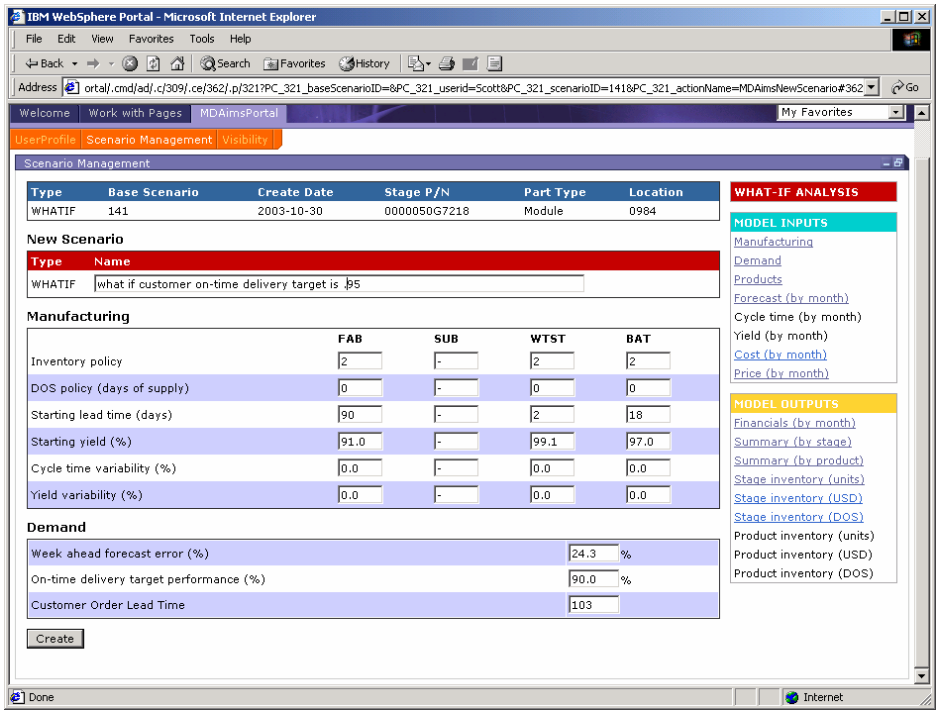

Figure 11: Portlet View for What-If Analyses.

6 Summary and Future Study

The ability to effectively manage extended value networks to respond to customer needs is critical in today's rapidly changing business environments. We presented a technical framework that supports Sense-and-Respond by enabling proactive management and control of business resources. Sense and Respond Value Net is a new paradigm that integrates real-time decision support, risk and resource management, supply chain optimization, and business processes. It blends business and IT to support value net optimization in uncertain and dynamic environments.
We also described two pilot engagements with IBM's Personal Computing Division and IBM's Microelectronics Division where the Sense and Respond Value Net technical framework was applied. Our pilots and experience indicate that with careful planning and focused scope, enterprises can take advantages of this new paradigm, even with partial, incremental implementation on some of the capabilities discussed.

The technologies discussed in this chapter are either available today, or are emerging. However, the integration of these technologies still poses significant challenges that need to be addressed. For example, the innovative applications of Web-Services, Component-Based Modeling, and Rapid Integration of these technologies in the Sense and Respond framework need further studies. Another critical issue is the data availability and reliability. Businesses are normally reluctant to share sensitive data. And the reliability of data, about people, organizations, customers and partners can affect value net decisions. Support for trust-enabled value nets and technologies to help assess reliability and third party services to filter and aggregate sensitive data can fundamentally change how the value nets are formed, interact, share knowledge, use information, and make decisions [15].

In addition to process and technology, the transformation into an integrated Sense and Respond enterprise requires a mastery of organizational complexity and culture. Transforming business to enable proactive Sense and Respond capabilities require fundamental changes in how people manage information, collaborate, and use the technologies. The cultural and transformational aspects of Sense and Respond are critical success factors in implementation, yet they are often neglected by efforts seeking real-time responses to events. Hence, additional investigation and research

about business ecosystems and the social aspects of participants, and their effects on value nets are needed. We believe the early adopters, who can effectively manage the technologies and organizational changes needed for enabling the proactive Sense and Respond capabilities in an incremental and transformational approach will enjoy significant competitive advantages.

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