Supply Chain Management: An Overview

1

Hartmut Stadtler

What is the essence of *Supply Chain Management* (SCM)? How does it relate to Advanced Planning? In which sense are the underlying planning concepts "advanced"? What are the origins of SCM? These as well as related questions will be answered in this chapter.

1.1 Definitions

During the 1990s several authors tried to put the essence of SCM into a single definition. Its constituents are

- The object of the management philosophy
- The target group
- The objective(s)
- The broad means for achieving these objectives.

The object of SCM obviously is the *supply chain* which represents a "... network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer" (Christopher 2005, p. 17). In a broad sense a supply chain consists of two or more legally separated organizations, being linked by material, information and financial flows. These organizations may be firms producing parts, components and end products, logistic service providers and even the ultimate consumer (synonym: customer) himself. So, the above definition of a supply chain also incorporates the target group—the ultimate customer.

As Fig. 1.1 shows, a network usually will not only focus on flows within a (single) chain, but will have to deal with divergent and convergent flows within a complex

H. Stadtler (✉)
Institute for Logistics and Transport, University of Hamburg, Von-Melle-Park 5, 20146 Hamburg, Germany
e-mail: hartmut.stadtler@uni-hamburg.de

H. Stadtler, C. Kilger and H. Meyr (eds.), *Supply Chain Management and Advanced Planning*, Springer Texts in Business and Economics,
DOI 10.1007/978-3-642-55309-7_1, © Springer-Verlag Berlin Heidelberg 2015

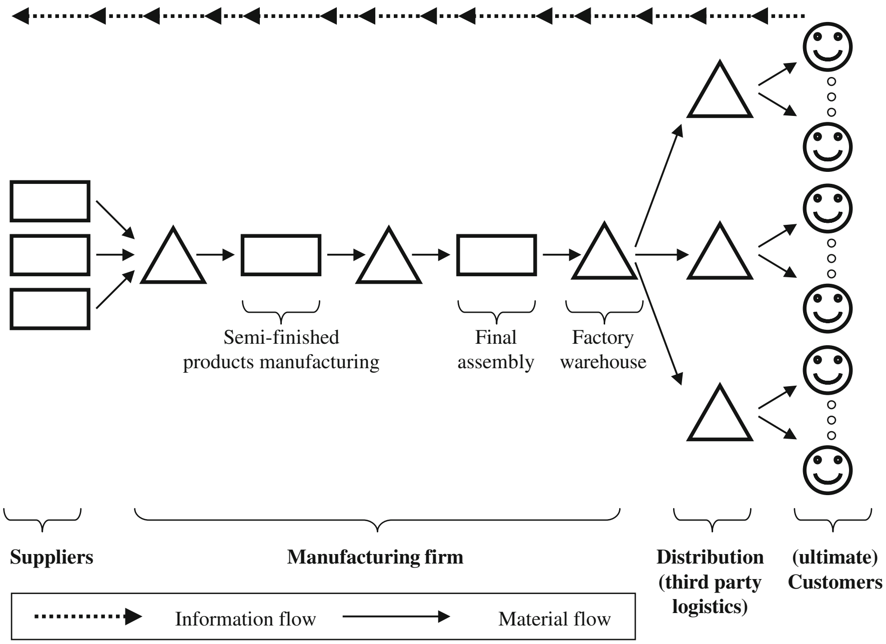

Fig. 1.1 Supply chain (example)

network resulting from many different customer orders to be handled in parallel. In order to ease complexity, a given organization may concentrate only on a portion of the overall supply chain. As an example, looking in the downstream direction the view of an organization may be limited by the customers of its customers while it ends with the suppliers of its suppliers in the upstream direction.

In a narrow sense the term supply chain is also applied to a large company with several sites often located in different countries. Coordinating material, information and financial flows for such a multinational company in an efficient manner is still a formidable task. Decision-making, however, should be easier, since these sites are part of one large organization with a single top management level. A supply chain in the broad sense is also called an *inter-organizational* supply chain, while the term *intra-organizational* relates to a supply chain in the narrow sense. Irrespective of this distinction, a close cooperation between the different functional units like marketing, production, procurement, logistics and finance is mandatory—a prerequisite being no matter of course in today's firms.

The objective governing all endeavors within a supply chain is seen as increasing competitiveness. This is because no single organizational unit now is solely responsible for the competitiveness of its products and services in the eyes of the ultimate customer, but the supply chain as a whole. Hence, competition has shifted from single companies to supply chains. Obviously, to convince an individual company to become a part of a supply chain requires a *win-win situation* for each participant in the long run, while this may not be the case for all entities in the short run. One generally accepted impediment for improving competitiveness is to provide superior customer service which will be discussed in greater detail below (Sect. 1.2.1). Alternatively, a firm may increase its competitiveness by fulfilling a prespecified, generally accepted customer service level at minimum costs.

There are two broad means for improving the competitiveness of a supply chain. One is a closer *integration* (or cooperation) of the organizations involved and the other is a better *coordination* of material, information and financial flows (Lee and Ng 1998, p. 1). Overcoming organizational barriers, aligning strategies and speeding up flows along the supply chain are common subjects in this respect.

We are now able to define the term *Supply Chain Management* as the task of integrating organizational units along a supply chain and coordinating material, information and financial flows in order to fulfill (ultimate) customer demands with the aim of improving the competitiveness of a supply chain as a whole.[1,2]

1.2 Building Blocks

The *House of SCM* (see Fig. 1.2) illustrates the many facets of SCM. The roof stands for the ultimate goal of SCM—competitiveness—customer service indicates the means. Competitiveness can be improved in many ways, e.g. by reducing costs, increasing flexibility with respect to changes in customer demands or by providing a superior quality of products and services.

The roof rests on two pillars representing the two main components of SCM, namely the integration of a network of organizations and the coordination of information, material and financial flows. The figure also shows that there are many disciplines that formed the foundations of SCM.

The two main components which incur some degree of novelty, will now be broken down into their building blocks. Firstly, forming a supply chain requires the *choice of suitable partners* for a mid-term partnership. Secondly, becoming an effective and successful *network organization*, consisting of legally separated organizations calls for actually practicing *inter-organizational collaboration*. Thirdly,

[1]Our definition largely corresponds with that of the Council of Supply Chain Management Professionals (CSMP) stating that "Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model" (The Council of Supply Chain Management Professionals 2013, p. 187).

[2]A definition of Supply Chain Management which is very close to the mission of logistics is proposed by Simchi-Levi et al.: "Supply Chain Management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs while satisfying service level requirements" (Simchi-Levi et al. 2008, p. 1).

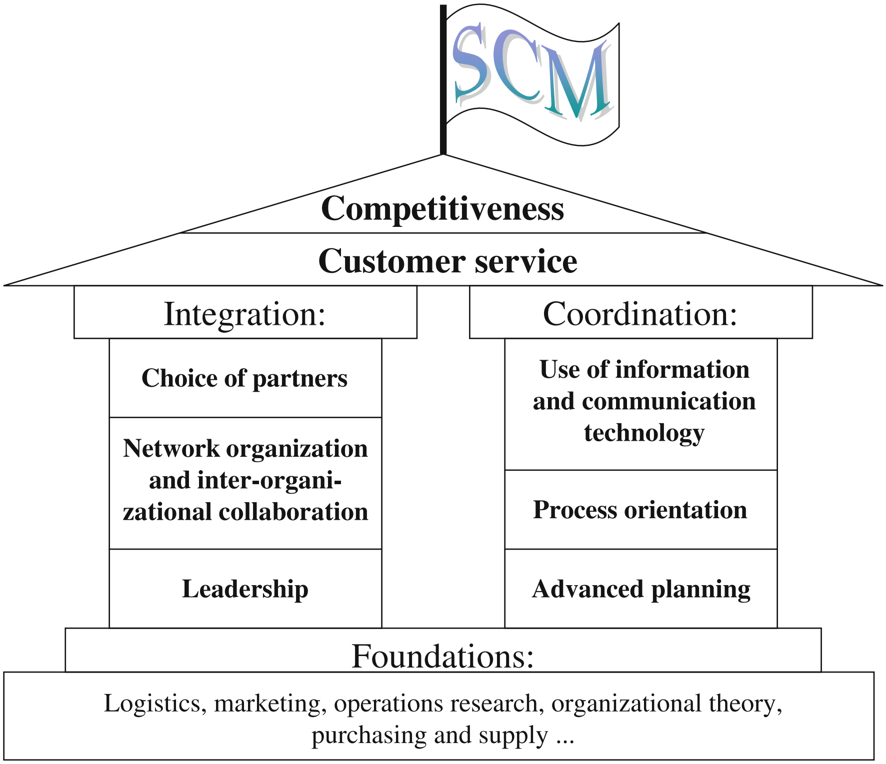

Fig. 1.2 House of SCM

for an inter-organizational supply chain, new concepts of *leadership* aligning strategies of the partners involved are important.

