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### Tasks, hierarchies, and flexibility

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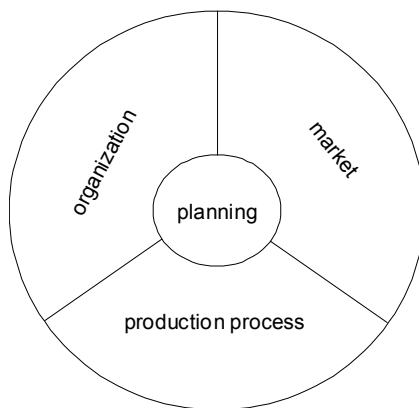
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# Chapter 2. Food Processing Industries

## 2.1. Introduction

In order to be able to determine how planning can contribute to flexibility, we first need to specify what flexibility is. For that reason, this chapter contains an overview of production system and market characteristics in the food processing industries. Furthermore, we elaborate upon the consequences of the changes in the market requirements on production in food processing industries. Because our interest is in planning, we will discuss these consequences in the context of planning and production control. Three areas of food producing companies that somehow have a relation to planning will be described (Figure 2.1). First, we will describe typical market characteristics of food processing industries in this research. Second, some organizational characteristics and typical organizational structures will be discussed, and third, we describe the production system as it appears in most small and medium sized food processing industries. After that, the influence of these areas on the planning function will be discussed.



**Figure 2.1.** Elements that relate to planning

This chapter will sketch the circumstances in which most day-to-day planners in small and medium sized food processing industries work. Not all possible characteristics will be described nor will the described characteristics occur in all companies. The information in this chapter is based on a literature review and case studies. Generic production and production planning and control literature is used to provide a background. Literature about the process industries provides somewhat more specific information about the companies in our research domain, and still forms a large base of research. Literature that is specific to production and production planning and control in food processing industries is rather limited, but often highly appropriate.

The cases that were used in this study fall in four categories: (1) short visits to factories, for example for a student's master thesis, (2) exploratory small visits that were made specifically for this research without an extensive exploration, (3) more detailed research at two companies, and (4) one case study to illustrate the designs that are made. Cases of the first two categories will not be described. The two cases of the third category will be described next, and the case of the fourth category will be described in Chapter 6.

There are some restrictions to the kinds of companies that are the aim of this research. First, they are rather small, typically between 50 and 150 employees. Second, they produce different products both to stock and to order. Third, customers are retail organizations. We will not say that the results of this research can not be used by companies that do not comply to these characteristics. Nor will we claim that all companies that do comply can use the results. We only state that the companies at which the research is conducted all comply to these characteristics. In Chapter 7, we will explore how the results can be generalized.

The following two sections describe two cases in food processing industries. We will describe concisely the production process, the kinds of customers, the organization of production control, the planning, the kind of computer support used, and the (potential) problems found.

## **2.2. Introductory case 1: a chocolate factory**

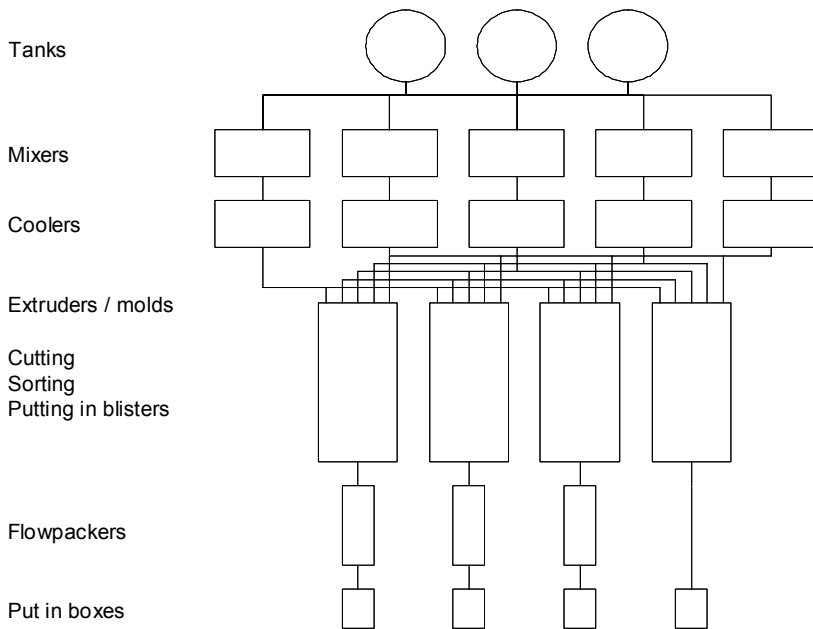
A manufacturer makes chocolate in all kinds of forms such as bars, sticks, and coins. The production process of all the different products is roughly as follows. First, the liquid chocolate that is stored in tanks is transported to the appropriate mixer. A human operator puts ingredients such as sugar, butter, flavors, and coloring matter to the chocolate (following the recipe), and the substance is mixed for a while. The substance that is now available in the mixing tank is one batch. The mixing tank can not be used again until it is empty. From here, the process is a continuous flow until the products are finished. The substance is first put through coolers which is a delicate process with very small margins for the speed of cooling. After that, the cooled chocolate is put through extruders or in molds. Two production lines use an extruder, and two production lines use a mold. Some additional operations must be performed, such as cutting, sorting, putting the products in trays, wrapping it in tinfoil, and putting it in boxes (Figure 2.2).

All coolers are connected to all extruders and molds, which means that the variety that is available in colors and flavors can be used for all product forms.

The customers are mainly retail organizations that carry their own brand of chocolate bars. These customers order the same products each week but the amounts differ. The factory carries also some brands of its own for which the products are made to stock. Some large orders are split into several smaller orders that are produced separately. Examples are chocolate letters for Sinterklaas, large export orders, and special product actions.

There are five people who's task has to do with production control. The logistics manager has the overall production control responsibilities. Next to being ultimately

responsible for the planning, he makes each month a capacity planning with a horizon of three months. A clerical employee takes care of stocks of raw material and packaging. He also simulates the planning when it is finished to check if it is feasible with respect to the raw material and packaging that is needed. The physical distribution coordinator deals with foreign orders. There are two production planners. One planner has the responsibility for the products that use the extruder lines, and one planner has the responsibility for the products that use the mold lines. Products for the extruder and products for the molds are relatively independent, although some machines in the processing phase can be used by both (the tanks and mixers) and some machines in the packaging phase can be moved from one line to another.



