Types of Supply Chains 3

Herbert Meyr and Hartmut Stadtler

The SCOR-model presented in Sect. 2.2.2 is an excellent tool to analyze, visualize, and discuss the structure of the supply chain, and to reveal redundancies and weaknesses. It enables the formulation of structural changes and strategies to improve the performance of the supply chain as a whole.

However, when it comes to planning, the SCOR-model needs to be supplemented. To be able to identify the type of decision problems facing the supply chain and guide the selection of standard or specialized modules, models and algorithms for decision making, this chapter defines a "supply chain typology", supporting the SCOR-model at level 2. Two examples illustrate the use of the typology and will be resumed in Chap. 4 in order to design planning concepts fitting the particular requirements of these two types of supply chains.

3.1 Motivation and Basics

In the early days of production planning and control a single concept and software system was applied in industry — material requirements planning (MRP) — irrespective of the many different requirements existing in diverse areas such as the production of foods or automobiles. On the other hand, if a production manager was asked whether the production system he manages is unique and requires special purpose decision-making tools, most probably the answer would be "yes".

H. Meyr (✉)
Department of Supply Chain Management (580C), University of Hohenheim, 70593 Stuttgart, Germany
e-mail: H.Meyr@uni-hohenheim.de

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

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As regards the type of decisions to be made, the truth lies somewhere in the middle of these two extremes. Abstracting from minor specialties usually reveals that there are common features in today's production and distribution systems which require similar decision support and thus can be supported by the same software modules.

APS are much more versatile than MRP and ERP systems due to their modeling capabilities and different solution procedures (even for one module). Modules offered by a software vendor may still better fit one type of supply chain than another. So, it is our aim to outline a *supply chain typology* which allows to describe a given supply chain by a set of attributes which we feel might be important for decision-making and the selection of an APS. Attributes may have nominal properties (e.g. a product is storable or not), ordinal properties (e.g. an entity's power or impact on decision-making is regarded higher or lower than average) or cardinal properties (i.e. the attribute can be counted, like the number of legally separated entities within a supply chain).

Attributes with a similar focus will be grouped into a peculiar category to better reveal the structure of our typology (see Tables 3.1 and 3.2). We will discriminate "functional" attributes to be applied to each organization, entity, member, or location of a supply chain as well as "structural" attributes describing the relations among its entities.

Note that further typologies with different attributes are necessary if other objectives are pursued when characterizing and categorizing supply chains. A summary of such typologies (e.g., the ones of Lejeune and Yakova 2005 and Vonderembse et al. 2006) is given by Knackstedt (2009).

3.2 Functional Attributes

Functional attributes (see Table 3.1) of an entity are grouped into the four categories

- Procurement type
- Production type
- Distribution type
- Sales type.

The **procurement type** relates to the *number* (few ... many) and *type of products* to be procured, the latter one ranging from standard products to highly specific products requiring special product know-how or production process know-how (or equipment). The following attribute depicts the *sourcing type*, better known by its properties: single sourcing, double sourcing and multiple sourcing. Single sourcing exists if there is a unique supplier for a certain product to be procured. In double sourcing there are two suppliers, each fulfilling a portion of demand for the product to be procured (e.g. 60 % of the demand is fulfilled by the main supplier, 40 % by the second supplier). Sourcing contracts with suppliers are usually valid in the medium-term (e.g. a product's life cycle). Otherwise, products can be sourced from multiple suppliers. Next, the *flexibility of suppliers* with respect to the amounts to be supplied may be important. Amounts may either be fixed, have a lower or upper

Table 3.1 Functional attributes of a supply chain typology

	Functional attributes
Categories	Attributes
Procurement type	Number and type of products procured Sourcing type Flexibility of suppliers Supplier lead time and reliability Materials' life cycle
Production type	Organization of the production process Repetition of operations Changeover characteristics Bottlenecks in production Working time flexibility etc.
Distribution type	Distribution structure Pattern of delivery Deployment of transportation means Loading restrictions
Sales type	Relation to customers Availability of future demands Demand curve Products' life cycle Number of product types Degree of customization Bill of materials (BOM) Portion of service operations

bound due to given contracts with suppliers or may be freely available. *Lead time* and *reliability of suppliers* are closely related. The lead time of a supplier defines the average time interval between ordering a specific material and its arrival. Usually, the shorter lead times are, the more reliable the promised arrival dates are. The *life cycles of* components or *materials* have direct impact on the risk of obsolescence of inventories. The shorter the life cycles are, the more often one has to care about substituting old materials with newer ones.

