Chapter 6

Illustrative case study

This chapter[1] illustrates the conceptual production planning and inventory control framework for combined make-to-order/make-to-stock situations developed in chapter 2. The framework is applied in the case of a firm that produces 230 products on a single line with limited capacity. Areas of improvements in the framework have been identified and possible analytical decision aids are suggested. In particular, short term batch scheduling problem requires more attention and a heuristic to solve that problem is provided.

6.1 Introduction

In this chapter we deal with the implementation of a production planning and scheduling framework for a medium-sized multi-product food processing company in the Netherlands. Before outlining the details of the generic problem and the solution approach it is appropriate to give a brief description of the plant under consideration. Throughout the discussion, we avoid excessive details of the case to keep it illustrative so that a lot of companies can associate themselves with the situation in this study.

The company produces 230 different products, which differ in recipe (40 types), granule (30 sizes) and packaging. The production process has three steps: processing, granulating and packaging (see figure 6.1). The processing stage consists of several steps: mixing of raw materials according to recipe and a number

[1]The content of this chapter are from: 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.

of subsequent processing steps that are executed without interruption or intermediate storage. Then the semi-manufactured product may be stored in one of the 11 silos or can be granulated, directly. Next, the product is separated into several fractions that are made of the same recipe but differ in the size of the granule. In the last step the product is put into bags of different sizes with (sometimes) a client-specific text on it. Now, the finished product can either be delivered to the customer or can be stored. The material flow is divergent—there are 40 types of recipes, 110 semi-finished products after the granulation stage, and 230 stock keeping units (SKUs) after the packaging stage.

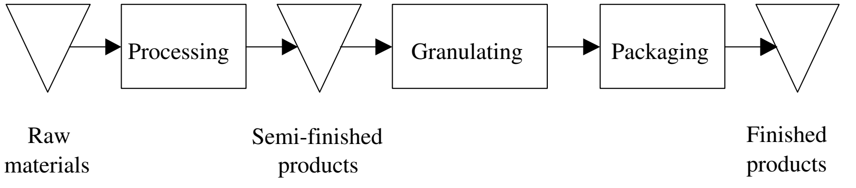


Figure 6.1: The production process at the food processing company

For many years it was a common policy for the company to produce in large batches to keep production costs low and limit the number of setups. This seemed to be a good policy. The last decade showed a number of changes, gradually growing in significance. Firstly, consumers' wishes seem to be changing in an ever-growing rate, causing an increase in packaging sizes, the number of products, as well as in the number of new products introduced. Secondly, many retail players in the food supply chain are restructuring their supply chain both in a physical and information flow sense. The aims are reduction in inventories, faster replenishment and shortening of cycle times. The result for the case company is that logistical performance needs to be improved: faster, reliable, and more dependable. In the similar companies, there are examples of reductions in lead-time from 120 hours in the past to 48 hours now and still further reductions are to be expected. Thirdly, the above-mentioned changes have to be realized in a market characterized by low margins in retailing, and mergers and acquisitions in retail chains. Both lead to a downward pressure on prices paid to producers.

As a consequence of the huge increase in product variety and shorter lead-time requirements of the customers, the company is forced to shift a part of its production system from make-to-stock (MTS) to make-to-order (MTO) and has to operate under a hybrid MTO-MTS strategy. For this typical food-processing firm with limited capacity, producing a very large number of products on pure MTS basis is not viable because of unpredictable demand and the perishable nature of the products. Also, pure MTO is ruled out because of the large number of relatively long, costly setups that are required. On the one hand there is a need to be flexible and react to customer demand, and on the other hand there is a wish to restrict setups and produce economically using stable, repetitive cycles. In the production inventory research related to food processing industries (e.g. Claassen and Van Beek 1993, Randhawa et al. 1994, Tadei et al. 1995), combined MTO-MTS production situations have been ignored with the notable exception of Soman et al. (2004a). They discuss various MTO-MTS issues that companies need to address viz. MTO or MTO decision, finding suitable production inventory policy, operations scheduling, etc. All these issues have to be tackled in the presence of specific characteristics of the plant e.g. limited shelf life of products, sequence dependent setup times when shifting from one recipe to the other (these recipes have different colours), very short customer lead-times. Obviously all these issues cannot be resolved simultaneously. They provide a decision hierarchy based on the state-of-the-art literature study but it remained to be seen whether this framework could be applied in a real life setting.