**Figure 2.2.** Layout of chocolate factory

The planning of the molded chocolate is mostly for the Dutch market and around 90% is produced to stock. The main goal is to keep the stock levels high enough. As a rule, stock levels should be three weeks. Customer orders have a delivery time of 10 working days (2 weeks). The extruded chocolate is mainly sold abroad. About 90% is produced to order and only a small amount is produced to stock. The planning process is roughly the same for both planners. First, at the beginning of the week a list is made that contains customer and stock orders that must be produced in the next week. Then, orders are clustered and ordered in such a way that production can proceed for a full day without major setups. The room that is left at each day is then filled with orders that have their due date after the next week, and stock products. This planning is finished on Thursday. On that day, there is a meeting with

the production manager, the planners, and the shift leaders at which the planning is discussed. Possibly, some changes must be made. At Friday, the planning is released to the production floor.

The planners use 5 computer systems: a system in which the orders are put by the sales department, a system for production control with the flow of goods and recipes, a system for stock levels and the location of products in the warehouse, a system that tracks the level of liquid chocolate in the tanks, and a spreadsheet to make the planning. The outcomes of all steps in the production process are written down. This information is collected during the day and entered in the production control system the day after. The level of integration of these systems is very low; there are no automatic links between databases. Orders, for example, are manually entered in both the system of the sales department, and in the spreadsheet that is used by the planners. Stock levels are usually printed once or twice a week on a large list, that is manually checked by the planners during the planning process. Also, planners sometimes walk to the storage rooms to check for the availability of ingredients. The analysis revealed the following problems or potential problems:

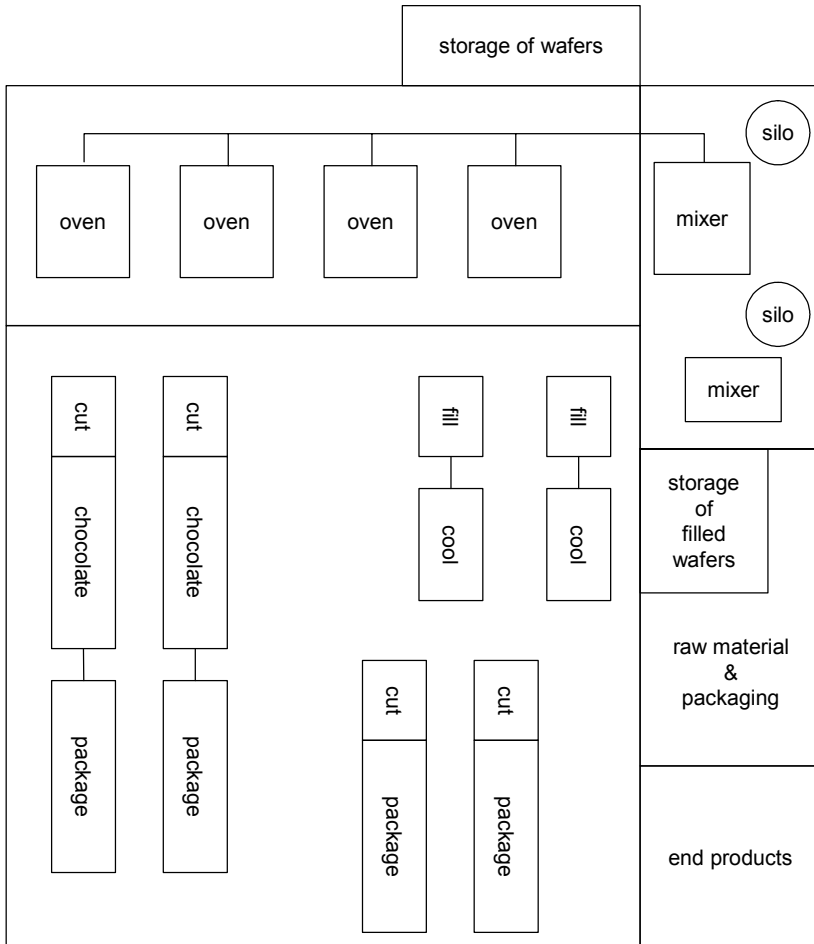
1. The stock levels in the systems are not the same as the stock levels in reality.
2. Different systems sometimes provide different stock level values for a product.
3. Raw material and packaging are sometimes not at the place they are supposed to be.
4. Events on the production floor are fed back the day after. Therefore, there can be no fast reaction to formal information.
5. Ordering of raw material and packaging from production to the warehouse is sometimes late.
6. Feedback of the availability of raw material and packaging for the planning (the simulation) is somewhat late in the planning process.
7. The computer systems suffice but are rather outdated.
8. Registration of production events is labor intensive and sometimes postponed if there is more urgent work to do.
9. Alternative routings for products are not structurally known.
10. Delivery performance is not as high as the manufacturer wants.

All in all, the factory appears very well organized, and these problems only indicate possibilities for improvement.

### **2.3. Introductory case 2: a cookie factory**

A manufacturer of filled wafers has the following production process. First, large wafers are made in ovens. These wafers can be used immediately, but they can also be put in a heated room. If the wafers are not used immediately, they attract moisture, which causes the wafers to get out of shape. Hence, if they are put in the heated room, they must lay there for at least two weeks, after which they are straight

again because they have dried fully by then. The next processing step is filling the wafers. This means that crème is put on one wafer, after which another wafer is put on top of it. This can be done for a maximum of nine levels. Subsequently, the wafers are cut and sometimes topped with chocolate. After this, the wafers can be put into a tray, and the trays are flow-packed and boxed. The packaging form differs per product (Figure 2.3).



**Figure 2.3.** Layout of cookie factory

Packaging machines can be moved to form a packaging line. There are six possible packaging line configurations but at most four can be run simultaneously due to scarcity of packaging machines. Baking the wafers, filling and cooling the wafers, and cutting and packaging the wafers are decoupled from each other. Both baked wafers and filled wafers can be stored.

Customers are retail organizations both in the Netherlands (around 40%) and abroad (around 60%). The number of customer orders for the Netherlands is around

40 per week. Around 75% of the local orders are delivered from stock, and 80% of the Dutch customers have a fixed delivery day each week. There are approximately 5 foreign orders per week that are each composed of 2 to 4 different products. The size of foreign orders is typically a full truckload or container, which is far larger than domestic orders.

