# Chapter 2

# Production planning in the consumer packaged goods industry

Chapter 1 presented the motivation for the focus of this thesis, which is production planning in the consumer packaged goods industry—more specifically, lot-sizing and scheduling. However, this planning cannot be considered separately, as will be shown in Section 2.1. In fact, the whole supply chain needs to be regarded in order to adequately develop models and methods (cf. Silver et al., 1998, p. 36). For this reason, a supply chain typology is presented in Section 2.2, which will help describe the supply chain in general and the regarded production system in particular. Based on that typology, a detailed characterization of the consumer goods industry is then presented and the planning requirements for lot-sizing and scheduling will be derived. Furthermore, in Section 2.4, an operational planning concept will be introduced which meets the identified requirements. Finally, the general structure and functionality of an APS will be briefly sketched in the last section.

## 2.1 Supply Chain Planning

In a consumer packaged goods company, a large number of decisions have to be made day by day. Such decision making needs to be supported by planning, which is an instrument for preparing decisions in a situation of uncertainty. The main tasks of planning are to identify and evaluate alternative courses of action (cf. Fleischmann et al., 2008, p. 81). Accordingly, making the right decisions is the aim of "Supply Chain Planning".

Following the definition of Fleischmann and Meyr (2003), we understand Supply Chain Planning (SCP) "as a generic term for the whole range of those decisions on the design of the supply chain, on the mid–term coordination and on the short–term scheduling of the processes in the supply chain." As can be seen from this definition, decisions have differing importances and concern different planning horizons. For this reason, we typically

F. Seeanner, *Multi-Stage Simultaneous Lot-Sizing and Scheduling,* Produktion und Logistik,
DOI 10.1007/978-3-658-02089-7_2, © Springer Fachmedien Wiesbaden 2013

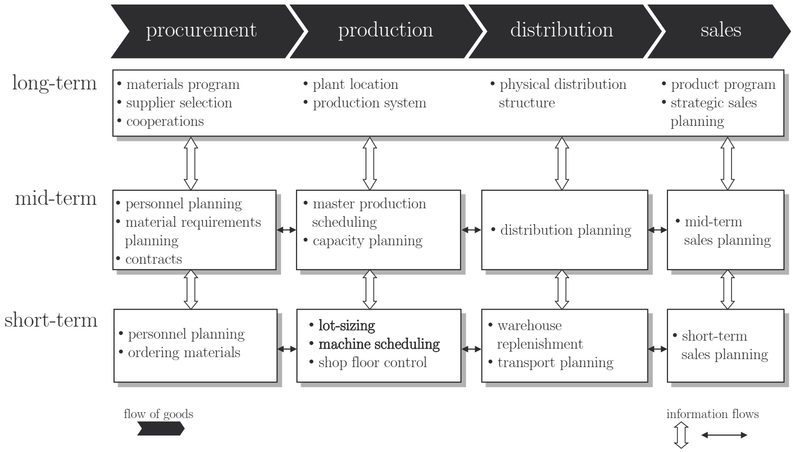


Figure 2.1: The Supply Chain Planning Matrix (Fleischmann et al., 2008, p. 87).

distinguish between three different planning levels (cf. Anthony, 1965):

**Long-term planning** covers strategic decisions about the future development of the supply chain. This includes decisions about the design of the supply chain network. The planned and implemented measures usually affect several years.

The main task of **mid-term planning** is to concretize regular operations based on the strategic decisions. Therefore, rough quantities and points in time for the material flow have to be determined. The horizon generally covers 6–24 months.

Depending on the decisions of the two upper levels, **short-term planning** has to specify detailed instructions for the execution and control of operations. The planning horizon ranges from a few days to several months (cf. Fleischmann et al., 2008, p. 82).

But planning decisions not only differ with respect to their horizon, they can also be assigned to different functional areas. Typically, the four functional processes procurement, production, distribution, and sales are differentiated.[1]

Rohde et al. (2000) identify general supply chain planning tasks[2] that can be assigned to different planning levels and functional processes. The result is the Supply Chain Planning Matrix (see Figure 2.1) which gives an overview of the material and informational flows between the different planning tasks. As already mentioned, the long-term tasks concern the design of the network. The SCP Matrix lists all these tasks in the same "box" to emphasize the strong interdependency: the supply chain member has to decide which markets to enter

[1]Moreover, Fleischmann et al. (2008, p. 86) state that every supply chain can be split into several internal ones where each of them consists of these four processes.