The framework from chapter 2 looks tailor-made for the case company because of the similar environmental setting. The aim of this chapter is to implement this particular production planning and scheduling framework for the combined MTO-MTS production situation in food processing industries and test its applicability. Moreover, we identify the areas of improvements and suggest analytical decision aids. In particular, we provide a heuristic for a short-term batch scheduling problem that, in our view, demands more attention. Although the push for development of such an heuristic comes from a particular case, the approach is more generic in nature.

The chapter is organised as follows. In section 6.2, we describe the current planning and scheduling method at the case company and the associated problems. In section 6.3, we apply the hierarchical planning model as discussed in chapter 2, Soman et al. (2004a) in the case of the plant under consideration. Section 6.4 outlines a heuristic algorithm for the short-term MTO-MTS batch-scheduling problem. Conclusions and suggestions for future research are provided in section 6.5.

6.2 Current planning and scheduling practice

The case study was carried out for a period of 6 months in which the researchers regularly visited the company. Data collection was by interviewing the people, studying documents and analyzing numerical data. We do have access to the order book and production book for last couple of years. One of the authors has long-term contact with the firm and a number of Master's thesis projects have been carried out previously. Both the length of the study period and the use of different methods, interviews with different persons from various departments and the combination of qualitative and quantitative data, as suggested by McCulcheon and Meredith (1993), improves our data validation and the reliability of the findings. Based on our understanding, we now describe the current scheduling practices at the firm and identify the problems associated with it.

The production planning in the company consists of a two-stage hierarchy—medium term planning and detailed scheduling. Medium term planning is mostly carried out by the enterprise resource planning (ERP) software. Though the company uses this mainly for non-manufacturing functions (e.g. accounting, purchasing etc.), it is also deployed for generating purchase orders for raw materials and production orders for semi-finished or end products. These MRP runs are executed weekly. The detailed scheduling level transforms the weekly production orders into production schedule comprising of: the sequence of production orders, and the run-length and the starting time for each production order. The detailed scheduling activities in the plans are performed manually.

As mentioned above, the detailed scheduling method is aimed at answering what, how much, and when to produce. Everyday, the planner and scheduler receive a list of orders from the sales department. This list consists of known (accepted) orders which have due dates attached to them. Based on the inventory levels on hand, it is determined if these customer orders can be shipped from finished goods inventory or from the intermediate silos or need to be produced completely. Now the planner knows what to produce. Next question is how much to produce. Here, an estimate is first made about the time before the next production starts (cycle time) for the same recipe. This estimate is based on the demand pattern realised during the last four weeks and planner's experience. The production quantity is then determined by adding the known demand during the cycle time and demand forecast during the cycle. There are various production quantity modifiers because of technological constraints, which are mostly in the form of minimum and maximum batch sizes, and yield losses etc. Applying these modifiers gives the production order quantities. When to

