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A web-based logistics management system for agile supply demand network design

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Abstract

Purpose – Online, on-demand and real-time availability of information to all members of a manufacturing system enables them to be agile and in the best position to react quickly, efficiently, synchronously, and collectively to the changing market. This paper proposes an integrated web-based logistics management system for agile supply demand network design (ASDN).

Design/methodology/approach – The paper presents a software system, which is distributed as open source. A case study of ABB Company in Finland has been undertaken and this demonstrates the validity of ASDN in designing and managing supply demand networks.

Findings – Current software applications, such as ERP, WMS and EAI do not support a higher-level decision making. There are several performance measures, which are directly connected to structure of the network.

Practical implications – The presented software supports modeling, analyzing and limited optimizing of supply demand networks. Also discussed is the network level logistics analysis that is behind the modeling tool.

Originality/value – The paper introduces the ASDN software, which is freely available for research and commercial uses. The case example shows how this type of network architecture-related decisions can be analyzed.

Keywords Logistics data processing, Agile production, Supply and demand, Network operating systems, Software tools

Paper type Case study

1. Introduction

Today's dynamic business environment is continuously changing because of globalization, regulatory changes, increasing intensity of competition, increasingly demanding customers, new information technology, and mergers and acquisitions (Wing *et al.*, 2006). This has resulted in markets that can be characterized as increasingly turbulent and volatile and has caused many organizations to seek to improve their competency through agile business (White *et al.*, 2005). Agility might, therefore, be defined as the ability of an organization to reconfigure operations, processes, and business relationships efficiently while at the same time flourishing in an environment of continuous change (Martin, 2000).

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More and more companies have recognized that individual businesses no longer compete as stand-alone entities, but rather as supply chains (Gregory *et al.*, 1999). A supply-chain is a network of facilities and distribution points that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers (Ganeshan and Harrison, 1995). We are now entering the era of "network competition" where the market and customer will be won by those companies who can better structure, coordinate and manage the relationships with their partners in a network committed to better, closer, and more agile relationships with their final customers (Martin, 2000). Traditional "make-or-buy" decisions can be highly complex and emotive under such an environment that involves consideration of issues such as efficiency and risk dimensions relating to supplier quality, lead times and delivery reliability, strategy directions, working capital, and detailed financial evaluation (Chung *et al.*, 2004).

Many supply chain management studies have focused on removing or reducing the uncertainty within a supply chain as far as possible, in order to facilitate a more predicable response to change in downstream demand (Naylor, 2000). Agile business flows extend from the customer interface at marketing and sales through production and procurement to the building of relationships with suppliers. Key to the success of an agile supply chain is the speed and flexibility with which these activities can be accomplished and the realization that customer needs and customer satisfaction are the very reasons for the network (Lee and Lau, 1999). If implemented properly, this will provide a new dimension to competing: quickly introducing new customized high quality products and delivering them with unprecedented lead times, swift decisions and manufacturing products with high velocity (Dekkers and van Luttervelt, 2006; Fisher, 1997).

Implementing agile supply chain strategies poses both business and technical challenges. In this paper, we address these issues and propose a technically feasible solution to support the company in quickly designing a supply chain and optimizing it for mixed performance measures. The agile supply-demand design (ASDN) software provides support to the manager in making improved business decisions that lead to maximizing customer service and profits by capitalizing on the added-value of the entire supply chain. The motivation for this study is to explore the behavior of an industry supply chain using computer-based software which integrates simulation, evaluation and optimization.

ASDN concentrates upon the development of IT architectures to support global supply demand network modeling and design, screening presently network-level control, optimizing supply chain for fast response time and improved financial performance. Methods, tools, interfaces, architectures and applications are being developed to address these particular needs.

The rest of the paper is organized as follow. Section 2 describes the new approach of agile supply chain management. Section 3 discusses the enabling IT technology for the information system. An overview of the generic architecture is presented in Section 4. A case study and practical implications are reported in Sections 5 and 6, respectively. Finally, the conclusions and suggestions for future work are drawn in Section 7.

2. Agile supply chain management

The origin of agility firstly comes from the manufacturing function and with the concept of flexible manufacturing systems (Parthasarthy and Prakash, 1992).

McCarthy and Tsinopoulos (2003) believe the key issues of successful manufacturing are organizations, processes and products that can sense and change or be changed in response to customers' varying demands. A comprehensive definition of organizational agility is provided by Kidd (2000):

> An agile enterprise is a fast moving, adaptable and robust business. It is capable of rapid adaptation in response to unexpected and unpredicted changes and events, market opportunities, and customer requirements. Such a business is founded to facilitate speed, adaptation and robustness and delivers a coordinated enterprise that is capable of achieving competitive performance in a highly dynamic and unpredictable business environment that is unsuited to current enterprise practices.

With the new trend of globalization and product customization, business competition is already shifting from single organization to supply chains where several companies pool their core competency together. The focus of agility has also moved from a single organization to a supply demand networks. The organizational agility needs to be built on dispersed networks. The agile supply chain is an approach for managing supply chains in volatile markets (Naylor *et al.*, 1999). Charles (1998) stated that a company's real core capability lies in its ability to design and manage the supply chain in order to gain maximum advantage in a market where competitive forces are changing. Goldman *et al.* (1995) summarized the essential features of the agile business environment through a survey among 500 modern manufacturing companies:

- customers were demanding increasingly challenging service-level agreements;
- customer needs were constantly changing;
- the ability to meet changing customer needs was regarded as a source of competitive advantage;
- new processes and new business models were being regularly introduced by big industry players; and
- satisfying customers' needs required flexible manufacturing operations in place.