The **production type** is formed by many attributes. The two most prominent attributes are the *organization of the production process* and *the repetition of operations*. Process organization and flow lines represent well-known properties of the production process. Process organization requires that all resources capable of performing a special task (like drilling) are located in the same area (a shop). Usually a product has to pass through several shops until it is finished. A flow shop exists if all products pass the shops in the same order, otherwise it is a job shop. A flow line exists in case resources are arranged next to each other corresponding to the sequence of operations required by the products to be manufactured on it. Usually capacities within a flow line are synchronized and intermediate inventories are not possible. Hence, for planning purposes a flow line can be regarded as a single entity.

The attribute *repetition of operations* has three broad properties, mass production, batch production and making one-of-a-kind products. In mass production the same product is generated constantly over a long period of time. In batch production several units of a given operation are grouped together to form a batch (or lot) and are executed one after the other. Several batches are loaded on a resource sequentially. At the start of a batch a setup is required, incurring some setup costs or setup time. When making one-of-a-kind products which are specific to a (customer) order, special care is needed to schedule the many operations usually belonging to a (customer) order.

The influence of setup costs and setup times may be higher or lower. Therefore, their degree can further be specified by an optional attribute *changeover characteristics*. If setup costs (or times) even vary with respect to the sequence of the batches or lots, "sequence dependent" changeover costs are given. If production capacity is a serious problem, the attribute *bottlenecks in production* tries to characterize why. In a multi-stage production system, the bottleneck machines may be stationary and known, or shifting (frequently) depending on the mix of demand. One way to increase capacity is to provide more working time (e.g. by means of overtime or additional shifts). The capability and lead times to adapt working time to changing demand pattern are described by the attribute *working time flexibility*. For further specifications of the production type see Schneeweiss (2002, p. 10) and Silver et al. (1998, p. 36).

The **distribution type** consists of the distribution structure, the pattern of delivery, the deployment of transportation means, and possible loading restrictions. The *distribution structure* describes the network of links between the factory (warehouse) and the customer(s). A one-stage distribution structure exists if there are only direct links between a factory (warehouse) and its customers. In case the distribution network has one intermediate layer (e.g. either central warehouses (CW) or regional warehouses (RW)) a two stage distribution structure is given. A three stage distribution structure incorporates an additional layer (e.g. CW *and* RW).

The *pattern of delivery* is either cyclic or dynamic. In a cyclic pattern, goods are transported at fixed intervals of time (e.g. round-the-world ship departures). A dynamic pattern is given if delivery is made depending on demand (for transportation). As regards the *deployment of transportation means* one can distinguish the deployment of vehicles on routes (either standard routes or variable routes depending on demand) and simply a given transportation capacity on individual links in the distribution network. It may even be possible to assume unlimited transportation capacities and to consider only a given cost function (e.g. based on a contract with a large third-party service provider). *Loading restrictions* (like the requirement of a full truck load) may form a further requirement.

The **sales type** of an entity in the supply chain largely depends on the *relation to its customers*. One extreme may be a downstream entity in the supply chain (with some kind of "agreement" regarding expected demands and an open information flow) while the other extreme may be a pure market relation with many competitors (e.g. auctions via Internet conducted by the purchasing departments of a large company). This attribute is closely related to the *availability of future demands*.

These may be known (by contract) or have to be forecast. The existence of (reliable) demand forecasts is best described by the length of the forecast horizon. Besides the general availability of demand information, the shape of the *demand curve* is of interest. Demand for a specific product may, for example, be quite static, sporadic, or seasonal.

The typical length and the current stage of a *product's life cycle* significantly influence appropriate marketing, production planning and financial strategies. As regards the products to be sold one should discriminate the *number of product types* offered and the *degree of customization*. The latter one may range from standard products to highly specific products (in accordance to the products procured). In the light of mass customization some way in the middle becomes more and more important: constituting customer-specific products from a variety of product options and alternatives being offered. The attribute *bill of materials (BOM)* shows the way that raw materials and components are composed or decomposed in order to generate the final products. If raw materials are just changed in their sizes and shapes, a serial structure is given. In a convergent structure, several input products are assembled (or mixed) to form a single output product. Whereas in a divergent structure, a single input product is disassembled (or split) and several output products are the result. Of course, a structure of a mixture type—combining both convergent and divergent properties—is also possible.