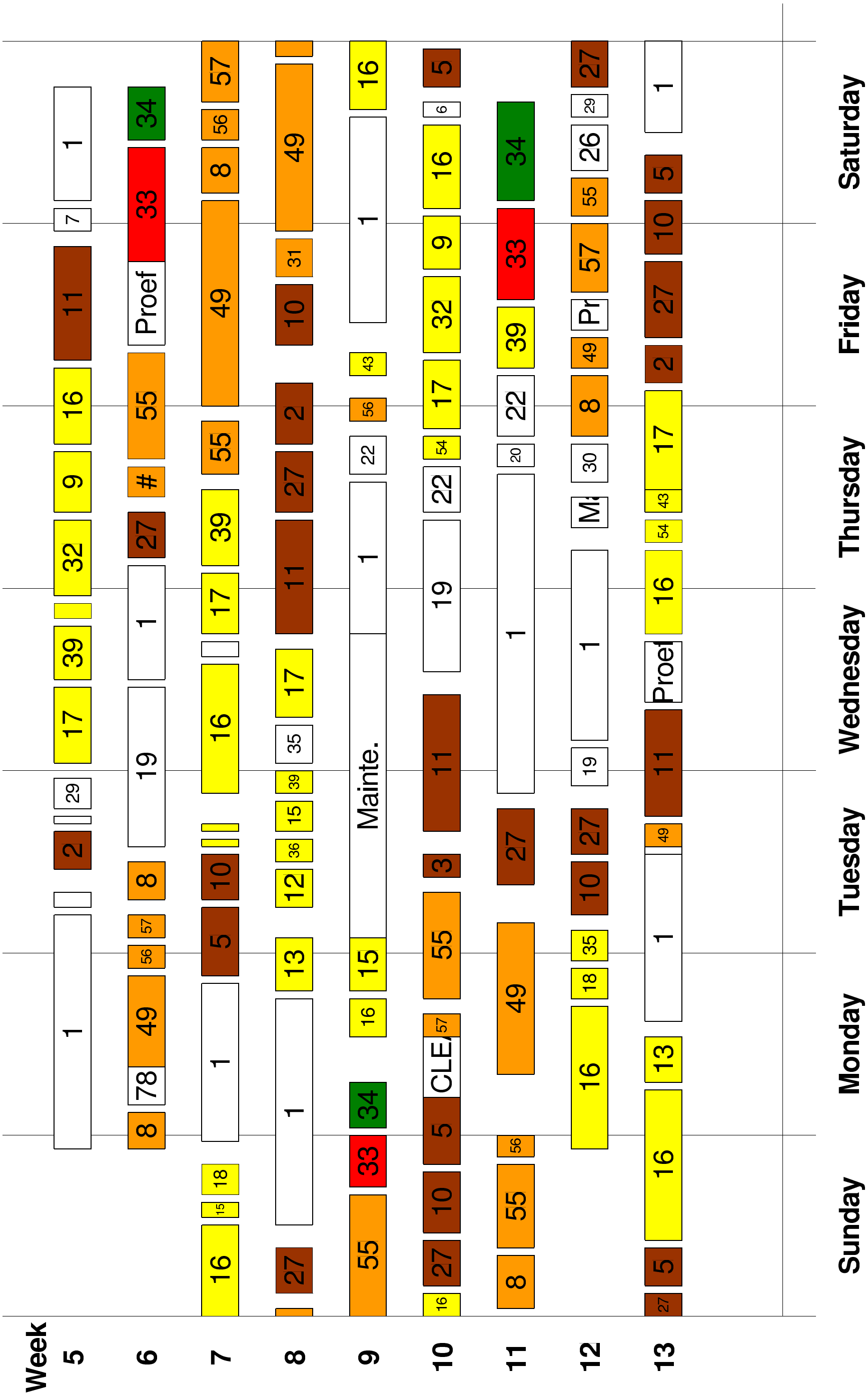


Figure 6.2: Planned production schedule

produce is answered next. The orders are scheduled backwards from their due dates. It can be placed in the sequence in such a way that it fits in the preferred colour sequence which minimises the total setup time.

The current detailed planning and scheduling procedure is manual. Although some rules of thumb have been developed over the years, it is effectively a trial-and-error method with lot of daily adjustments. Figure 6.2 shows a typical production schedule generated during the period of week 5 to week 13 in 2004 for the processing stage. The numbers in the boxes represent recipe number and the length of the box shows the length of the planned production runs.

One can observe a few problems with the current scheduling procedure-

1. Though the company works 6-days-a-week, invariably there is production scheduled on almost all the Sundays.
2. The schedules do not show any regular pattern, which may be desirable for raw material and manpower planning. The cycle times for recipes vary a lot from one cycle to another. The cycle time calculation is too crude.
3. Although production orders belonging to the same colour are reasonably clubbed together, there seems to be no preferred fixed production sequence between colours.
4. Schedules often fail to realise weekly production targets, and frequent rescheduling takes place.
5. Inventory levels tend to grow.
6. MTO-MTS segregation is not very clear.

6.3 Application of MTO-MTS hierarchical planning

It is clear from the discussion in the previous section that the production planning and scheduling procedures in the company can be considerably improved if some formalised approach is followed. The approach that we follow is the conceptual hierarchical production planning framework for MTO-MTS production situations as discussed in chapter 2, Soman et al. (2004a). It is reproduced in figure 6.3. The MTO/MTS segregation is determined first. Then, a capacity coordination plan, which provides lot sizes and safety stocks for MTS products, is determined. Finally, detailed scheduling decisions are worked out. We are particularly interested in testing the applicability of the framework and the development of analytical/quantitative decision aids in the context of the hierarchy.