To be truly agile, Goldman *et al.* (1991) created a demand for identifying the menu of agility-enabled attributes required for an organization to build an agile supply chain and from which organization leaders could select required items. According to Christopher (2000), agile supply chain must possess four key enablers/pillars, as shown in Figure 1. The agile supply chain is market sensitive that is capable to receive the real-time demand change and make quick response. The use of information technology to share data between participants creates a virtual supply chain. Virtual supply chains are information-based rather than inventory-based. Integration and cooperation synchronize the decision along the supply chain, reduce inventory buffer and improve efficiency. Network-based supply chain structure requires that companies in the chain have a common identity, which can range from commitment to agile practices, compatibility of structure, information architecture and tradable competencies.

Traditional SCM policies are process-driven and have used production to forecast policy. They cannot effectively or efficiently support a customer-driven and dynamically changing market. Agile supply chain management has been proposed as a new approach to provide a competitive strategy for such a business environment. Agile organizations are market-driven, with more product research and short development and introduction cycles. The focus is on quickly satisfying the supply

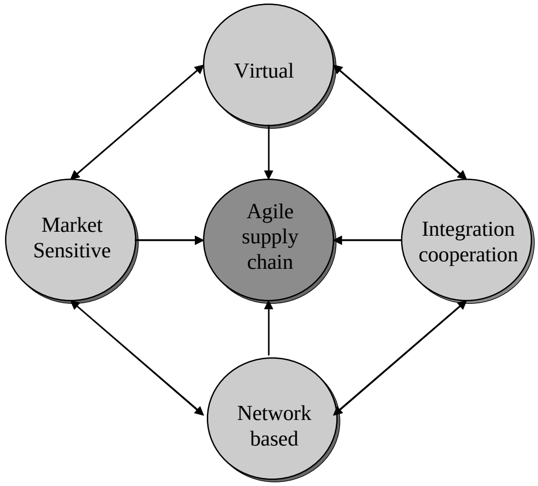

Figure 1.
Characteristics of an agile supply chain

chain, the chain of events form a customer's order inquiry through complete satisfaction of that customer.

Agile supply chains require structural changes in how companies manage their operations. These changes require:

- companies to collaborate with supply chain partners and synchronize their operations;
- full utilization of Internet technology, providing interoperability among partners as a key enabler of innovative supply chain strategy; and
- a new supply chain infrastructure and operations model to achieve these goals.

An agile supply chain operation no longer follows a linear model. This system is a network-based operation that requires timely availability of information throughout the system in order to allow cooperative and synchronized flow of material, products and information among all participants. An agile supply chain should be truly collaborative and should provide several benefits, as outlined below:

- *Visibility*. Supply chain participants must have full and thorough visibility into customer demand, supply sources, production planning and scheduling, manufacturing capability, inventory level, promotion plan and transportation channels in order to make systematic optimized decisions. Companies can maximize their opportunities to find the most cost-efficient adjustments to schedules, inventory levels and operations. The faster materials, information, and decision flow through an organization, the faster it can respond to the demands of the market.
- *Flexibility*. The flexibility offered by an organization through its range and adaptability attributes is a positive enabler of its supply chain agility. Four types of flexibilities have been identified as key issues: product development flexibility, sourcing flexibility, manufacturing flexibility, logistics flexibility.

- *Speed*. A measure of the end-to-end cycle time made up of the sequential manufacturing, order/demand processing and delivery/distribution cycle time. It describes how quickly the supply chain senses routine and unanticipated demand and effectively broadcast the signal for an intelligent supply chain response.
- *Predictability*. The response of the supply chain should be predictable from control point of view. Whatever kind of flexibility and speed the supply chain possesses, it has to be under control, understandable and acknowledged by all the supply chain participants. The predictability may be seen as an emergent property, but it may be stated as a robustness requirement for designed networks as well.
- *Scalability*. Any supply demand network must have the ability to scale with demand and accommodate all kinds of unexpected events. Using a Java-based architecture, in conjunction with the internet's dynamic nature, companies can quickly response to changes in demand, production, supply and covert the uncertainty into opportunity.

3. IT for integrated agile supply chain

Information systems are recognized as being a critical factor in achieving agility in the supply chain in a similar way to the contribution flexible manufacturing systems made in the past to agile manufacturing (Christopher, 2000). Breu *et al.* (2001) argued that information systems are seen to assume a fundamental role in developing agility, as the notions of speed and flexibility would be inconceivable without them. According to Devor *et al.* (1997), recent advances in information networking, processing and electronic commerce are rapidly expanding the capability to achieve powerful interactive links among organizational and functional units of the agile enterprise. Gunasekaran (1998) pointed out the benefits of information systems to the agile enterprise include: enterprise-wide concurrent operations that cover all the functions of the company, agreed communications and software standards, electronic commerce on international multimedia networks and better mathematical understanding of representation methods used in design.

Figure 2 shows a framework for the development of IT for agile SCM. It addresses the major solutions and methodologies in current efforts to use IT for agile SCM which include:

- Strategic and operational planning.
- Integrated supply chain management solutions provided by i2, SAP, Oracle, etc.
- Optimization methodologies like linear programming (LP), generic algorithm (GA), constraint-based algorithm (CA).
- Different types of e-commerce.
- Advanced technology like EDI, XML, agent, etc.
- Transactional information system.

