Tasks, hierarchies, and flexibility
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Chapter 1. Introduction

An everlasting trade-off in many industries is the one between efficiency and flexibility. In this thesis, we investigate how this trade-off is dealt with in the food processing industries. More specifically, we look at the way that the flexibility of the production system is related to production planning. In this chapter, we introduce the problem field. Section 1.1 contains a concise overview of the market characteristics of the food processing industries, Section 1.2 discusses how the planning is performed and what kinds of planning support are used, and Section 1.3 contains the research question and outline of the thesis.

1.1. Market characteristics of the Food Processing Industries

In food industry, agricultural material is processed to food. Food industries are a major industrial sector in the Netherlands. In 1996, the industrial turnover of the food sector was approximately 95 billion guilders, 25 percent of the total industrial turnover. More than 10 percent of all companies operates in the food industries. The food sector provides more than 17 percent of the Dutch employment (CBS, 1996) (Table 1.1). Examples of product categories in food industries are meat, fish, vegetables and fruit, oils, diary, animal food, beverages, and tobacco.

<table>
<thead>
<tr>
<th></th>
<th>Food sector</th>
<th>Total industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of enterprises</td>
<td>6.812</td>
<td>62.152</td>
</tr>
<tr>
<td>Number of employees</td>
<td>144.645</td>
<td>847.591</td>
</tr>
<tr>
<td>Total production value</td>
<td>95.383</td>
<td>384.447</td>
</tr>
<tr>
<td>Value added</td>
<td>24.323</td>
<td>116.010</td>
</tr>
<tr>
<td>Labor costs</td>
<td>10.480</td>
<td>65.527</td>
</tr>
<tr>
<td>Gross result</td>
<td>7.869</td>
<td>29.492</td>
</tr>
</tbody>
</table>

Table 1.1. Industrial figures of the food sector and the total industry in the Netherlands in 1998 (CBS, 2000)

The production of food proceeds through a number of stages. Most raw material in food industries is agricultural. Those products come from farmers that either grow vegetables such as potatoes or keep livestock such as cows and pigs. If these are consumable without processing or packaging, they can be distributed directly to wholesale traders or retailers. Most products, however, are processed and packaged before they are shipped to consumers. The processing of raw material to consumer products often involves multiple phases (Van den Berg, 1993):

- Cleaning and assorting
- Gathering essential ingredients and separating eatable ingredients from unusable ingredients
• Preparation of eatable and digestible food by e.g., cooking, baking, malting, etc.
• Fermentation by microorganisms and enzymes to enhance taste, digestibility, nutritional value, and to reduce decay.
• Preparation of instant meals

The processing is usually divided between several producers. Some producers make industrial products that are used by other producers. Usually they produce in large quantities. Other producers make consumer products. They must deal with many different forms of packaging and the quantities per package are typically smaller. Most enterprises that make consumer products deliver to wholesale trade and purchase coalitions, who in turn deliver to retail traders (Figure 1.1).

![Figure 1.1. Stages in food industries](image)

This research deals with small and medium-sized producers of customer food products that deliver to wholesale, retailers, and purchase coalitions. In recent years, manufacturers of consumer food products face increasing requirements concerning quality, flexibility, and price. We will shortly discuss several developments that have contributed to this. First, consumer behavior is changed. The increased number of one and two person households brings about different demands, consumers get more exacting in the scope of products they want to be offered, and they are less predictable in their behavior than they used to be. This has resulted in more product types with respect to, for example, flavor, packaging size, and composition of different products in one packaging. The total market volume has not risen as fast as the number of products that is offered, and the consequence is a decreased volume per product type.

Second, retailers and purchase coalitions have introduced their own brands as alternatives for A-brands and B-brands. Such brands in the Netherlands are for example Albert Heijn and Edah. These brands are often made in the same facilities as B-brands, but production is spread out over multiple organizations. For these brands, producers are relative easily exchangeable for one another, which results in increased power potential of retail organizations (Hutchins, 1997).