The coordination of flows along the supply chain can be executed efficiently by utilizing the latest developments in *information and communication technology*. These allow processes formerly executed manually to be automated. Above all, activities at the interface of two entities can be scrutinized, while duplicate activities (like keying in the data of a consignment) can be reduced to a single activity. *Process orientation* thus often incorporates a redesign followed by a standardization of the new process.

For executing customer orders, the availability of materials, personnel, machinery and tools has to be planned. Although production and distribution planning as well as purchasing have been in use for several decades, these mostly have been isolated and limited in scope. Coordinating plans over several sites and several legally separated organizations represents a new challenge that is taken up by *Advanced Planning* (Systems).

Subsequently, we will describe the house of SCM in greater detail, starting with the roof, followed by its two pillars and ending with some references to its foundations.

1.2.1 Customer Service

Customer service is a multi-dimensional notion. According to a survey conducted by LaLonde and Zinszer (cited in Christopher 2005, p. 48) there are three elements of customer service:

- Pre-transaction
- Transaction
- Post-transaction elements.

Some of these elements will be illustrated in the following text.

Pre-transactional elements relate to a company's activities preceding a contract. They concern customer access to information regarding the products and services a firm offers and the existence of an adequate link between organizations involved. Obviously, for standard products ordered routinely (like screws), an impersonal purchase via the Internet may be sufficient. Large projects, however, like a construction of a business building will require several, intense personal links between the organizations involved at different levels of the hierarchy. Finally, flexibility to meet individual customer requirements may be an important element for qualifying for and winning an order.

Transactional elements are all those which contribute to order fulfillment in the eyes of a customer. The availability of products (from stock) may be one option. If a product or service has to be made on demand, order cycle times play an important role. During delivery times a customer may be provided with information on the current status and location of an order. The delivery of goods can include several additional services, like an introduction into the use of a product, its maintenance, etc.

Post-transactional elements mostly concern the service provided once the order is fulfilled. This includes elements like repairing or exchanging defective parts and maintenance, the way customer complaints are dealt with and product warranties (Christopher 2005, p. 50).

For measuring customer service and for setting targets, key performance indicators are used in practice, such as the maximum order lead time, the portion of orders delivered within x days, the portion of orders without rejects or the fill rate (for details see Sect. 2.3 and Silver et al. 1998, p. 243).

If a certain level or standard of customer service has been agreed upon, it must be broken down so that each entity of the supply chain knows how to contribute to its achievement. Consider order lead times offered to customers as an example (Fig. 1.3).

Assume a delivery time of 9 days has to be offered to customers. Now, following each activity upstream in the supply chain with its expected lead times for information and material flows, it becomes clear, where the *decoupling point*

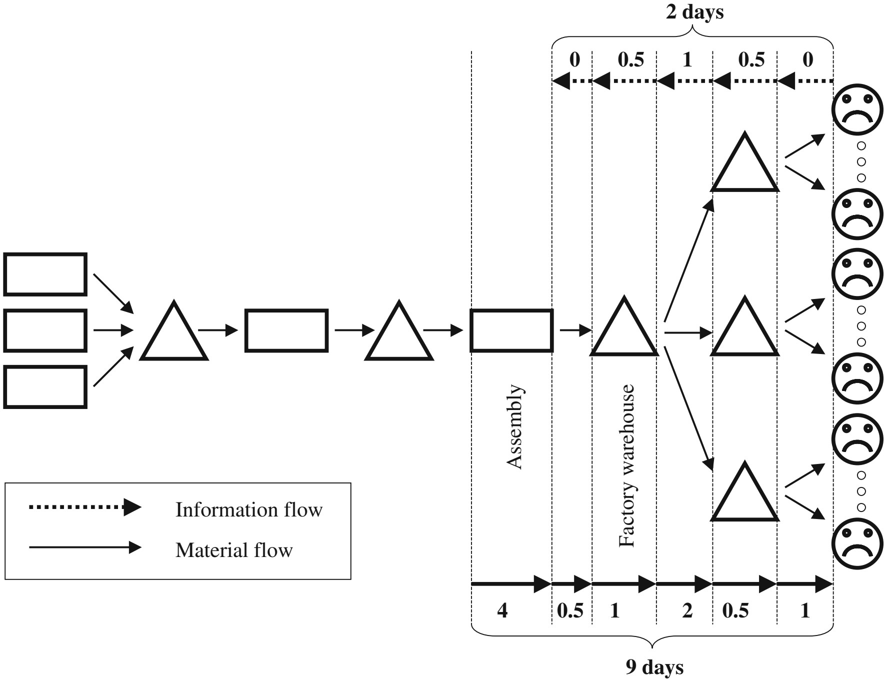

Fig. 1.3 Order lead time and decoupling point

between the two options production-to-stock and production-to-order currently can be located. Since the actual lead times for assembly totals 11 days, this would require to assemble-to-stock.

Stocks held at the decoupling point incur costs and increase overall throughput times. A decoupling point requires that no customized items or components have to be produced upstream. Ideally, items produced on stock have a large commonality so that they can be used within several products. This will reduce the risk of holding the “wrong” stocks, if there is an unexpected shift in products’ demand.

If accumulated lead times of customer specific parts exceed expected delivery times, the supply chain as a whole—perhaps including key customers—has to look for either reducing lead times for material or for information flows (e.g. transferring orders by electronic means may save 1 day while an additional day may be saved by advanced scheduling techniques at the assembly plant, thereby allowing to *assemble-to-order* while suppliers *manufacture-to-stock*).

1.2.2 Integration

As has been stated above, a supply chain in the broad sense consists of several legally separated firms collaborating in the generation of a product or service with the aim of improving the competitiveness of a supply chain as a whole. Integration refers to the special building blocks that cause these firms to collaborate in the long term, namely

- Choice of partners
- Network organization and inter-organizational collaboration
- Leadership.

The *choice of partners* starts with analyzing the activities associated with generating a product or service for a certain market segment (see also Chap. 2). Firstly, activities will be assigned to existing members of a supply chain, if these relate to their core competencies. Secondly, activities relating to standard products and services widely available on the market and with no potential of differentiation in the eyes of the ultimate customers, will be bought from outside the supply chain. Thirdly, for all remaining activities, a partner to join the supply chain has to be looked for in the course of a make-or-buy decision procedure (Schneider et al. 1994).

Selection criteria should not be based solely on costs, but on the future potential of a partner to support the competitiveness of the supply chain. A suitable organizational culture and a commitment to contribute to the aims of the supply chain will be of great importance. A possible partner may bring in specialized know-how regarding a production process or know-how of products and their development. In case of a global supply chain, additional criteria have to be considered (like taxes, exchange rates, etc., see Chap. 6).

The assignment of activities to those members within the supply chain who can perform them best as well as the ability to adapt the structure of a supply chain quickly according to market needs are seen as a major advantage compared with traditional hierarchies.

From the perspective of organizational theory, supply chains are a special form of a *network organization*. They consist of loosely coupled, independent actors with equal rights. Their organizational structure is adapted dynamically according to the tasks to be performed and the aims of the network organization as a whole (Hilse et al. 1999; Sydow 2005, p. 30). A supply chain may be regarded as a single (virtual) entity by its customers. The term virtual firm, however, is used for a network of firms collaborating only in the short term, sometimes only for fulfilling a single customer order.