From the data management point-of-view of supply chain information system, Helo and Bulcsu (2005) group the applications into two classes: transactional and analytical software applications. Transactional software applications are engaged with

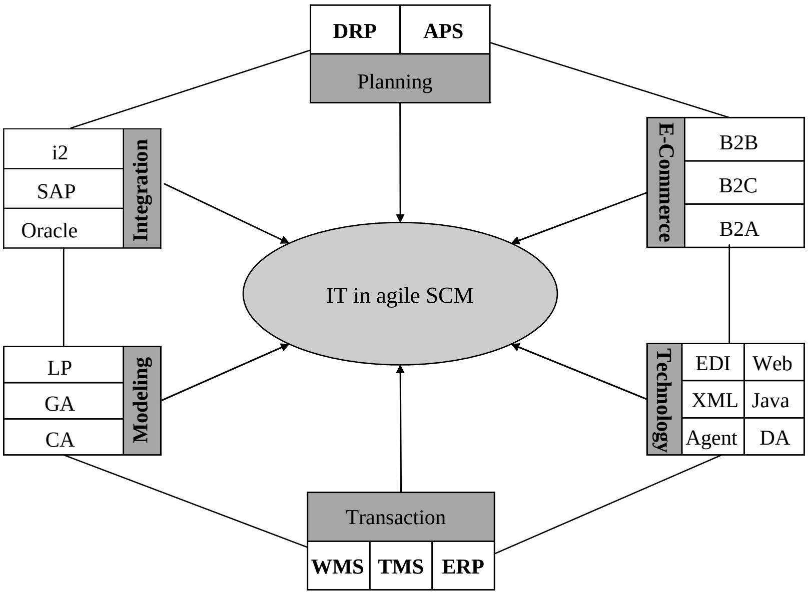

Figure 2.
A framework of IT for agile SCM

acquiring, processing and communicating raw data about the firm's past and current supply network operations. This group of software builds up POS systems, general ledger systems, quarterly sales reports, e-commerce systems, etc. Analytical software applications deal with developing and applying systems for evaluating and disseminating decisions models based on supply chain decision databases.

Starting in 1990, organizations all over the world have been experiencing increasing national and international competition. Strategic alliances among organizations have been growing. Organization structures are starting to align with process. Manufacturing systems have been enhanced with information technology tools such as warehouse management system (WMS) and transport management system (TMS), enterprise resource planning (ERP) systems, etc. WMS provides real time view on material flows within the warehouse like tracking and keeping note of the movement and storage of material within a warehouse facilitating the optimal use of space, labor and equipment (Helo and Bulcsu, 2005). TMS facilitates the procurement of transportation services, the short-term planning and optimization of transportation activities, and the execution of transportation plants with continuous analysis and collaboration (Helo and Bulcsu, 2005). ERP systems monitor material, orders, schedules, finished goods inventory, and other information throughout the entire organization. They promise the seamless integration of all the information flowing through the company, including financial, accounting, human resources and customer information (Yeng *et al.*, 2002).

Systems like ERP, TMS, and WMS are powerful in the consistent management of elementary business data, such as customers and sales orders, items and prices, warehouses and bins, resources and work orders, suppliers and purchase orders (Martin, 2004). However, they focus on coordination of the processes within the organization. Therefore, WMS, TMS and ERP are fit for internal logistics management; they miss the coordination capabilities without holistic views required for the management of agile supply chains (Martin, 2004).

Electronic data interchange (EDI) helped to link computer applications across organizational boundaries at the transaction level by electronically exchanging transaction data without the need for human intervention (Yuan *et al.*, 1999). This reduced transaction cost, provided increased accuracy, and increased responsiveness. It made new ideas such as just-in-time delivery and vendor managed inventory possible.

Recently, supply chain management systems have been developed by companies such as i2, SAP, Oracle, etc. These companies provide analytical applications for production scheduling, manufacturing planning, transportation planning, demand planning, and revenue management in order to optimize the use of supply, manufacturing, distribution, and transportation resources to meet the demand.

However, whilst the deployment of such systems may have improved the efficiency and effectiveness within their own organization, most of the information systems like ERP, APS and EDI interface are not suitable for the agile supply chain. ERP systems focus on the integral management of processes within a company. Because of its central architecture, an ERP system assumes one central organization, but in dynamic network there is no central point of authority. Therefore, ERP is suitable for internal logistics management, but lacks the autonomy and flexibility required by networked organizations. As for the EDI, company systems can mutually be linked through EDI interface that resembles the network structure. But EDI does not provide additional functions for logistics control across organizations. EDI interfaces just focus on data exchange. An important part of the agility approach is the ability to form deeply integrated links with a wide range of trading partners and be able to quickly dissolve these and reform such deep linkages with new partners as required by changing market conditions.

To counter the recent focus on internal information systems, it is forecast that over the coming decade emphasis will shift from the individual firm to improving collaboration between organizations (Hagel and Brow, 2001). A number of recent developments in information systems and technology appear to promise the ability to significantly improve the collaboration between trading partners in ways that can increase agility.

4. Software architecture and implementation

4.1 Overview of ASDN

An overview of the ASDN system is shown in Figure 3. ASDN is based on an integrated Java Web Applet and equipped with interactive communication capabilities between peripheral software tools. It operates as an information platform and supply chain design center, by which organizations integrate with their customers and suppliers and quickly build supply demand network. The services can be accessed via a browser or integrated into an organization's existing back-end systems through its open architecture. Within the organization, it integrates traditional information systems like ERP, TMS, and WMS to acquire on-time, accurate and complete information. Outside the organization, web-centric ASDN links the customer and supplier to form an agile supply demand network through the internet. The information, activities and decisions along the entire supply chain are visualized, synchronized and optimized by ASDN.