We want to know if some important decisions are missing from the conceptual hierarchy. These decisions then can be brought in to refine the hierarchy.

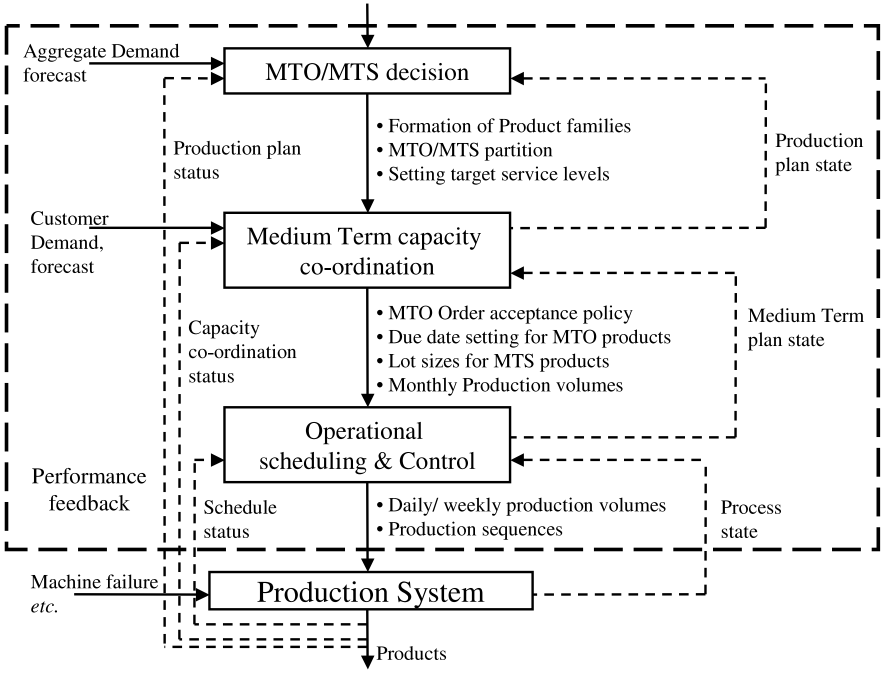


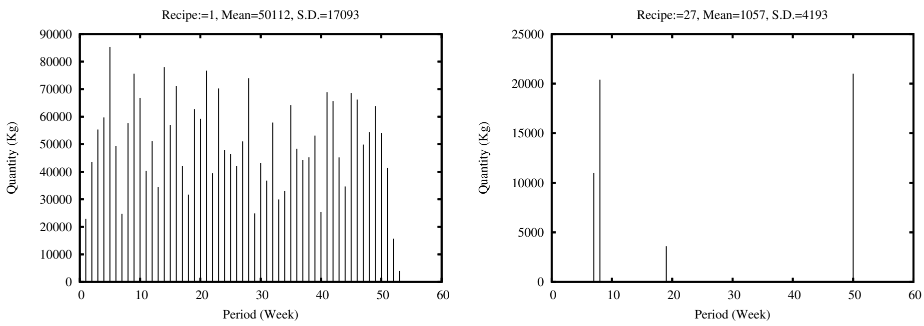
Figure 6.3: Hierarchical approach to MTO-MTS problem

6.3.1 MTO/MTS

The hierarchy advocates the use of the customer order decoupling point (CODP) concept as a qualitative way to make the MTO/MTS decision. The CODP separates the order-driven activities from the forecast driven activities and is the main stocking point from which deliveries to customers are made. The concept uses product-market and product-process characteristics and considering the desired service level and associated inventory costs helps in locating the decoupling point and thus, the MTO/MTS decision. The elaboration and application of the CODP concept in the food company in the case is reported in Van Donk (2001).

The demand analysis forms the main activity in order to segregate MTO and MTS products. The classical pareto analysis is the starting point. Many companies, categorise the items into either A, B, or C categories. Category A items are MTS items while items belonging to B and C category are MTO items (e.g.

