

Chapter 7

Summary and discussion

Food processing industries are experiencing growing logistical demands, growing variety of products, and intense competition and as a reaction they are trying to move a part of their traditional make-to-stock (MTS) production to follow a make-to-order (MTO) strategy. This has resulted in a production situation, which is characterised by limited capacity, which is highly utilised and by a combination of make-to-order (MTO) and make-to-stock (MTS). The purpose of this thesis has been to gain insight into planning and scheduling issues in these capacitated, combined make-to-order and make-to-stock food production systems. An attempt has been made to address both the theoretical and practical aspects associated with the various subproblems involved. In section 1.2 we formulated the objectives of this research: (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 specific models for planning and scheduling in combined MTO-MTS, and (3) to use these models for improving the way planners in food processing industries do their work.

In the following sections, we take stock of the results achieved in view of these objectives.

7.1 Main issues in planning and control of MTO-MTS production

Chapter 2 addressed the objective of identifying the main issues in planning and control of combined MTO-MTS production in food processing industry. A background knowledge was gathered via a thorough literature review and some empirical evidence. The literature on MTO-MTS was evaluated vis-a-vis spe-

cific characteristics of food processing industries, e.g. presence of setup time, shelf life etc. We conclude that useful ideas are present but the majority of contributions do not address these specific characteristics of food processing. We identified the main issues and developed a generic hierarchical framework for planning and control in a combined MTO-MTS system in food processing. The framework consists of three levels associated with the three main issues identified:

- **Make-to-order versus make-to-stock decision:** The decision to produce a product to stock or on order is a strategic choice. It involves a trade-off between the product-process characteristics on one hand and the market demands on the other side.
- **Medium term capacity coordination:** The capacity allocation among MTO and MTS products, order acceptance rules, lot sizes for MTS products are to be decided at this level. The main problem here is to buffer (in time and quantity) the uncertainty of orders. This is to be done by appropriate inventory levels for the MTS products and due-dates for the MTO products.
- **Short term scheduling and sequencing:** These are the operational issues that firms need to answer on a regular basis. The firms need to define the scheduling rules for variety of situations that may arise answering the questions– which product to produce next and in how much quantity?

This conceptual framework suggested can be seen as a first attempt to structure the production planning decisions in a combined MTO-MTS production situation. It is a generic way of looking at the decision-making and is not an in-depth prescription for structuring the specific levels for all the MTO-MTS situations. Still, it can be used as a starting point for designing or redesigning the planning and scheduling hierarchy structure for a particular situation.

We conclude that the framework is a valuable contribution to both the description of the MTO-MTS production situation and possibly to the managerial decision making in organisations as illustrated in chapter 6. Moreover, this framework provides key areas for which specific planning and scheduling models in combined MTO-MTS can be developed.

7.2 Models for planning and scheduling in combined MTO-MTS

Chapters 3, 4, 5 relate to the second research objective of developing models needed to improve our knowledge in planning and control of combined MTO-

MTS situations. This objective has been fulfilled by exploring the hierarchical framework developed. We developed analytical tools and models to gain insights into three subproblems— MTO versus MTS, Medium term capacity coordination, Short term scheduling and sequencing— identified in the hierarchy. These tools and models are described in chapters 3, 4, and 5 respectively.

7.2.1 Make-to-order versus make-to-stock

Chapter 3 presented a Microsoft Access/Excel based simple but comprehensive and practical tool that aids in the MTO or MTS decision. There are some useful concepts existing in the theory viz. ABC analysis, demand variability analysis, customer order decoupling point, order penetration point. These concepts have matured greatly and are easy to understand. However, the MTO versus MTS decision using these concepts involves only item-by-item decision using item specific attributes such as demand volume, variability, manufacturing lead-time, etc. It is also felt that these concepts fail to take limited capacity into account. In light of the capacity limitation and the competition among the products for the shared capacity, the application of these concepts for the MTO-MTS categorization decision is not straight forward and is rather difficult. The model presented in this thesis takes into account the capacity constraints using a rough-cut capacity planning. This is used in conjunction with the delivery service requirements, demand profile, and cost considerations which have been identified as the most important factors in deciding MTO-MTS partition. It is argued that this is the first ever attempt to bring together and quantify the qualitative concepts in the form of a decision aid for food processing industries. Although this decision aid has not been used and implemented, so far, in a real life setting there are no reasons why it should not help practitioners.