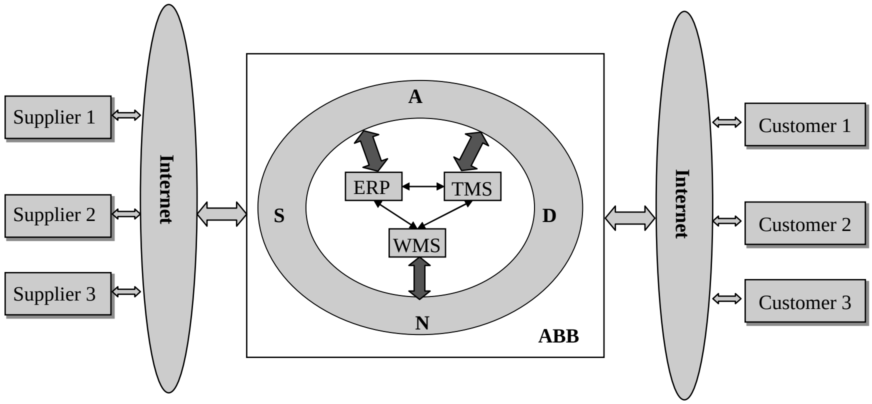

Figure 3.
Overview of ASDN

By providing a common infrastructure along with modeling platform and optimization algorithms, ASDN offers a simple means for transforming static supply chains into dynamic, web-centric, agile supply chains that are closely integrated with the manufacturer's functional legacy systems like ERP, TMS and WMS. ASDN focuses on developing a computer-based decision-making support system that allows all members of the supply demand network to collaboratively manage and control the production and distribution policies. The ability to interface with existing manufacturing systems allows manufacturers to continually follow a centrally planned system but manage tactical and operational issues and use a variety of tools for systematic optimization of the entire supply chain. Whereas the ERP, WMS and TMS focus on internal management, the ASDN adds functions and data for external management to the supply chain structure. An important feature of ASDN is the ability for multiple organizations in the supply chain to connect with each other, allowing improved performance of the entire chain since information from any tier in the supply chain is available to any other organization in the chain.

For the support of the agile supply chain, some supplementary system variables and analytic optimizing algorithm are included in the ASDN. ASDN supports configuration flexibility, view flexibility and algorithm flexibility. Configuration flexibility is the ability to configure an alternative supply chain scenario based on the main supply demand network and get the analysis results quickly. View flexibility refers to diversified reports that analyze supply chain scenarios from different types of aspects like inventory amount, value-added, service level, etc. Algorithm flexibility includes optimization algorithm selection in the lot size calculator which provides a variety of algorithms that are suitable for specific production circumstance.

4.2 Architecture of ASDN

ASDN software has been coded in Java applet which is encapsulated in a web page and accessible by users through the web server. Common user can make query and receive result from web server through applet. The latest version of ASDN is automated updated by web server without the interaction of human user. The generic architecture of ASDN application server is shown in Figure 4. ASDN adopts modular architecture design that the main functions are encapsulated in separated modules which are easy to modify and upgrade. The key functional modules in ASDN are modeling,

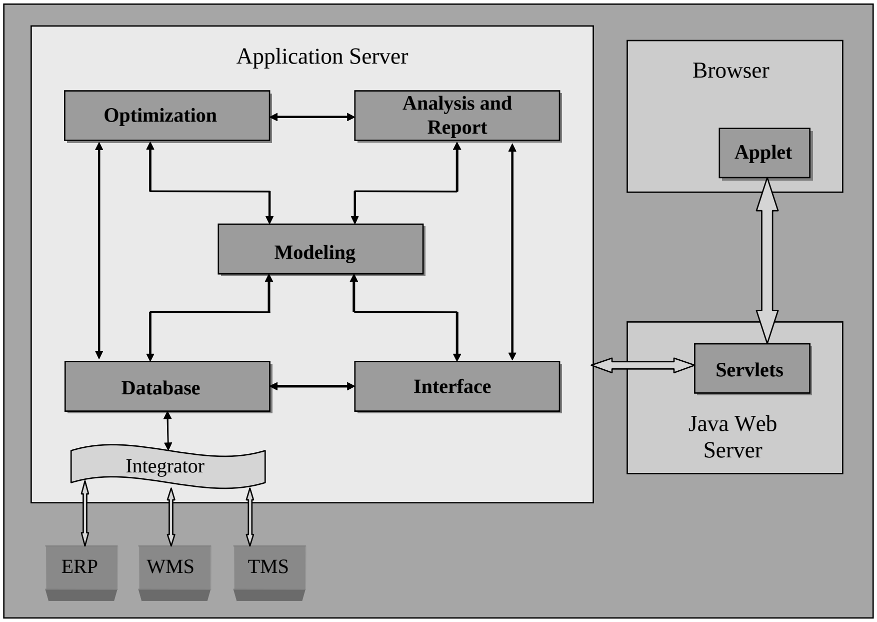

Figure 4.
Architecture of ASDN

optimization, analysis and report, interface, and database. It aims for modeling, analyzing, optimizing supply demand network, forms a scalable, extensible and interoperable application environment.

Modeling module. It facilitates the user building and configuring the supply chain model quickly and efficiently. Users can easily click and drop in the main window to draw the supply chain nodes and link the nodes with transport arrows. All the related data and information of the network are retrieved and processes by this module to provide a straightforward and clear model structure.

Optimization module. A variety of build-in mathematical algorithms are provided to optimize specified performance of supply demand network. User could select the optimizing models in order to adapt various operational circumstances. Comprehensive analytical models and real-time calculation optimize the supply chain from a systematic view. The model customization function allows the user modify or replace the embedded algorithm according to concrete optimization requirement.

Analysis and report module. This module analyzes the supply demand network performance from different kinds of aspect and visualizes the result by a variety of geographic and tabular reports. It helps planners and managers to observe the supply demand network in a holistic view and examine issues such as:

- the network service level and overall cost;
- order fulfillment for end customer;
- total inventory amounts and value;
- capacity bottleneck of the network; and
- capital throughput per day.

Interface. This enables the users and other systems transform the data to ASDN and assess the concerned output information. Also it can graphically represent the network distribution including the location of facilities, transport channel, the attribute of supplier and customers with all details. Three types of interfaces are equipped in ASDN:

(1) User interface to the designer, for example, the supply managers establish nodes, input parameter, build supply chain and optimize performance through user-friendly interface.

(2) Database interface, which is responsible to retrieve, manipulate and update data directly to/from the database. It acts as the only channel for database access which separates the physical database from the Internet connection such that the database is protected from illegal access and security is achieved.

