11 Smart and Sustainable Supply Chains

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Introduction

Over the last decades, companies have utilized supply chain management principles and practices as instruments to gain advantage in competition between business networks. In this chapter, we explore the use of Information and Communication Technologies to make supply chains smart and sustainable.

It is customary to refer to the supply chain instead of the supply network, and we shall adhere to this convention. According to the definition of the Council for Logistics Management, Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and logistics. It involves the planning and control of the forward and reverse flows and storage of goods, services and related information within the supply chain in order to meet customer requirements. Importantly, it also includes coordination and collaboration with channel partners, such as suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies (www.clm1.org).

Recently, an increased focus on sustainable supply chain management practices has been evident. This is due to external drivers such as environmental legislation and customer requirements, as well as internal drivers, such as business economics.

In sustainable supply chains, the creation of economic value is based on efficient processes that minimize consumption of scarce resources. For example, waste materials during production, distribution and use are collected, sorted, and recycled. Products and service packages are designed in such a way that repair and maintenance, updates, and returns of products are synchronized with value recovery processes, such as remanufacturing and refurbishing. These processes extend the life of products and parts to several use cycles. Customer relationships that support the use of the prod-

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uct instead of ownership are also extended through the provision of customized services such as proactive maintenance and repair, updates based on user profiles, and profitable take-back options (Van Nunen and Zuidwijk, 2004). Sustainable supply chains are henceforth characterized by three P's:

Profit	Creation of economic value through efficient use of scarce resources and design of innovative packages of products and services that create opportunities both for suppliers and customers.
People	Creation of customer value through the offering of profitable service packages while taking social responsibilities of environmental impact due to sourcing, making, delivering, and returning products.
Planet	Minimizing the consumption of natural resources through efficient use of materials and energy, and reducing the environmental impact of hazardous waste.

As indicated above, some sustainable supply chains are characterized by the fact that value is being recovered from product returns. Figure 11.1 represents the basic processes in these so-called closed loop supply chains. The forward supply chain processes are source, make, deliver, and use of the products by the end customers. After the initial delivery of the product to the end customer, additional deliveries of parts may be required to repair or upgrade the products installed in the market. Customer returns consist of e.g. products at the end of their life or parts that have been replaced during repair. During the manufacturing process, returns are generated that consist of e.g. raw materials surplus, quality test returns and production leftovers. Returns can also be initiated by an actor in the distribution channel and include product recalls due to safety or health problems with the product, commercial returns induced by agreed take back options, collection of perished goods or redistribution of goods. Returns are collected via the forward distribution channels or via special reverse channels. The quantity, quality and timing of returns can be anticipated using monitoring data, but in quite a few present day cases, test data is obtained only after arrival at the collection facility. Based on the quality assessment and demand, returns are either disposed or forwarded to recovery options. Recovery processes such as recycling recover value on the material level, while remanufacturing and refurbishing restore products to as good as new state and upgraded state, respectively. In some cases, products are simply returned to the market after repackaging. As indicated in Figure 11.1 the recovered materials, parts and products are fed into the forward supply chain.

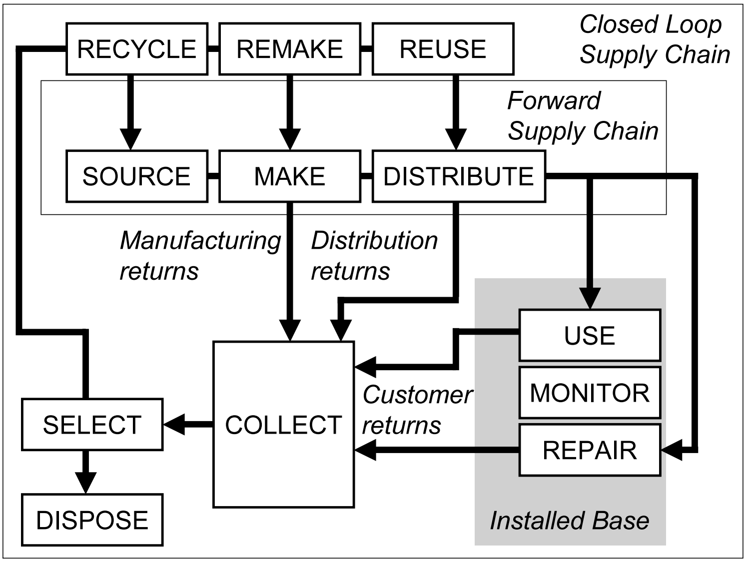

Fig 11.1 Closed Loop Supply Chain

Among others, costs of resources, governmental policies and regulations, and customer markets, are important drivers for the geographic positioning of facilities and resources that support the processes and flows in Figure 11.1. As a result, they are dispersed across continents. The management of supply chains that span the globe is confronted with additional challenges in terms of coordination and collaboration. Global transport systems, for example, involve several transport modes, such as aircraft, sea vessel, train, truck and barge, transshipment hubs at air- and sea ports, and a diversity of organizations that are involved directly or indirectly in the logistics processes. Logistics service providers add value by coordinating these transport chains while using Information and Communication Technology as an enabler.