The production planning is split in four stages: (1) the planning of the orders that must be produced, (2) the planning of the packaging lines, (3) the planning of the fill lines, and (4) the planning of the ovens. These four plans are made by different persons. At Thursday, a list is made with products that must be made the next week. A list with orders for the Netherlands is printed from a computer system. Export orders and stock levels are kept manually. These three lists are the basis to make the list with production orders. This planning is made before noon. It is discussed with the plant manager and the production leader, after which it is possibly altered. The finished order planning is the basis of the plans for the packaging lines, the fill lines, and the ovens. These production stages are decoupled in the production process, so the plans can be made somewhat independent. The preferred sequences of production differ in the subsequent stages. The plan for the packaging lines is made once a week, and the plans for the fill lines and the ovens are made on a daily basis. However, the order planning and the packaging line planning are adjusted frequently during the week.

The company uses a system for logistical control that handles order processing, accounting, and planning. There is also a spreadsheet that contains the recipes and that can calculate the needs for raw material and packaging on the basis of the amount of end products that must be made. There are several problems that make the production control system somewhat inappropriate. First, the system does not account for capacity. The order planning module only accounts for due date and throughput time. Second, the time of operations is rounded up to at least one day. Therefore, it is not possible to plan multiple operations on one day. Third, operations and materials are planned per week, so it is not possible to plan each day for the following day. From the analysis, we concluded the following problems or potential problems:

1. There are four people that are each responsible for a part of the planning. Because the plans are dependent, those four people must meet and discuss their plans regularly. This makes the throughput time of the making of the plan rather long. Furthermore, the way in which changes of one of the plans is communicated is mostly ad hoc. Therefore, it can happen that someone learns about a change too late.
2. Raw material and packaging is sometimes not available. The cause is that it is checked somewhat late if everything that is required according to the plan is actually available. The place that needs the plan as the first is the fill lines, but it gets the planning as the latest.
3. Computer support for the planning is mostly absent. The planning is made manually on paper or in a word processor.

Although the case descriptions are of course examples, we have seen these kinds of problems occur in other companies as well. In the remainder of this chapter, market and production system characteristics will be explored in more detail, and the findings will be confirmed by literature.

#### 2.4. Market characteristics: supply chain and competition

The value chain of the food industries proceeds from farmer to industry to retailers to consumers. Meulenberg & Viaene (1998) show some examples (Table 2.1).

Farmer Consumer	Farmer Middleman Consumer	Farmer Wholesaler Retailer Consumer	Farmer Wholesaler Industry Retailer Consumer	Industry Farmer Industry Retailer Consumer
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**Table 2.1.** Examples of food chains (Meulenberg & Viaene, 1998, p. 5).

In this research, we look at planning issues in the food processing industries. Before aspects of food processing industries are discussed in more detail, we first look at developments of the supply chain of the food industries. Van der Vorst (2000, p. 5) provides an overview of these developments (Table 2.2). Concentration and cooperation of retail organizations have resulted in changes in the power balance in the value chain. Meulenberg & Viaene (1998, p. 19) state three reasons why food retail chains have substantial bargaining power. First, food retail chains have concentrated to an oligopolistic market. Macchietto (1996) reports about this that “the industry is characterized by a small number of very large players, with global, integrated product development, manufacturing and distribution networks, and strong product brands. [...] In the UK 5 big retailers share approximately 80% of the market. They have very large buying muscles and command much attention from their manufacturing suppliers. The retailing end of the business is characterized by high volume, low inventory, short lead times, wide variety of products, and strong competition on price”. Second, there is a surplus of production capacity in food processing industries. Third, products are often only to a limited amount unique and producers are exchangeable. One of the effects of the changes in the power balance is that the retail organizations can require that the products can be replenished at short notice. Or, reasoned from the perspective of the producer, that the order lead time must become shorter (Table 2.3). This shortening of lead times has consequences for many aspects that are engaged in production, such as order processing, materials management, planning, and shipping. Some of these aspects will be discussed in the coming sections.



Stage in the supply chain	Developments
Growers/ producers	Increasing production costs due to governmental rules concerning environmental and consumer-related issues
	Lower prices due to liberalization of markets
	Reducing number of and scaling-up of farms in the EU
Wholesalers	Scaling-up and concentration
	Global sourcing
Food industry	World-wide concentration of food producers
	Increasing power of retailers
	Differentiation by A-brands
Retailers	Advanced processing and Information and Communication Technologies
	World-wide concentration of retailers
	Growing strength of supermarket own-label products
	More consumer knowledge through new Information Technologies
	Growing relative importance of supermarkets for grocery purchase
Consumer markets	New ways of distributing food to consumers
	Saturated markets
	Mass customization

**Table 2.2.** Developments in the food supply chain (Van der Vorst, 2000, p. 5)

Lead-time	Supplier/DC	DC/Store
Past	120-48 hours	48-36 hours
Present	48-24 hours	18-12 hours
Future	12-4 hours	18-4 hours

**Table 2.3.** Lead-time from supplier to distribution centre (DC) to store at Albert Heijn (Willemse, 1996).

Demographic changes in the population of consumers and changes in consumer behavior have also resulted in changes in food processing industries. Families become smaller and the number of two income households becomes larger. Heilig (1993, p. 81) discusses three trends. First, traditional dishes that are prepared from raw products are being replaced by industrially produced food. Second, seasonal patterns in food consumption disappear, and third, exotic food is gaining popularity. Other trends are that life-span of products is shortened and that there is a tendency of diversification (Nakhla, 1995, p. 86).

Macchietto (1996) discusses some effects of changes in the food industries on production and production control: "... it is clear that the food manufacturing focus is expected to be for the foreseeable future on safe, efficient, and responsive operation of integrated plants producing a variety of products. The pressure on margins requires minimum wastage and high resource utilization. This demands

maximum flexibility from manufacturing operations, hence the ability to handle short product runs, variable batch sizes, frequent, high speed changeovers, robust control of individual batch operations and the ability to quickly introduce new product formulations". These issues will be further elaborated upon in the section about production control. First, however, we will discuss organizational issues and production characteristics of food processing industries in more detail.

## **2.5. Organizational characteristics**

The number of employees of small and middle sized food processing industries typically ranges between 30 and 150 for the production floor. Production mostly stops at nights and in weekends but sometimes production also proceeds then. The organizational structure depends mostly on the history and ownership of the firms. Most of these companies have an origin as a family business that has grown throughout the years. This has consequences for the way that such organizations are managed. Decisions in firms that are owned by the managing director are usually taken in a more centralized way than in firms that are a division of a large corporation. There is a trend of concentration in the food processing industries, although not as extreme as in retail. We will use the categorization that is described by Mintzberg (1979) to illustrate how food processing firms are mostly organized.