(3) System interface to local information systems, for example, interface between ASDN and other systems like ERP, TMS, MRS to retrieve some elementary information.

Database module. It stores the data and information related to supply demand network, customer demand, supply ontology, etc. For example, the attributes of each company node that describe its status would be stored in the database and shared by the authorized users. The integrator is used to transform the data and information between ASDN and transactional systems according to prescribed rules and format.

Integrator. Traditional approaches such as ERP, WMS, TMS to planning and scheduling the shop floor activities are heterogeneous and distributed; they do not consider the constraints of other domains simultaneously. In spite of being sub-optimal, these approaches have been in vogue due to the unavailability of a unified framework. The integrator provides a way to integrate planning and scheduling activities dispersed in diversified legacy systems. Legacy systems have been wrapped with API's, which provide them with limited communication capability where TCP/IP is chosen as the low-level transport mechanism. Integrator adopts agent KQML (knowledge query manipulation language) messages and a subset of KIF (knowledge interchange format) to interact with ERP, WMS, TMS systems, which allow them effectively share information, knowledge and services.

5. Application

In order to demonstrate the application of the ASDN software, a case study involving an existing agile supply chain has been taken. The investigated supply chain in ABB Company produces and delivers electrical product globally. ABB is a multi-national company that produces electrical products in more than 250 factories in five continents. In the year 2003, the revenues of ABB electrical company were 132 €132 m, the number of employees was 625 and 37,870 products items were manufactured. The current market of ABB is highly customized, so most of the customer orders are less than ten items with unique product specifications that need engineering-to-order. The ABB electrical company is willing to maintain its performance by re-engineering time to time its global supply demand network. One of the key objectives is achieve fast and reliable operations for its products and services. The ASDN software provides a platform for this type of strategic network analysis.

This section of the paper shows the main steps how a network level analysis could be performed. The boundaries of the system are production start using raw materials on the upstream, and sales to customers on the downstream. The supply chain is capacity-constrained with long lead time and an increasing dynamic market in combination with decreasing product life cycles. This puts great pressure on time to market, product quality and supply chain flexibility. For reasons of confidentiality, the data and figures used in the paper have been modified.

5.1 Starting ASDN

In order to build the supply demand network of ABB electrical product, we first initiate ASDN software from its web server (http://sourceforge.net/projects/asdn), which is supported by Java Virtual Machine. The basic elements for modeling an industrial logistic network and the relationship between elements are also shown in Figure 5.

- *Node.* A basic unit of a network; represents a company.
- *Arrow.* An element of a network; represents supplier customer relationships (transfer of goods from a supplier to a customer) between two companies.
- *Attribute.* The data and information used to describe and differentiate individual node and arrow.
- *Network.* A combination of nodes and arrows that represents a certain layout of supplier-customer relationships between companies.
- *Scenario.* A certain layout of supplier-customer relationships between companies and/or values of companies' attributes.

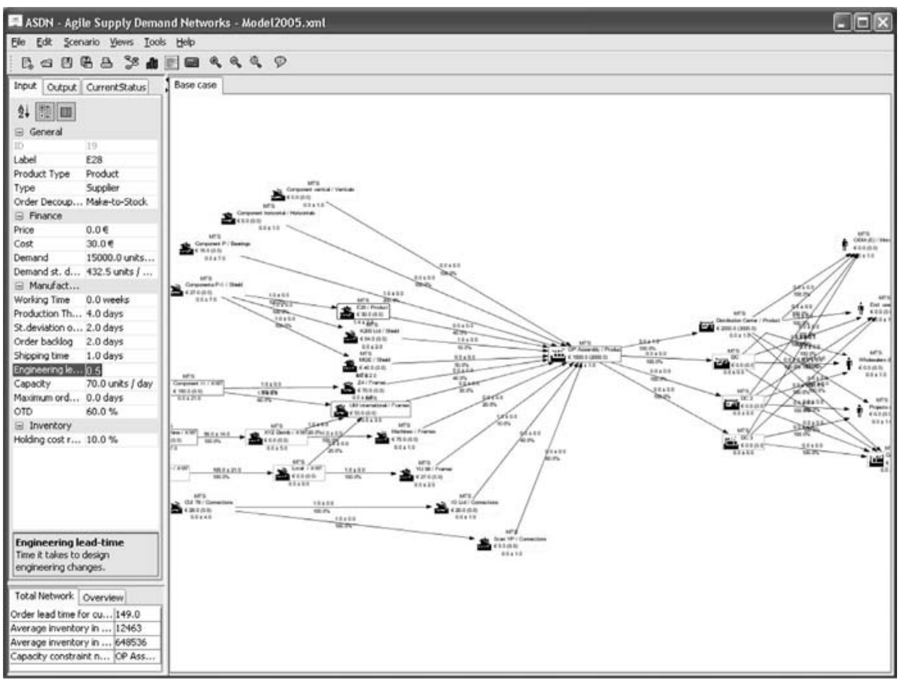

Figure 5.
Electrical supply demand network of ABB

5.2 Model construction

ASDN uses an icon–driven interface (main window) for the construction of a diagram representation of an industrial logistics network. Building the network construction is then accomplished through a series of steps:

(1) the necessary nodes including supplier, manufacturer, DC and retailer are added in the main window;

(2) the data of the nodes are then modified to correspond with the requirement we are building; and

(3) finally, the nodes are connected with arrows to complete the construction and the type of arrows is then modified to correspond with the requirement of delivery.

Figure 6 shows the supply demand network of the ABB Company. This example contains seven parts or material suppliers, eight component assemblies, one final manufacturer, four distribution centers and five end customers. This model is describing one product family consisting several hundreds of variants. Each node is filled with its attribute value including the cost, manufacturing time, capacity, etc. The arrow is assigned to basic information like the transportation channel, cost, lead time, frequency, etc.