Apart from selling tangible goods the *portion of service operations* is constantly growing (e.g. the training of a customer's personnel).

3.3 Structural Attributes

Structural attributes (see Table 3.2) of a supply chain are grouped into the two categories

- Topography of a supply chain
- Integration and coordination.

As regards the **topography of a supply chain** the attribute *network structure* describes the material flows from upstream to downstream entities which are either serial, convergent, divergent, or a mixture of the three. Note that the network structure often coincides with the BOM. The *degree of globalization* ranges from supply chains operating in a single country to those with entities in several continents. Global supply chains not only have to take into account tariffs and impediments to trade as well as exchange rates varying over time, but also can profit from them. Also the *location of the decoupling point(s)* within the supply chain has to be mentioned. It is the first stage (or location) in the flow of materials where a further processing step or a change in the location of a product will only be executed with respect to a customer order (see also Sect. 1.2). Note, the decoupling point may differ between product groups. Starting with the most upstream location of a decoupling point we have engineer-to-order (with no make-to-stock at all), followed by manufacture-to-order of parts, then assemble-to-order and deliver-to-order. In a vendor managed inventory system a supplier even has to deliver-to-stock since there

Table 3.2 Structural attributes of a supply chain typology

Structural attributes	
Categories	Attributes
Topography of a supply chain	Network structure
	Degree of globalization
	Location of decoupling point(s)
	Major constraints
Integration and coordination	Legal position
	Balance of power
	Direction of coordination
	Type of information exchanged

are no orders from the buyer to replenish inventories. The attribute *major constraints* gives an impression what the main bottlenecks of the supply chain (as a whole) are. These may, for example, be limited production capabilities of some member(s) or the limited availability of some critical materials.

Integration and coordination concerns the attributes legal position, balance of power, direction of coordination and type of information exchanged. The *legal position* of entities has already been mentioned. In case entities are legally separated, an inter-organizational supply chain exists, otherwise it is called intra-organizational. For intra-organizational supply chains it will be much easier to coordinate flows centrally than for inter-organizational supply chains. Also the *balance of power* within an inter-organizational supply chain plays a vital role for decision-making. A dominant member in the supply chain can act as a focal firm. On the other hand, we have a supply chain of equals, named a polycentric supply chain.

As regards information flows, several attributes may be considered. As an example consider the *direction of coordination*. It may be purely vertical or purely horizontal or a mixture of both. Vertical information flows comply with hierarchical planning. On the other hand, horizontal flows may exist between two adjacent entities within the supply chain which can easily and quickly make use of local information (e.g. to overcome the effects of a breakdown of a machine). Also the *type of information exchanged* between members influences planning (e.g. some entities may hesitate to reveal their manufacturing costs but are willing to provide information about available capacities).

While attributes describing a production type are generally accepted and validated for a long time, typologies of the service sector are relatively new and of growing interest (for an early survey see Cook et al. 1999). Also, the aforementioned attributes only provide a basis for a rough grouping of decision problems which may be refined further according to the needs of a given SCM project. For this, special purpose typologies can be of help (e.g. for production processes concerning cutting and packing see Dyckhoff and Finke 1992). In some cases, this will also indicate that special purpose solution procedures may be needed, currently not provided by APS.

In order to reduce the burden associated with an (extensive) typology, one should bear in mind its aim. Since decision-making and decision support is of interest here, one might concentrate on activities to be performed on those products and services regarded most important (e.g. "A" products in an ABC-classification based on the annual turnover, see Silver et al. 1998, p. 32). Furthermore, attention can be focused on those activities which either have to be performed on potential bottlenecks along the supply chain or which affect critical performance criteria considerably (e.g. order lead-time).

Once a list of functional attributes has been established for each entity of a supply chain, it will show the degree of diversity existing in the supply chain. For partners having similar properties the choice of an appropriate decision-making tool (or module of an APS) can be made jointly, saving costs and time. In order to demonstrate the applicability of the above typology, it will be used in the following two sections for the different supply chain types *consumer goods industries* and *computer assembly*. We will come back to these two examples in Sect. 4.3 and in our case studies (Part IV).