Inter-organizational collaboration is a necessity for an effective supply chain. A supply chain is regarded as a cross between a pure market interaction and a hierarchy. It tries to combine the best features of the two. Ideally, each entity within a supply chain will concentrate on its core competencies and will be relieved from stringent decision procedures and administrative routines attributed to a large hierarchy. Information and know-how is shared openly among members. Competition among members along the supply chain is substituted by the commitment to improve competitiveness of the supply chain as a whole. A risk still remains, however, that collaboration is canceled at some time. These features are assumed to enhance innovativeness and flexibility with respect to taking up new market trends (Burns and Stalker 1961, p. 121).

Although legally independent, entities within a supply chain are economically dependent on each other. Obviously, the structure of a supply chain will remain stable, only if there is a win-win situation for each member—at least in the long run. If this is not achieved in the short term by usual price mechanisms, compensation schemes must be looked for. To enforce the coherence of supply chain members several types of bonds may be used. These are

- "Technical bonds which are related to the technologies employed by the firms
- Knowledge bonds related to the parties' knowledge about their business
- Social bonds in the form of personal confidence
- Administrative bonds related to the administrative routines and procedures of the firms
- Legal bonds in the form of contracts between the firms" (Håkansson and Johanson 1997, p. 462).

An additional bond may be introduced by exchanging contributions to capital. Bonds must be practiced continuously to build up a certain degree of trust—the basis of a long-term partnership. In the case of a global supply chain special attention has to be paid to inter-cultural business communications (Ulijn and Strother 1995).

Leadership, being the third building block of integration, is a delicate theme in light of the ideal of self-organizing, poly-centric actors forming a supply chain. At least some decisions should be made for the supply chain as a whole, like the cancellation of a partnership or the integration of a new partner. Similarly, aligning strategies among partners may require some form of leadership (as an example see Rockhold et al. 1998).

In practice, leadership may be executed either by a focal company or a steering committee. A *focal company* is usually a member having the largest (financial) power, the best know-how of products and processes or has the greatest share of values created during order fulfillment. In some cases, the focal company may also be the founder of a supply chain. For these reasons, decisions made by the focal company will be accepted by all members. On the other hand, a *steering committee* may be introduced, consisting of representatives of all members of a supply chain. The rules of decision-making—like the number of votes per member—are subject to negotiations.

Despite the advantages attributed to a supply chain, one should bear in mind that its structure is vulnerable—the exit of one partner may jeopardize the survival of the supply chain as a whole. Also, a member may run the risk of becoming unattractive and of being substituted by a competitor once his know-how has been dispensed within the supply chain.

Last but not least, the coordination of activities across organizations must not exceed comparable efforts within a hierarchy. In light of the latest developments in information and communication technology as well as software for planning material flows, this requirement has now been fulfilled to a large extent.

1.2.3 Coordination

The coordination of information, material and financial flows—the second main component of SCM—comprises three building blocks:

- Utilization of information and communication technology
- Process orientation
- Advanced planning.

Advances in *information technology* (IT) made it possible to process information at different locations in the supply chain and thus enable the application of advanced planning. Cheap and large storage devices allow for the storage and retrieval of historical mass data, such as past sales. These Data Warehouses may now be used for a better analysis of customer habits as well as for more precise demand forecasts. Graphical user interfaces allow users to access and manipulate data more easily.

Communication via electronic data interchange (EDI) can be established via private and public nets, the most popular being the Internet. Members within a supply chain can thus be informed instantaneously and cheaply. As an example, a sudden breakdown of a production-line can be distributed to all members of a supply chain concerned as a so-called alert.

Rigid standards formerly introduced for communication in special lines of businesses (like ODETTE in the automotive industry) are now being substituted by more flexible meta-languages (like the extensible markup language (XML)).

Communication links can be differentiated according to the parties involved (Corsten and Gössinger 2008): business (B), consumer (C) or administration (A). Two communication links will be discussed here:

Business-to-Business (B2B) communications allow companies to redesign processes, like that of purchasing. Manual tasks, e.g. placing an order for a standard item, can now be taken over by computer. It then controls the entire process, from transmitting the order, order acceptance by the supplier and order execution, until the consignment is received and checked. Finally, the amount payable is transferred to the supplier's account automatically. Automated purchasing allowed the Ford Motor Company to reduce its staff in the purchasing function drastically (Hammer and Champy 2003, p. 57). Other advantages stem from increased speed and reduced errors.

Furthermore, firms can make use of Internet based marketplaces, also called e-hubs (Kaplan and Sawhney 2000). These marketplaces can be distinguished by four characteristics:

- The specificity of goods (either being manufacturing or operating inputs)
- The duration of the relationship (discriminated by systematic or spot sourcing)
- The pricing mechanism (with either fixed prices, e.g. an electronic catalog, or price negotiations in the form of an auction)
- The bias of an e-hub, which may favor either the seller, the buyer or take a neutral position.

Due to the global access to the Internet, not only strong competition and reduced purchasing prices may result, but also new sales opportunities. Note that market places play a role especially at the interface between two or more supply chains while the coordination of flows among different companies within a supply chain is supported by collaborative planning (see Chap. 14).

Business-to-Consumer (B2C) communications aim at approaching the individual end user via the Internet. Several challenges have to be addressed here, like a user-friendly access to information regarding products and services, securing safety of payments and finally the transport of goods or services to the customer. B2C opens up a further marketing channel to end users and offers a means for incorporating end users within a supply chain.

The second building block, *process orientation*, aims at coordinating all the activities involved in customer order fulfillment in the most efficient way. It starts with an analysis of the existing supply chain, the current allocation of activities to its members. Key performance indicators can reveal weaknesses, bottlenecks and waste within a supply chain, especially at the interface between its members. A comparison with best practices may support this effort (for more details see Chap. 2). As a result, some activities will be subject to improvement efforts, while some others may be reallocated. The building block "process orientation" has much in common with business process reengineering (Hammer and Champy 1993); however, it will not necessarily result in a radical redesign. As Hammer (2001, p. 84) puts it, "streamlining cross-company processes is the next great frontier for reducing costs, enhancing quality, and speeding operations."

Advanced planning—the third building block—incorporates long-term, mid-term and short-term planning levels. Software products—called *Advanced Planning Systems*—are now available to support these planning tasks. Although an Advanced Planning System (APS) is separated into several modules, effective information flows between these modules should make it a coherent software suite. Customizing these modules according to the specific needs of a supply chain requires specific skills, e.g. in systems and data modeling, data processing and solution methods.

APS do not substitute, but supplement existing *Enterprise Resource Planning* (ERP) systems. APS now take over the planning tasks, while an ERP system is still required as a transaction and execution system (for orders). The advantages of the new architecture have to be viewed in light of well-known deficiencies of traditional ERP systems with regard to planning (Drexl et al. 1994). In essence, an ERP system models the different planning tasks inadequately. Furthermore, these planning tasks are executed sequentially, without allowing for revisions to upper-level decisions. Some tasks, like bill of materials processing (BOMP), do not consider capacities at all. Furthermore, lead times are used as a fixed input for the BOMP, even though it is common knowledge that lead times are the result of planning. It is not surprising that users of ERP systems complain about long lead times and many orders exceeding dead lines. Also, production planning and distribution planning are more or less separated systems. Last but not least, the focus of ERP systems has been a single firm, while APS have been designed also for inter-organizational supply chains.

Although separated in several modules, APS are intended to remedy the defects of ERP systems through a closer integration of modules, adequate modeling of bottleneck capacities, a hierarchical planning concept and the use of the latest algorithmic developments. Since planning is now executed in a computer's core storage, plans may be updated easily and continuously (e.g. in the case of a breakdown of a production line).

Planning now results in the capability to realize bottlenecks in advance and to make the best use of them. Alternative modes of operations may be evaluated, thus reducing costs and improving profits. Different scenarios of future developments can be planned for in order to identify a robust next step for the upcoming planning interval. Furthermore, it is no longer necessary to provide lead time estimates as an input for planning. This should enable companies using APS to reduce planned lead times drastically compared with those resulting from an ERP system.