Considering the complex production modes in the manufacturing industry, ASDN supports company taking different production type according to their status and roles in the supply chain. Each node could be specified as supplier, manufacturer, warehouse, distributor, retailer, or customer. Also different production types like

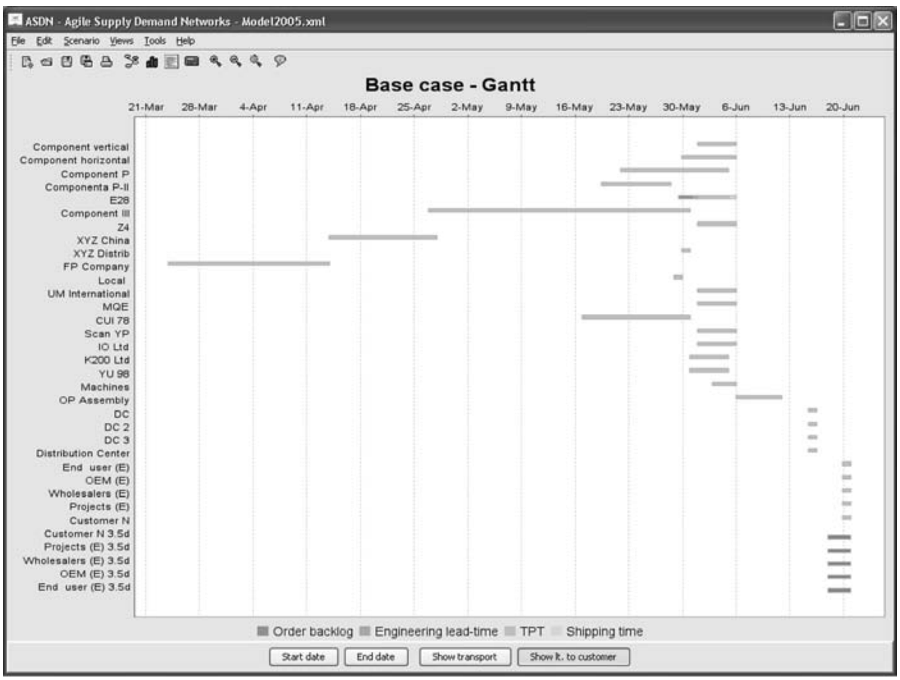

Figure 6.
Lead time Gantt graph of network

make-to-order, make-to-stock, assembly-to-order, engineering-to-order can be assigned to the company nodes. In ASDN, production type represents operational control policy. Embedded analysis tools will select different formula to calculate the node output attribute like lead time, inventory, and throughput according to the node production type.

The user may modify the functions on-line including the inventory models. Two tabular reports in ASDN record the detailed information of supply demand network nodes and arrows. The supply managers observe the running condition of each node and compare different suppliers. The user also can configure the existing supply chain scenario to other solution by modifying the attribute data of nodes in the table. The system shows the overall performance of the network as key indicators for decision making.

5.3 Model analysis

After the current status of the supply demand network is constructed, the next task is to analyze and improve it. ASDN provides the user with a variety of analysis tools that visualize the supply chain from multiple dimensions. Given the basic node attributes such demand, lead time, and the service level, network designers can observe various performances for obtaining managerial insight and optimizing the entire network. These performance measures include the internal and external response time, cycle stock, inbound inventory and outbound inventory, and capital throughput in the network. Customers also can customize the analysis report according to their specific requirements. ASDN explicitly incorporates the congestion effects due to capacity limitation at each node, and the interference effect because of multi-product flows through each node.

In order to provide multiple products to global market, the example network is quite complex, and involves several tiers and participants. Owing to the highly customization of the demand, most of the customer orders are fulfilled as a project that the supply demand network is specially build for. Before the ASDN is implemented, very few managers had a clear overall view about how the network operates. Now based on the various analysis tools provided by ASDN, supply managers in the ABB Company could easily take a snap-shot of the supply demand network from the concerned angle.

5.3.1 Lead time Gantt graph. Figure 6 shows the lead time view of the network by using the Gantt graph which gives the user a clear picture about how the supply chain reacts to the final customer order, which company is the bottleneck that hampers the entire material flow, what is the available due time promise for the next customer order, etc. The Gantt graph could be adjusted to observe the impact of different time periods on the network. Users select the relevant time period like transport time, engineering time and order backlog time and check the change of network schedule.

From Figure 6, the ABB supply manager found that the FP Company which provides the component X187 has the longest lead time of 16 days. This company is located in India, so that the transport time is quite long and on-time delivery (OTD) level is rather low. Although when compared to other suppliers, the cost of this India Company is low that is nearly 20 percent cheaper. Its long lead time and low OTD cause trouble in later stages. Based on this the ABB Company could consider using a third party logistics company to improve the situation.

5.3.2 Service chart. Companies always pay high attention to their OTD level since it is a very important performance measure of customer satisfaction. However, most companies only have the vision of individual OTD and ignore the network OTD. They fail to align the supplier OTD with their own OTD and suffer unnecessary delay and waste in the chain. It is difficult to find the influence of downstream supplier OTD to the upstream manufacturer OTD and balance the systematic OTD. Figure 7 shows the service chart of the ABB network. It is clearly shown that the low downstream supplier OTD cause great delay of the assembly plant which can only achieve 20 percent OTD. In order to improve the OTD of assembly plants, we adjusted the OTD of the two worst-performing suppliers. The OTD of the component from Supplier F Ltd is improved from 50 to 80 percent while the OTD of the component from China is improved from 55 to 85 percent. Based on the ASDN views, the manager can easily identify the problem area and simulate to find the optimal balancing OTD through the service chart tool.

