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Inter-company Supply Chain Planning – Extending the Current Modeling Perspective

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Inter-company Supply Chain Planning
– Extending the Current Modeling Perspective

Abstract

Many companies are implementing new mechanisms to better manage operations across units in a supply chain. Both the operations management literature and the accounting literature are investigating such inter-organizational developments. Since supply chain planning (SCP) typically started across several units within the domain of a *single company*, the models that have been developed in inventory theory assume a single company perspective. SCP from a centralized perspective optimizes objectives at the level of the total chain. However, it is mainstream thought nowadays in the operations management literature that the planning function should focus as much as possible on the entire supply chain rather than on a single unit in the supply chain. Consequently, SCP across *independent companies* has seen some attempts in practice, although inventory models have not been formulated so far. The accounting literature has started to examine the conditions under which information exchange mechanisms and other elements of SCP are beneficial to each individual company in the supply chain. The present paper builds on this perspective of the individual units' objectives. Each unit will often be part of different supply chains, and we investigate how decisions made by the SCP functions of those different supply chains may interfere at the level of the unit. These planning decisions may not be in that unit's best interest, which would prevent independent companies from engaging in SCP. This paper introduces two new concepts to describe and support SCP across independent companies: outsourced SCP and between-supply-chain coordination.

1. Introduction

Companies are finding new ways for managing operations across organizations in a supply chains and this issue is receiving much attention in many different areas of the literature. We use the term Supply Chain Planning (SCP) here, to denote that this paper is about operational control of timing and quantities of goods flows and decisions on the parameters for controlling this goods flow.

Several developments have created a need for SCP. First, customers demand shorter delivery times, more flexibility, and faster introduction of new products (Gilmore and Pine, 1997; Lampel and Mintzberg, 1996; Anderson *et al.*, 1997, Feitzinger and Lee, 1997; Buzzel and Ortmeyer, 1995). Managing the supply chain is difficult, because many companies are organized functionally around subsequent stages of production. Serving customers better requires synchronization of these different functions, such as marketing, sales, distribution, manufacturing, and purchasing. Second, better synchronization is not only important across functional boundaries, but also across national boundaries. Spanning these boundaries has especially occurred in Europe. Many companies in Europe have moved from strong country organizations with local production, products, and customers, to an organization where production becomes more specialized and one factory serves a specific part of the product range for the whole of Europe. Sales and marketing become partly centralized. This moves demand management, product allocation, marketing, and distribution to a European level and there is a need to manage the supply chain on a European scale. A third development is that streamlining of operations across a chain of *separate* companies has become more important because this creates opportunities to offer better service to consumers against lower costs for the supply chain. In the food industry, Efficient Consumer Response (ECR) is the overall name for many concepts and initiatives to reduce costs by removing unnecessary activities – particularly handling - and better coordinating existing operations, enabled by improved information technology.

Current SCP concepts are based on some form of central planning of supply chains. Planning objectives are formulated at the level of the chain, planning decisions are governed by central guidelines, and there are no barriers for information exchange. SCP concepts can be found in the Operations Management literature, but also in documentation regarding SCP software systems. The centralized perspective is understandable, because SCP started across different units that belong to a single company. However, as companies start to develop inter-company SCP to better manage operations across a chain of independent companies, the centralized perspective may not be appropriate anymore. Independent companies try to satisfy their own objectives (instead of objectives at the level of the supply chain). They may not be willing to share all data required to "optimize" the chain as a whole, and they may not be willing to hand over decision-making authorities to a central supply chain planner.

The objective of this paper is to present and discuss a new perspective of SCP, for hybrid transformation, storage and transportation processes, which are (partly) performed by independent companies in the supply web. The paper aims to contribute to the accounting literature, which has started to examine the circumstances and contractual arrangements under which information exchange mechanisms and other elements of supply chain coordination are beneficial to each individual player in the value chain. Further, we intend to contribute to the operations management literature by putting forward a possible perspective for inter-company supply chain planning and suggesting modeling avenues to support this perspective.

We have called our perspective the unit perspective, as opposed to the more common central perspective in the operations management literature. We will name an individual link a *unit.* A unit can be a company, a business unit, a production department or warehouse, etc. We define a framework that includes alternative types of SCP, along with central SCP in its more common sense.

In Sections 2 and 3, we will first briefly review the literature and the state-of-the-art in commercially available supply chain software. It is relevant to look at software to understand current concepts of SCP, because much of these concepts are developed by innovative software companies. Most software available in the market of ERP (Enterprise Resources Planning) software now supports some kind of SCP concept. On the one hand, we see the applications that have been developed by the ERP vendors, like SAP and BAAN, which essentially present a multi-site solution that is strongly based on MRP-type logic. On the other hand, we see the approaches that have been developed by the decision support software vendors (like I2, Red Pepper, and

Manugistics), who claim to add various ways of constraint planning approaches. Most of these concepts have developed from expanding MRP and DRP logic throughout the chain, assuming a central function that controls the entire supply chain. The suppliers of these systems have adopted the MRP model and added functionality to tackle supply constraints set by capacity and material.