3.4 Example for the Consumer Goods Industry

First, the typology will be applied for supply chains where consumer goods are produced and sold. Functional attributes are presented for the consumer goods manufacturing entity only. Structural attributes consider the supply chain as a whole comprising both manufacturers and retailers. Some attributes of our typology are not used within the example because they play only a minor role in supply chains of the consumer goods type. This kind of supply chain is considered again in Sect. 4.3.1 and in Chap. 21. Therefore, our description is rather detailed and affects additional proprietary attributes not mentioned explicitly in the above (universal) typology.

Table 3.3 summarizes the characteristics of the consumer goods supply chain. Since the products to be sold are the determining factor of our example, we start illustrating the *sales type* category.

Sales Type. In the remainder we concentrate on the subset of consumer goods that comprises standard products with a low volume, weight and value per item (e.g. food, beverages, office supplies, or low tech electronics). Since quite often these standard products are just packaged in different sizes or under several brand names, some sort of "divergent" BOM is given. Thus, a typical consumer goods manufacturer offers several hundreds of final items that are technologically related.

The final customer expects to find his preferred brand in the shelf of a grocery or electronics store. If the desired product is not available, he probably changes his mind and buys a comparable product of another manufacturer. This behavior is due to the low degree of product differentiation predominant in the consumer goods industry. Therefore, consumer goods manufacturers are forced to produce to stock by means of demand estimates.

Table 3.3 Supply chain typology for the consumer goods industry

Functional attributes	
Attributes (see Table 3.1)	Contents
Number and type of products procured	Few, standard (raw materials)
Sourcing type	Multiple
Supplier lead time and reliability	Short, reliable
Materials' life cycle	Long
Organization of the production process	Flow line
Repetition of operations	Batch production
Changeover characteristics	High, sequ. dep. setup times and costs
Bottlenecks in production	Known, stationary
Working time flexibility	Low
Distribution structure	Three stages
Pattern of delivery	Dynamic
Deployment of transportation means	Unlimited, routes (3rd stage)
Availability of future demands	Forecast
Demand curve	Seasonal
Products' life cycle	Several years
Number of product types	Hundreds
Degree of customization	Standard products
Bill of materials (BOM)	Divergent
Portion of service operations	Tangible goods
Structural attributes	
Attributes (see Table 3.2)	Contents
Network structure	Mixture
Degree of globalization	Several countries
Location of decoupling point(s)	Deliver-to-order
Major constraints	Capacity of flow lines
Legal position	Intra-organizational
Balance of power	Customers
Direction of coordination	Mixture
Type of information exchanged	Nearly unlimited

Since the product life cycle of standard products typically extends over several years, a solid data basis for forecasting is available. However, demand for some products may be subject to seasonal influences (e.g. for ice cream or light bulbs) or price promotions.

If consumer goods are standardized, the emphasis of marketing has to be set on service level and price. Altogether, a strictly competitive market is given.

Distribution Type. Consumer goods are distributed via wholesalers and/or retailers to the final customers. The distribution network of a consumer goods manufacturer quite often comprises three distribution stages (see Fleischmann 1998 and Fig. 3.1).

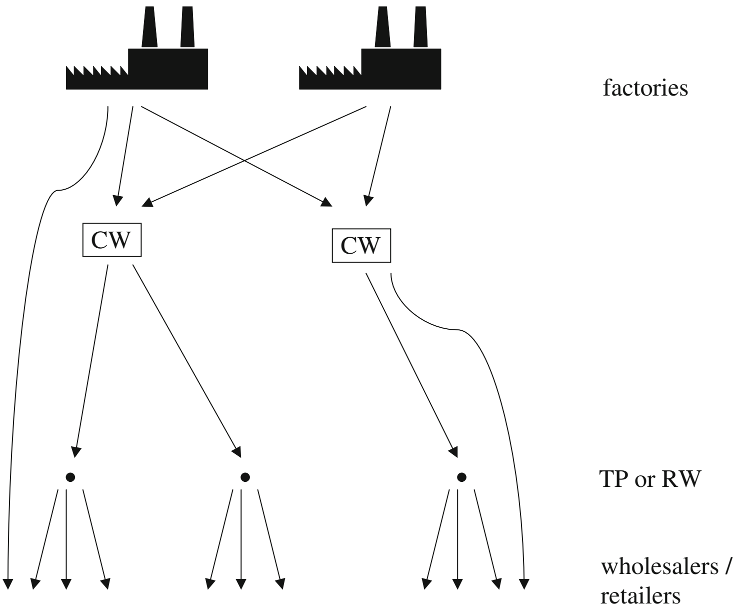

Fig. 3.1 Three-stage distribution system

The product program of the manufacturer is supplied by one or a few factories. Thereby, some product types may be produced in more than one site. The finished goods can temporarily be stored in a few CWs, each of them offering the whole range of products. Large orders of the manufacturer's customers (i.e. wholesalers, retailers or department stores) can be delivered directly from the factory or CW to the respective unloading point.