Third, the direct customers of the food processing companies, i.e., large retailers, wholesale dealers, and purchase coalitions, have centralized in order to gain scale efficiencies. Coalitions can negotiate better about prices, and demand better delivery performance. In addition, forecasting has become more difficult with the enlarged number of product types. This uncertainty is passed on by the retailers to their producers. Retailers more and more order small quantities frequently, instead of large quantities on a less frequent basis. In this way, they run less risk to be left with
outdated stock. In addition, the ‘best before’ date on the packaging must always be as recent as possible, so retailers have the longest possible period to sell the products. The other side of the coin, however, is that the producer can not produce to stock, since the ‘best before’ date must be as new as possible, and the amount of production is only known shortly before production starts. De Toni & Tonchia (1998, p. 1593) relate these issues to the flexibility of a producer: “[..] the conditions which mostly determine the request for flexibility which emerge from the literature, can be listed as follows:

1. The variability of the demand (random or seasonal)
2. Shorter life-cycles of the products and technologies
3. Wider range of products
4. Increased customizations
5. Shorter delivery times”

All in all, large retailers, wholesale dealers, and purchase coalitions exert pressure on food processing industries, and in order to stay competitive, quality, flexibility, and logistic performance must improve continually. As do the retailers, the producers also more and more work together or even merge. This makes the position of small independent manufacturers even harder. The implications for the internal organization and coordination of these companies are extensive. Product improvement, changes in the packaging, changes in the assortment, etc., require continuous attention, but investments for this are not backed by a large conglomerate of companies. The organization must be able to quickly respond to customer demands, manage different packaging forms, produce small quantities, and above all they must have a high efficiency as well. Retail organizations have realized that, in order to reach this, they should cooperate with their suppliers. This topic is dealt with by Efficient Consumer Response (ECR), a specific form of Supply Chain Management for the food industries. The main idea behind ECR is that producers and retailers work together to satisfy consumers in an efficient way, which could lead to a reduction of costs of between 5 and 10 percent (Sloot & van Kleef, 1996).

Three areas in which Efficient Consumer Response measures are being proposed are product group management, product replenishment, and enabling technologies (Coopers & Lybrand, 1997). Product group management deals with the product assortment, special product actions, and product introductions. Product replenishment deals with measures to see to a prompt supply of consumers. The products should be at the right place at the right time. Enabling technologies such as Point of Sale terminals and Electronic Data Interchange are used to exchange information between links in the supply chain so the former two become possible. Ideally, information should flow through the supply chain without unnecessary barriers so continuous replenishment becomes possible (Food Engineering, 1995), i.e., Just in Time production in the chain of consumer food products (Houghton & Portougal, 1997). The goal of this is that consumers always get fresh products while there does not have to be unnecessary stock. In other words, it would be more
accurate to talk about demand chain management in stead of supply chain management since the chain starts at the customer (Vollmann et al., 1997, p. 810). This ‘buy one/make one’, however, can be an expensive way to restock a distribution center (Andraski, 1997), so the point is to find a good balance between order size, lead time, and restocking costs.

To reach the goals of Efficient Consumer Response, producers must be internally organized in such a way that a fast response to market demands is possible. Our research interest is in flexibility requirements of product replenishment at the side of the producer. Many products are specific for one customer because the recipe can only be used for one customer or packaging is printed with the brand of the customer. These products can often not be produced to stock, because the customers want the most recent best-before date. Hence, such products must be produced to order. There are several reasons for producers to prefer long lead times of orders, e.g., lead time of purchasing the necessary raw material and packaging (the procurement lead time), and merging of orders to produce in large batches and avoid setups. This opposes production to order on short notice, something that is needed to follow the market demands. Our case studies indicate that companies struggle with this contradiction. To follow the market has extensive consequences. Organizational procedures and structures are apt to change but it is not trivial how this should be done.