In Section 4, we will discuss various levels of autonomy in SCP, together with the corresponding perspectives. Section 5 illustrates how an existing model from inventory theory, based on the central perspective, can be used, with little amendments, to support decision-making in decentralized supply chains. The loss of economies of scale and possible optimality, due to a more decentralized model with limited information, is discussed in Section 6 when the concept of 'between-supply-chain coordination' is introduced. Finally, Section 7 contains the conclusions of this paper and summarizes possible avenues for further research.

2. Literature Review

'Supply Chain Planning' is difficult to find as a single concept in the academic literature, except for publications over the last three years. Research regarding this topic can be found in different areas of the literature. In this section, we briefly review SCP concepts that can be found in the literature on multi-echelon inventory theory, production control, agent-based systems, and management accounting.

Three review papers essentially cover the development of multi-echelon inventory theory over the last thirty years. In these papers, an emphasis can be found on research results from the last decade. In this period, a more operational focus of the researchers and an increase in computer power has led to the analysis of much more realistic models and to the development of very good and fast approximation procedures for practical situations. The primary objective of most papers has been the reduction of operational cost. Costs incurred basically include inventory costs and shortage costs. The paper by Van Houtum *et al.* (1996) and the book chapters by Federgruen (1993) and Axsäter (1993) provide an overview of the work in this area. Since shortage costs or opportunity costs may be hard to determine in applied situations, another line of research in these inventory models has focused on a service objective. An overview of this research is provided by Diks *et al.* (1996). All authors seem to agree that application of the research results is possible in practice, since the models increasingly realistically model the supply chain. Implicitly, they then refer to the physical model of the supply chain, where especially for divergent networks powerful tools are available. The research work referred to in these papers assumes that the supply chain or value network under concern is either centrally controlled or the control policies and their parameters for the decentralized functions are centrally set.

The second domain in the literature is production control. Production control is defined by Bertrand *et al.* (1990) as 'the coordination of supply and production activities in manufacturing systems to achieve a specified delivery flexibility and delivery reliability at minimum cost'. Production control has traditionally focussed on control within a single company, and even within a single plant or production department. In this domain, many developments have taken place in the research community, of which we mention the development of MRP and related goods flow control methodologies, work order release strategies, scheduling and sequencing rules and algorithms, and lot sizing models. In the last few years, we can see an expansion of these research results into the chain of production activities outside the individual plant or production department. Given the available models, the application and expansion has been restricted to centrally governed or owned supply chains. Bertrand *et al.* (1990) address, within the single company supply chain, the problem of what decisions to delegate to more or less autonomous units within the company.

SCP is also discussed in the area of information technology. Current developments in real-life supply chains, such as ECR and the full implementation of ERP systems, would not have been possible without the developments in information technology. Therefore, we tend to see an increasing attention of supply chain management issues in the IT literature. In this paper, we only mention the research in the area of the use of agent based systems in supply chains. This would appear to offer another perspective besides the centralized perspective. With agent based systems, decision makers in the supply chain are modeled as individual agents, each of which is acting according to its own rules and principles. Communication between the autonomous agents then leads to an overall 'behavior' of the system. The behavior results from the actions of the individual agents and is not 'overall' determined. Further, the actions of the agents are generally based on local information. Results of prototype systems have been reported in the literature. We are not aware of results regarding performance in terms of traditional performance measures like service level and costs. The objective of the research in this area is twofold. First, it attempts to model actual and real unit behavior in the agents with the objective to analyze its effects on the total performance of the chain. Second, it is interested in examining the improvement that can be made by enabling more intense communication between the agents. Its objective is not, unlike the other modeling domains discussed here, to improve, change, or optimize the internal behavior of the agents such that an overall improvement of the system results. An initial overview of the intentions of this line of work has been provided by Durfee *et al.* (1989).

In the accounting literature, SCP has also been discussed. The starting point here is mostly the interest of the individual company in the chain. Recent papers start to examine the circumstances under which information exchange mechanisms and other elements of supply chain coordination are beneficial to each individual player in the value chain. Radhakrishnan and Srinidhi (1997) show that a retailer may not benefit from information exchange because there is a cost of foregone information rent. Empirical research has investigated the extent of cost data disclosure (Munday, 1992). There is also literature on how closer supplier relations are expected to lead to changes in supplier selection and monitoring (Hopwood, 1996; Gietzman, 1996) and how this relates to company performance (Ittner et al. 1997). Changes in supplier relations can also change the dominance of some parties in supply chains (Frances and Garnsey 1996).

3. SCP in current information systems

In this section, we discuss SCP concepts as they are reflected in the currently available SCP software. It is important to address the way in which current software models supply chains, since the realization of inter-company planning concepts is only possible if the units and chains are also captured in the information systems in the same way.

A first objective of many information systems is to support the planning of the total supply chain of a single company. The software provides greater visibility across the chain of globally dispersed plants, distribution centers, customers, etc. The following quote serves as a typical illustration in what kind of situations the software aims to support planners (Red Pepper, 1996):

"Scenario 1: High European demand is expected for a new product.

