

Chapter 1

Prologue

The majority of the research into production/inventory control systems in process industry has mainly consisted of reporting general process characteristics, high-volume production scheduling, and mixed integer linear programming (MILP) formulations for specific problems such as determining recipes (blending problem). However, the control of a production situation characterised by– limited capacity, which is highly utilized, and by a combination of make-to-order (MTO) and make-to-stock (MTS) products, which is very common in process industry and more specifically food processing industry, has not been duly addressed in the current literature. The discussion in this prologue deals with how the process industry production control problem has been addressed previously, the specific problem on hand, and the approach that will be used to solve it.

1.1 Introduction

Almost 22% of the total turnover of the Dutch industry is provided by the food industry (CBS Statline, general industrial statistics 2001). The research subject of this thesis is founded in this industry. Since the profit margins in food industry are diminishing, a small decrease in production and inventory costs because of better production control can give a significant increase in profits. In this thesis the combined make-to-order and make-to-stock production strategy is studied.

A thorough look at the production management research literature reveals that a majority of it has been for industries handling discrete units that are fabricated and/or assembled during manufacturing. This research has resulted in numerous successful developments in taxonomies, production and inventory management systems, and implementation strategies for the discrete industries.

The process industries (to which food industries are mostly classified as belonging to), although more automated than discrete industries at the process control level, lag behind discrete industries when it comes to research in overall production planning and control tools. A brief overview of past and current research in the process industry is presented in table 1.1. The literature can be classified under different categories.

The first category reports general characteristics of the industry. There is a great deal of the process industry research that does this. A more exhaustive list of literature in this category can be found in [Dennis and Meredith \(2000\)](#). This literature focuses on process industry uniqueness and compares it to discrete industries and talks about– yield variability, variations in raw material quality, variations in BoM, divergent flows, unit of measure differences, number of packaging, technical constraints of batching and storage possibilities– which are of great importance to process industries. It is also very clear that one of the main areas of attention in process industry is the orientation on the use of capacity.

The second category in the generic classification captures much of the current scheduling practices in process industries. [Taylor and Bolander \(1997\)](#) are advocating and illustrating a technique called process flow scheduling (PFS) from early 1980's. However, this research has focussed primarily on high volume process flow manufacturers. [Nakhla \(1995\)](#) uses conventional priority rules and techniques for scheduling the flow shop in a food industry. [Van Donk and Van Dam \(1996\)](#) have described a framework for designing a planning and scheduling system, which uses the concepts of process routings and capacity groups to analyze the structure of the scheduling problem.

The third category of the literature deals with the special production control problems posed by typical process industry characteristics such as by-products, co-products, or recipe-flexibility. For a more elaborate and up-to-date review of the production planning approaches in the process industry, please refer to [Crama et al. \(2001\)](#) and [Kallrath \(2002\)](#).

We can also classify the literature based on the problem solving approach used. This is shown in the right column of table 1.1. The typical solution approaches are simulation, mixed integer linear programming (MILP) based optimization, analytical models, artificial intelligence (AI) models, and the combination of two or more of these approaches. Simulation and MILP has been most commonly used. [Reklaitis \(1995\)](#) has a detailed discussion on these various approaches and

Table 1.1: Process industry literature: an overview

Generic classification	Classification solution approaches
1. Process industry uniqueness- e.g. Fransoo and Rutten (1994)	(a) Simulation based- e.g. Baudet et al. (1995)
2. Scheduling- e.g. Taylor and Bolander (1997) , Nakhla (1995) , Van Donk and Van Dam (1996)	(b) Model based optimization- MILP- e.g. Reklaitis (1995)
3. Specific production control problems- e.g. Rutten (1995) , Baudet et al. (1995)	(c) Analytical models- Queuing theory- e.g. Carr et al. (1993)
	(d) AI-related methods
	(e) Combination of two or more of the above- e.g. Rutten (1995) , Van Dam (1995)

related literature.

In the proposed study, we focus on food processing industries in particular. In addition to the fact that food industry accounts for 22% of the total Dutch industrial output, there are others reasons as well–

1. The research in food processing industries has mainly focussed on food engineering issues. In the operations management area, there has been some research on outbound logistics but not much work has been done in the production planning and control area. This research is likely to benefit the industry (consisting of numerous SMEs and a few very big players) in the way they carry out their production control function.
2. It is likely that the food industry in the developing countries will grow rapidly. For example, a study conducted by the Confederation of Indian Industry (CII) and McKinsey & Company, Inc. shows that– a) Food offers what is unquestionably one of the largest opportunities in India today, and b) The food industry will grow threefold to reach US \$60 billion, a figure well in excess of the entire Indian manufacturing sector today. The improved and proven knowledge of production control in food processing industry is hence likely to be of immense benefit.

In the next section, we spell out the specific problem that will be addressed in this thesis.

1.2 Research objectives

For many years it was a common policy for food processing companies to produce in large batches to keep production costs low and limit the number of setups. The research literature also focussed on this. However, now industries are experiencing growing logistical demands, growing variety of products and intense competition and as a reaction they are trying to relocate their decoupling point and are moving a part of their production to follow a make-to-order strategy (Van Donk 2001). This has resulted in a production situation characterised by a combination of make-to-order (MTO) and make-to-stock (MTS) in addition to the key existing characteristic of limited and highly utilized capacity. This thesis focuses on the following questions arising because of this situation:

- What products should be made to stock and what products should be made to order?
- What are the main factors to be taken into account for the control of such production situations?
- How can we manage and control such a combined production mode?

The existing theory does not give much of an answer to these questions. The analytical and quantitative tools are not available– to measure the interaction effect between the level of stock and orders; or to give an answer to the question– how much MTO is possible on a limited capacity; if and how the kind of demand or production facilities influence the nature and possibilities of control.