7.2.2 Medium-term capacity coordination

In chapter 4 the focus was on two aspects in medium term capacity coordination: shelf life for products and incorporating MTO in the ELSP procedure. The researchers working on ELSP with shelf life considerations have a tendency to focus on the option of deliberately reducing production rates. In food processing industry this option is not at all applicable since it will result in products with quality and yield that is different than expected. Also, the previous research has considered only the common cycle approach i.e. all the products are produced exactly once in the cycle. In this thesis, these assumptions have been relaxed. We allow products to be produced more than once in a cycle by using

the basic period approach. Haessler's procedure has been adapted for determining the cycle times for the lot-scheduling problem to account for constraints imposed by shelf life of products. The proposed algorithm can *never* result in higher cost solutions than the common cycle approach. In the worst case, the procedure yields the common cycle solution. If the diversity in the shelf life of products is more, then the cost benefits that are achieved through the use of our procedure are quite significant (up to 40% lower costs in the experiments carried out).

The second aspect at the medium term level discussed some possible ways of incorporating MTO in ELSP procedures. The discussion is qualitative and conceptual in nature. We specially looked at various demand patterns, presence of product families, and structure of setup in and between these product families. Some suggestions and managerial insights are provided for these situations. Moreover, the ideas presented here can be used as a starting point in translating into analytical models. In particular, it is possible to modify the existing ELSP procedures to account for the various demand and setup characteristics along with the presence of MTO items. These options, generally speaking, are to- (a) treat MTO items as if belonging to a separate product family, (b) produce additional stock in MTS items, (c) reserve capacity for MTO in each cycle, or (d) use the idle time in a pure MTS situation.

7.2.3 Short-term scheduling and sequencing

Chapter 5 tries to fill the void in operational scheduling literature on hybrid MTO-MTS production situations. Four different, proven run-out time based dynamic scheduling methods from the pure MTS literature are adapted and compared for their performance to check if they are also suitable for hybrid production mode. Though the study remains inconclusive in some respects, when it comes to the choice of a suitable scheduling, it is clear that the methods that perform well for pure MTS situations do not necessarily perform well for hybrid MTO/MTS situation. It is felt that the choice of scheduling rules to control a hybrid MTO/MTS production system should not be restricted to a tool that will ensure optimal cost performance for the system. Other performance measures, and considerations such as simplicity in the applicability of the rule may well prove to be a dominant factor in deciding scheduling rules. For example, in the simulation study presented EMQ and Fransoo methods which are simpler and unsophisticated as compared to Vergin and Lee and Gascon methods perform reasonably good for all performance measures. It was also clear from the study that, irrespective of the method used, the companies should be very

careful in accepting special business in the form of MTO products in the cases of high system utilisation. In such cases (near 100% utilisation), it may be wiser to phase out some MTS products in order to include special business opportunities from special orders/ MTO products, which typically have a higher contribution margin.

7.3 Illustration of planning and control models

The third research objective was addressed by means of an illustrative case study and involved the application of tools and models developed in a real life setting. This is reported in chapter 6. The case study presented in this chapter is quite generic in nature and a lot of companies can relate their situation with the one described in the chapter. In particular, the applicability of the hierarchical planning framework suggested in chapter 2 is investigated. It was observed that the framework is quite simple, generic, and yet very useful as a tool for designing the planning and scheduling hierarchy for the combined MTO-MTS production situations. A heuristic for the MTO-MTS short-term batch scheduling problem is also provided. This heuristic can replace or can be used in tandem with the manual detailed scheduling method that is currently used in the company.