Williams 1984). We think that this categorisation is too simplistic and does not account for differences in uncertainty that exists in the demand among various products. For some products, demand is uncertain but predictable and for others demand is not predictable. Examples of such observed demands for some recipes are given in figure 6.4. It is obvious that one should not treat these recipes in the same way.



(a) Uncertain but predictable demand (b) Unpredictable demand

Figure 6.4: Example of observed demand for some recipes

We follow the RDV analysis suggested in chapter 3. Such demand variability analysis is also suggested in D'Alessandro and Baveja (2000) and followed by Huiskonen et al. (2003) to segment products into homogeneous groups. Figure 6.5 shows a plot of average weekly demand on the x-axis and demand variability on the y-axis. The products in the high-volume, low variability are candidates for MTS production. Most of the product recipes belong to low volume, high variability category and should be produced on MTO basis. Many recipes belong to high volume, high variability category and should be produced on MTS basis. However, more inventory levels would be required for such recipes. It is recommended that closer ties should be sought with the customers in order to reduce their variability.

While doing this analysis, some difficulty arises because of the subjectivity involved in drawing up the lines that partition high demand items from the low demand items and high demand variability and low demand variability. However, some simple rules can be derived. For example, in this case the typical production batch is 1700 kg, therefore the products with average weekly demand greater than 3400 kg (two batches per week) were designated as high volume. This roughly translates into minimum production run length of 2 hours. These

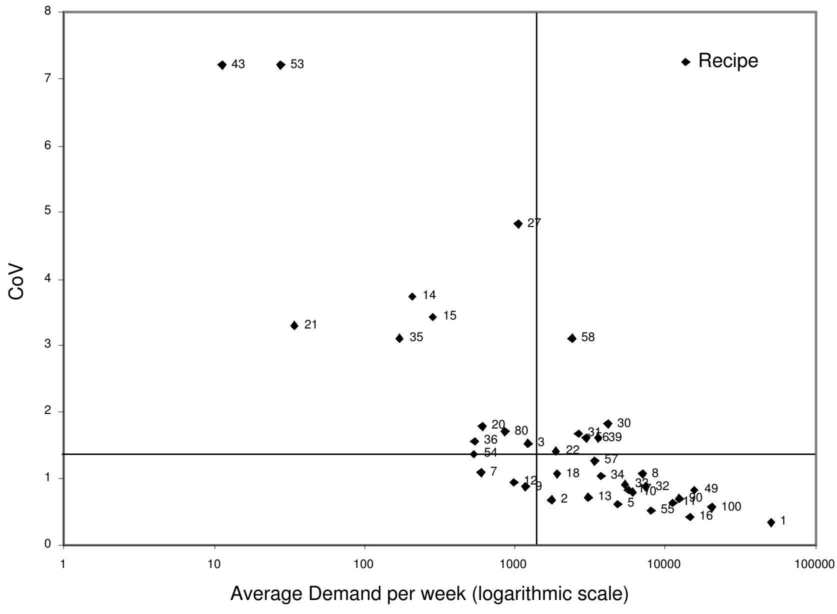


Figure 6.5: Demand variability analysis

partitioning lines are the likely areas of conflicts as well as newer opportunities for sales and production departments. For example, classifying a particular product as MTO rather than MTS can have serious implication in terms of longer lead-times for customers, less inventory, more setup time but this also allows differentiated service for different customer classes.

The product-process analysis is also undertaken. In general, the typical MTO candidates are items with low setup times, items with high holding costs, customized products, and highly perishable products.

Moving a lot of products from MTS to MTO is likely to provide some improvements in the customer service. This is largely due to the fact that currently too many end items are stored and cause problems with inventory control and shelf lives of the products. With the suggested MTO/MTS segregation, the number of obsolete products as well as inventory costs are expected to be far less than they are now.

The MTO or MTS decision is strategically oriented and is complicated due to complex trade-offs involved between various demand and product-process characteristics. We submit that no MTO/MTS partition can be claimed as an optimal one. As a starting point for the implementation, joint meetings of sales and production people should be arranged to show the result of detailed analysis[2] and discuss the implications of various scenarios. In spite of this, in principle, one has to and one can decide upon a certain MTO/MTS segregation. We now turn our attention to the medium term capacity planning level.