5.3.3 Inventory amount and inventory value. Since, the ABB supply chain is serving the customized market, the high demand uncertainty causes huge inventories in different stock-points. ASDN allows the user track three types of inventory: safety stock inbound, safety stock outbound and cycle stock. Users click node and check the output attribute to get the inventory status. The manager can have a view of the inventory state of a supplier. This can include basic property of a supplier like production type, lead time, demand deviation, shipping time, capacity, etc. as well as calculated outputs of each node which includes the information of average inventory in units, inventory turn rates, cycle stock, inbound stock, outbound stock and capacity utilization, etc.

Figure 8 shows the supply manager an overall view of the inventory amounts and how the value is spread along the network. Various colors represent different types of inventory. For example, the red color refers to the safety stock; the green color points to the cycle stock. It is obvious that the inventory levels at the final assembly plant and

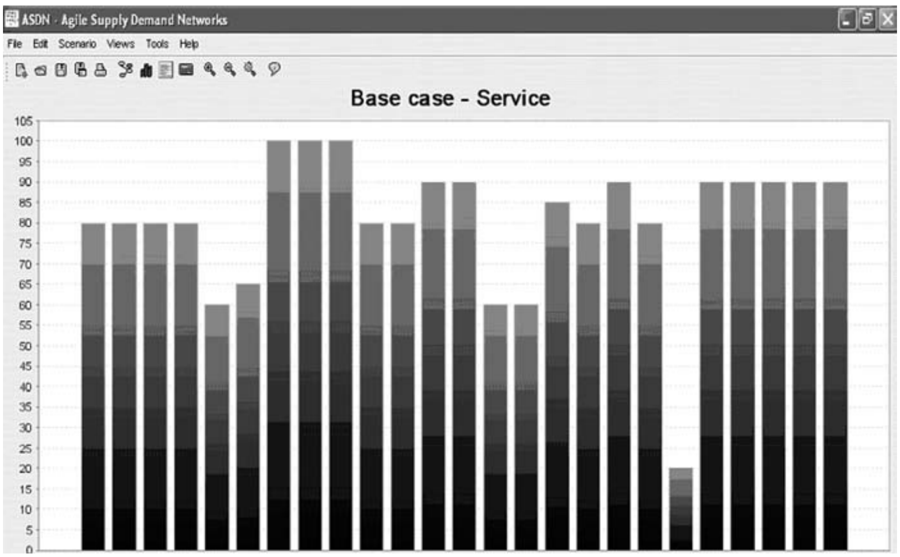

Figure 7.
Service levels chart for ABB electrical supply chain

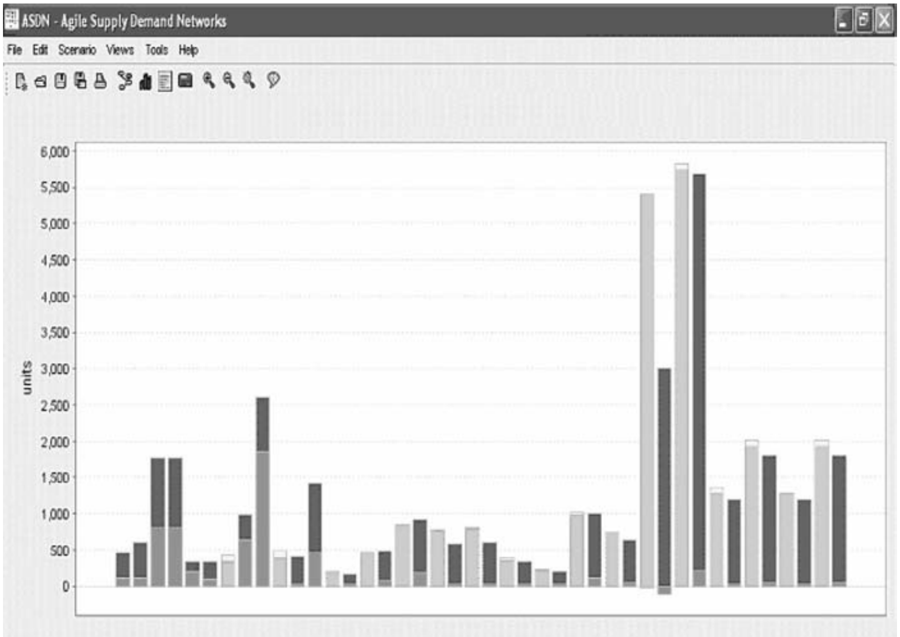

Figure 8.
Inventory (pcs) in different stages of supply chain

distribution center are quite high either in amount or value. The manager should shift the inventory from downstream plants to the upstream supplier to balance the network.

5.3.4 Inventory vs service level transport. Supply managers always find themselves in a dilemma to balance the inventory and service level. The improvement of service level always accompanies with the increase of the inventory which in turn leads to higher cost. It takes a lot of time and effort for the company to find the balancing point that maintains a good service level without comprising too much on cost. ASDN provides an analytic tool to support this decision-making process. As shown in Figure 9, the curve describes the relationship between inventory value and service level. For the component supplier, 752,000 inventory items can maintain 62 percent service level, while 761,000 items achieves a 97 percent service level. The supply manager could observe the curve of each supplier separately through ASDN. Therefore, the decision makers now can more easily find the balancing point of inventory and service level according to their financial status and market expectation.

5.4 Model improvements

Now the network model has been built and analyzed, we are ready to optimize it. ASDN calculates the optimal values through a series of build-in mathematical models, which can be modified by the user. Integrated inventory management can be achieved by application of analytical inventory control and optimization method for every single stock-point. Loose coupling enables the ASDN to combine integration and flexibility.