- Does the European plant have enough capacity or material to accommodate the demand increase?
- Should the American or Asian plants increase production in response to demand increase?
- Do those facilities have the raw material on hand?
- What strategy results in the lowest cost, considering transportation, storage, material, and production costs

Scenario 2: A customer on the phone requests 10,000 units for delivery next Thursday.

- Do you have enough product inventory locally?
- Can you support this request from other warehouses?
- If you have only 5000 in stock, do you have the capacity and the raw material to produce the remainder?
- Is it possible to manufacture and ship the product and meet the customer's Thursday requirement?

Scenario 3: A supplier has just informed the factory that an expected delivery of raw material will be delayed by one week.

- What customers will be affected?
- How should you allocate the material you have on hand?
- If you delay production of some products, what other products can you make earlier?
- Is the required material available from another source?"

This quote illustrates that the currently available SCP software addresses complexity and dynamics issues, but does not address the uncertainty issue. The software that aims to deal with situations as the ones described above has been developed by expanding MRP and DRP concepts throughout the supply chain, using information about activities, resources, and constraints in the entire chain. The objective is to "integrate world-wide factories and distribution centers together into one cohesive manufacturing enterprise" (Red Pepper, 1996), and to provide "companies with global visibility throughout the entire supply chain. This visibility enables planners to consider all constraints—including their impact on all supply chain resources—resulting in plans that are inherently feasible" (i2, 1997).

A second objective of information systems is to support planning the extended supply chain. An extended supply chain consists of several independent companies that work together to coordinate their operations. The planning concept that is reflected in the current software and in the innovations that the companies are developing is centralized planning. Ideally, the software would like to provide planners with the same information as the single-company supply chain and should allow them to manage the extended supply chain as if it were one company.

The natural starting point for a better planning of the extended supply chain is that information systems facilitate the exchange of information. Point-of-sale information can be fed back into the chain to provide companies further upstream with a better view of current demand. Companies could also share forecasts of end-customer demand. Next steps are "to feed material requirements and fulfillment data directly to the systems of suppliers of parts and distributors of finished goods" (SAP, 1997). The Internet enables such developments and companies are developing standards for business transactions.

The vision of information system companies goes much further. The basic concept is to include suppliers and customers completely into a single model of the supply chain and "to collect comprehensive, accurate and timely information over the entire supply chain" (SAP, 1997). "New virtual organizations require a vision that redesigns and supports supply chain activities as collaborative, synchronized processes that respond rapidly to changing business conditions" (SAP, 1997). "On the supply side, real-time data on materials availability, transportation, labor and other factors can be used to initiate change across the product cycle as conditions mandate. On the demand side, forecasts, based on up-to-the-minute data from point-of-sale and marketing enable companies to set safe inventory levels based on realistic projections, not historical data. If production falls off schedule due to labor shortages or machinery downtime, appropriate changes can be made by supply planners, customer service representatives and logistics planners both upstream and downstream." (SAP, 1997) The vision leads to a "supply chain cockpit", that can manage the extended supply chain that consists of different companies as if it were a single company.

Barriers to information exchange are identified, but these are limited to technical issues. A major challenge is to integrate information consistently. "Supply chain systems must cope with the complexity of integrating information from any number of disparate information systems spanning the entire length of the supply chain." Not all solutions that single company systems use, are applicable to supply chains. Systems within a single company utilize a database as the basis of communication within the organization, with individual information systems assessing data via any of a number of standard networking protocols. Several companies, however, could use many different disparate database architectures. "It is doubtful that any company could persuade every member of its supply chain to agree on a single, standard database architecture" So, protocols and standards for information exchange are developed.

To conclude this section, we find that the modeling presumptions underlying these information systems are about central planning of supply chains. They are designed for the supply chains that have been designated as such by the chain owners. The assumption of a central view of the supply chain is predominant in the currently available software. Note that this view is independent of the way the actual planning algorithms and decision support is executed. This may still be done in a decentralized way. The information systems recognize the fact that a SCP concept can be decentralized, but it remains based on a central, overview model of the supply chain. The state of the art in the modeling used in SCP information systems does not appear to go beyond this centralized viewpoint.

4. "Outsourced" SCP to Model a New Perspective

In this Section, we discuss an alternative paradigm for looking at SCP. We define the central planning concept, as we have seen this in the literature and in current software systems, and we define alternative forms of SCP. In next sections, we discuss the setting for SCP and this leads to a discussion on problems with the application of central planning models. We use four types of SCP concepts here, which are depicted in Table 1.

Table 1. Various types of SCP

		Objectives	
		Supply Chain level	*Unit level*
Planning	*Central*	Centralized	Outsourced
	Local	Delegated	Autonomous

Under an "autonomous" planning concept, units make decisions that are aimed at optimizing the units' objectives. Now suppose that some units want to achieve better results by working together and engage in SCP. Based on the reviews described in Sections 2 and 3, available concepts for SCP would typically be either "centralized" or "delegated" SCP, as defined in Table 1. In both centralized and delegated planning, there are objectives at the level of the supply chain, e.g., service to the end customer (consumers), total supply chain inventories, total supply chain costs. The SCP function makes decisions that are aimed at achieving these supply chain level objectives. The planning function may be centralized, but the execution of the planning function may also be (partly) delegated to the entities that comprise the chain. Such delegation is based on central decisions regarding which decisions local entities may take and within which boundaries. Installation stock policies would be an example of delegated planning. In both cases, a central planning function decides on supply chain objectives and designs the structure for planning and control.