Since most orders are of rather small size and have to be transported over long distances, a further distribution stage consisting of RWs or stock-less transshipment points (TP) is often used. The customers in the vicinity (at most 100 km radius) of such a RW/TP are supplied in 1-day tours starting from this RW/TP. Over the (typically) long distance between the CW and the RW/TP all orders of the respective region are bundled (usually by third-party service providers) so that a high transport utilization is achieved.

As opposite to RWs, no stock is held in TPs, thus causing lower inventory holding, but higher transportation costs due to the higher delivery frequency. A similar distribution structure may be used by major sales chains which replenish their (large number of) department stores from their own retail CWs.

Production Type. Production of consumer goods often comprises only one or two production stages, e.g. manufacturing and packaging. On each production stage one or a few parallel (continuous) production lines (flow lines) are organized in a flow shop. A line executes various operations. But since these operations are strictly coordinated, each line may be planned as a single unit. The lines show a high degree of automation and are very capital intensive. Because of this automation, however, short and reliable throughput times can be achieved.

The capacity of the production lines is limited and they are usually highly utilized. Therefore, they represent potential bottlenecks. For the handling of the lines, few but well-trained operators are necessary. A short-term expansion of working time is normally not possible. The working time of the whole team supervising a line has to be determined on a mid-term time range. However, in many companies the lines are already operating seven days a week, 24 h a day.

As mentioned above, there are a lot of final items. But these are often technologically related and can be assigned to a few *setup families*. Changeovers between items of the same family are negligible. But changeovers between items of different families cause high setup costs and setup times. Therefore, batch production is inevitable. The degree of these costs and times may vary notably with respect to the family produced last on the same line (sequence dependent setup times and costs).

Procurement Type. Consumer goods frequently have a rather simple BOM. In these cases only few suppliers have to be coordinated. As long as not sophisticated components, but mainly standard products (e.g. raw materials) are needed, procurement is not really a problem. The lead time of raw materials is short and reliable. The life cycles of these materials are rather long. Therefore, mid- and long-term contracts and cooperations ensure the desired flow of raw materials from the suppliers to the manufacturer. Nevertheless, if there should be any unexpected problems in sourcing material, because of the high degree of standardization it is quite easy to fall back on alternative suppliers on the short-term (multiple sourcing).

Topography of the Supply Chain. The production network (maybe several sites producing the same product), the distribution network of the manufacturer and possibly the distribution network of large wholesalers/retailers contain both divergent and convergent elements thus forming a network structure of the mixture type. Production and distribution networks usually extend over several countries, sometimes even over multiple continents. Since products are made to stock, the decoupling point of the manufacturer is settled in CWs or RWs, from which goods are delivered to order. While procurement is quite unproblematic, the limited capacity of the flow lines is the major constraint of the whole supply chain.

Integration and Coordination. Because of the low differentiation the balance of power is shifted towards the customers, i.e. the retailers. As regards the consumer goods manufacturing entity, there is a strong need for intra-organizational coordination. Several organizational units of the same company (e.g. order management, sales, manufacturing, procurement) have to exchange information horizontally. Furthermore, the central planning unit has to coordinate the bulk of decentral units by sending directives and gathering feedback, thus inducing heavy vertical information traffic. Since all of these units belong to the same company, information should be freely available.

In addition, new logistical concepts of SCM result in special emphasis on inter-organizational relations within the supply chain, particularly on the interface between consumer goods manufacturers and large retailers. In particular, a number of companies have made positive experience with:

- The flow of information between the manufacturers and retailers is improved by EDI or WWW connections.
- Short delivery cycles (with rather small quantities) are established in order to closely connect the material flow with the demand of final customers (*Continuous Replenishment/Efficient Consumer Response (ECR)*).
- Traditional responsibilities are changed. Large retailers abstain more and more from sending orders to their suppliers, i.e. the consumer goods manufacturers. Instead they install consignation stores whose contents are owned by their suppliers until the goods are withdrawn by the retailer. A supplier is responsible for filling up his inventory to an extent which is convenient for both the supplier and the retailer. As already mentioned, such an agreement is called *vendor managed inventory* (VMI).