[2]"General" means that the tasks do not have to appear in every company, as they vary from industry to industry. Nevertheless, the reader gets an impression of the typical decision problems a planner has to face.

or remain in, with existing or with new products. The chosen product program directly influences the materials program. As today more and more components are purchased, the suppliers have to be selected carefully in terms of product quality, service, and further properties.[3] Another topic is to build cooperations with suppliers. By sharing information about final customer demands and production capacities (among other things), such a collaboration may help to reduce, e.g., inventories, and thus costs, on both sides. Moreover, the decisions about the product and material program are also directly connected to decisions about the location of plants and the corresponding production systems, as they have an effect on how a customer can be reached. Since the location and capacity of a plant influence the physical distribution structure, they are also usually planned together. Depending on the product program and the sales forecast, the number of warehouses has to be determined or the decision for a logistic service provider has to be taken (cf. Fleischmann et al., 2008, pp. 88 and 89).

On the mid-term level, sales planning has to forecast the potential sales in specific regions. Based on the given network and these sales forecasts, a rough capacity planning needs to be executed and a master production schedule specified. This schedule, which may concern several facilities simultaneously, determines the rough quantities which have to be produced in certain periods, in order to deal with time-varying demands. With the help of capacity planning, the required material as well as the required personnel has to be calculated and the appropriate contracts need to be signed. Furthermore, distribution planning determines the transport needs between the warehouses and the necessary stock levels. It also decides whether an external logistic service provider has to be contracted (cf. Fleischmann et al., 2008, p. 89).

On the short-term level, sales planning is responsible for detailed forecasts (if needed) and demand fulfillment. In the latter case, sales staff has to check whether a customer order can be satisfied with the products already available or whether a new production order has to be created. Distribution planning determines the detailed schedule for transport to replenish the stocks in the warehouses or to deliver them to the customers (cf. Fleischmann et al., 2008, p. 92). As already outlined in Section 1.1, minimizing setup costs and minimizing inventory holding costs are competing objectives. Accordingly, one of the main tasks of short-term production planning is to decide about the size of a "production lot", which is the quantity of a product that should be made at once. Figure 2.2 illustrates this trade-off between setup costs and holding costs as a function of the lot-size. In addition to this lot-sizing issue, another important short-term planning task is to schedule the lots on the machines.[4] Moreover, the shop floor control monitors all production activities and resources

[3] Usually an ABC-classification is executed (see Silver et al. (1998)) to focus on the most important A-products and their suppliers.

[4] Note that lot-sizing and scheduling is not necessarily a short-term planning task. Because of high setup times (several days or even weeks) and long production runs, it might also be a mid-term task (see also Suerie, 2005b, p. 69).

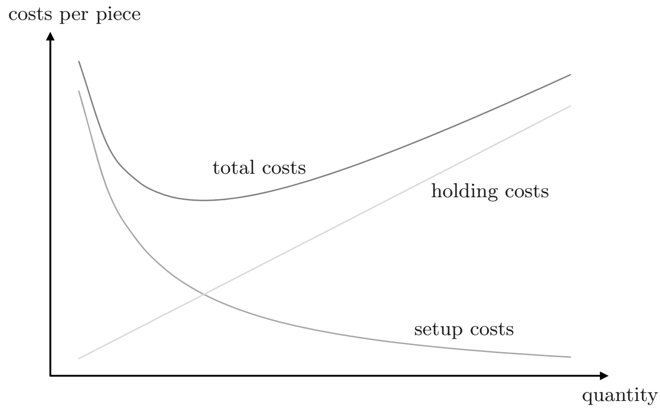


Figure 2.2: Trade-off between fixed and variable costs per piece of a production lot (cf. Harris, 1913).

to assure an optimal capacity utilization. Based on the short-term production schedule, a time-efficient shift schedule (extra shifts, overtime, capabilities of personnel, etc.) has to be determined.

As shown with the Supply Chain Planning Matrix, there are strong interdependencies between the different planning levels (vertically) and even between different tasks on the same level (horizontally). Therefore, a simultaneous consideration of all tasks would be preferable. But this monolithic planning approach is unrealistic, since the problem becomes much too complex and thus is not solvable at all. On the contrary, a pure successive planning approach might miss optimality by a great deal. A compromise is to decompose the tasks hierarchically which has several advantages (cf. Dempster et al. (1981) and Fleischmann and Meyr (2003)):

Since planning uncertainty increases with the length of the planning horizon, different planning levels should be based on different degrees of aggregation. For instance, on a strategic level, it might be sufficient to consider the yearly output for a product family of a whole plant and the demand of an entire sales region. Besides, this aggregation is also necessary because it is impossible to get detailed forecasts for several years at once. Another reason for such a decomposition is that the shorter the planning horizon, the more frequently the planning needs to be executed. Furthermore, strategic decisions are usually made centrally by a top manager, whereas on, e.g., the operational level, the production planners of different plants decide in a decentralized fashion.