A most favourable feature of APS is seen in its ability to check whether a (new) customer order with a given due date can be accepted (ATP, see Chap. 9). In case there are insufficient stocks at hand, it is even possible to generate a tentative schedule, inserting the new customer order into a current machine schedule where it fits best. Obviously, these new features allow a supply chain to comply better with accepted due dates, to become more flexible and to operate more economically.

We would like to add that proposals for a better integration of organizational units cannot be separated from the notion of the coordination of flows and vice versa. The choice of partners in a supply chain or the effectiveness of a postponement strategy can best be evaluated by advanced planning. On the other hand, the structure of a network organization sets up the frame for optimizing flows within a supply chain.

1.2.4 Relating SCM to Strategy

According to Porter (2008, p. 53) a "strategy is the creation of a unique and valuable position, involving a different set of activities." A company can obtain a unique and valuable position by either performing different activities than its rivals or by performing similar activities in different ways.

This can best be demonstrated by means of an example. The IKEA company has focused on the home furnishing needs of a specific customer group. The target group is price-sensitive and prepared to do its own pickup and delivery as well as the final assembly. IKEA's activities have been created according to these customer needs, which also have influenced the products' design and the structure of the SC. For instance, IKEA's showroom and warehouse are under one roof. A more precise description of the activities relating to IKEA's strategic position is given by the following activity-system map (see Fig. 1.4).

Here, activities, like "self assembly by customers", are exhibited as well as the major links between dependent activities. For instance, "inhouse product design focused on cost of manufacturing" together with "100 % sourcing from long term suppliers" directly contribute to "low manufacturing cost". Shaded activities represent high-order strategic themes. IKEA's activity-system map also demonstrates that there are usually many interacting activities contributing to an overall strategy.

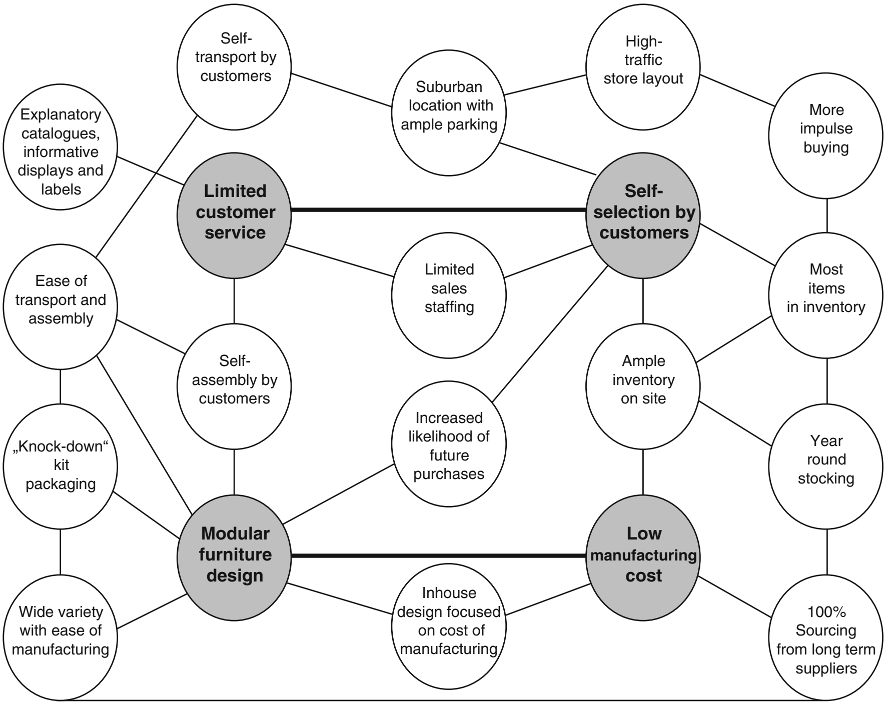

Fig. 1.4 Activity-systems map describing IKEA's strategic position (Porter 2008, p. 48)

Another important part of strategy is the creation of fit among a SC's activities. "The success of a strategy depends on doing many things well—not just a few—and integrating among them" (Porter 2008, p. 62). A given strategy will be successful only if all these activities will be aligned, or even better, if they reinforce each other.

The highest level of fit between all these activities—called optimization of effort (Porter 2008, p. 60)—is reached when there is coordination and information exchange across activities to eliminate redundancy and minimize wasted effort.

Now recall that SCM has been defined as integrating organizational units along a SC and coordinating activities related to information, material and financial flows. Hence, SCM is *not* a strategy on its own. Instead, SCM can and should be an integral part of a SC's strategy as well as the individual partners' business strategies. For example,

- SCM is an approach for generating competitive advantage by integrating organizational units and coordinating flows.
- SCM comprises specific activities, especially those concerning the order fulfillment process, which may be part of a SC's strategy.
- SCM utilizes specific tools best suited to reach the aspired level of fit among all strategic activities of a given SC.

There are a number of excellent textbooks (e.g. Aaker 2001) on generating a strategy for an intra-organizational SC (company), which we will not review in detail here. In summary two main lines of thought prevail:

- The resource-based view
- The market-based view.

A resource can be "…all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. , controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness" (Barney 1991, p. 101). The focus here is on developing the resources' potentials.

Considering the market-based view (Porter 2008, p. 2) an industry—usually consisting of several markets—is looked for, where the company can best exist against *competitive forces* given by

- Industry competitors
- Potential entrants
- Power of buyers and suppliers or
- New product or service substitutes.

As one might expect the two views are not antagonistic but rather complement each other. For a deeper understanding the reader is referred to two case studies describing the generation of SC strategies in the apparel (Berry et al. 1999) and the lighting industry (Childerhouse et al. 2002).

Note, that creating and implementing a strategy within a single corporation may already be a difficult task, but it will be even more challenging in an inter-organizational SC. Namely, strategies of individual partners have to be aligned with the SC's overall strategy. In an inter-organizational SC further issues have to be addressed. Some of these, like the fit of companies, have already been discussed as part of the pillar "integration" of the House of SCM (see Sect. 1.2.2). Now, when formulating a SC-wide strategy, aspiration levels for the different issues of integration have to be added as well as (rough) paths for their achievement.

Even if contracts are binding SC partners, a SC is vulnerable and only created for a limited period of time. Hence, it seems wise to take into account and prepare "emergency plans" in case of separation. These may require

- Good relations to alternative suppliers and customers currently not part of the SC, enabling a company (or SC) to become part of another SC
- The installation of flexible (production) capacities that may also be used in another SC
- Engaging in several SCs to balance risks.

We would like to add that the discussion of strategies in the literature is dominated by the premise of pure competition. In the area of SCM, strategies for *collaboration* come into play. One of the difficulties is in finding a fair compromise of the sometimes diverging interests among SC partners. As an example consider the setting of fair *transfer prices* for products and services among SC partners. Given a fixed sales price the ultimate consumer is willing to pay for the end-product an increase of the transfer price granted to one SC member will incur a "loss" for

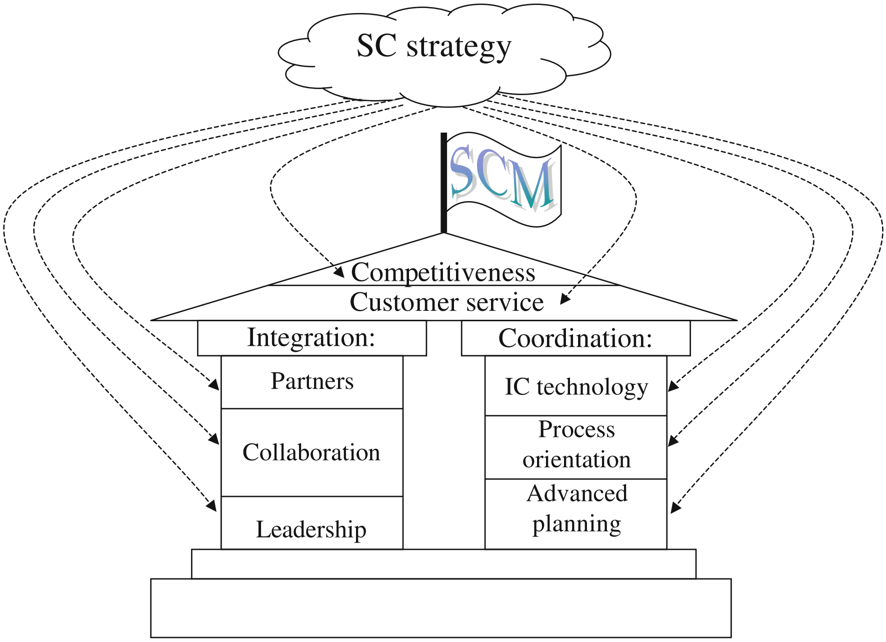

Fig. 1.5 The impact of a SC's strategy on the building blocks of SCM

the others. Furthermore, SC partners must be concerned that decentral investment decisions are made for the benefit of the SC as a whole, which may require specific subsidies, incentives or guarantees by the other SC partners.