However, centralized and delegated SCP may not be realistic in the context of independent units with objectives at the unit level, and which will only decide to hand over decision making authority to a SCP function if that better meets these objectives. New concepts for SCP are needed to describe and support SCP in that context. We introduce the concept of "outsourced" planning in this paper. Outsourced planning is a new concept in the sense that decisions about objectives and decisions about the planning and control structure are not controlled by a central planning function, but by the individual units in the chain. The objectives of these units are leading. There are no identified supply chain objectives, there are only individual units with their own objectives. Even if the units intend (or are forced by one dominant unit in the chain) to work together and coordinate their actions intensively, that is still their own decision, made in their own interest. We do not claim that units cannot "act as one", but that they do so motivated by local objectives, not by supply chain objectives. In outsourced SCP, units have agreed to have a central planning function doing some of the planning. Units decide how much of the local planning they want to hand over to a central planning function. The control structure is established by transferring authority to a central function, rather than by delegating from the central function.

Now the question becomes: Does outsourced SCP need different planning models from centralized or delegated SCP? In this paper, we argue that outsourced SCP does need some different planning models. The essential difference between outsourced SCP and centralized / delegated SCP is, that the latter planning functions only have to optimize the chain result. However, the outsourced SCP function must not only make decisions that optimize supply chain objectives, but at the same time must make decisions that are acceptable for the individual units in the chain. SCP will only be introduced or continued, if each unit in the chain has sufficient benefits from it. In the next section, we discuss why optimizing the supply chain may not be beneficial for each unit in the chain.

5. Supply chain optimization versus unit optimization

In the context of autonomous or outsourced SCP, there is a fundamental problem with the models that assume centralized or delegated SCP. Our argument builds on the following presumptions:

- Units only engage in SCP if it serves towards their own objectives. SCP may reduce total costs of the chain, and/or may increase total chain profits, and/or may improve service to end-customers of the chain. The units in the chain will negotiate transfer prices and other conditions such that they can improve their individual financial results.
- Units are part of more than one supply chain.
- Units' financial results are determined by all transactions together. These include transactions that are completed based on the outsourced SCP function *and* transactions that are completed based on a local planning function or other outsourced SCP functions not being part of this particular supply chain. We denote the first type of transactions as transactions within the (considered) supply chain and these last types of transactions as transactions outside of the (considered) supply chain. Transactions within and outside of the chain are interdependent, and

therefore optimizing supply chain objectives may not optimize an individual unit's results, not even if each unit in the chain receives a fair share of the total chain benefits.

The first presumption has been discussed in the previous section. We will now further discuss the second and third presumption.

We assume that each unit has supplier/customer relationships with several other units. A unit is part of a *supply web.* A supply *chain* is a strict subset from the supply web. A supply chain is a defined system of several units that have supplier/customer relationships. We assume that for planning purposes a definition of a supply chain cannot include all the customers and suppliers of each entity in the chain. Therefore, units are part of multiple supply chains. An exception could be if an important unit is able to define its chain in such a manner, that all major customers and suppliers are included. Then our argument does not apply to that particular unit, but it will apply to the other entities in the chain. A simple example may illustrate these concepts of unit, web, and multiple chains. This example is graphically represented in Figure 1. The supply web of Company B consists of ACDF. Suppose we define chain ABC for planning purposes. Units A, B, and C are all part of this chain, but not all their suppliers and customers are included. If, e.g., we also define chain DBF, then unit B is part of two chains.

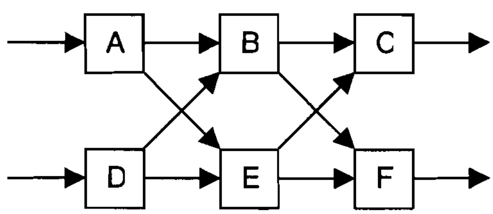

Figure 1. Simple example of a supply web

We use this simple supply web to discuss how outsourced SCP may be unprofitable for individual units in a particular supply chain. We analyze the situation from the perspective of unit B. Profit can be seen a consisting of two parts: profit obtained through business within and outside of the chain. The internal profit of the supply chain ABC is defined as the cumulative profit that is realized by the units A, B, and C through goods traded in the supply chain ABC. The external profit of unit B is defined as the profit realized by unit B through goods traded outside of the supply chain ABC:

$$P_B = f_B \, . \, P_{ABC} + P'_{ABC}$$

where:

P_B	=	total profit of unit B
f_B	=	unit B's fraction of total profit of supply chain ABC
P_{ABC}	=	internal profit of supply chain ABC
P'_{ABC}	=	external profit of B, i.e., unit B's profit obtained as a result of transactions with units D and F