3.5 Example for Computer Assembly

Now a second application of the above general typology will be presented. In order to offer a quite contrary example, a *computer assembly* supply chain has been chosen. A particular instance of this type of supply chain will be described in the case study in Chap. 23. Table 3.4 summarizes the properties of that type so that a direct comparison with the consumer goods type (Table 3.3) is possible. Again, functional attributes are only shown for the computer manufacturing entity, whereas structural attributes characterize the interrelations between different entities of the supply chain.

Sales Type. Computers have a strictly convergent BOM. The system unit is assembled from several components like the housing, the system board, the Central Processing Unit (CPU), hard disk(s), a sound card etc. The degree of customization varies between the two extremes

- *Standard products* with *fixed configurations*, i.e. only some predefined types are offered. Customers merely can choose between these types, but no changes or extensions (at least at the system unit) are possible.
- *Customized products* which are completely *configurable*. In this case the customer specifies which components he wants to get from what supplier or at least the options of the components he wants to get (like a "slow" CPU, but a "high-end" graphics card). The manufacturer tests whether the requested configuration is technically feasible and calculates the price. Because of the ability to combine many different components—again obtainable from several alternative suppliers—an incredibly large number of possible final items is given.

Of course, the usual practice is somewhere in between. For example, some standard computers are defined with a few options like additional RAM or a Blu-Ray drive

Table 3.4 Supply chain typology for computer assembly

Functional Attributes	
Attributes (see Table 3.1)	Contents (fixed/configurable)
Number and type of products procured	Many, standard and specific
Sourcing type	Multiple
Supplier lead time and reliability	Short and long, unreliable
Materials' life cycle	Short
Organization of the production process	Flow shop and cellular
Repetition of operations	Larger/smaller batches
Changeover characteristics	Irrelevant
Bottlenecks in production	Low importance
Working time flexibility	High
Distribution structure	Two stages
Pattern of delivery	Dynamic
Deployment of transportation means	Individual links
Availability of future demands	Forecasts and orders
Demand curve	Weakly seasonal
Products' life cycle	Few months
Number of product types	Few/many
Degree of customization	Standard/customized
Bill of materials (BOM)	Convergent
Portion of service operations	Tangible goods
Structural Attributes	
Attributes (see Table 3.2)	Contents
Network structure	Mixture
Degree of globalization	Several countries
Location of decoupling point(s)	Assemble-/configure-to-order
Major constraints	Material
Legal position	Inter- and intra-organizational
Balance of power	Suppliers and customers
Direction of coordination	Mixture
Type of information exchanged	Forecasts and orders

instead of an ordinary DVD. Or only a limited number of hard disks, CPUs, housings etc. is offered and the customer can only choose between these alternatives. The corresponding final items then have already been tested for technical feasibility and prices have been assigned. In the following, just the two extreme cases are considered.

The computer itself consists of the system unit and some accessories like cables, software, a manual, or a keyboard. A typical order of a customer comprises several order lines for different product families (e.g. desktop computers, servers, notebooks) and external units (peripherals) like speakers, monitors, printers and so on. If customers call for delivery of "complete orders", all order lines of an order have to be delivered simultaneously to the customer (e.g. because printers without computers are useless for the customer). Thus, the BOM comprises several stages like the order itself (consisting of several order lines for computers of different product families and peripherals), computers (system unit and accessories) and system units (housing, main board, etc.). Some computer manufacturers are also responsible for the assembly of the system board from several components like the Printed Circuit Board, chips, etc.

There is a low product differentiation. Price, speed and reliability of the promised due dates are the key performance indicators. The planned order lead times vary — dependent on the product family — between a few days and a few weeks. Because of technological improvements a fast changing environment has to be mastered. Due to the short product life cycles of only a few months, there is a high risk of obsolescence. Total customer demand is known for the next few days only. For the further future, the probability of having fully specified customer orders on hand decreases drastically. Then, (not yet known) customer orders have to be anticipated by forecasts. Demand is weakly influenced by seasonal effects like the Christmas business or year's end business of authorities.