Since generally applicable rules for calculating fair transfer prices or compensations are still missing (proposals for special situations can be found in Cachon and Lariviere 2005; Dudek 2009; Pfeiffer 1999), negotiations come into play in practice. These become even more delicate if SC partners are reluctant to reveal their (true) cost structure and if the power of SC partners governs the outcome of negotiations.

Collaboration may also exist among competing SCs, e.g. in product distribution to consolidate consignments for the same destination (as in the food industry Fleischmann 1999) or in combining demands for standard parts to increase the purchasing power (as in the automobile industry).

By now it should be clear that a favorable SC strategy always has to be specific in considering a SC's potentials. Copying recipes drawn from *benchmarking studies* or an analysis of *success factors* (see e.g. Fröhlich and Westbrook 2001; Jayaram et al. 2004; Fettke 2007) may be a good starting point but will not result in a unique and valuable position. In any case, a SC's strategy will guide the specific design of building blocks best serving a SC's needs (see Fig. 1.5).

For those interested in learning more about the first ideas and publications having influenced our current view of SCM, a section about its origins follows.

1.2.5 Foundations

For operating a supply chain successfully, many more ingredients are needed than those that have been reported in the literature in recent years in subjects like

- Logistics and transportation
- Marketing
- Operations research
- Organizational behavior, industrial organization and transaction cost economics
- Purchasing and supply
- ...

to name only a few (for a complete list see Croom et al. 2000, p. 70).

Certainly there are strong links between SCM and logistics, as can be observed when looking at the five principles of logistics thinking (Pfohl 2010, p. 20):

- Thinking in values and benefits
- Systems thinking
- Total cost thinking
- Service orientation
- Striving for efficiency.

Thinking in terms of values and benefits implies that it is the (ultimate) customer who assigns a value to a product. The value and benefit of a product can be improved with its availability when and where it is actually needed. Systems thinking requires examination of all entities involved in the process of generating a product or service simultaneously. Optimal solutions are aimed at the process as a whole, while being aware that optimal solutions for individual entities may turn out to be suboptimal. All activities are oriented towards a given service level. Service orientation is not limited to the ultimate customer, but also applies to each entity receiving a product or service from a supplier. Efficiency comprises several dimensions. The technological dimension requires the choice of processes, which results in a given output without wasting inputs. Furthermore, decision-making will be guided by economical goals, relating to current profits and future potentials. These two dimensions will be supplemented by a social and ecological dimension.

Another subject, operations research, has contributed to the model building and model solving required for coordinating flows along the supply chain. The basics of model building have already been developed in the 1960s and 1970s. However, only with the rise of powerful computers, large in-core storage devices and the availability of adequate solution methods, like Mathematical Programming and powerful meta-heuristics (e.g. genetic algorithms and tabu search), are these models now solvable with reasonable computational efforts (see Part VI).

Note that the vast body of literature on SCM has concentrated so far on the *integration* of inter-organizational supply chains. However, with regard to the *coordination* of flows, efforts still concentrate on intra-organizational supply chains. While it will not be too difficult to apply APS to an inter-organizational supply chain with a central planning unit, new challenges arise in decentralized planning (like the availability of data required for planning, coordinating plans, compensation schemes, etc.). Recalling that ERP systems only incorporate unconnected, insufficient analytical models (like for single level, uncapacitated lot-sizing), APS—even for intra-organizational supply chains—represent great progress. So, the term *advanced* in APS has to be evaluated in view of the insufficient decision support offered by ERP systems until now.

For those interested in learning more about the first ideas and publications that have influenced our current view of SCM, a section about its origins will follow.

1.3 Origins

The term SCM has been created by two consultants, Oliver and Webber, as early as 1982. The supply chain in their view lifts the mission of logistics to become a top management concern, since "...only top management can assure that conflicting functional objectives along the supply chain are reconciled and balanced ...and finally, that an integrated systems strategy that reduces the level of vulnerability is developed and implemented" (Oliver and Webber 1992, p. 66). In their view, coordinating material, information and financial flows within a large multi-national firm is a challenging and rewarding task. Obviously, forming a supply chain out of a group of individual companies so that it acts like a single entity is even harder.

Research into the integration and coordination of different functional units started much earlier than the creation of the term SCM in 1982. These efforts can be traced back in such diverse fields as logistics, marketing, organizational theory, operations management and operations research. Selected focal contributions are briefly reviewed below without claiming completeness (for further information see Ganeshan et al. 1998). These contributions are

- Channel research (Alderson 1957)
- Collaboration and cooperation (Bowersox 1969)
- Location and control of inventories in production-distribution networks (Hanssmann 1959)
- Bullwhip effect in production-distribution systems (Forrester 1958)
- Hierarchical production planning (Hax and Meal 1975).

1.3.1 Channel Research

Alderson (1957) put forward *channel research* as a special field of marketing research. He had already argued that the principles of *postponement* require that "...changes in form and identity occur at the latest possible point in the marketing flow; and changes in inventory location occur at the latest possible point in time" (Alderson 1957, p. 424). Postponement serves to reduce market risk, because the product will stay in an undifferentiated state as long as possible allowing to better cope with unexpected market shifts. Also postponement can reduce transportation costs, since products will be held back in the supply chain as far as possible (e.g. at the factory warehouse) until they are actually needed downstream (e.g. at a distribution center) thereby reducing the need for the transport of goods between distribution centers in the case of a shortage of goods or an imbalance in the distribution of stocks. Thirdly, when examining the postponability of a (production) step, it might be discovered that it can be eliminated entirely, i.e. "…if a step is not performed prematurely, it may never have to be performed" (Alderson 1957, p. 426). As an example, Alderson reported on the elimination of bagging wheat in sacks. Instead, a truck with an open box body had been chosen.

The three principles of postponement are still applied today. With regard to elimination, we can see that customers pick their goods directly from pallets thus eliminating the need for the retailer to put the goods on shelves. Another example are the customers of IKEA, who perform the assembly of furniture by themselves.

However, one should bear in mind that postponement in product differentiation requires that a product has already been designed for it, i.e. modifying a product to become customer specific should both be possible technically and economically later on. The capability of assessing the effects of postponement in a supply chain wide context is the achievement of advanced planning today. Thus, the different alternatives of postponement had been analyzed and simulated before Hewlett Packard introduced postponement successfully for its deskjet printer lines (Lee and Billington 1995).

1.3.2 Collaboration and Coordination

Bowersox (1969) described the state of knowledge in marketing, physical distribution and systems thinking. There had already been an awareness that the individual objectives of the different functional units within a firm may counteract overall efficiency. For example (Bowersox 1969, p. 64):

- Manufacturing traditionally desires long production runs and the lowest procurement costs.
- Marketing traditionally prefers finished goods inventory staging and broad assortments in forward markets.
- Finance traditionally favors low inventories.
- Physical distribution advocates total cost considerations relating to a firm's physical distribution mission.

Long production runs reduce the setup costs per product unit while resulting in higher inventory holding costs. Similarly, end product inventories allow short delivery times, but increase inventory holding costs. On the other hand, raw materials and parts used up in the production of end products may no longer be used within other end products, thus limiting the flexibility to cope with shifts in end product demands (see postponement).

