A DECISION AID FOR MAKE-TO-ORDER AND MAKE-TO-STOCK CLASSIFICATION IN FOOD PROCESSING INDUSTRIES

Dirk Pieter van Donk, Chetan Anil Soman and Gerard Gaalman

Faculty of Management and Organisation, University of Groningen,
P.O.Box 800, 9700 AV Groningen,Tel +31 50 3637345, e-mail: d.p.van.donk@.rug.nl

ABSTRACT

Managers in food processing industries find it difficult to decide which products can be best produced as make to order and which products as make to stock. Academic research has dealt with this problem, but mostly only one of several aspects has been taken into account. The paper discusses the existing approaches and based on those, it presents a decision tool for managers, that is implemented in MS Access/ Excel. The tool consolidates various theoretical concepts like ABC analysis and order decoupling point and is relatively easy to use for managers to be helpful in their decision-making. The main contribution is that these approaches are integrated in a logical way and that capacity aspects (that are important for food processing) are incorporated. Further research should incorporate more manufacturing aspects, while practical testing is needed as well.

Keywords: Make-to-order, make-to-stock, decision aid, food processing industries

INTRODUCTION

Production strategies are often classified as make-to-order, make-to-stock, or assemble-to-order in textbooks on production management, e.g. Slack et al. (2001) and Vollman et al. (1997). The main concern in discussing these different production strategies is to find out what consequences a particular production strategy has on production planning and control such as the choice for an appropriate master production scheduling (MPS) approach. In most textbooks and scientific articles, however, it is assumed that the strategy that a particular product should follow has been decided and is given. Moreover, frequently it is assumed that all products of a company are produced as either make to stock or make to order. In other words, that a company has to follow a make-to-order or make-to-stock strategy for all products, while also a combined make-to-stock and make-to-order strategy might be possible. In this paper, we address how to make the decision for production to stock or production to order in situations where both are possible and realistic. This type of decision is at the trategical and tactical level and should be made once or twice a year.

In the food processing industries this question has specific relevance due to a number of industry specific circumstances (Van Donk, 2001). On the one-hand food processing industries have a number of specific product and process characteristics such as limited shelf-life for products and raw materials, high capacity utilisation due to expensive equipment, sequence dependent set-up structure and high cleaning time. On the other hand, food processing industries face increased competition, shorter product life cycles, growth in number of recipes and SKUs and shorter delivery windows. Due to these competitive factors these industries have to produce part of their products as make-to-order (Soman et al, 2004). Traditionally, food-processing industries like other process industries have been associated with commodity products and flow-oriented processes (Taylor et al., 1981; Vollman et al., 1997 (p.7-8); Dennis and Meredith, 2000) and hence make-to-stock used to be the most likely policy.

So far, the area of combined make-to-order and make-to-stock has been relatively ignored in production management literature on food processing. Some work has been done in planning and scheduling. Soman et al. (2004) review the literature. However, the decision whether to produce to stock or to order has not been dealt with in a systematic way. We observed in day-to-day business that the difference between the two types of production is not always and that managers in food processing industries find it difficult to decide which products to make to order and which products to stock. In general such decisions need to be made in cooperation between production and marketing/sales managers, who hardly communicate and lack the tools to develop a proper discussion. Development of a decision tool has been a concern for academic researchers as well.

The literature proposes a number of concepts to support the decision-making, such as ABC analysis, ‘customer order decoupling point’ (Hoekstra and Romme, 1992), the similar concept of ‘order penetration point’ (Olhager, 2003) and ‘lead-time gap’ (Christopher, 1998).

Within ABC analysis it is usually proposed that high volume items are produced to stock while low volume items are considered as make to order. Williams (1984) and Carr et al. (1993) use mathematical models that result in the same division. This way of classification, however, considers only the demand/volume factor.

The ‘customer order decoupling point’ (CODP) concept, developed by Hoekstra and Romme (1992), is more comprehensive and looks at market, product and production related factors to arrive at the MTO/MTS decision. Using product-market and process characteristics and considering the desired service level and associated inventory costs, this concept helps in locating the decoupling point and thus, the MTO/MTS decision. This concept has been used in a number of case studies across various manufacturing sectors (Olhager, 2003) including food processing e.g. Van Donk (2001). However, as Van Donk notices, the approach is rather qualitative and more appropriate to understand and analyse situations than to decide on.

Sox et al. (1997), Arreola-Risa and DeCroix (1998) and Li (1992) provide additional insights in the partitioning decision by experimenting and analysing more formal, mathematical models of production situations having both make-to-order and make-to-stock.

Most of the above contributions pay attention to only one aspect of the MTO-MTS decision problem. While they do make valuable contributions, their application in practice is in most cases difficult. Some of them are too qualitative to be applicable; others are too mathematical to be applicable. The main shortcomings of the above approaches are that they decide on a one-by-one or item-by-item basis and capacity constraints are not included. The application is further worsened due to the fact that specific food processing characteristics are not taken into account (with the exception of Van Donk (2001)).