Distribution Type. Typical customers are system integrators offering overall solutions for big corporate customers, medium and small business customers, and consumer market stores which sell standard computers ("consumer PCs") to private customers. In this case, often a two-stage distribution system is used where computers and peripherals are merged by logistics service providers in distribution centers to constitute a complete order. Sometimes manufacturers sell directly to private customers via the Internet. Then, a parcel service is responsible for the delivery to the final customer. It is interesting to note that in the "complete order" case the last stage of the BOM is settled in a distribution center.

Production Type. The main production processes are the "assembly of the system board", the "assembly of the system unit", the "loading of the software", a final "testing" and the "packing" (assembly of the computer). The "assembly of the system board" may be done in-house or in an additional upstream factory, also owned by the computer manufacturing company. But system boards may also be bought from external suppliers. Anyway, system boards are assembled on highly automated flow lines with very short throughput times.

The key process "assembly of the system unit" is also done in flow line organization, but manually. Sometimes a cellular organization is given. Despite of the manual work and the possibly high degree of customization, processing times are stable. Only low skilled personnel is necessary. Therefore, additional staff can be hired on the short term and working time flexibility is high. Fixed configurations can be assembled in large batches. Open configurations, however, have to be produced in small batches because of the individuality of customer demand. Nevertheless, due to the nature of the setup processes (e.g. providing components of the next batch in parallel to the assembly of the current batch), there are no significant setup costs or times. Altogether, serious bottlenecks in production are missing and production capacity does not play a critical role.

Procurement Type. Because of the rather simple production processes, the key competencies of a computer manufacturer actually are the synchronization of suppliers and sales and order management, respectively. Thousands of components, accessories and external units have to be purchased and must be right in place before the assembly or delivery. The products procured are very inhomogeneous. Standard components as well as highly specific components have to be ordered. Supplier lead times range from a few days to several months and are most of the time very unreliable.

Just as it is the case for computers, life cycles of components are often very short due to technological progress. So there is also a high risk of obsolescence at the supply side. Because of mid- to long-term contracts with critical suppliers, there may exist both upper and lower bounds on supply quantities. Such contracts are particularly important when supply shortages can occur and multiple sourcing is not possible, i.e. when the balance of power is shifted towards the supplier.

For some components like hard disks multiple sourcing is common practice. These components are bought from several suppliers. Thus, at least for standard products the computer manufacturer is free to substitute components and to increase orders for alternative suppliers if the one originally planned runs into trouble. Also "downgrading" of components is a practicable (but expensive) way to deal with shortage situations: in this case, a lower value component—being requested but out of stock—is replaced by an alternative component with higher value. For example, a 1,000 GB hard disk is assembled instead of a 750 GB hard disk because the requested lower value component is not in stock any more. Since the price has been fixed earlier and cannot be re-adjusted, the customer does not need to be informed.

Topography of the Supply Chain. The network structure is of a mixture type: lots of suppliers (of components, accessories and peripherals) are linked with a few assembly sites (for system boards and several product families), a few distribution centers, and with a large number of customers (of different types as described above). The whole network may extend over several countries.

Nowadays, most computer manufacturers have successfully shifted their deliver-to-order decoupling point upstream in order to reduce the risky and expensive finished product inventory. In case of fixed configurations, an assemble-to-order decoupling point is now common practice, i.e. computers are only assembled if a respective customer order for a standard configuration has arrived. For open configurations an engineer-to-order decoupling point is given, i.e. an incoming customer request has also to be checked for technological feasibility and an individual price has to be set. Shifting the decoupling point upstream reduces finished product inventory and hedges against demand uncertainty, but also increases order lead times (as long as throughput times are not simultaneously decreased). The performance of the supply chain is primarily limited by constraints on material supply and not by scarce assembly capacity.

Integration and Coordination. Both inter- and intra-organizational members participate at computer assembly supply chains. So there is a need for collaboration between legally independent companies (e.g. by exchanging demand information like forecasts and orders horizontally) as well as a need for vertical coordination of different organizational units of the computer manufacturing company itself. Thus, the direction of coordination is of a mixture type.

Both suppliers and customers may have a high power within such supply chains. The power is extremely high for suppliers that reside in some sort of monopoly or oligopoly like vendors of operating systems or CPUs. As shown above, long-term contracts may ensure the desired flow of critical components from these suppliers.

We will next time come back to the *consumer goods manufacturing* and *computer assembly* types of supply chains in Sect. 4.3. There, the particular planning requirements of these two supply chain types and planning concepts fitting them are derived from the attributes shown above.

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