Furthermore, Bowersox criticized the fact that physical distribution systems mainly have been studied from the vantage point of vertically integrated organizations. "A more useful viewpoint is that physical distribution activities and related activities seldom terminate when product ownership transfer occurs" (Bowersox 1969, p. 65). If the interface between two or more physical distribution systems is not properly defined and synchronized, this "…may well lead to excessive cost generation and customer service impairment" (Bowersox 1969, p. 67).

Although arguing from the viewpoint of physical distribution, Bowersox had already advocated a need for intra-organizational as well as inter-organizational *cooperation and coordination*.

1.3.3 Location and Control of Inventories in Production-Distribution Networks

Hanssmann (1959) was the first to publish an analytical model of interacting inventories in a supply chain with three serial inventory locations. At each location a periodic review, order-up-to-level inventory system is used. There are positive lead times, which are integer multiples of the review period. Customer demands are assumed to be normally distributed. Decision support is provided for two cases: the location of inventory, if only one single inventory location is allowed in the supply chain and the control of inventories if all three inventory locations may be used. Shortage costs and inventory holding costs are considered as well as revenues from sales which are assumed to be a function of delivery time. As a solution method, dynamic programming is proposed.

The location and allocation of inventories in serial, convergent and divergent supply chains is still an important topic of research today.

1.3.4 Bullwhip Effect in Production-Distribution Systems

The *bullwhip effect* describes the increasing amplification of orders and inventory occurring within a supply chain the more one moves upstream. Surprisingly, this phenomenon also occurs even if end item demand is fairly stable. This phenomenon will be explained more deeply, since it is regarded as a classic of SCM.

Already in 1952 Simon (1952) discovered the bullwhip effect. A few years later, Forrester (1958) analyzed the dynamic behavior of production control in industrial production-distribution systems intensively. The simplest system studied is a supply chain made of a retailer, a distribution center, a factory warehouse and a production site (Fig. 1.6). Each entity can only make use of locally available information when making its ordering decisions for coping with demands. Another important feature are time delays between decision-making (e.g. ordering) and its realization (e.g. receipt of the corresponding shipment). These delays are indicated in Fig. 1.6 as numbers on top of respective arcs (measured in weeks). The assumption is that a customer order comes in. Then the retailer requires 1 week to deliver it from stock. The lead time between an incoming customer order and the decision to replenish inventory is 3 weeks (including processing the order), while order transmission to the distribution center takes another half week. The distribution center requires 1 week to process the order, while shipping the order to the retailer takes another week. Thus, five and a half weeks pass from an incoming customer order until the

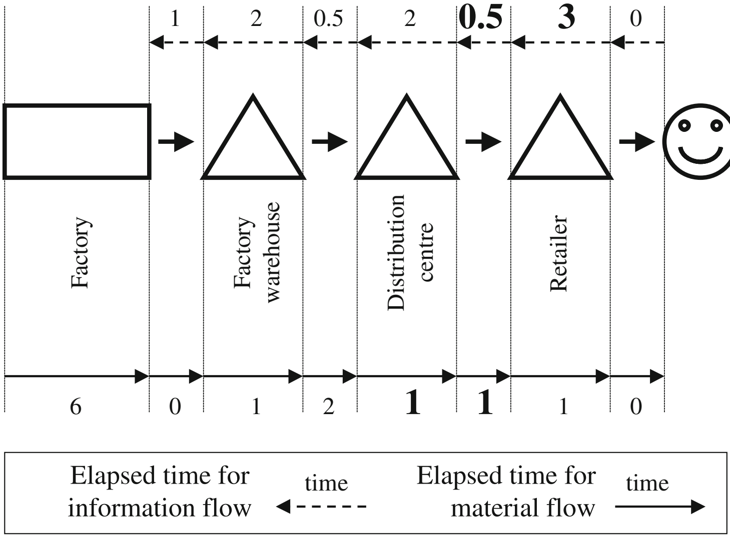

Fig. 1.6 Supply chain modeled by Forrester (1961, p. 22)

replenishment of the retailer's inventory (see Fig. 1.6: sum of bold numbers). Further lead times for upstream entities can be derived in the same way from Fig. 1.6.

Forrester has shown the effects of a single, sudden 10 % increase in retail sales on orders placed and inventory levels of each entity in the supply chain (see Fig. 1.7). He concludes (Forrester 1961, p. 25) that "…orders at factory warehouse reach, at the 14th week, a peak of 34 % above the previous December" and "…the factory output, delayed by a factory lead time of 6 weeks, reaches a peak in the 21st week, an amount 45 % above the previous December." Obviously, these amplified fluctuations in ordering and inventory levels result in avoidable inventory and shortage costs and an unstable system behavior. Although the time unit of 1 week seems outdated nowadays, replacing it by a day may reflect current practices better and will not disturb the structure of the model. These so-called information-feedback systems have been studied extensively with the help of a simulation package (DYNAMO).

In order to show the relevance of the work of Forrester on today's topics in SCM, we will add some newer findings here.

The introduction of the so-called *beer distribution game*, by Sterman (1989), has drawn great attention from researchers and practitioners alike to study the bullwhip effect again. Looking at an industrial production-distribution system from the perspective of bounded human rationality, Sterman studied the ordering behavior of individuals possessing only isolated, local information.

In such an environment, where an individual's knowledge is limited to its current inventory status, the actual amount ordered by its direct successors in the supply chain and knowledge about its past performance, a human being tends to overreact by an amplification of orders placed. Even worse, amplification and phase lags of

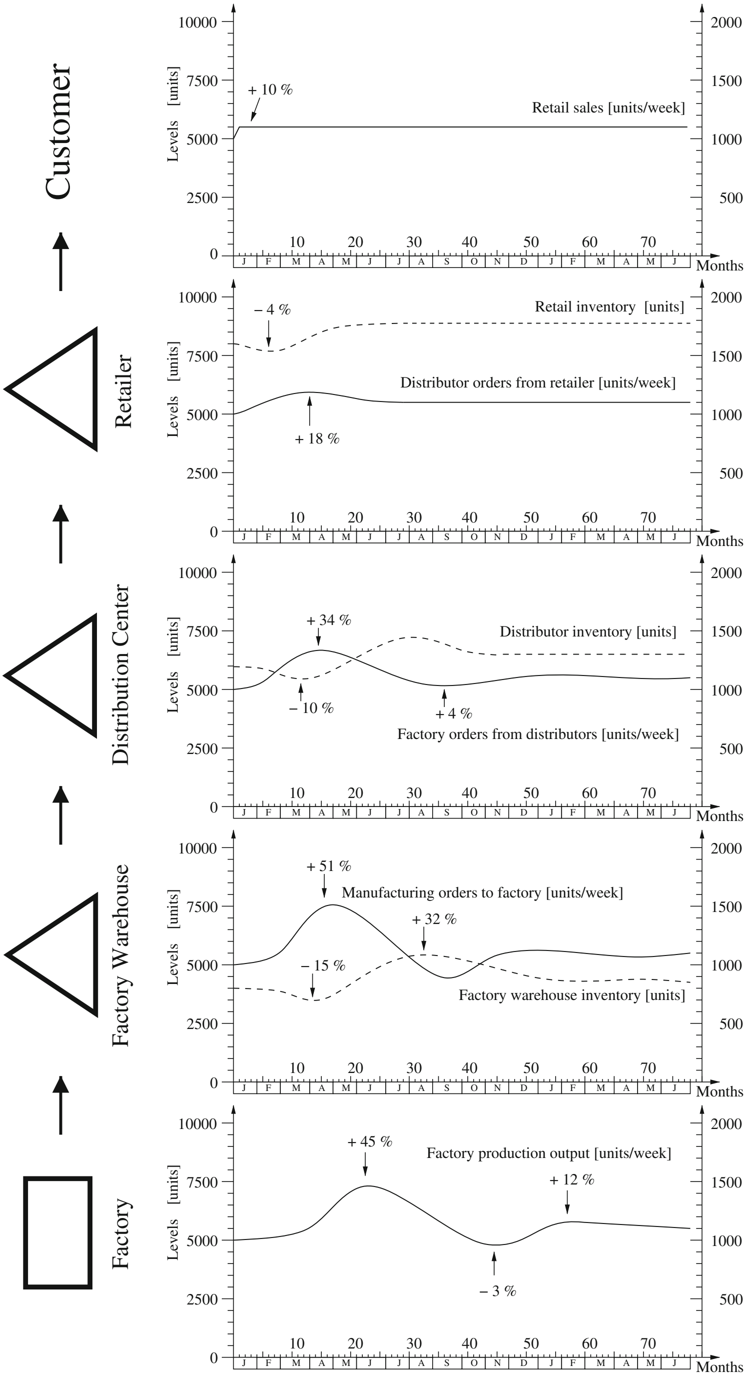

Fig. 1.7 The bullwhip effect (along the lines of Forrester 1961, p. 24)

ordering increase steadily the more one moves upstream the supply chain. This has to be interpreted in light of a given, nearly stable end item demand with just one (large) increase in demand levels at an early period of the game.