ASDN provides several spreadsheet models for logistic networks, with data covering different inputs and outputs throughout the network. The user may, for

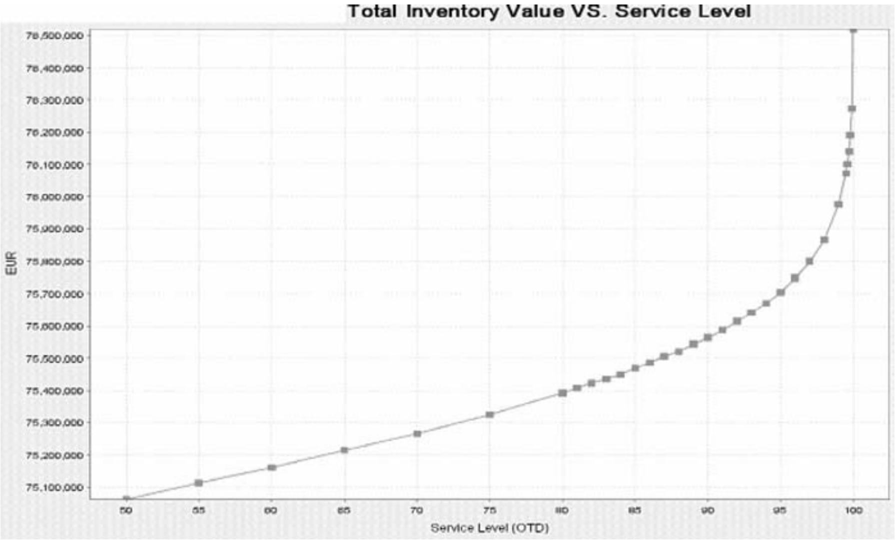

Figure 9.
Inventory vs Service level chart of electrical supply chain

example, use *Goal Seek* functionality where new scenarios are created by setting objectives with regard to inventory level, lead-time and service level.

5.5 Result

ASDN has facilitated the ABB Company to build the supply demand network quickly and create a structured way to identify and prioritize supply chain improvements. It has given the managers more clear information visibility across the entire dispersed network which helps them in prioritizing and expediting the improvement projects currently in place. One of these piloting projects, which dealt with restructuring geographic inventory management and improving delivery performance, achieved results of reducing customer lead-time by 35 percent and improving the OTD at the same time. At its best, the ASDN type of software can enable the inventory manage and control through detailed review, scheduling replenishment time in each node, and assigning customer orders to the best point of supply based on lead time and availability. The combination of advanced computational OR techniques with a friendly graphical user interface proves to be adequate for the management and optimization.

ASDN implementation has improved ABB customer responsiveness and reliability, delivery performance and agility, reduced inventory carrying and obsolescence costs, and resource fluctuations in several business areas and products. The major advantages of ASDN type of approach could be summarized as:

- user-friendly graphical interface;
- diversified performance analysis and report;
- multiple what-if scenarios; and
- real time calculation and optimization of network.

6. Discussion

Whilst case study research does not seek to be representative, the case undertaken suggests a number of interesting themes that deserve further discussion.

First, ASDN software system offers a new infrastructure for dispersed logistics networks including highly customized and dynamic market. This system is web-based, distributed so that it can span multiple firms. The deployment of advanced technology such as object-oriented methodology, Java, and XML allows the system to support a decentralized, collaborative supply chain decision-making process in which the general goals and directions are still set centrally, yet the execution process benefits from an internet-based decentralized system. Such an integrated, collaborative system is a necessity for a constantly changing and highly customized business market.

Second, the visualization ability makes ASDN a centralized information platform and a powerful decision-support tool for network architecture decisions. The heterogeneous and diversified information of supply chain operation like product composition, supplier capabilities, demand pattern, lead time and cost structure which previously have been spread in different functional departments and organizations, now are collected and visualized through the ASDN network window. Based on the information, a unified and complete supply demand network can be designed and visualized. The visibility of the entire system through an information network to all members reduces chaos in the system, since all participants can view the whole picture. Additionally, when the business operations become "Web centric" new functionalities and opportunities, such as customer profiling, also can be realized.

Third, a variety of analysis tools support the supply managers in observing the network from all kinds of directions. The tools statistically analyze and visualize the entire supply demand network performance such as inventory value, service level, capital throughput, etc. Different types of representation format such as text, graphics, table and charts provide flexibility to envisage the result. Based on the analysis result, human decision makers can identify bottlenecks, determine measures and optimize decisions.

One of the most important uses of the analytical capability in ASDN has been the ability to determine, understand, and incorporate marginal cost data. Without this data, it is nearly impossible to determine whether or not to accept incremental orders, buy additional product, or schedule more capacity. The value-added activities in the supply chain are evaluated and measured by explicit monetary value. The various changes in demand, supply and product would be finally reflected on the difference of added-value. Therefore, supply managers can make quick responses based on the result of value change. Also, it is very convenient to evaluate different supply demand network configurations by comparing their net revenue.

The attempt of ASDN to build network models is probably of interest to both supply chain and information systems managers who are seeking means to improve the agility of their dispersed networks. The synthesis of the most recent thinking in the supply chain management domain, with emergent developments information systems, will also make this paper of interest to academics from both of these fields, together with academics from other fields interested in the improvement of inter-organizational relationships.

7. Conclusion

Today's global businesses must be agile and responsive in order to be competitive. Additionally, the infusion of information technology into every aspect of operations is transforming the business environment from a production-centric model to one that is information and customer centric. This paper has presented a framework for the design of ASDN that can be used to model, analyze and optimize the dispersed networks. Performance measures such as cost, inventory, value-added, lead time and throughput in the network are analyzed and optimized through a set of embedded analytical models. The structured and detailed analyses of the different supply chain scenario provide clear and comprehensive holistic view to supply chain designer. Computing may help collecting information and suggesting new scenarios, but still the most important strategic decisions such as measures and objectives remain as human work – the decisions of business managers.

The ASDN software presents an open source approach for logistics analysis and lot of its development is based on community. The future will show where this consulting-oriented software will be in the next few years. The developments in real-time enterprise systems as well as optimization tools and agent based simulation present all possible development pathways. At the moment it seems obvious that the modeling focus from single echelons and chains has shifted to networks permanently.

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