For all these reasons, it makes sense to build "planning modules" which integrate the decisions which should be made simultaneously (cf. Fleischmann and Meyr, 2003). The aim of *hierarchical planning* is to find the right level of detail and the right planning horizon for the modules, and to coordinate them. The modules are arranged hierarchically and they exchange information and instructions (cf. Hax and Meal (1975) as well as Schneeweiss (2003)).

To decide whether the planning tasks of lot-sizing and machine scheduling should build a common planning module, the supply chain of the consumer packaged goods industry has to be analyzed. For that purpose, we introduce a typology in the next section which helps to characterize the supply chain.

## 2.2 Supply chain typology

Meyr and Stadtler (2008) present a *supply chain typology*[5] which allows identifying the planning/decision problems of a supply chain. They differentiate between functional and structural attributes.

### 2.2.1 Functional attributes

Meyr and Stadtler follow the logic of the Supply Chain Planning Matrix to structure the functional attributes of a supply chain (see Section 2.1). Accordingly, these attributes describe the procurement, production, distribution, and sales type of each member in the supply chain. An overview of the categories and attributes considered is given in Table 2.1.

To begin with the inbound side of a supply chain member, the procurement type has to be determined. At first, the type and the number of products which are procured have to be considered. The product type may range from rather simple standard products such as raw materials (e.g., milk or cereals) up to very complex and specialized items (e.g., entire consoles for car manufacturing). Since the products can be procured from different suppliers, the sourcing type describes their number (single-, double-, or multi-sourcing). Furthermore, the flexibility of a supplier in terms of quantities plays an important role, as well as the lead time and reliability (cf. Meyr and Stadtler, 2008, p. 66). A further relevant topic is the life-cycle of the externally obtained products, as a short life carries the risk that the product gets obsolescent in stock.

The production process can be organized in different ways, such as in a job shop or flow shop system. The repetition of operations is closely linked to the production type. It may vary from mass production (with a continuous repetition) to one–of–a–kind production (without any repetition). But there are also intermediate degrees between these two extremes. Then, typically, batches or lots have to be built (see also page 9). Before the

[5]This typology is supposed to be supplementing the SCOR-model which was published by the Supply Chain Council (2011). For further reading, see Suerie and Wagner (2008), among others.

| **Functional attributes** | |
|---|---|
| Categories | Attributes |
| Procurement type | number and type of products procured<br>sourcing type<br>flexibility of suppliers<br>supplier lead time and reliability<br>materials' life cycle |
| Production type | organization of the production process<br>repetition of operations<br>changeover characteristics<br>bottlenecks in production<br>working time flexibility |
| Distribution type | distribution structure<br>pattern of delivery<br>deployment of means of transportation<br>loading restrictions |
| Sales type | relation to customers<br>availability of future demand<br>demand curve<br>number of product types<br>bill-of-materials (BOM)<br>product life cycle<br>degree of customization<br>portion of service operations |

Table 2.1: Functional attributes of a supply chain typology (adapted from Meyr and Stadtler, 2008, p. 67).

production of such a batch (lot) can be started, usually a setup needs to be executed to prepare the machine. Accordingly, the changeover characteristics describe the time and costs which are necessary for this preparation. Setup times and costs can be either dependent or independent of the sequence of the batches or lots. Furthermore, if there are bottlenecks in production, the types of the bottlenecks have to be examined as well as the flexibility of extending or reducing the working time.

To analyze the distribution type, we have to consider the product flow to the customer / supply chain neighbor. First of all, the distribution structure may consist of several stages with different types, such as a two- or three-stage structure with central and regional warehouses. Another important issue is how regularly the supply chain neighbors are delivered (cyclic or dynamic). Besides, further loading restrictions, such as "full truck load" have to be identified.