7.4 Discussion (Food for thought)

In this thesis, a few models and tools for planning and control in the combined MTO-MTS food processing industries are developed. In spite of our claim that the hierarchical framework developed here is likely to be applicable in most of the MTO-MTS production situations, we acknowledge that the combined MTO-MTS research field is still an open ground, especially when it comes to the analytical models to suit the individual cases. In this section, we provide a few research guidelines. First, we revisit some of the assumptions that we have made, and later point out the important issues in combined MTO/MTS production situation that are related to this text but fall outside its scope. Here, it may be recalled that the future research possibilities in each of subproblems have been discussed in the associated chapters.

7.4.1 Assumptions revisited

In chapter 2, we listed specific characteristics of the food processing industries and commented that each of these factors has to be taken into account for developing a production planning and control framework. Although, in most of

the real life cases only a subset of these characteristics is present, it is quite clear that we, ourselves, have not considered many of those factors. We left out some of them explicitly (e.g. two or more stage production, process yield, multiple recipes for a product) to limit the size but not the scope of problem. Assumptions about other characteristics and various procedures followed in the thesis, warrant some comments. These are discussed below.

- **Strict MTO versus MTS classification:** We assumed that the products are either MTO or MTS. In practice, however, it is not uncommon to have production runs of some products on MTO basis although they have been classified as MTS. It is possible to define some policies like make-peaks-to-order (for very high customer order quantities and, of course, if customer is willing to wait) and schedule them in the periods of low demand.
- **Presence of setup time:** We mentioned the presence of sequence dependent setup time in food processing industries but instead used sequence independent setup times in some of the models. It is possible to extend the ELSP model with shelf life considerations to account for sequence dependent setup time.
- **Presence of large setup times:** The time spent on executing setup (and changeovers) in food processing industries is a major managerial issue. Some practitioners seem to reject the ELSP type of (sum of inventory and setup) cost minimisation approach. Instead, they advocate use of a setup time budget, e.g. 10% of total available time, and then try to find production cycles that meet this budgetary constraint while minimising the sum of inventory and setup cost. The ELSP literature lacks such type of approach. In our research, we account for such concerns implicitly by specifying the minimum runlength condition at the operational scheduling and sequencing level. It however, remains to be seen, if incorporating setup time budgetary constraints at the medium-term capacity coordination level are indeed better.
- **Run-out time based sequencing at the operational level:** The run-out time based scheduling methods were chosen because of their simplicity, intuitive stockout avoidance possibilities, and wider acceptance amongst the practitioners. However, it was found that these methods are too dynamic in nature and may not be suitable in the case of sequence dependent setups. Fixed sequenced policies are expected to perform better there since a preferred sequence that minimises setup time and provides extra productive capacity will be deployed. The short-term batch scheduling heuristic presented in chapter 6 is one such example.

- Due date for MTO items: The simulation study in chapter 5 assumed that the due date for MTO items is zero i.e. they are due as soon as they arrive. This was done in order to find out the lead-times that are achievable for MTO items by the use of simple policy of giving them priority during the production. Nevertheless, the discussion in section 4.5, provides some guidelines for due-date setting for MTO items.
- ELSP procedures: We used Doll and Whybark (1973) and Haessler (1979) procedure for determining the target cycles. The demand uncertainty was not included in the calculation of optimal cycle. It is possible to use the methods described in Kelle et al. (1994) and Fransoo et al. (1995). These methods include the costs of holding safety stock (to ensure a required service level) in the total cost function. The determination of cycle time is iterative since the safety stock levels depend on the cycle time itself which has to be calculated. We deployed the traditional approach: use deterministic ELSP and add safety stocks. Here, it may be again stressed that we have used not only the Doll and Whybark method but also the Haessler's procedure, which has a built-in feasible schedule generation method. This leads to an increase in cycle time for attaining schedule feasibility and hence the less variability over the cycle time. Also, some amount of idle time is then present (to avoid interference) in some basic periods, which can also be used to address the stochastic demand. Moreover, when these methods are used in conjunction with run-out time based sequencing at the operational level, as pointed out in chapter 5, the achieved cycle times vary a lot. This means that we have uncertainty in the protection interval as well. This adds complexity to the safety stock calculations.
- Safety stock calculation: We calculated safety stock so as to achieve the required (95%) service level during the protection interval (cycle time). In this calculation, we ignored the costs associated with this stock and the lost sales (or backordering) costs. However, as seen from the results of chapter 5, these costs can be very significant even with the modest ratio of 1 between inventory cost and lost-sales cost. The safety stock calculation method which incorporates lost-sales (and/or backordering) cost is likely to improve the cost and line item fill rate performance of the system in the case of all scheduling rules.