This behavior which is far from optimal for the total supply chain, has been observed in many independent repetitions of the beer distribution game as well as in industrial practice. Actually, the term bullwhip effect has been coined by managers at Procter & Gamble when examining the demand for Pampers disposable diapers (according to Lee et al. 1997).

Obviously, real world production-distribution systems are a lot more complex than those described above. However, examining behavioral patterns and policies often adopted by local managers, may amplify fluctuations even further. Studying the causes of the bullwhip effect and its cures have become a very rich area of research in SCM. Recently, Lee et al. (1997) divided recommendations to counteract the bullwhip effect into four categories:

- Avoid multiple demand forecast updates
- Break order batches
- Stabilize prices
- Eliminate gaming in shortage situations.

Avoiding *multiple demand forecasts* means that ordering decisions should always be based on ultimate customer demand and not on the ordering behavior of an immediate downstream partner, since the ordering behavior of an immediate downstream partner usually will show amplifications due to order batching and possible overreactions. With the advent of EDI and the capability to input sales made with the ultimate customer (point-of-sale (POS) data), accurate and timely data can be made available to each entity in the supply chain, thus also reducing the time-lag in the feedback system drastically. If ultimate customer demands are not available, even simple forecasting techniques (see Chap. 7) will prevent human overreactions and smooth demand forecasts.

In a more radical approach, one could change from decentralized decision-making to generating procurement plans centrally. Even the ultimate customer may be included in these procurement plans, as is the case in *vendor managed inventory* (VMI). Here the supply chain, however, has to bear the responsibility that the ultimate customer will not run out of stock. Finally, the downstream entity(s) could even be bypassed by executing sales directly with the ultimate customer (a well-known example are direct sales of Dell Computers).

Order batching is a common decision for cutting fixed costs incurred in placing an order. Ordering costs can be cut down drastically by using EDI for order transmission as well as a standardization of the (redesigned) ordering procedure. Transportation costs can be reduced if full truck loads are used. This should not, however, be achieved by increasing batch sizes, but rather by asking distributors to order assortments of different products simultaneously. Likewise, the use of third-party logistics companies helps making small batch replenishments economical by consolidating loads from multiple suppliers that are located near each other and thereby achieving economies of scale resulting from full truck loads. Similarly, a third-party logistics company may use assortments to full truckloads when delivering goods. This may give rise to cutting replenishment intervals drastically, resulting in less safety stocks needed without sacrificing service levels or increasing transportation costs.

Since marketing initiatives, which try to influence demands by wholesale price discounting, also contribute to the bullwhip effect, they should be abandoned. This understanding has moved companies to *stabilize prices* by guaranteeing their customers an every day low price.

The fourth category for counteracting the bullwhip effect intends to *eliminate gaming* in shortage situations. Here, gaming means that customers order additional, non-required amounts, since they expect to receive only a portion of outstanding orders due to a shortage situation. This behavior can be influenced by introducing more stringent cancellation policies, accepting only orders in proportion to past sales records and sharing capacity and inventory information.

Many of the recommendations given above for counteracting the bullwhip effect profit from recent advances in communication technology and large database management systems containing accurate and timely information about the current and past states of each entity in the supply chain. Many time delays existing in production-distribution systems either are reduced drastically or even no longer exist, thus reducing problems encountered in feedback systems. Furthermore, to overcome cognitive limitations, a mathematical model of the supply chain may be generated and used to support the decision-making of individuals (Haehling von Lanzenauer and Pilz-Glombik 2000). This research also indicates that an APS, with its modeling features and state-of-the-art solution procedures, can be a means to counteract the bullwhip effect.

1.3.5 Hierarchical Production Planning

Although detailed mathematical models have been proposed for production planning much earlier, Hax and Meal (1975) have shown how to build hierarchically coordinated, solvable models that provide effective decision support for the different decision-making levels within a hierarchical organization. Although first presented as a decision support system for a real world tire manufacturing firm, the versatility of the approach soon became clear. In brief, *hierarchical (production) planning* is based on the following five elements:

- Decomposition and hierarchical structure
- Aggregation
- Hierarchical coordination
- Model building
- Model solving.

The overall decision problem is decomposed into two or more decision levels. Decisions to be made are assigned to each level so that the top level includes the most important, long-term decisions—i.e. those with the greatest impact on profitability and competitiveness. A separation into distinct decision levels is called *hierarchical* if for each level a single upper level can be identified which is allowed

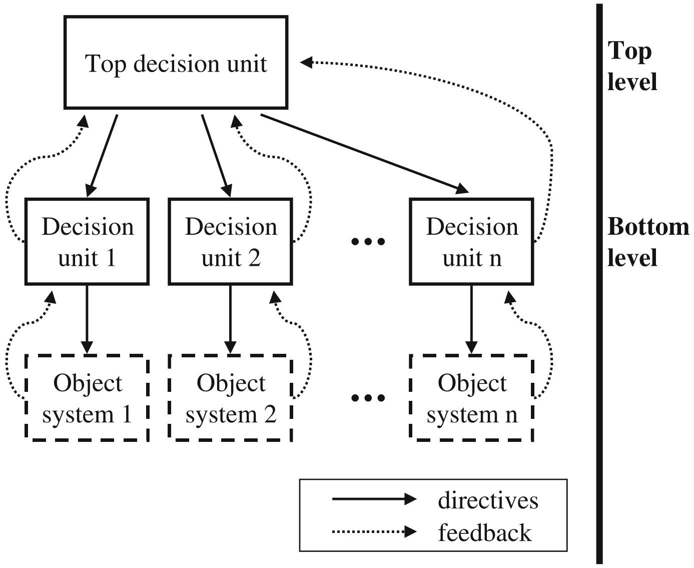

Fig. 1.8 Basic structure of a hierarchical planning system

to set the frame within which decisions of the subordinated level have to take place (with the exception of the top level of the hierarchy). Note, there may be several separate decision units (e.g. production sites) within a given decision level coordinated by a single upper level.

Like decomposition, *aggregation* serves to reduce problem complexity. It also can diminish uncertainty (e.g. of demand forecasts). Aggregation is possible in three areas: time, products and resources. As an example, consider an upper level where time may be aggregated into time buckets of 1 week and only main end products are taken into account—irrespective of their variants, while available capacities at a production site are viewed as a rough maximum (weekly) output rate.

Hierarchical coordination is achieved by directives and feedback. The most obvious directive is target setting by the upper level (e.g. setting a target inventory level for an end product at the planning horizon of the lower level). Another way is to provide prices for utilizing resources (e.g. a price for using additional personnel). A decision unit, on the other hand, may return a feedback to its upper level regarding the fulfillment of targets. These now allow the upper level to revise plans, to better coordinate lower-level decisions and to enable feasible plans at the lower level. These explanations are illustrated in Fig. 1.8. Here, the object system can be interpreted as the production process to be controlled.

For each decision unit a *model* is generated that adequately represents the decision situation and anticipates lower level reactions on possible directives. It also links targets set by the upper level to detailed decisions to be made at the decision unit considered. Thereby the upper level plan will be disaggregated. If a mathematical model is chosen, solvability has to be taken into account, too.

Finally, a suitable *solution procedure* has to be chosen for each model. Here, not only optimum seeking algorithms may be employed, but also manual procedures or group decision-making may be possible.