The European project RevLog (Reverse Logistics), which focused on the management of closed loop supply chains and logistics in particular, resulted in the development of quantitative methods for optimizing closed loop supply chains (Dekker et al., 2004) and applications in practical environments reported in case studies (Flapper et al., 2004).

Monitoring and Controlling Supply Chains

Monitoring and control of supply chain operations and flows has always been aimed at mitigating uncertainty through information retrieval and process interventions. Information and Communication Technology now acts as an enabler by lowering the costs for these activities through automation. Computational power as well as embedded sensors and chips, available against low costs, help create smart products and smart processes through the entire global supply chain. The application of new technology enables supply chains to become more responsive and proactive, with a large role for autonomous decision making- and event-handling technology, and henceforth utilizing human intelligence only where it is truly required. In the case of maritime transport of fruits and vegetables, the development of smart reefer containers is under development as can be seen in the exposition below.

Monitoring the global food supply chain of maritime reefer containers.

Reefer containers deploy climate control in order to minimize deterioration of product quality. Transport of reefer containers is still characterized by high energy costs and use of harmful chemicals. Moreover, short interruptions in the control of the so-called cold chain may result in immediate deterioration of product quality. Design principles for new types of reefer containers include the use of embedded monitoring and control devices enabling remote climate control in order to arrive at sustainable supply chain processes characterized by more efficient use of energy and less use of hazardous chemicals. In this manner, a reefer container should be used as a smart container, in which sensors can monitor cargo status, and recognize when certain parameters, such as levels of ethanol, acetaldehyde, carbon dioxide and oxygen, lead to e.g. fermentation or respiration. Remote monitoring may induce appropriate action to maintain the quality of the cargo through e.g. an injection system for chemicals. The sensor devices need to have certain characteristics, like robustness, low energy usage, accuracy, sensitivity, low-costs, precision, employability, and appropriate size and shape. A supervisory control strategy is to maintain the best product quality at all times through continuously determining the best condition strategy for the cargo. The control strategy's target is to optimize transport through leverage between energy savings, quality and logistics, while taking into account external influences such as weather conditions.

New monitoring technologies that enable remote identification, diagnosis and maintenance are used in supply chains in which customers, products and processes are monitored worldwide. For example, recovery processes are commonly associated with uncertain yields. Monitoring these processes provides immediate yield information and may even help improve yields. Customers have their own requirements, usage patterns, and budget. Monitoring usage profiles together with preferences may enhance customer relationships while respecting customer autonomy and privacy.

In order to manage products, processes and customers, information on the following attributes is required: The state of the product, such as usage and repair history, and configuration, product preferences of the customer including user requirements and budget, and recovery options for a product. The recovered value of the product can be measured in terms of market price for the recovered item minus costs of the chosen recovery option. Therefore, the value of the recovered product depends on the product state, the customer preferences and the available recovery processes. Since the value of recovered products like computers deteriorates in time due to technical and market properties, information needs to be provided in a timely fashion so that product returns and recovery processes do not suffer from serious lead times. Maintenance and repair of business machines installed at customers using smart product technology is the issue of the exposition below.

Monitoring and controlling copiers and printers at customers

CopyMagic assembles copiers and printers, but actually sells document handling services to its customers. The customers will buy the function of these business machines that enable a smooth flow of information and documentation through their offices. In particular, smart copiers and printers contain sensors and processors that measure, analyse and report on machine status to enable pro-active maintenance planning, remote usage control, and even self-maintenance to enhance the operational readiness of the installed machinery. Moreover, comparing actual usage profiles with product and service capabilities may result in beneficial upgrade proposals to the customer. These upgrades can be offered against sharp prices when synchronized with demand and supply of recovered parts and products elsewhere in the market. The customer experiences a copying and printing function that is not only very reliable, but also matches his requirements throughout the development of his business. On the other hand, CopyMagic can offer these enhanced services in a sustainable way by monitoring the products installed in the market, and controlling forward and reverse flows of parts and products. Although the technology has become available, the integration of product and services development, customer relationships management, and marketing remains challenging.

From Tracking and Tracing to Sensing and Pacing

In today's supply chains, data and information is available in every node and link in the chain. Processes are monitored and controlled automatically, as well as products which get a certain amount of intelligence built in through the application of embedded chips, sensors and software. Smart Products are capable of sensing their own technical status through e.g. temperature or movement sensors, register usage patterns, perform diagnosis and even conduct self-repair, such as image enhancement in a copier when image quality has degraded. These products either flow through the supply chain or are involved in adding value processes, such as production or distribution.

Software developments play a large role in this trend. From the functions of data storage and basic financial transaction-processing in the 1960s, enterprise software today provides the backbone systems for almost all companies. Enterprise Resource Planning (ERP), Advanced Planning Systems (APS), Customer Relationships Management (CRM), Supplier Relationships Management (SRM), and Product Lifecycle Management (PLM) systems are widely deployed in large multi-nationals, as well as in SME's.