The sales type is mainly characterized by the relation to the customer(s), which may range from a single direct supply chain neighbor to an anonymous market with thousands of participants. This relation also determines whether future demands are available as orders or forecasts. Especially for forecasts, the demand curve, which might be static, seasonal, and so on, needs to be known. For selling the products, the degree of customization, the number of different product types, and the product life cycle play an important role, as they directly influence sales activities like marketing. Closely related to these product properties, the bill-of-materials (BOM) describes how raw materials and components are processed for final items. In general, products might consist of different parts and components. In accordance with the relationship between items and their components, four different product structures are usually distinguished. If a product is only processed in further production steps, a serial product structure is assumed. However, if an item has exactly one component as predecessor, there is a divergent structure. Vice versa, a convergent structure means each item goes into exactly one product. Accordingly, a general structure shows none of these relationships. Since the bill-of-materials is a description of the product structure, the term BOM is often used synonymously with the term product structure in the literature. Another way to describe the product structure is a gozinto graph (see Figure 2.3). This is a directed graph where the nodes represent products and each arc is weighted with a "gozinto factor" which shows how many items of the source-product go into the sink-product.

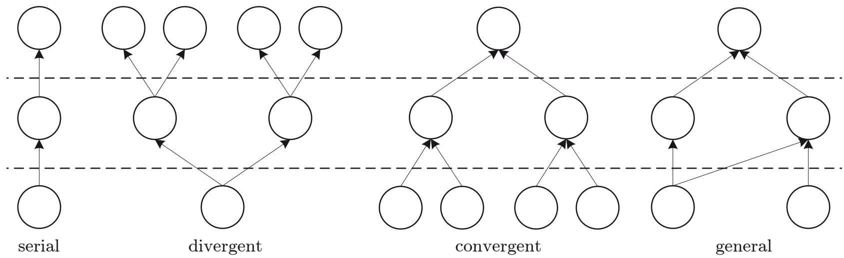


Figure 2.3: Gozinto graphs of the four product structures.

### 2.2.2 Structural attributes

The structural attributes given in Table 2.2 help describe the linkage between the members of a supply chain. They can be roughly grouped into the categories "topography" and "coordination and integration" (cf. Meyr and Stadtler, 2008, p. 69). The first category contains all attributes which characterize the supply chain. The network structure shows the links along the material flows in the supply chain. Moreover, the whole network may span several countries. Besides, the location of the decoupling point indicates which processes are executed before a customer order arrives (anticipative) or after (reactive). Finally, the major constraints arising through limitations of resources such as capacity, labor, and material have to be considered.

The integration and coordination of the supply chain members has to be analyzed as well. If legally separated companies build a supply chain, the legal position of each company is a relevant attribute. Accordingly, the balance of power must be considered, too. The direction

| **Structural attributes** | |
|---|---|
| Categories | Attributes |
| Topography of a supply chain | network structure<br>degree of globalization<br>location of decoupling point(s)<br>major constraints |
| Integration and coordination | legal position<br>balance of power<br>direction of coordination<br>type of information exchanged |

Table 2.2: Structural attributes of a supply chain typology (Meyr and Stadtler, 2008, p. 69).

of coordination which is also very important can usually be derived from the two previous attributes. Between different companies, the direction is horizontal, whereas it is vertical within a single company. Finally, the type of information which is exchanged between supply chain partners should be specified.

## 2.3 The supply chain of the consumer packaged goods industry

With the help of the typology presented in the previous section, the supply chain of the consumer packaged goods industry can be characterized (cf. Fleischmann and Meyr (2003) as well as Meyr and Stadtler (2008)).[6] At first, the *topography of the supply chain* and the *integration and coordination* will be explained. Afterwards, the functional attributes of the supply chain member "manufacturer" will be illustrated with a strong emphasis on the production and the sales type[7] categories due to the focus of this thesis.

### 2.3.1 Topography

Consumer packaged goods companies usually produce at several places in different countries. Furthermore, the raw materials are often purchased from different parts of the world and the finished products are distributed globally as well. Accordingly, the production and distribution network is widely ramified.

Especially in the consumer goods industry, final customer demands need to be met directly. If an item is not available on time, then, typically, sales are lost. Accordingly, the

[6]Not all of the companies in that industry have to show exactly the same characteristics. However, for those which can be characterized in a similar fashion, the models and solution methods presented in this thesis should be applicable.