We assume that unit B will outsource planning activities to a SCP function if its total profit increases compared to not engaging in such a scheme.[1] Outsourcing its SCP for the benefit of supply chain ABC for unit B is only acceptable if:

$$f_B \,.\, \delta P_{ABC} + \delta P'_{ABC} > \varepsilon$$

where:

δ = change

We assume the following simple cost structure:

$$P_B = f_B\,(s_i\,D_i - b_i\,P_i - \Delta_i\,) + s'_B\,D'_B - b'_B\,P'_B - \Delta'_B$$

where:

i	units in the chain (A, B, C)
P_i	Volume purchased by unit *i* for chain production
P'_i	Volume purchased by unit *i* for non chain production
D_i	Volume sold by unit *i* to customers of supply chain (A,B,C)
D'_i	Volume sold by unit *i* to customers not of the supply chain (A,B,C)
s_i	Selling Price unit *i* to customers of the supply chain (A,B,C)
s'_i	Selling Price unit *i* to customers not of the supply chain (A,B,C)
b_i	Buying Price unit *i* for chain production
b'_i	Buying Price unit *i* for non chain production
Δ_i	Added Value unit *i* for supply chain production (fixed and variable cost)
Δ'_i	Added Value unit *i* for non chain production (fixed and variable cost)

Improving the supply chain profit may reduce Company B's external profit at the same time. On balance, Company B's total profit may deteriorate. For example:

- Chain volumes and outside volumes interact: Changing D_B implies changing D'_B in the other direction. Because of that, the internal profit may increase, but unit B's external profit may decrease, and the net result may be detrimental for B.
- Quality and cost interactions. Suppose the supply chain changes quality and added value Δ_B in order to increase internal profit via changes in buying prices b_i, or added values Δ_i (A or C). There is interaction, if Company B must also change quality and added value for non chain production Δ'_B and if B's other supplier cannot adjust prices b'_B accordingly. Then Company B's external profit is reduced.

[1] The situation becomes more complex when E and B are competitors and B's objective is to maintain a competitive advantage towards E. B will evaluate Supply Chain decisions on the difference $P_B - P_E$. Conflicts may arise from interactions due to A being a supplier to both E and B, and/or due to C being a customer from both E and B. For example: B needs a more reliable delivery from A to improve the chain result. A can do so efficiently and can do so even more efficiently with a next customer E. For example: B and C work together to improve B's quality and to improve the chain profit. Later C can do the same more efficiently with E.

- Quality and price interactions. Suppose the supply chain changes quality and added value Δ_B in order to increase internal profit via changes in selling prices s_i. There is interaction, if Company B must also change quality and added value for non chain production Δ'_B and if B cannot adjust selling prices to its other customer s'_B.
- Price interactions. Suppose the supply chain changes selling prices to increase internal profits via changes in volume. This may effect prices that companies in the chain can charge other customers, who may however have different price elasticity and therefore outside profits may decrease.

The effects discussed above may be more significant, if a unit's
- supply chain volume is small relative to the outside volume;
- portion of the supply chain profit is small;
- chain volume and outside volume are negatively correlated (for example because of market demand constraints or because of production level constraints);
- suppliers inside and outside the chain have different quality-price or volume-price relationships;
- customers inside and outside the chain have different quality-price or volume-price relationships.

In this section we have discussed the problem that centralized or delegated SCP may not be acceptable for a unit, because achieving supply chain objectives may be contradictory to achieving that individual unit's objectives. In other words: SCP decisions may improve supply chain profit, but these may reduce, at the same time, the profit of an individual unit in the chain. If instances in practice exist where centralized of delegated SCP is not a viable option, introducing outsourced SCP may be a realistic view. It is however unclear whether the current OR models and software concepts can support these types of decision-making. In the next section, we will further explore this avenue and find indications as to what kind of adaptations are necessary in modeling.

6. Use of a Multi-Echelon Inventory Model to Support Outsourced SCP

We have argued that the current models do not support the planning decisions of the outsourced SCP function explicitly, as they only view the central perspective of the chain and not the unit perspective. However, to support some decisions, we can make use of available models with only minor modifications. An example would be the following (see Figure 2).

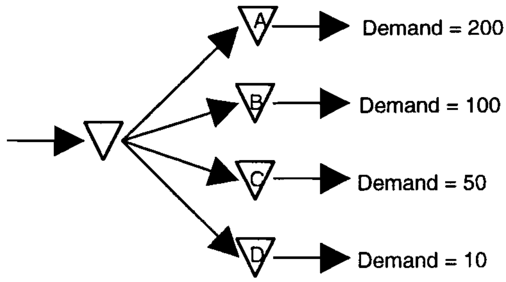

Figure 2. Divergent distribution structure with one manufacturer and four retailers.