Mintzberg distinguishes the strategic apex, the middle line, the technostructure, the support staff, and the operating core (Figure 2.4). The strategic apex generally consists of the board of directors, led by the managing director. Common functions in the board of directors are a marketing manager, a financial or accounting manager, and a plant or production manager. Depending on the size and complexity of the firm, there could also be managers for research and development, logistics, and other functional areas. Purchasing of critical raw material that needs to be bought with long term contracts might also be a task of the board of directors. The firms in this research are mostly too small to have a separate middle management. Often, foremen or team managers are the link between the strategic apex and the operating core. The operating core deals with the primary process. Functional areas with respect to the flow and transformation of goods are purchasing, warehousing, production, sales, and shipping. The support staff consists of functions such as legal counseling, public relations, research and development, quality control, etc. Finally, the technostructure's purpose is to make the work of others more effective. Here, apparent functions are strategic planning, training, maintenance, process control, and production planning. Due to the size of many companies in the food processing industries, employees often perform multiple functions (e.g., there could be someone who performs research and development, quality control, and process control), or functions are not performed at all (e.g., training and legal counseling).

Formal authority relations and coordination of work are mostly organized by process and function. This means that work is organized in a traditional hierarchical way. For example, in production departments, there can be a straight hierarchy with operators that function under the responsibility of a team leader, the team leaders work under a shift leader, and the shift leaders report to a production manager.

Figure 2.4 depicts an example of an organizational structure in food processing industries.

Planning is often the link between marketing or sales and production. Therefore, the placement in the hierarchy has an impact on the power balance. The appropriate place of production planning in the hierarchy is, both in organization theory and in practice, not clear. In most cases, the planning department is positioned in one of four possible settings: there is a planning department next to the production and sales departments; the whole planning department falls under the production manager; the whole planning department falls under the sales manager; or some people in the planning department fall under the production manager and some people fall under the responsibility of the sales manager.



**Figure 2.4.** Example of organizational structure in food processing industries

If the planning is positioned either in production or sales, there can be a clear emphasis of interests. In the mixed form, some people in the planning department function under the production department, and some people function under the sales department. Then, a conflict in interests can first be tackled in the planning department itself, before higher levels in the hierarchy must be involved. Even if the organizational structure and authority relations are agreed upon in an organization, perceived goal differences between employees of marketing, production, and planning can impede the “functioning of organizations as single integrated wholes” (Nauta & Sanders, 2000, p.30).

In the following sections, the functions of the operating core will be explained in more detail, since an understanding of the primary process is necessary in order to be able to analyze and design the planning function.

## 2.6. Production system characteristics

The production system consists of all activities that engage in the production of food. These activities are not limited to physical transformations. Activities such as internal transportation and some management activities also belong to the production system. In this section, we describe in two parts the elements of the production system that usually exist in food processing organizations. First, the physical aspects of production will be discussed, and second, we will describe common control functions of production processes.

### 2.6.1. Physical aspects

As said, a production system is a collection of interrelated activities involved in the production of goods and services. The elements of a production system can be modeled as consisting of inputs, conversion and creation processes, and outputs (Figure 2.5).

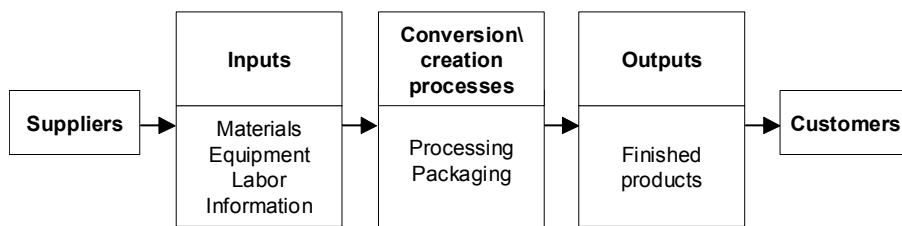


Figure 2.5. Production system

Note that the organizational structure, control aspects, or human task performance of these functions are not discussed in this section. These were discussed in the section about organizational characteristics (Section 2.5) and will be discussed further in the section about production control.

We will use the elements in this model to describe common characteristics of production systems in food processing industries. The external elements (the suppliers and customers) were already described in Section 2.4. Here, we describe the internal aspects.

#### 2.6.1.1. Inputs

#### 2.6.2. Materials

Two kinds of materials can be distinguished: raw material and packaging. Raw material is used to actually make the products. The raw material suppliers for consumer food producing organizations are mainly industrial organizations that make bulk products. Usually, there are two kinds of raw material for consumer food producers. First, there is raw material that constitutes most of the product and that is used in high volumes. Examples are liquid chocolate, flour, butter, milk, sugar, water, etc. These kinds of products can usually be delivered at short notice and in high volume. Second, there is raw material that is used in smaller quantities, for

example flavors, scents, coloring matter, etc. These substances are often predominant at distinguishing the product features from a customer point of view. Procurement lead times of these products can be long. Raw material in food processing industries has two important features that influence production control. First, the agricultural nature makes that variability in certain aspects is high. It is not always exactly known beforehand how much will be delivered, the quality of the raw material can vary, and the price of raw material can fluctuate, e.g., with seasons. This variation can lead to variations in the recipe to keep the product characteristics constant (Rutten, 1995; Fransoo & Rutten, 1994). Note that food processing industries that make consumer products usually get their raw material from food industries that (pre)process agricultural material. Most of the variability is leveled there. Therefore, the variability is not as high in these industries. Second, raw material can be perishable, for example milk. These kinds of products must be processed before they decay. This has consequences for the frequency and quantity of orders, and for the sequence of production.

Packaging has two functions. First, it is used to protect the food from damage and decay. Second, packaging determines the appearance of the product. Much products use both kinds: an inner wrapper for protection, and an outer wrapper with brand specific depictions and product information. Often, packaging is available on demand. Then, the organization itself has a only a small stock of packaging, and the supplier can replenish it at short notice.