[7]As Meyr and Stadtler (2008) point out, the final products (consumer goods) represent the determining factor of the supply chain.

delivery time has to be reduced to a minimum, which can be achieved by keeping finished goods in stock. This approach is called a Make-To-Stock (MTS) production, where the whole production process is decoupled from customer orders. Hence, the finished goods inventory

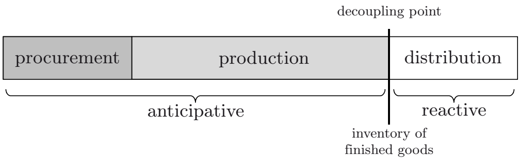


Figure 2.4: Decoupling point in a Make-To-Stock environment (adapted from Fleischmann and Meyr, 2004).

represents the decoupling point by definition (see Figure 2.4). This means that the whole production process is anticipative, and thus based on demand forecasts. Accordingly, forecasting accurately the demand is a very important task in an MTS environment (Vollmann et al., 2005, pp. 21–22). Because of the location of the decoupling point, central and regional warehouses are needed near the markets all over the world.

The major constraint is the limited production capacity. Due to the high degree of automation of the production lines this capacity is usually very expensive.

### 2.3.2 Integration and coordination

Since consumer goods are substitutable, due to their low product differentiation, the retailers (customers) are in a powerful position (buyer's market). Because of the global presence and competitive pressure, information must be exchanged horizontally as well as vertically to coordinate the supply chain.

### 2.3.3 Functional attributes of the manufacturer

#### 2.3.3.1 Procurement type

For producing consumer packaged goods, mainly raw materials such as dairy or cereals have to be procured. Usually, there are several possible suppliers on the market (multi-sourcing) with short lead-times. Moreover, long-term contracts are often signed with suppliers in order to bind them, even though the availability and quality of natural products cannot be guaranteed (e.g., due to bad weather and other critical factors).

#### 2.3.3.2 Production type

**Organization of the production process** Usually, the whole production process consists of several sub-processes, where each of these processes changes an item in the sense of adding value. Generally speaking, a sub-process transforms input, in the form of resources and pre-items, to output, in the form of intermediate and final products (cf. Meredith and Shafer, 2010, p. 8). In our case, such a transformation process corresponds to a certain functionality which is offered by a machine. We define this functionality as a production stage.[8]

The organization is mainly described by the layout of the machines and the flow of jobs/products (Silver et al., 1998, p. 669). The production in the consumer goods industry is usually organized as a flexible flow line system. But since there are different definitions of such a flow line in the literature (cf. Quadt and Kuhn (2007, pp. 686–687) and Ruiz and Rodríguez (2010) among others)[9], we need to specify this term for the consumer packaged goods industry. Hence, we define a flow line as illustrated in Figure 2.5: All products have to follow the same flow through the system, from production stage 1 to $E$. The production stages are serially arranged. At each stage, one or several parallel machines can be used alternatively as they provide partly the same functionality. They can be either identical in terms of the same setup and production times or heterogeneous with different times and speeds. A product may skip one or more production stages. Furthermore, the stages can be decoupled by buffers. The lots do not have to be transferred in whole batches in general, but can be streamed. That is why through-put times are low. This decrease, in turn, reduces the Work-In-Process (WIP) stocks as well.

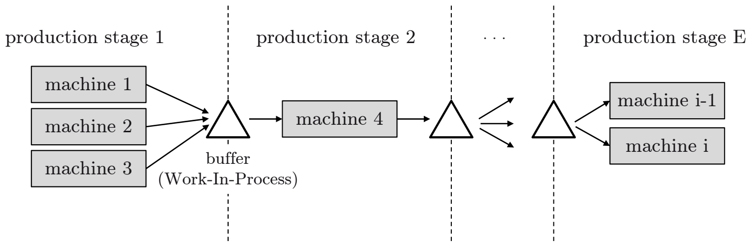


Figure 2.5: A flexible flow line in the consumer goods industry.

Note that "machine" is used here as a generic term for a planning resource which is considered as a whole. For instance, such a planning unit might be a (chemical) reactor. But also a flow shop with a pre-defined material flow can be aggregated to a single resource *production line*. Due to this aggregate view, we can assume that there are only two or three

[8]Accordingly, we get a "new" product at each stage, since value is added.

[9]The definitions are usually driven by the regarded industry. For instance, Quadt (2004) considers the case of the semi-conductor industry, where the machines at each stage have to be identical and the products have to be processed at all stages.

http://www.springer.com/978-3-658-02088-0

Multi-Stage Simultaneous Lot-Sizing and Scheduling
Planning of Flow Lines with Shifting Bottlenecks
Seeanner, F.
2013, XXVI, 182 p. 68 illus., Softcover
ISBN: 978-3-658-02088-0