The control function that decides on the moment of product replenishment is planning. This research investigates the way how planning can contribute to deal with problems that arise from the increased market pressure. In other words, we want to know how planning can deal with shorter lead times, more orders, smaller batch sizes, and increased logistic performance requirements. Before we postulate the research questions, we will first describe the way in which planning and planning support appear in the food processing industries.

1.2. Planning in the Food Processing Industries

1.2.1. Planning
The production plan specifies what products will be made at what time, which machines will be used, and possibly who will operate the machines. In food processing industries, there are usually one or more planners to make production plans. Planning involves, for example, decisions about:

- How much should we approximately make the next three months?
- What capacity is needed in the coming months?
- What customer orders should be produced next week?
- What stock products should be replenished? How much must be produced for stock replenishment?
- What production lines should be used?
- What orders are assigned to which production line?
• When exactly is which order to be produced?

The planning task in production organizations must always weigh the interests of several organizational functions, e.g., the production floor, the warehouse, purchasing, sales, etc. The organizational context that deals with the coordination of these aspects is often referred to as production planning and control (Vollmann et al., 1997). Production planning and control is concerned with the processes that are needed to produce timely and efficiently with the right quality. Production planning and control decisions balance the requirements of the market, such as delivery performance and product quality, with factors that are internal to the producer, such as working hours, setup costs, production batch sizes, purchasing batch sizes, capacity usage, etc.

Organizational structures with respect to production planning and control are rather uniform throughout industry. A common picture of an organizational arrangement is the following. The management team sets long term goals, account managers provide demand forecasts, the production manager decides on capacity and available resources, the planner puts the actual orders on a plan, and the foremen on the production floor decide on the actual production time within the time frame given by the planner.

The decisions that a planner makes determine to a certain extent both the internal performance of the production unit and the external performance towards the customer (Sanderson, 1989). It is not unusual that due to short term disturbances such as rush orders and stock-outs of raw material, planners lack time to look at planning issues that are not very urgent. Nakhla (1995, p. 87) states about this that “.. the planned schedule at first is more a system of hypotheses concerning the state of the workshop and of a certain commercial demand, than a true forecast.” This makes that the emphasis of the planning activities is on adjustment on a day-to-day basis. In the remainder, we will refer to the planning activities that are performed daily as day-to-day planning. These activities are often subject to myopic fire fighting tactics that human planners practice (Smith, 1992). Short term fire fighting could hinder medium- and long-term considerations. An important reason for this is the increase in complexity that results from, for example, shorter delivery times and smaller orders. Because the capacity that is available must be used efficiently, changes must be acted on at short notice. It is not hard to imagine that an increase in the number of orders leads to more work for the planning, and that a decrease in lead time for orders will leave less time to put them in the planning. Unfortunately, there is not much knowledge that relates the factors that determine the planning environment to the organization or realization of the planning. Thus, if the circumstances change, it is not easy to determine how the planning procedures and the planning organization should change.

The following section will discuss planning support that is (or can be) used in food processing industries.
1.2.2. **Computerized planning support**

Planning in small and medium sized food processing industries is mostly performed either manually or with the help of only a spreadsheet. Olhager & Wikner (2000) state that a spreadsheet is not sufficient in process flow scheduling problems, and Green (1996) also notes that spreadsheets do not suffice in cases where multiple products are run in a single production environment and rules restrict the sequences in which they should be run. This is often the case in food processing industries. In principle, spreadsheets with solvers can be used to generate schedules, but it requires expertise to model a scheduling problem mathematically, and spreadsheets might not be powerful enough to solve scheduling problems in a timely fashion. Kondili et al. (1993) state that the flexibility that batch plants offer with respect to the manufacturing of relatively small amounts of large numbers of different products can only be utilized by sophisticated planning tools. Available support in the form of production control systems and scheduling systems, however, is hardly ever used in practice. This can result in errors or missed opportunities, because without the help of adequate computer support, planners can not quickly oversee the consequences of changes in the current schedule in case of a disturbance (Jakeman, 1994).