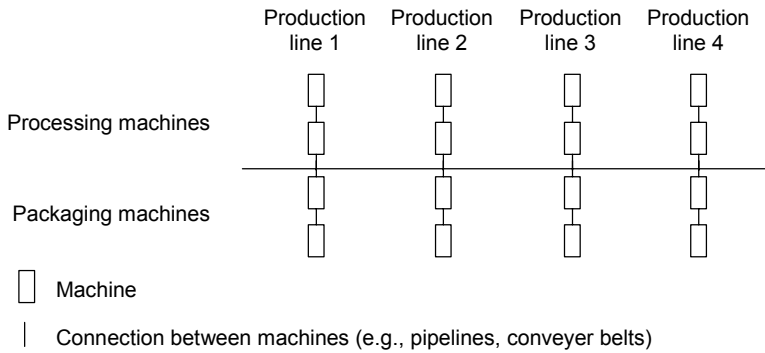
### 2.6.3. *Equipment*

There are two types of functions of equipment in food processing industries: processing and packaging. These two functions are mostly performed by different machines, but there are also machines that can perform both functions. In the remainder, the term equipment will be used to refer to a machine from a functional perspective. Processing equipment transforms raw material in the eatable or drinkable product. Packaging equipment puts this in packaging. The differences in these kinds of equipment lead to a separation in a processing phase and a packaging phase in production. In the processing phase, the equipment typically consists of kettles, ovens, pipelines, mixers, conveyor belts, etc. In the packaging phase, packaging machines are used to put foil or tin foil around the product and to put the discrete units into trays, tin cans, or boxes. Somewhere in the processing phase or the packaging phase, the products must be transformed into discrete units. From a production control perspective, the technical aspects of such equipment is not important. Rather, it is functional aspects that can influence planning decisions:

- One batch in the processing phase can be used for multiple products in the packaging phase. Therefore, orders that can be created from one batch should be planned together to fill one such batch.
- Buffers (e.g., a kettle that can hold milk without decay) make that processing can be planned separately from packaging.

- Change-over time (cleaning of and changes to equipment due to product changeovers) during production hours means a loss of production time. Planning must take this into account because change-over time can be sequence dependent (e.g., a pipeline must be cleaned if white yoghurt is produced after strawberry yoghurt, but not the other way around).
- Differences in production speed can indicate preferred machines for some products.

The layout in food processing industries is mostly a mix of process layout and product layout (Figure 2.6).



**Figure 2.6.** Typical layout in food processing industries

Because all processing machines are grouped together and all packaging machines are grouped together, there is a process layout. But, since the machines are connected in the sequence of processes, there also is a product layout with batch production. Note that there can be the possibility to change the flow, i.e., a product that is processed at production line 1 can be packaged at packaging line 3. The occurrence of both process and product layout induces specific issues for coordination at the production floor, which will be discussed in the subsection about control aspects.

#### 2.6.4. Information

Both the information content and information flows depend heavily on case specific characteristics, but there are several generic information types that are used in the production system. First, personnel must know what must be made at what time. This information comes from the planning. Often, the planning only gives a sequence of orders (sometimes with due dates) without specifying exact starting and ending times. Second, it must be known how to make the products. This information is often automated, but books in which operators must manually search recipes are also frequently used. Third, there must be coordination between the several phases in the process, e.g., the packaging department must know when exactly one batch will be finished and the next will be started to be able to prepare a setup. Products that are

discrete can be identified by physically attaching product information, something which is more difficult with non-discrete products.

The inputs that are discussed in this sub-section are used in the production process. Material is transformed by equipment on the basis of information. We proceed by elaborating upon production processes in food processing industries.

#### *2.6.4.1. Processes*

Although food is usually composed of several ingredients, production is mostly divergent because of a large variety of products that is created by different packaging forms, and sometimes by-products. Some processing operations can occur after packaging, e.g., cooking of sausages. The processing phase has characteristics of both continuous and batch production. The packaging phase is often purely batch oriented. The throughput time of a batch in both kinds of processes is often small, in the order of magnitude of hours, although processing steps can sometimes also take longer, e.g., days. Both kinds of processes will be discussed below.

#### *2.6.5. Processing phase*

In the processing phase, the actual food products are made. This is done by all kinds of physical, chemical, and biological processes, e.g. (Bruin, 1992; Macchietto, 1996):

- Separation processes (e.g., diffusional extraction, concentration of juices, separation of flour)
- Assembly or texturizing processes (e.g., emulsion processes for margarine and ice cream, foaming of whipped cream, extrusion processes, dough making)
- (Bio)conversion processes (e.g., sugar fermentation to alcohols, roasting)
- Preservation processes (e.g., retorting to eliminate microbial, enzymatic or chemical spoilage).

Processes in the processing phase are often variable to a certain extent. The duration and yield of processes can both fluctuate. This uncertainty can result in control problems. Ways to deal with this are to use a mean yield in the recipe, create a safety buffer of raw materials that have the most variable yield, create safety time in the production plan (Fransoo & Rutten, 1994), and to maintain a stock of end-products. Sometimes, there is a pre-processing phase (to make some half-products beforehand) that can be performed independently of the main production process because the half-products can be stocked. This is important for production control because it allows decoupling of processes.

The processing phase has some characteristics that are associated with continuous or flow production because it deals with bulk quantities of homogeneous products. On the other hand, there are several reasons that operations that are basically continuous in nature are nonetheless produced in batches. First, there is only a

limited amount needed of a product. A following product might need another recipe which results in a forced interruption of a continuous process. Second, some processes require batch-wise production because operations such as mixing and heating take place in kettles. Third, hygienic requirements necessitate frequent cleaning. Processes that are continuous need periodical interruptions for cleaning, and cleaning operations need to be scheduled (Liu & Macchietto, 1997). Fourth, product decay leads to a limitation of storage life which in turn can lead to separation into batches. Fifth, lot traceability requirements can lead to artificial separation into batches (Macchietto, 1996).

The charge unit size is often a tank or a vessel, and the batch size is a number of charges. From one batch, a lot of consumer units can be produced. Often, even several types of consumer products can be made from one charge by switching the packaging size or brand. An effect of production in batches is that if quality is poor, the whole batch must be rejected (Fransoo & Rutten, 1994).

#### *2.6.6. Packaging phase*

Two functions of packaging can be distinguished: protective packaging and cosmetic packaging. Some packaging has both functions. Examples are cartons or bottles for dairy products, and trays with an airtight plastic wrapper for biscuits and cookies. Similar products (i.e., from the viewpoint of the processing phase) can be packaged differently. Examples are differences in packaging size, and differences in the labels on the packaging.

According to our observations, production interruptions occur more often in the packaging phase than in the processing phase, especially if the products are small and discrete, e.g. cookies. Products sometimes fall crooked on conveyor belts, thereby causing congestion. In addition, it is not rare that machines are old and frequently get jammed with the product or with the packaging.