6.3.2 Medium term capacity-planning

The aim of this planning level is to balance the demand and the capacity. On the basis of orders on-hand and the forecast of customer orders, and the available capacities and stocks the decisions are made concerning the allocation of production orders to planning periods. This level specifies the target inventory levels for MTS product in each planning period. The target production run length and production cycle length for each family and/or product has to be specified.

Due to presence of relatively large and sequence dependent setups, the option of creating a recurring, cyclic production seems attractive. Establishing such patterns has been a subject of study of the vast literature on the Economic Lot Scheduling Problem— ELSP (see Silver et al. 1998 and the reference therein). However, within this literature the focus is on make-to-stock items and the aim is to minimise the total amount of inventory and setups costs. Incorporating make-to-order items has not yet been studied in that part of the literature. The literature on combined MTO-MTS does not address this problem of determining the production cycle as well. Specifically, common characteristics in food processing as sequence-dependent setups or limited shelf lives are not addressed.

The main problem in incorporating MTO items is the unpredictive nature of demand in terms of quantity and/or timing. We consider various alternatives to make adaptations to ELSP approaches to be able to incorporate make-to-order and make-to-stock items in a production cycle (see Van Donk et al. 2003 for a more elaborate discussion). These options 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 the pure MTS situation.

In our case, the number of MTO recipes and actual MTO orders is quite high. Though the demand for each and every individual MTO item is not known, the aggregate demand for MTO items is constant across time periods (weekly buckets). This allows us to use the standard ELSP procedures with the additional

[2]Such analysis can be done by the decision aid developed in chapter 3.

constraint on the capacity. We reserve certain capacity for MTO in each cycle and then allocate remaining capacity among the MTS products in such a way that the sum of inventory and setup costs is minimised. The capacity planned (reserved) for MTO can be used to produce the MTO items that are actually ordered during each cycle.

The ELSP solution provides us the frequency of production and target cycle lengths for the MTS products. The safety stock levels are then determined by deploying the standard textbook method (Silver et al. 1998) that uses the demand variance and the desired service levels.

6.3.3 Scheduling

At this level, there are scheduling and control decisions. The production orders are to be sequenced and scheduled. The sequence should be so as to meet the inventory targets set at the capacity coordination levels while minimising the total setup and cleaning times. The problem we are dealing with here is essentially a short-term batch-scheduling problem (e.g. Méndez and Cerdá 2002). The presence of MTO products alongside MTS products and their interaction with the limited shared capacity opens interesting possibilities as well as problems for production scheduling. For example, on the one hand, MTS products might be manufactured to fill capacity in periods of low demand for MTO items but on the other hand, we do not yet fully understand these interactions. The production planning framework does not provide any specific way of tackling this. This is a major area where some analytical aids are needed most. This need is also apparent from our discussion of current scheduling practices in section 6.2. We provide a heuristic to solve this problem in the next section.

6.4 Short-term batch scheduling problem

Based on our analysis of the case, we state the following assumptions and the requirements—

- The processing stage is the bottleneck
- There is sufficient silo space
- Granulating and packaging facilities have enough capacity
- The production run for any order should never be less than the specified minimum run time

- Changeover times are sequence dependent (family setup structure)
- A specified time period is one-week long
- MTO orders have to be shipped before certain due dates
- MTS (replenishment) orders are to be completed before the end of the planning period

At the beginning of every week, it is aimed to determine a production schedule comprising of:

- The set of production orders to be accomplished at the processing stage
- The sequence of production orders
- The run-length and the starting time for each production order

so as to minimize the overall make-span while strictly meeting the specified due dates for MTO orders.

We now provide a step-by-approach to solve the MTO-MTS batch-scheduling problem. The outline of the scheduling procedure is shown in figure 6.6.

Step 1. Generate the candidate list for production orders
To determine which products to produce, a list of candidate production orders is created at the beginning of the week. The list includes all the MTO orders that are due in the forthcoming week (and all unfinished and over-due orders from the previous weeks) and all the MTS products that are likely to runout in the coming week. The runout time is defined as the number of days the current inventory is likely to last based on the expected usage rate.