Having focused on island-automation, such systems still do not truly support the core supply chain management concepts, despite the success of tools such as Enterprise Application Integration (EAI). However, with the appearance and rise of new generations of technology such as Web Services, the Semantic Web, Grid Computing, Ubiquitous Computing, Business Intelligence, Electronic Auction mechanisms, and Agent Technology we may expect smart business networks to become a reality soon; see for example (Fleisch, 2001) and (Hagel, 2002). An important example related to smart products is Agent technology, which consists of software behaving autonomous, proactive, goal-oriented, and truly focused on communication and interaction with other agents to arrive at solutions.

Dynamic planning and control of road logistics through a Multi-Agent System

Agents are a powerful, natural metaphor for conceptualizing, designing and implementing complex, distributed applications (Scholz-Reiter and Höhns, 2002). The nature of intelligent agents enables decentralized control of (processes of) the enterprise, which is desirable in a dynamic and flexible environment. Wooldridge & Jennings (1995) define the four main characteristics of an agent: (1) autonomy, (2) social ability, (3) reactivity, and (4) pro-activeness. Erasmus University Rotterdam participates in a large Dutch government funded research project titled DEAL, which stands for Distributed Engine for Advanced Logistics (DEAL project proposal, 2002). This project aims at creating an agent-based-system to support a network based truck-scheduling system. In the DEAL architecture, each truck, shipment, truck-company and customer is represented by an agent. An agent representing a truck resides on the truck's board computer and is aware of its location, speed and planned route. An agent that represents cargo is aware of its planned destination, penalties for late delivery, specific transportation requirements etc. As cargo is presented to the DEAL network, agents are created that represent the cargo. These agents then start negotiating with nearby trucks. Based on the negotiation rules, goals and constraints, a successful 'Deal' is made. Trucks of different truck companies can collaborate by exchanging cargo whenever this is in their mutual benefit. As multiple customers and suppliers are connected through DEAL, this agent system is an example of a true supply network-wide inter-organizational information system. Future generations of the platform are likely to link tightly with all kinds of external monitoring and control systems, to make the planning and execution of road-transportation even more dynamic, and cost-optimal. Examples include a strong integration with traffic technologies (such as traffic-congestion information systems), dynamic cargo functionalities (when cargo is tagged with an RFID+ chip, it is no longer passive when transported), and cost-saving-leveraging technology (like links with information on dynamic fuel pricing, toll, et cetera). The DEAL project demonstrates that the use of this new generation of technologies (encapsulating all three categories of technology as shown in), can provide good help in actually achieving dynamic control in supply chains, in order to achieve true Sustainable Smart Networks.

Other important developments are the advances made in mobile telephony and data-communication. Technologies such as 3G telecom make it possible to submit large data streams in real-time from anywhere in the network. The exchange of data in global supply chains is a prerequisite for coordination and collaboration. Moreover, combined with location-determination technologies such as GPS or the European alternative to GPS, Galileo, which is to be integrated with GPS by 2008, supply chains are no longer bounded to fixed tracking and tracing points, but can be controlled and optimized in real-time, all around the globe, resulting in sensing and pacing the supply chain; see Figure 11.2.

Micro technology and its application in supply chains and products are a third important technological development. Products can be quipped with smart sensors, (RFID) chips, or small computers. Furthermore we see an increasing utilization of micro technology in resources such as trucks (e.g. board computers), warehouses, and even on shelves in the shop.

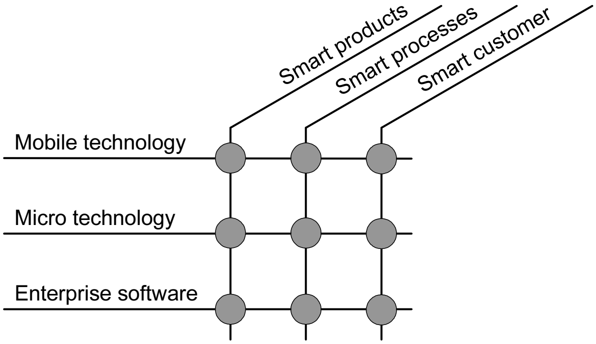

Fig 11.2 Technological developments enable smart products, processes and customers

Conclusions

The coordination of global supply chain activities through collaboration with customers and suppliers enhances performance in supply chains. Enabling technologies support data exchange, automated control mechanisms, and integrated planning involving smart processes and products. The benefits are not only in terms of profit, but also in terms of planet and people, so that these technologies may contribute to the sustainability of supply chains.

The aforementioned technological developments contribute to the availability of a vast amount of data and processing power in the supply chain. The challenges are in utilizing these capabilities as information and intelligence. Some of today's most innovative companies do pioneer in their supply chains already, and achieve promising results. However, the best is yet to come.

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Section 2

Execution of Smart Business Networks