With our research, we plan to attain an improved knowledge on the planning and control in the production environment with **limited capacity and combination of MTO and MTS products**. The main problem to be solved by planners is finding a balance between the possibilities of buffering (in time and quantity) the uncertainty of orders by finding suitable levels of stocks of MTS products. The solutions to that will be restricted by performance measures on dependability, speed, cost, capacity and utilization, while demand will be uncertain as well as production capacity. So far, little is known on finding this balance. Specific food industry characteristics like limited shelf life of products will also be addressed.

The main research objectives are as follows:

1. To identify the main issues that determine the nature and possibilities for controlling and planning the capacity-oriented combined MTO-MTS production in food processing industries.

2. To develop models for planning and scheduling in combined MTO-MTS production in food processing industries.
3. To use the models developed for improving the way planners in food processing industries do their work.

The research consists of three stages corresponding to these three research objectives: (1) Building a framework for production control in combined MTO-MTS production, (2) Development of analytical and simulation models, and (3) Illustration of the production control framework in a real-life setting.

1.3 Thesis outline

The first research objective is addressed by Chapter 2. It is a state-of-the-art literature survey on the combined MTO-MTS production situation. It discusses the relevance of the surveyed literature in the context of food processing literature and then proposes a comprehensive hierarchical planning framework covering the important decisions in the combined MTO-MTS production situation. This hierarchy is also intended to provide a proper setting for discussing various MTO-MTS issues in the later chapters. Chapters 3, 4, and 5 address the second research objective and are devoted to MTO or MTS decision, medium term capacity coordination, and short term scheduling models, respectively. The third research objective is addressed by an illustrative case study in chapter 6. In each of these chapters the focus is on food processing industries and the presentation is organized as follows:

1. Provide a self-contained exposition of the sub-problem. This allows readers to treat each chapter as a stand-alone piece of research.
2. Discuss algorithmic, computational, and implementation issues, where relevant.
3. Provide a comprehensive list of topics to further probe into.

Chapter 2 provides a literature overview of MTO-MTS literature. The chapter starts by examining the recent trends in many industries and especially food processing industries and how they are forcing food producers to move from pure MTS to combined MTO-MTS production situation. After a detailed overview of the MTO-MTS literature, it is evaluated for its applicability in the context of special product, process, plant, and market characteristics of the food processing firms. Next, various MTO-MTS production decisions are categorized into 3 different types viz. MTO or MTS decision, Production Inventory decisions, and

Operational decisions. These decisions are presented in the form of conceptual hierarchical production planning framework. Though it is just another way of looking at the decision-making and a generic but not an in-depth prescription for structuring the specific levels for all the MTO-MTS situations, it can be used as a starting point for designing or redesigning the planning and scheduling hierarchy structure for a particular situation.

The MTO or MTS decision constitutes the subject of Chapter 3. A simple, quantitative but practical tool that aids in MTO or MTS decision is presented in this chapter. The tool is largely based on a number of well-known theoretical concepts.

Chapter 4, on medium term capacity coordination, is in two parts. Both parts deal with multi-product lot sizing issues under limited capacity. Limited shelf life for products is very common in food processing industry and is considered in the context of lot scheduling problem in the first part of the chapter. A heuristic is suggested for the problem along with an illustrative example to show the superiority of the approach above existing approaches. In the second part, we discuss various ways of incorporating MTO items in economic lot scheduling problem (ELSP). Some guidelines are provided regarding the choice of each of these MTO incorporation.

Operations scheduling forms the subject matter of chapter 5. We first introduce classical dynamic runout scheduling methods in pure MTS situations. Next, we make some adaptation to include MTO products in these models. We then compare and discuss the performance of these methods through a simulation study.

Chapter 6 illustrates the hierarchical planning framework presented in chapter 2 and the insights gathered from chapters 3, 4, and 5 by reporting a real-life case study. Areas of improvements in the framework have been identified and possible decisions aids are suggested. In particular, the short-term batch-scheduling problem requires more attention and we provide a heuristic to solve that problem.

In chapter 7, we summarise the findings of thesis and look back on the assumptions that we made. Other important issues in combined MTO-MTS production situations that fall outside the scope of this thesis are also discussed.

The thesis is a compilation of the following papers that are published or are under review and a recent contribution in the form of chapter 3.

1. Chapter 2: Soman, C. A., Van Donk, D. P. and Gaalman, G. (2004a), Combined make-to-order and make-to-stock in a food production system, *International Journal of Production Economics*, **90**(2), 223–235.
2. Chapter 4: Soman, C. A., Van Donk, D. P. and Gaalman, G. (2004b), A basic period approach to the economic lot scheduling problem with shelf life considerations, *International Journal of Production Research*, **42**(8), 1677–1689.
3. Chapter 4: Van Donk, D. P., Soman, C. A. and Gaalman, G. (2003), ELSP with combined make-to-order and make-to-stock: Practical challenges in food processing industry, 1st joint POMS-EUROMA International Conference, Como Lake, Italy, vol. II, pp. 769–778.
4. Chapter 5: Soman, C. A., Van Donk, D. P. and Gaalman, G. (2004d), Comparison of dynamic scheduling policies for hybrid make-to-order and make-to-stock production systems with stochastic demand, *International Journal of Production Economics*, Article in press.
5. Chapter 6: Soman, C. A., Van Donk, D. P. and Gaalman, G. (2004e), Capacitated planning and scheduling in combined make-to-order and make-to-stock food industry: An illustrative case study, 13th International symposium on inventories, Budapest, Hungary, August 2004, Under review.