The product list is sorted on the due-date (runout time) in ascending order. The runout time is also calculated for products that are not likely to runout in the coming week. These are waitlisted candidates and will be included in the production schedule only if there is some idle capacity left. In short, we have created a list of 'must-order' products and 'can-order' products.

Step 2. Generate the preferred production sequence
The 'must-order' products are grouped based on their colour, i.e. family type. The families are lined up one-after-another in such a way that the setup time is minimized. This is a travelling salesman problem but it is of manageable size in the context of the case discussed. The colour sequence is typically from a

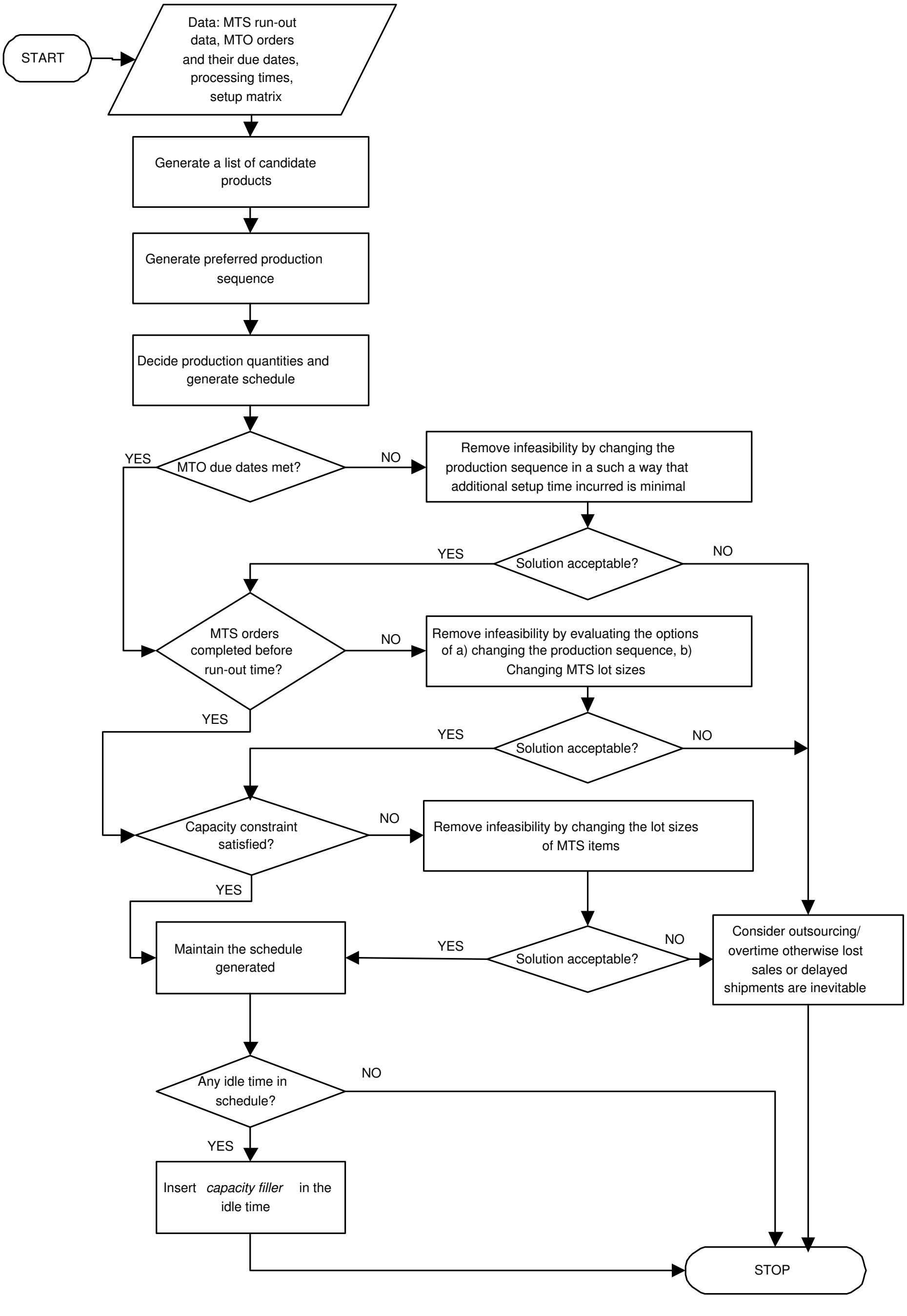


Figure 6.6: Flowchart of the MTO-MTS short term batch scheduling heuristic

light shade to a darker one or vice versa. Within the family the products are sequenced based on their due date. MTO orders are given preference within the family.