Let us consider a manufacturer that delivers to four retailers. In autonomous planning, each company would make their decisions based on information about demand from their own customers. The retailers would require a particular service level from the manufacturer (e.g., 95%) and they would set their inventory parameters accordingly. Suppose that the fractions of demand that each of these retailers consumes is Pareto distributed. Retailer A has 56% of total demand, B 28%, C 15%, and D 3%. Further, it is assumed that the coefficient of variation in demand that the retailers face is higher if the demand level is lower (for A 0.25, B 0.5, C 1.0, and D 2.0).

Results are in the top line ('A+B+C+D') of Table 2. In the case where all four retailers require a 95% service level (fill rate) from the manufacturer, the manufacturer needs to keep 607 units of inventory, with a total system inventory of 1878. We obtained these results using the allocation functions developed by Diks *et al.* (1998). In this model, the sum of inventory and backorder costs is minimized for a linear or divergent *n*-echelon distribution structure. We added a computational search procedure, which sets the parameters for inventory holding cost and backorder cost such that the service level experienced by the distributor is equal to the actually realized optimal experienced service level under these parameters. This is comparable to searching for the overage and underage costs in a newsboy model to obtain a specific service level. In this result, retailers have low inventories, but inventories with the manufacturer are high. These high inventory levels in the total web could be reduced by some form of SCP.

Table 2. Inventory costs at various levels of outsourcing SCP.

Retailers Requiring a 95% Service Level	% of Total Demand under Outsourced Planning Control	Inventory at Manufacturer (I)	Inventory at Retailers under Autonomous Planning Control (II)	Inventory at Retailers under Outsourced Planning Control (III)	Total Inventory in System (I)+(II)+(III)
A+B+C+D	0	607	1271	0	1878
B+C+D	56	470	751	851	2072
C+D	83	331	372	1195	1898
D	97	112	85	1427	1624
None	100	0	0	1487	1487

In centralized SCP, one planning function would have information on consumer demand, inventory at the retailer, and inventory at the manufacturer. The retailers would specify the required service level to consumers, the SCP function would set parameters for inventory levels at the manufacturer and the retailers, and for service levels from the manufacturer. The SCP function would ration in case of shortages.

The results for the centralized model are in the bottom line of Table 2 ('None'). The SCP function could use current models, such as the allocation functions developed by Diks *et al.* (1998). An optimal policy, supply chain wide, including all four retailers, would result in zero inventory at the manufacturer and 1487 units of inventory in the entire system. Even if the manufacturer would pay for a considerable part of these inventory costs, it would still be beneficial to do so. Since the total inventory in the system decreases, we assume transfer pricing policies will take care of negotiations and benefits will be spread over all units in the system. We do not address this issue in this paper. Centralized SCP requires that the SCP function has information about the consumer demand. In reality, this may not be the case. Especially information about the variance of consumer demand may not be available to the rest of the supply chain. The average demand may be known through marketing data companies.

If companies are not willing to exchange all information and let a SCP function make all decisions, a new form of SCP is required. Above, we have called this form outsourced SCP. The manufacturer and its largest customer (Retailer A) could set up an outsourced SCP function. That function would have to achieve a specified service level to consumers with the lowest inventory in the chain. There would be no separate objective for the service level from the manufacturer. The SCP function would need a separate inventory at the manufacturer to be able to control the chain. The SCP function would have information about consumer demand with Retailer A, inventory at Retailer A, and inventory at the manufacturer. Now the important question is whether both the manufacturer and Retailer A would want to engage in outsourced SCP. The outsourced SCP function would reduce inventory at the manufacturer and increase inventory with retailer A. Again, if the total inventory in the system would be reduced, we assume that the parties would be able to conclude negotiations on this.

These results are in the second line of Table 2 ('B+C+D'). The total inventory in the system increases. The manufacturer and Retailer A will not benefit from outsourced SCP. Even though it may be efficient for the chain Manufacturer-Retailer A, the total cost increases because of interactions with other units. This is mainly due to a large reduction in the pooling effect if we take the largest customer out of the existing allocation system. The supply chain has been decomposed: within each company that constitutes the chain, resources are used exclusively for the supply chain. The resources are not available for sharing with other suppliers or customers. In this particular example, only if the three largest out of the four total customers join in the project (case 'D'), system costs decrease as compared to the base case ('A+B+C+D').

To briefly summarize the results from this example:

- autonomous planning in this example leads to high inventories;
- centralized SCP would be optimal, but may not be realistic;
- outsourced SCP might be more realistic in terms of information exchange, but is unattractive in its present form for the companies in the supply chain.

Models are needed that can support outsourced SCP, whereby decisions are acceptable for each unit in the chain. This is further discussed in the next section.

Although we do not intend to draw any general conclusions from this example, the example illustrates how current planning models, which have been developed for centralized or delegated SCP, might be adapted to support outsourced SCP. We added a computational search procedure to an existing allocation approach. In order to do this, we had to split the system into two separate systems, each having its own inventory and allocation policy and inventory position. This is a firm decomposition of the entire system into two, completely separate subsystems. We will address this issue in the next section.