7.4.2 Related research possibilities

In this section we dwell on the important issues in combined MTO/MTS production situation that fall outside the scope of this text.

- **Order acceptance:** In this text, the order acceptance, which is at the interface of sales and manufacturing functions, was not considered. Further, it was assumed that all orders are accepted. The simulation model described in chapter 5 can be deployed in order acceptance with certain adaptation. It can be used to look-ahead a few periods in the future and hence predicting the order completion date and also to check its impact on existing production orders. This information can then be used for better due-date and price quotation. Development of such an order acceptance tool is an interesting research agenda.
- **Costing of special products:** Conventional cost accounting methods have certain drawbacks. Often, high-volume, standard products are overcosted, whereas customer specific, low volume MTO products tend to be undercosted. This is in spite of the fact that MTO products are produced in small batches and consume more resources. These special products are, however, generally speaking high contribution margin products. In a way, the MTS products tend to subsidise MTO products. Because of this, the companies run the risk of accepting increasing share of MTO products due to their apparent higher contribution margins. Orders for such MTO products are accepted without considering their impact on other regular MTS products. It is clear from the discussion in chapter 5 that such strategy can have negative influence on the performance in high utilisation cases. A special care has to be taken to accept such orders. It is hypothesised that the use of activity based costing would result in more accurate costing than the conventional costing methods.
- **Product offering:** The ever increasing product variety results in many low (and intermittent) demand items. The demand for these items is difficult to forecast. The production and inventory costs are also generally higher for these items than for high demand items of similar complexity. In this thesis, items for which a probability distribution for demand is not available or possible to estimate are, by definition, MTO items. A strategy of making such items on order and giving them priority during the production was followed. Another strategy, of course, is not to offer these products, i.e. to drop them altogether from the product portfolio. The food processing industries are generally reluctant to drop recipes (products) and not to add them. This is mainly due to their desire for a full product line which would enable them to become one-stop supplier. It is recommended that the companies should undertake a periodic review of their product offering in order to eliminate few products before their

financial burden is irrefutable. Such a product offering review– (a) will keep the manufacturer’s focus on main and more lucrative business, and (b) its repetitiveness is likely to refine the cost and revenue criteria of the company.

- Seasonal demand and supply: The demand was assumed stationary in this text. The models presented are based on the average demand. These models will have to be adapted for reacting to seasonality in the demand. A lot of food industries like beer, ice-cream, juice etc. face this problem. In such cases aggregate capacity requirements are seasonal and exceed the equipment capacity in certain seasons. Due to this, a build-up of the inventories before these seasons is necessary. The limited shelf life of products limit such possibility. The scheduling policies presented in this paper must be modified to be consistent with decisions made at a tactical level concerning production smoothing over the longer term. Similarly, seasonality in raw material supply can have serious implications for the planning framework.
- Parallel lines: A lot of companies offering large number of products, are traditionally using a costly, high-speed equipment for MTS products and a small, flexible equipment for low volume or special products. Increasing number of product variety and SKUs may lead companies to re-evaluate their machinery investment plans. Deciding on the number and types of equipment in order to meet the growing logistical demands is an interesting area for further study.