Hierarchical planning has attracted both researchers and practitioners alike. Thus, a large amount of knowledge has been accumulated so far (for more details see Schneeweiss 2003). Since hierarchical planning represents an appealing approach in conquering complex decision problems, while incorporating the experience of human decision-makers at different levels of an organization, it is not surprising that today's APS are constructed along the principles of hierarchical planning (see Chap. 4 for more details).

References

Aaker, D. (2001). *Developing business strategies* (6th ed.). New York: Wiley.

Alderson, W. (1957). *Marketing behavior and executive action*. Homewood: R. D. Irwin.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management Studies, 17*, 99–120.

Berry, W., Hill, T., & Klompmaker, J. (1999). Aligning marketing and manufacturing strategies with the market. *International Journal of Production Research, 37*, 3599–3618.

Bowersox, D. (1969). Physical distribution development, current status, and potential. *Journal of Marketing, 33*, 63–70.

Burns, T., & Stalker, G. (1961). *The management of innovation*. Oxford: Tavistock Publications.

Cachon, G., & Lariviere, M. (2005). Supply chain coordination with revenue-sharing contracts: Strengths and limitations. *Management Science, 51*(1), 30–44.

Childerhouse, P., Aitken, J., & Towill, D. (2002). Analysis and design of focused demand chains. *Journal of Operations Management, 20*, 675–689.

Christopher, M. (2005). *Logistics and supply chain management, creating value-adding networks* (3rd ed.). Harlow: Financial Times Prentice Hall.

Corsten, H., & Gössinger, R. (2008). *Einführung in das Supply Chain Management* (2nd ed.). München: Oldenbourg.

Croom, S., Romano, P., & Giannakis, M. (2000). Supply chain management: An analytical framework for critical literature review. *European Journal of Purchasing & Supply Management, 6*, 67–83.

Drexl, A., Fleischmann, B., Günther, H.-O., Stadtler, H., & Tempelmeier, H. (1994). Konzeptionelle Grundlagen kapazitätsorientierter PPS-Systeme. *Zeitschrift für betriebswirtschaftliche Forschung, 46*, 1022–1045.

Dudek, G. (2009). *Collaborative planning in supply chains: A negotiation-based approach*. *Lecture Notes in Economics and Mathematical Systems* (Vol. 533, 2nd ed.). Berlin: Springer.

Fettke, P. (2007). Supply Chain Management: Stand der empirischen Forschung. *Zeitschrift für Betriebswirtschaft, 77*(4), 417–462.

Fleischmann, B. (1999). Kooperation von Herstellern in der Konsumgüterdistribution. In E. Engelhard & E. Sinz (Eds.), *Kooperation im Wettbewerb: Neue Formen und Gestaltungskonzepte im Zeichen der Gobalisierung und Informationstechnologie* (pp. 68–196). Wiesbaden: Gabler.

Forrester, J. (1958). Industrial dynamics: A major breakthrough for decision makers. *Harvard Business Review, 36*, 37–66.

Forrester, J. (1961). *Industrial dynamics*. New York/London: MIT Press.

Fröhlich, M. T., & Westbrook, R. (2001). Arcs of integration: An international study of supply chain strategies. *Journal of Operations Management, 19*, 185–200.

Ganeshan, R., Jack, E., Magazine, M., & Stephens, P. (1998). A taxonomic review of supply chain management research. In S. Tayur, R. Ganeshan, & M. Magazine (Eds.), *Quantitative models for supply chain management* (pp. 839–879). Dordrecht: Kluwer Academic.

Haehling von Lanzenauer, C., & Pilz-Glombik, K. (2000). A supply chain optimization model for MIT's beerdistribution game. *Zeitschrift für Betriebswirtschaft, 70*(1), 101–116.

Håkansson, H., & Johanson, J. (1997). Formal and informal cooperation strategies in international networks. In D. Ford (Ed.), *Understanding business markets* (2nd ed., pp. 100–111). London: Academic.

Hammer, M., & Champy, J. (1993). *Reengineering the corporation*. New York: HarperBusiness.

Hammer, M. (2001). The superefficient company, *Harvard Business Review, 79*(9), 82–91.

Hammer, M., & Champy, J. (2003). *Reengineering the corporation: A manifesto for business revolution* (2nd revised and updated ed.). New York: Harper Collins.

Hanssmann, F. (1959). Optimal inventory location and control in production and distribution networks. *Operations Research, 7*(4): 483–498.

Hax, A. C., & Meal, H. C. (1975). *Hierarchical integration of production planning and scheduling*. *North-Holland/TIMS Studies in the Management Sciences*. Amsterdam: North-Holland.

Hilse, H., Götz, K., & Zapf, D. (1999). Netzwerk contra Hierarchie: Die Abbildung organisationsstruktureller Widersprüche in einem neuartigen Potential für Rollenstress. In K. Götz (Ed.), *Führungskultur: Die organisationale Perspektive* (pp. 29–44). München: Hampp.

Jayaram, J., Kannan, V., & Tan, K. (2004). Influence of initiators on supply chain value creation. *International Journal of Production Research, 42*, 4377–4399.

Kaplan, S. N., & Sawhney, M. (2000). E-hubs: The new b2b marketplaces. *Harvard Business Review, 78*, 97–103.

Lee, H., & Billington, C. (1995). The evolution of supply-chain-integration models in practice at Hewlett-Packard. *Interfaces, 25*(5), 42–63.

Lee, H., & Ng, S. (1998). Preface to global supply chain and technology management. In H. Lee & S. Ng (Eds.), *Global supply chain and technology management*. *POMS Series in Technology and Operations Management* (Vol. 1, pp. 1–3). Miami: Production and Operations Management Society.

Lee, H., Padmanabhan, V., & Whang, S. (1997). The bullwhip effect in supply chains. *Sloan Management Review, 38*, 93–102.

Oliver, R., & Webber, M. D. (1992). Supply-chain management: Logistics catches up with strategy. In M. Christopher (Ed.), *Logistics: The strategic issues* (pp. 63–75). London: Chapman and Hall (Reprint from Outlook (1982)).

Pfeiffer, T. (1999). Transfer pricing and decentralized dynamic lot-sizing in multistage, multiproduct prodcution processes. *European Journal of Operational Research, 116*, 319–330.

Pfohl, H.-C. (2010). *Logistiksysteme: Betriebswirtschaftliche Grundlagen* (8th ed.). Berlin: Springer.

Porter, M. E. (2008). *On competition* (2nd updated and expanded ed.). Boston: Harvard Businesss School Publishing.

Rockhold, S., Lee, H., & Hall, R. (1998). Strategic alignment of a global supply chain for business success. In H. Lee & S. Ng (Eds.), *Global supply chain and technology management*. *POMS Series in Technology and Operations Management* (Vol. 1, pp. 16–29). Miami: Production and Operations Management Society.

Schneeweiss, C. (2003). *Distributed decision making* (2nd ed.). Berlin: Springer.

Schneider, D., Bauer, C., & Hopfmann, L. (1994). *Re-Design der Wertkette durch make or buy*. Wiesbaden: Gabler.

Silver, E., Pyke, D., & Peterson, R. (1998). *Inventory management and production planning and scheduling* (3rd ed.). New York: Wiley.

Simchi-Levi, D., Kaminski, P., & Simchi-Levi, E. (2008). *Designing and managing the supply chain: Concepts, strategies and case studies* (3rd ed.). Boston: McGraw-Hill.

Simon, H. A. (1952). On the application of servomechanism theory in the study of production control. *Econometrica, 20*(2), 247–268.

Sterman, J. (1989). Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment. *Management Science, 35*(3), 321–339.

Sydow, J. (2005). *Strategische Netzwerke: Evolution und Organisation* (1st ed., 6th reprint ed.). Wiesbaden: Gabler.

The Council of Supply Chain Management Professionals. (2013). Supply chain and logistics terms and glossary. http://cscmp.org/sites/default/files/user_uploads/resources/downloads/glossary-2013.pdf. Visited on Feb 28, 2014.

Ulijn, J., & Strother, J. (1995). *Communicating in business and technology: From psycholinguistic theory to international practice*. Frankfurt am Main: Peter Lang.