7. Outsourced SCP Requires Between-Supply-Chain Coordination

Models are needed that can support outsourced SCP, whereby decisions are acceptable for each unit in the supply chain. Some type of coordination between the supply chains is required, to control the effects of interaction between supply chains. We will denote this as 'between-supply-chain coordination'. We distinguish two types of between-supply-chain coordination:

1. Direct coordination between chains when chains have private resources with common capabilities.
2. Coordination through an autonomous resource planner when separate supply chains share resources

In the first type, each supply chain has its own private resources (see Figure 3). Without further agreements, this would avoid interactions and each supply chain planner could just make decisions to optimize the chain, without these decisions affecting other suppliers/customers of supply chain companies. To gain efficiency, however, some interactions would be allowed and there would be strict agreements between supply chains to govern decisions about the use of private resources by the other chain. In the example in Section 6, suppose that the SCP function for chain Manufacturer-Retailer A controls the entire inventory at the manufacturer, both for the chain and for the other retailers (see Fig. 3). The SCP function would have to achieve the required service level to consumers who buy at Retailer A and would have to achieve a required service level to the Retailers B, C and D. The SCP function wouldn't need information about customer demand from retailer B, C and D, only information about orders from those retailers. Current planning models do not yet fully address these types of situations and further research is required.

Sharing of resources could also be used between different outsourced SCP functions. Suppose that the manufacturer and Retailers B, C, and D would together outsource their SCP function, apart from the outsourced SCP function of the manufacturer and retailer A. Both supply chain planners will then have their own inventory at the manufacturer. However, they could make agreements about using each other's inventories (when shortages occur at different moments for the two chains).

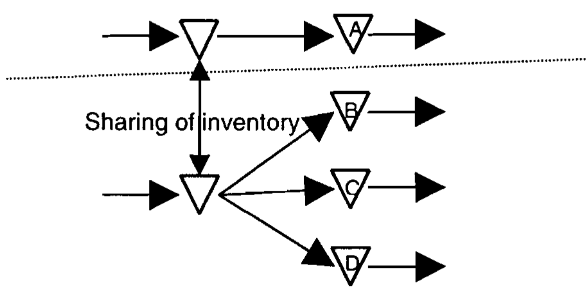

Figure 3. Direct coordination between supply chains that have private resources

Information systems could support the process of SCP functions exchanging resources. Agreements need to be formalized and the system can signal that decisions go beyond agreed levels. When there are few exceptions, human planners can negotiate between them, using their own SCP systems. However, when there are many exceptions, there is a need to implement formal resolution mechanisms in the planning system. Imagine, for example, a wholesaler with an inventory for several tens of thousands of products. Inventory is used in several integrated supply chains, of which the planning function is outsourced to separate supply chain planners. There are agreements between the chains about limits for using the shared inventory. If demand in each of the supply chains is hard to predict, there may be many exceptions to the agreement and the planning system of the wholesaler should signal such exceptions. An example of resolution of interaction issues could be a market between supply chains where usage of shared resources is coordinated.

In the second type of between-supply-chain coordination, some resources are not private for individual chains. There is interaction between supply chains sharing resources. Without further agreements, such interaction could be unfavorable for individual units. Supply chains make agreements with a separate autonomous resource planning function. The resource planning function is responsible for planning of the shared resource in the most efficient way, within constraints that have been agreed with the different SCP functions. In our example, the outsourced SCP functions of the supply chains M-A and M-B-C-D could determine service levels and inventory levels to optimize their own supply chains *as if they would have a private inventory at the manufacturer*. Next, they give information about the required service level from the manufacturer to the resource planner who tries to achieve efficiency gains through sharing of resources. The resource planner plans the inventory and controls service levels for both supply chains. This is illustrated in Figure 4.

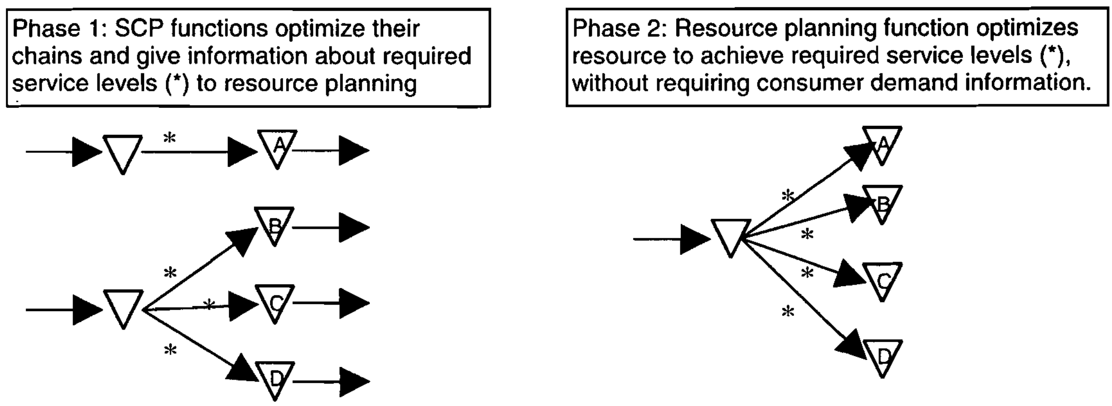

Figure 4. Between-Supply-Chain Coordination Through a Resource Planning Function

We have attempted to engineer such a solution for the case 'B+C+D' from section 6. In that case, retailer A outsourced its planning functions and retailers B, C, and D maintain an autonomous planning regime, demanding a 95% service level (fill rate) from their supplier. In the between-supply-chain coordination case, the manufacturer makes an additional resource planning decision, in which the inventory level at the manufacturer is optimized. Again, we used a search procedure that finds a solution, given the constraints on the service level. The procedure is similar in structure to the procedure applied in section 6. The results of this experiment are in Table 3.