The packaging phase is usually labor intensive. Sometimes parts of the packaging phase are entirely manual, for example removing broken products, putting biscuits in trays, etc. Automation of such processes is difficult and expensive. In addition, somebody must monitor the automated processes. Because a line-stop can result in losses of products, products are manually put on tables as much as possible if a packaging machine is jammed.

An important aspect in practice is that packaging lines need some time before they run smoothly after a major setup, for example because the final adjustment of the setup can only take place during running, or the line operators must get used to the current product. This is one of the reasons why frequent setups are avoided.

##### *2.6.6.1. Outputs*

The output of production processes can be separated in four categories: semi-finished or half products, end-products, by-products, and waste. Half products are usually stored only shortly at the production floor because shelf life and storage space are limited. The end-products are mostly stored on pallets to be shipped to a



distribution center at short notice. By-products are often sold, and waste is thrown away, sold to for example feed industry, or stored to be reused in future products.

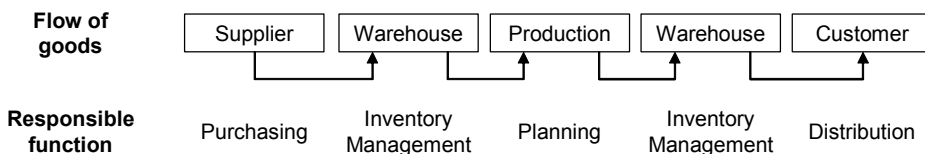
The description of inputs, process, and outputs concludes the discussion about the physical aspects of the production system. In the next section, we will describe how the various aspects of production systems are commonly controlled in food processing industries.

### 2.6.7. *Production control*

Production control deals with the control of transformation of goods or services in time. Such functions deal, for example, with the flow of materials, utilization of people and equipment, and coordination of internal activities with suppliers. Production control decisions must balance the requirements of the market, such as delivery performance and product quality, with internal organizational factors, such as working hours, setup costs, production batch sizes, capacity usage, etc. We distinguish two main categories of production control decisions: decisions with respect to materials management and decisions with respect to capacity use (Bertrand et al., 1990). Planning is part of the latter. Both types will be discussed here.

### 2.6.8. *Materials management*

There are several aspects of materials management that are common for small and medium sized food processing industries. First, material management mainly deals with stock management of raw material, packaging material, and finished goods. Material flows in food processing industries, which can be very complicated in a job shop, do not need special management due to the flow characteristic of facility layout and relatively short throughput times. The short throughput times also lead to a small amount of work in process compared to the stock of raw material and finished goods. Second, stock of finished goods (which usually concerns only products of own brands) is usually not stored very long at the production facility. Due to the high volume character of food processing industries, the products must be shipped shortly after they are produced, because there is not enough room at the manufacturing site. Often, finished products are shipped as soon as a truckload is produced to specialized distribution sites. Then, only the amount of stock matters, not the physical aspects of storage. Figure 2.7 contains a basic logistical chain. In this section we will explore aspects that are generic for food processing industries of each of the elements in Figure 2.7.



**Figure 2.7.** Basic logistical chain

The purchasing function decides what goods will be ordered and the moment to order them. This function must work closely together with both production control to ensure that the right products are ordered timely, and with inventory management to ensure that the stock positions will not become too high or too low. The warehouse is responsible for storage of goods that are delivered by the supplier and products that are made by the production department. Often, the warehouse is also responsible for the transport of those goods to the production floor and back. In food processing industries, there are two main aspects that determine how the goods will be stored (Table 2.4).

		Unit type	
		Non discrete	Discrete
Volume	High	Main ingredients, e.g., flour, milk, butter. Stored in silo's, tanks	(Mostly brand independent) packaging material, e.g. trays, boxes, wrappers. Stored in warehouse.
	Low	Additional ingredients, e.g., flavor, coloring, salt, sugar. Stored in barrels, bottles	(Mostly brand dependent) packaging material, e.g. trays, boxes, labels. Stored in warehouse. Available on demand

**Table 2.4.** Storage of products

First, volume can be high or low. Second, the type of product can be discrete or non-discrete. High volume non discrete products are usually stored in silo's and tanks. These are not necessarily placed in the warehouse. Rather, the location depends on the way they must be filled or emptied. Transport of such products mostly takes place by pipelines.

Inventory management functions must decide on the stock positions for the various products. Some aspects that must be taken into account are costs, decay, order lead time, and the expected use of material. In small and medium sized food processing industries, inventory management functions are usually performed by the purchasing department, the production manager, the planner, or the foremen. Stock positions can be calculated by production norms (current stock is the previous stock minus what is used for production according to the recipe) or by measurement. Although the latter is more accurate, the former is used more often because it takes less time and is accurate enough in most cases. There is, however, some variability in what is actually used during production. Frequent stock measurement is then used to make sure the stock figures do not deviate too much from reality. Still, during our observations we noted that unexpected stock-outs occur frequently because the stock levels are not registered correctly in the inventory system on which the planning is based.