There are two specialized forms of computer support that are available for planning. The first is support for planning in production control systems that encompass all logistical and production control decisions. The second is support in specialized scheduling systems. Both will be discussed briefly.

1.2.3. **Production control systems**

Production planning and control systems, or Enterprise Resource Planning (ERP) systems, not only provide support for production planning and control activities, but also for, e.g., customer relations, sales, warehousing, and accounting. There are several of such systems with specific functionality for food processing industries. Moret Ernst & Young (1995) describe 30 ERP-systems of which the vendors claim applicability in the food processing industries. These systems offer functionality for characteristics that occur in food processing industries such as recipe management, storage life of ingredients, production lot registration and traceability, divergent product structures, etc.

Day-to-day planning is a complex task in food processing industries due to sequence dependent setup times, decay of materials, restricted capacity, short delivery times, and because the range of products makes it difficult to meet the mix in demand (Moret Ernst & Young, 1995; Nakhla, 1995). ERP-systems provide support for the day-to-day planning level, but their functionality varies. Most systems that Moret Ernst & Young analyzed provide functionality for, e.g., specifying production sequences, finite capacity planning, assignment of oldest stock, updating stock positions, etc. It is noteworthy that these systems show relatively low implementation figures. According to the vendors, a total of 292 implementations has taken place in the food sector in the Netherlands. There are, however, several thousands of companies that fall in this sector. Producers in the food processing industries that do not use a production control system that is specific
for the food processing industries, must use something else to support day-to-day planning. There are several specialized computer systems for day-to-day planning, that can be used either stand-alone or linked to a production control system. This will be discussed next.

1.2.4. Scheduling systems

Production scheduling systems are computer programs that focus on the detailed production plan. Such systems provide functionality for, e.g., assigning orders to production lines, constraint checking, and capacity usage assessment. In comparison to production control systems, they cover much less areas. Whereas production control systems are often harnessed to cover all administrative functions and planning levels in the organization, scheduling systems focus only on sequencing and scheduling. The functionality they offer for this particular planning level is, however, much more elaborated. But, as with production control systems, application in practice is not widespread.

Benoy et al. (1994) provide a survey of 30 scheduling systems. These systems have functionality for optimization within finite capacity, constraint checking, and interactive scheduling. One could expect that these systems have enough functionality to support most requirements of planners. But as with the production control systems, implementation figures show a low degree of penetration in food processing industries. In the aforementioned survey, 26 of 30 vendors provided information about the number of installations. In the Netherlands they had at the time a total of 56 installations. This figure includes process, semi-process, repetitive, job shop, project, and service scheduling. Of course, not all scheduling systems were reviewed in this survey; the authors included a list of 25 system that did not participate in the reviewing process. In addition, presumably not all systems and vendors were known to the authors and custom made systems were not included. However, as already stated, there are several thousands of companies in food processing industries alone. The high costs of the systems could be an influence, especially in a sector where margins are low and the benefits of such a system might not be clear. Benoy et al. (1994) indicate prices that range from $17,000 to $300,000, and an additional yearly contribution of 10% to 15% must be paid for maintenance and customer support.

A survey reported by Lofvers (1998) shows the same picture with respect to implementations. Employees that are responsible for the daily production planning at 150 companies were questioned. Of these companies, 75 operate in process and semi-process industries. The survey is shown in Table 1.2.