Table 3. Inventory costs at various levels of outsourcing SCP.

Retailers Requiring a 95% Service Level	% of Total Demand under Outsourced Planning Control	Inventory at Manufacturer (I)	Inventory at Retailers under Autonomous Planning Control (II)	Inventory at Retailers under Outsourced Planning Control (III)	Total Inventory in System (I)+(II)+(III)
B+C+D	56	0	740	1058	1798

Note that the inventory at the manufacturer has reduced to zero. The inventory at retailer A needs to increase to 1058 to be able to maintain the 98% service level to the end customer. The inventory at the autonomous retailers remain about identical. Since the inventory of retailer A is considerably different from its inventory based on a separate chain model (as in Table 2), its demand data need to be communicated to the manufacturer in order to be able to reduce total system cost. Finally note that in this case the total system inventory is less than the inventory in the case when all retailers demand a 95% fill rate.

This section described between-supply-chain coordination. The objective of such coordination is to let supply chain planners make decisions that optimize the chain, but which are also acceptable for individual companies in the chain. Two different types of between-supply-chain coordination have been identified:
1. Mutual agreements between supply chains, who have private resources
2. Agreements between each supply chain and a resource planner, when separate supply chains share resources.

8. Conclusions

Current literature in multi-echelon inventory theory, production control, and information technology deals with SCP from a central perspective. The planning objectives are formulated at the level of the chain (e.g., service levels to customers of the chain, total supply chain profit/costs), all necessary information about units in the chain is available for the SCP function (e.g., demand, capacity, inventory of each unit), and the SCP function has the authority to make all planning decisions on behalf of the units in the chain. The accounting literature has started to examine the circumstances and contractual arrangements under which information exchange mechanisms and other elements of supply chain coordination are beneficial to each individual player in the value chain. We have called this the unit perspective, as opposed to the more common central perspective. The central perspective on SCP has been characterized as either "centralized" planning or "delegated" planning, depending on whether the planning function is executed centrally of locally. In this paper, we have discussed the consequences of the unit perspective for the use and development of operations control models rather than contractual arrangements, which typically cover a longer term horizon.

We have argued that units in a supply chain have their own objectives. These unit objectives may lead to barriers for unlimited exchange of information, and to companies not willing to transfer authority for making all planning decisions. New concepts for SCP are needed. To meet this need, we have introduced the concept of "outsourced" SCP. In outsourced SCP, individual units grant certain planning authority to a supply chain planner with full visibility of a particular supply chain. It is however not unlikely that there are instances in which the decision made by the supply chain planner do not line up with the interests of the individual unit having outsourced its decision authority. A particular supply chain decision or a supply chain policy may result in a lower performance of one of the units in the chain. Therefore, planning decisions made by the outsourced SCP function may not be acceptable for individual units in the chain. The most important issue linked to this conflict of interest lies in the fact that a unit is generally part of multiple, more or less independent supply chains. Allowing each of these supply chain planners to decide about a fraction of the resources of the unit, disregards the economies of scale that can be reached in the unit and which is directly related to the profit realized by the unit.

We have introduced the function of between-supply-chain coordination to achieve that decisions made by the SCP function are acceptable for all units in the chain. Between-supply-chain coordination should recognize the interests of individual units in the chain, without attempting to optimize an entire web of companies. Therefore, it vertically coordinates a number of goods flows, whereas the SCP function horizontally coordinates a goods flow. Two types of between-supply-chain coordination have been distinguished:

1. Direct coordination between supply chains with mutual agreements between supply chains. This is used when supply chains have private resources.
2. Indirect coordination with agreements between each supply chain and a resource planner. This is used when separate supply chains share resources.

Models to support between-supply-chain coordination need to have a number of characteristics. First, the model needs to be able to handle incompleteness of information. It is unlikely that there is complete transparence in the chain whereas at the same time all control is executed at unit level. Second, the model needs to be able to give the costs and benefits for the unit as opposed to the costs and benefits of the whole chain. Third, since the unit planner is likely to negotiate with the other units in the chain, the unit planner needs to have a complete view of the chain and, how limited the information may be, have some idea of the benefits and costs of some alternatives to the other parties in the chain.

The paper opens many new directions for future research. Current multi-echelon inventory models could be used to support the concept of outsourced planning, using various way of decomposition. Empirical research is also relevant to examine current practices regarding information exchange, division of decision authority, operational objectives. Furthermore, principle-agency theory and transaction cost theory might provide additional insights about the benefits of SCP decisions for individual units in the chain.

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