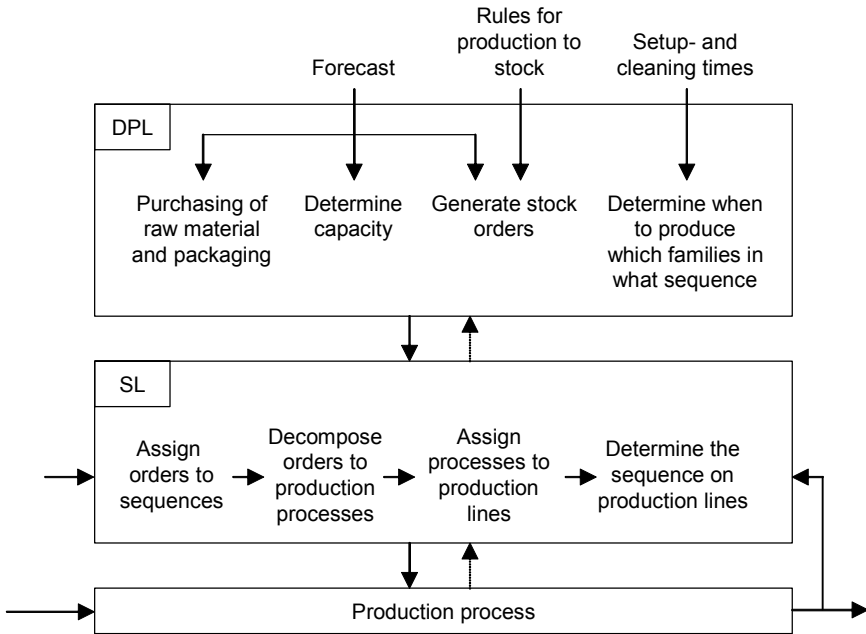
### 2.6.9. *Production planning*

We already noted that the combination of a product layout and a process layout has some consequences for production control. First, work at the functional areas must be coordinated. For example, if only one person must monitor all kettle processes, then there should not start too many new processes at the same time. Second, work at the production lines should be coordinated. This has mainly to do with the moment of product changeovers and production speed of the machines in the line. Such decisions are made at the production floor. There is usually almost continuous mutual adjustment about production speed and the exact moment of product changeovers. An overall coordination mechanism in the form of a production plan states what products must be made at approximately what moment. With the information from the production plan, all departments know what activities must be employed. It is necessary to know this in advance because there is often the need to make some preparations, to order raw material and packaging, and to make a personnel schedule. The production plan is made on the basis of expected and received customer orders and stock levels, within the scope of available raw material, available packaging, and capacity restrictions. The production plan usually states what products should be made in what time frame, and is based on average production speed. In order to typify production planning as it is encountered in food processing industries, we will first shortly elaborate upon production planning in a general sense.

There exists several production control frameworks in which planning activities are described. The frameworks include activities such as resource planning, demand management, master production scheduling, capacity planning, and materials planning. Example frameworks are MRP-II for discrete environments (Vollmann et al., 1997), and the Process Flow Scheduling framework (Bolander & Taylor, 1993) for process industries. The frameworks have separate sub-plans in an aggregation sense (e.g., rough cut capacity planning and detailed capacity planning) as well as in a decomposition sense (e.g., materials planning and capacity planning).

Production planning and control frameworks scarcely pay attention to day-to-day planning. The models in the frameworks usually stop at the level of order release, i.e., an order is released to the factory with a due date before which it must be produced. When the order must be handled exactly is then yet to be determined. How this must be decided on is usually not prescribed or described by production control frameworks. The actual assignment of orders to machines and production times is what we have called the day-to-day planning task. The path that leads to such a plan usually contains several levels. An apparent distinction in levels that stems from Operations Research is the one between sequencing and scheduling. Sequencing decides on the number and order of batches of different products that need to be manufactured to fulfill given production requirements. Scheduling determines the precise timing of each batch of material going through the system (Kondili et al., 1993). Van Dam (1995) and Van Dam et al. (1993) describe two levels with day-to-day planning activities they encountered in practice: a higher level labeled the Detail

Planning Level (DPL), and a lower level labeled the Scheduling Level (SL) (Figure 2.8).



**Figure 2.8.** Example of scheduling decision hierarchy (adapted from Van Dam et al., 1993)

The DPL deals with decisions that have an important impact on other scheduling decisions. DPL decisions often establish prerequisites that extend over individual orders, i.e., decisions at the detail planning level are made on the basis of aggregate measures or forecasted information. Decisions at the DPL usually concern balancing of capacities for the coming weeks, decisions with regard to overtime, number of shifts, number of employees, stock levels, purchasing of materials, the moments of major product changeovers, possibly the sequence of production, etc. These decisions determine the decision space for the scheduling level. Decisions at the SL can deal with allocation of production orders to production lines, assignment of operators to production lines, sequencing of orders, starting and finishing times of production, etc. There are two kinds of decisions at the SL. First, constructive scheduling decisions result in a schedule of a period before that period starts. Second, reactive planning (also called repair-based planning) means that an existing plan is adapted (Smith, 1995; Suresh & Chaudhuri, 1993). Repair-based scheduling decisions are based on unexpected events that occur during the period that the plan covers. Such events are, for example, stock-outs, machine breakdowns, rush orders, etc (Table 2.5). The division in a constructive phase and a reactive phase is also called offline scheduling versus online scheduling (Cott & Macchietto, 1989).

In the cases we studied, there are often three parties involved in the planning process: the production manager, one or more planners, and one or more foremen or operators in the production process. The allocation of decisions is highly case dependent, but some general remarks can be made. The production manager often deals with some decisions at the DPL that have an important impact on costs, such as the number of shifts, the production lines that are going to be used, the number of setups, etc.

Source	Event
Customer	New order
	Change of order
	Cancellation of order
Product	Rejection of batch due to quality problems
	Raw material out of stock
	Packaging out of stock
Process	Process duration differs from planned (e.g., due to short machine interruptions or processing uncertainties)
Machines	Breakdowns for longer periods
	New capacity available

**Table 2.5.** Examples of events

The planner deals with decisions at the DPL that have a more operational nature, such as determination of the size of stock orders. In addition, the planner makes SL decisions such as allocation of orders to production lines, sequencing decisions, and rescheduling. The foreman can sometimes decide on the sequence of production, and the exact starting time of production of an order.

## 2.7. Analysis of conflict

The previous sections describe numerous aspects of the market, organization, and production system in food processing industries. Figure 2.9 and Table 2.6 show that the various planning related functions present conflicting requirements with respect to the planning. In this section, we will recapture and analyze these conflicting requirements, and elaborate the planning requirements that are conflicting.

The design of a planning concept in production organizations must weigh the interests of the production department, the interests of the customers, and the efforts that are needed to make the plan. The following overview describes how a higher order frequency, smaller orders, and shorter lead times contradict the effects of the production characteristics.

- *Small orders.* Due to setup-times, cleaning times, and startup losses, long runs are preferable from a production perspective. Production batches are often preferred to provide a half day or a whole day of production time so changeovers can take place during lunch or in the evening. This contradicts

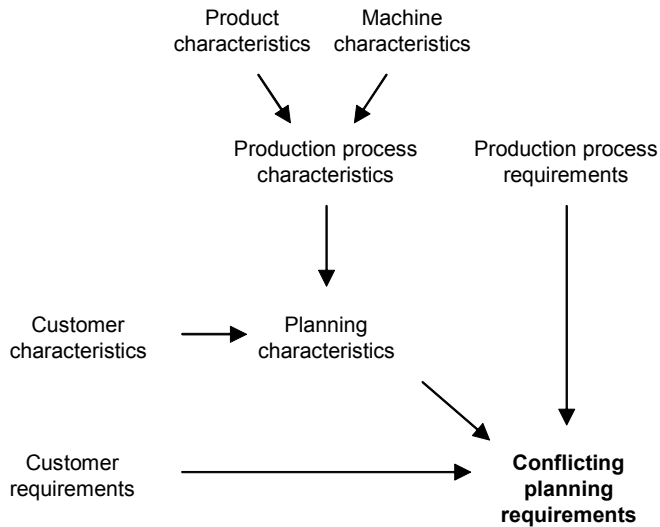


Figure 2.9. Conflicting planning requirements

the wishes from the market that orders should be small. Customer orders can be grouped, but this contradicts the requirement of short lead times, as will be explained next.