Notwithstanding the complicating factors of food processing industries, this pattern seems to occur throughout industry. Although implementation numbers are somewhat higher in discrete environments (Lofvers (1998) reports that 12% uses a scheduling system), the use of such systems still contrasts the fact that numerous systems are available.
<table>
<thead>
<tr>
<th>Way of planning</th>
<th>Percentage of companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic planning board</td>
<td>42%</td>
</tr>
<tr>
<td>Spreadsheet</td>
<td>34%</td>
</tr>
<tr>
<td>Pen and paper</td>
<td>12%</td>
</tr>
<tr>
<td>Physical planning board</td>
<td>7%</td>
</tr>
<tr>
<td>Scheduling system</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 1.2. Planning tools in process and semi-process industries (Lofvers, 1998)

The previous section stated that food processing industries are usually complex enough to justify the use of planning support. The facts that the amount of information that must be processed increases (more orders) and the required reaction time decreases (shortening of lead times), makes it remarkable that often only rudimentary planning support is used, if at all. But it is not really surprising, because theories that relate the way that the planning is made to the way that it should be supported are only just starting to appear. The developments and problems of day-to-day planning in food processing industries form the basis of the research question we will formulate in the next section.

1.3. Research outline

In the previous section we saw that the lead times and order frequencies that are asked by the customers of food processing industries are to some extent inconsistent with the flexibility that the production systems can offer. We define the flexibility of the production system as the extent to which the production system enables the producer to meet the customer’s wishes. The production system consists of both the physical system (e.g., machines, materials), the humans that work there, and the control functions. One of the control functions is day-to-day planning. We will investigate to what extent the day-to-day planning can contribute to the flexibility of the production system:

*How can day-to-day planning in the Food Processing Industries contribute to flexibility?*

According to the research question, planning is used as an instrument to contribute to flexibility. The presumption of this is that the planning can be designed. There are two main research directions that deal with planning. First, the planning problem can be the starting point of the analysis. Planning in the food processing industries can be formulated as a flow shop scheduling problem with sequence dependent setup-times and no pre-emption. The domain characteristics can be analyzed and used to formulate algorithms that can find good schedules. Second, the way in which the planning problem is handled by the (human) planner in the organization can be the starting point. An analysis of the task in its context can be used to propose alterations to the task and to design planning support. The task oriented approach is used in this
research. Thereby, we use the Scheduling Expertise Concept (SEC), a framework for task oriented planning support with mechanisms for reuse. The SEC is based on the following three considerations: (1) task oriented planning support has proven successful (Mietus, 1994), (2) the development of this kind of support is very time consuming (Smith & al., 1996), and (3) the task analyses and planning support systems show many similarities. The latter two presumptions lead to the requirement that the SEC should enable reuse of development efforts. There are two ways in which the SEC will be used in this research. First, this thesis contains extensive contributions to the SEC. The SEC is extended with task modeling and thoughts about reuse. This can be regarded as a first research result. Second, the SEC is applied to model and analyze planning in the food processing industries. The resulting planning concept is a second research result. The focus on the SEC in this research results in a theoretical emphasis. Empirical research is used to explore the research domain rather than to implement and test the concepts that are formulated as an answer to the research question.

The research question contains a number of concepts that can be researched individually before they are related to each other (Figure 1.2). In Chapter 2, we will explore the kinds of companies we look at: small and medium sized food processing industries that produce for consumer markets. Two exemplary case studies provide reference material. The case studies, in combination with literature that deals with the research domain, will be used to describe in more detail the organizational and production system characteristics in small and medium sized food processing industries.

Figure 1.2. Structure of the thesis

The extensions to the SEC are presented in Chapter 3 and Chapter 4, where literature studies on respectively planning tasks and planning support reuse approaches result
in a set of models that can be used to depict the planning domain, the planning task, and planning support. In Chapter 5, we deal with flexibility. Although many things influence the flexibility of production organizations, we focus on the relation between flexibility and planning. Chapter 5 uses the models from the SEC to describe the planning in food processing industries. In this way, the results from Chapter 2 (Food Processing Industry characteristics), and Chapter 4 (models that depict the planning task) are related to flexibility.

Chapter 3, Chapter 4, and Chapter 5 each pose requirements for planning support from their respective perspectives. In Chapter 6, we describe a system architecture and a prototype planning support system that enable both flexible planning (a functional requirement) and reusability (a design requirement). The thesis ends with conclusions, our thoughts on generalizations, and directions for further research in Chapter 7.