Step 3. The production quantities

For MTO orders, the production quantities are known and cannot be changed. For MTS orders, we use an order-up-to S policy. The S value is determined at the capacity coordination level (section 6.3.2). The production order quantity is the difference between S and on-hand inventory. The production order quantity is modified to the nearest multiple of the batch size (because of the batch production mode). There is also a restriction based on minimum run time. This acts as an order quantity modifier and avoids very short (and hence costly) production runs.

Now, we have a list of production orders, sequence of production orders, and production quantities (run-length) and thus can construct the initial production schedule. Note the completion time for each of the orders and the overall make-span.

Step 4. Feasibility checks

We carry out different feasibility checks on our production schedule. These are— (a) Due date compliance: It is checked whether MTO orders are completed before their due dates, (b) Stock out avoidance: Confirm that MTS orders are completed before their run-out times, (c) Capacity check: Confirm that overall make-span is less that or equal to the available weekly production hours.

If these checks are passed then the resulting schedule is feasible and optimal as well. If there is any idle capacity left in the schedule, we produce the 'stable demand' can-order product from the family that is produced at end of the schedule. The product will be inserted in the schedule in such a way that the feasibility is not lost. If this product has sufficient inventory to meet expected demand for the next week, then it is not produced. Instead, recipe 1, the product with highest and most regular demand in our case, is produced. This product insertion acts as a *capacity filler* and stores capacity in the form of inventory. There is no inventory obsolescence risk since these are regular demand products. This stored capacity also acts as a buffer against period of high demand.

Step 5. Schedule improvisation (achieving feasibility)

This is achieved by couple of ways-

a. If infeasibility is caused by due date constraint for MTO, we use the 'pair-wise interchange' to alter the production sequence. It is ensured that altering the production sequence results in minimal increase in the setup times.

b. If infeasibility is caused by non-conformance to MTS runout times, a couple of options are evaluated– (i) changing the lot sizes of a certain MTS items or all MTS items, or (ii) changing the production sequence as in (a) above. The lots of stable-and-high demand MTS items can be made smaller or can be split. Alternatively, lot sizes of all the products can be reduced proportionately.

c. In the case of violation of capacity constraint, we change the lot sizes of certain MTS items or all MTS items as in (b) above.

It is possible to have human intervention while removing the infeasibilities in the schedule. The scheduler can accept the suggested schedule and make modifications to it. In the case of outright rejection of the suggested schedule, outsourcing and overtime options need to be evaluated otherwise lost sales or delayed shipments to the customers are inevitable.

6.5 Conclusions and future research

The case study presented in this chapter is quite generic in nature. A number of food processing companies face the MTO-MTS problems described in the chapter. We particularly illustrated the applicability of the hierarchical planning framework suggested in chapter 2 and Soman et al. (2004a). We observe that the framework is quite simple, generic, and yet very useful as a tool for designing or redesigning the planning and scheduling hierarchy for the combined MTO-MTS production situations. The hierarchy, however, lacks analytical decision aids. We have identified and described a few possibilities in this chapter. In particular, we provide a heuristic for the MTO-MTS short term batch scheduling problem. This heuristic can replace or can be used in tandem with the manual detailed scheduling method that is currently used in the company. Here, we must state that the ideas and solutions suggested in this chapter have not been implemented yet but are definitely under the consideration of the firm.

Further research should be directed but need not be restricted to the following areas. Firstly, a generic MTO-MTS analytical toolbox can be developed which can be used by a lot of companies that face similar problems. Secondly, it would be interesting to study the implications of the various options of incorporating the MTO products, as suggested in section 6.3.2, in the ELSP procedures. Finally, it is possible to develop a MILP-based formulation of the MTO-MTS short term batch scheduling and the resulting solutions can be compared with those obtained by using the heuristics suggested in this chapter.

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