- *Short lead times and multiple products from one batch.* Sometimes several orders can be produced from one processing batch by changing the packaging. To change the packaging is usually not very time consuming. Therefore, grouping can be used to process small orders efficiently. However, because the processing batches (which are the groups of customer orders) must be attuned, the customer orders must be known beforehand. This opposes short lead time
- *Short lead times versus sequence dependent setup and cleaning times.* Due to sequence dependent setup-times and sequence dependent cleaning times, orders should be known beforehand so they can be sequenced in a way that minimizes setup and cleaning losses. This contradicts the wishes from the market that lead times should be short.
- *Short lead times and low inventories.* If the lead time of customer orders is shorter than the procurement lead time (the lead time that is needed to get raw material and packaging), then raw material and packaging must be stocked. Stock is avoided for a number of reasons: unexpected stock-outs can occur if the processing yields are unpredictable, stock costs money (holding costs and working capital costs), perishable raw material can not be put to stock very long, and producing from stock means that the manufacturer must sometimes reject an order if there is not enough.

<p><b>Product characteristics</b></p> <p>A1. Variable supply  A2. Variable quality  A3. Variable price  A4. Long procurement lead times  A5. Decay of materials (raw material, half products, end products)  A6. Huge volumes</p> <p><b>Machine characteristics</b></p> <p>B1. Extensive setup-times (especially of packaging machines)  B2. Extensive cleaning-times (especially of processing equipment)  B3. Time needed before production runs smoothly</p> <p><b>Production process characteristics</b></p> <p>C1. Processing equipment differs in preferred processing speed from packaging equipment  C2. Different (parallel) machines differ in processing speed for the same product  C3. Sequence-dependent setup-times  C4. Sequence-dependent cleaning-times  C5. Little or no intermediate storage (A5, A6)  C6. Flowshop production structure  C7. Variable yield (A2)  C8. Variable processing time (A2)  C9. Multiple recipes for a product (A1,A2,A3)  C10. Preprocessing  C11. Simultaneous product layout and process layout  C12. Divergence; half products can be packed to many types of end products</p> <p><b>Production process requirements</b></p> <p>D1. Low inventories  D2. Efficient production (low set-up and cleaning times)</p> <p><b>Customer characteristics</b></p> <p>E1. Many customer orders repeat each week with only little variation in the amount ordered  E2. Brands of customer and brands of producer</p>	<p><b>Customer requirements</b></p> <p>F1. Short lead time  F2. Small order size  F3. Wide variety of products  F4. Competitive price  F5. Lot traceability  F6. Good due date performance</p> <p><b>Planning characteristics</b></p> <p>G1. Multiple orders in production batches (C12)  G2. Fixed sequences (C4)  G3. No variable routings (C6)  G4. Production to order and production to stock (E2)  G5. Either frequent rescheduling or slack in the schedule (C7, C8)  G6. Successive processes can not be scheduled independently (A5, C5)  G7. Successive processes can be scheduled independently (C5, C10)  G8. Scheduling of the processing phase differs from scheduling of the packaging phase (B1, B2, C1)  G9. Stock products can be used to balance the schedule (G4)  G10. Predictions can be fairly accurate and the constructive planning phase can be based on existing patterns (E1)</p> <p><b>Planning requirements</b></p> <p>H1. Short throughput time of planning decisions (F1, F2)  H2. Long throughput time of planning decisions (G1, B1, B2, B3)  H3. Efficient schedules (D1, D2)  H4. Little due date violations (F6)  H5. Little planning effort needed</p>
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(References between brackets mean that a factor is (partly) caused by another factor)

**Table 2.6.** Characteristics of planning related elements in the food processing industries.

- *Short lead times and variability in processes.* The focus on high use of capacity usually leads to tight schedules in which there is not much slack to deal with variability in the production processes. Production to order with short lead times and low stocks of finished goods enlarge the risk that variability leads to stockouts or tardiness.
- *Short lead times and planning organization.* The organization of the planning is usually not geared towards adaptation of the plan. If lead times are shorter than the planning horizon, however, then orders should be processed in the existing schedule. Due to the sequential nature of much planning decisions (first determine capacity, then determine product families, then assign orders, etc.), it proves difficult to adjust an existing plan.

Short lead times and small order sizes clearly oppose efficient production in a number of ways. Most of these contradictions have their origin in physical aspects. Reducing cleaning times, setup times, startup losses, and variability of production processes, would remove a lot of barriers to short lead times and small orders. The contradiction that refers to the planning organization is not of a physical nature but has to do with the control of the production system. If plans could be adjusted easily, then lead times could be short, and physical characteristics would be the bottleneck instead of the planning. Therefore, we choose to investigate how the planning can deal with short lead times and small orders, and how this can be done without ignoring the physical restrictions. In other words, as is stated by the research question, how can the planning contribute to flexibility of the production system?

## **2.8. Conclusion**

This chapter contains three segments: two exemplary case studies, an overview of characteristics of food processing industries, and an analysis of how market requirements and production requirements result in opposing planning requirements. In an apparent situation of stability, the design choices represent the results of implicit or explicit considerations of these requirements. If there are prerequisites that change, however, then there should possibly be a reassessment. This is the case in the food processing industries with the order frequency and order lead time.

The conclusion that market and production requirements are in some ways contradictory is not surprising. Ample literature exists on this topic. The main contribution of this chapter is that it is specifically oriented towards the food processing industries. The analysis of the factors in the food processing industries that leads to the mismatch provides a background that can be used to research how we can deal with the conflicts. The research question will be answered in four steps. First, Chapter 3 will give a theoretical overview on planning and planning support. Chapter 4 provides a set of models with which planning situations can be described. The concepts that are discussed there will be used in Chapter 5 to design a planning



concept for food processing industries in which the aspects that were discussed in this chapter will be accounted for. Chapter 6 contains an example application of the concept that is proposed.