The contribution of this paper is that (i) we integrate various existing theoretical approaches that could be used for MTO versus MTS decision, (ii) we quantify decisions based on the qualitative arguments put forward previously and (iii) we translate them into a practical instrument. Still, we have to acknowledge that the present contribution is a first step in developing a more comprehensive decision support system

Our proposed approach starts with determining the service considerations for each product. Next, we employ a methodology developed in D’Allessandro and Baveja (2000) to analyse demand and group products into four different categories. Costs considerations as well as industry specific characteristics (e.g. set-ups and shelf-live) can be incorporated by adapting a model from Magee and Boodman (1967), while finally capacity considerations and limitations are checked. These four steps have been implemented in a Microsoft Access/Excel based tool.

The structure of this paper is as follows. The next section will briefly discuss the literature. Then, the main parts of the decision aid are discussed: general structure, demand analysis, economic considerations and capacity issues. The paper ends with conclusions and discusion points

LITERATURE REVIEW

In the food processing industries there is a distinction between recipes and products (or items). In many cases, a number of products (SKUs) will be obtained from one recipe by changing the type of packaging and/or label. Here, we choose to have the discussion based on recipes. A second definition related point is our definition of MTO, which is simple– there is no inventory held in stock for MTO recipes. There are several types of MTO recipes. We look at a specific class of MTO recipes. While the customer-specific, tailor-made, one-off recipes (products) are obviously MTO, there are certain recipes that could be produced either to stock or to order. Such recipes are considered for the MTO versus MTS categorisation decision in this paper. Assemble-to-order is, however, kept out of discussion since in many food processing industries intermediate storage possibilities are limited or do not exist at all.

There are a number of useful concepts and models available in the literature. ABC analysis (without product value) has been widely used with high volume A-class items produced to stock while low volume B and C class items considered as MTO. A number of the combined MTO-MTS papers (Williams, 1984; Carr et al., 1993) suggest the use of such simplistic rules. This way of classification, however, considers only the demand factor.

Li (1992) takes a marketing perspective. He studies the impact of market competition and customer behaviour based on price, quality and expected delivery lead-time on the MTO/MTS production decision in a single product case. Here, the discussion is on ’what happens when’ one of the factors changes. He concludes that competition can breed a demand for make-to-stock, just as other economic phenomenon such as economies of scale, uncertainty or seasonality and that delivery-time competition decreases producer’s welfare. Arreola-Risa and DeCroix (1998) provide optimality conditions for the MTO/ MTS partitioning in a multi-product, single machine case with the first-come-first-served scheduling rule. They study the effect of manufacturing (processing) time diversity on the MTO/MTS decision for backorder-cost cases of dollar per unit and dollar per unit per time. Their result, using M/G/1 queuing analysis, shows that holding cost rate, backordering cost rate and distributions of manufacturing times play an important role in MTO versus MTS decision. They conclude that reducing manufacturing time randomness leads to more MTO production.

Sox et al. (1997) focus on total quantity of inventory and on-time delivery, rather than costs. The goal is to fulfil orders within a certain service time window of T periods. The primary stock control parameter is the total base stock. They provide expressions for fill rate using M/M/1 queue with multiple products, base stock inventory policy, one-for-one inventory replenishment and first-in-first-out order scheduling with service within T periods. These results are used to allocate the aggregate inventory to the items. The high demand items get stocks assigned to them while low demand items do not. The service of these low demand items is maintained by giving them higher production priority when a demand occurs. Though the authors do not explicitly talk about the MTO/MTS decision, it is clear that their model can be used for that decision. It is felt that despite some restrictive assumptions, like no set-up or changeover time, the model can be extended for certain food (process) industries. A lot of food industries have special storage requirements, e.g. cold storage and a limited storage capacity. This may allow only a few products to be stored. This model can be used to decide which products get base stock assigned to them, i.e. which products to store.

The ‘customer order decoupling point’ (CODP) concept, as described by Hoekstra and Romme (1992), is more comprehensive and looks at market, product and production related factors to arrive at the MTO/MTS decision. The customer order decoupling point separates the order-driven activities from the forecast driven activities and is the main stocking point from which deliveries to customers are made. Using the product-market and process characteristics and considering the desired service level and associated inventory costs, this concept helps in locating the decoupling point and thus, the MTO/MTS decision. This concept has been used in a number of case studies across various manufacturing sectors including food processing e.g. Van Donk (2001). This concept is also known as ‘order penetration point’ (OPP) and has been discussed in Olhager (2003) and the references therein. Olhager (2003) further presents a conceptual impact model for the factors affecting the positioning of the order penetration point. Most of these papers on CODP and OPP discuss ’what happens when’ a certain factor forces the CODP to shift forward and backward. These papers recognise that the decoupling point choice involves a trade-off between delivery time and inventory costs. This trade-off can viewed as a problem of minimising the costs while meeting market requirements and satisfying process constraints. Regarding delivery time, the major factor is the production to delivery lead-time ratio (*P/D*) ratio (Christopher (1998) uses the term lead-time gap for the relation between production and delivery lead times) while the costs are mainly affected by the relative demand volatility (*RDV*). The *RDV* is defined as the coefficient of variation, i.e. the ratio of standard deviation of demand and the average demand.

We now take a closer look at the *P/D* ratio and the *RDV* since we will be making use of these factors in the next section.

If *P/D* is greater than one, MTO strategy is not possible and MTS is the only choice. If the ratio is less than one, MTO is possible but it may also be possible to produce to stock to gain economies of scale. This is expressed through the *RDV*, such that a low *RDV* indicates that some recipes can be produced to stock. If the *RDV* is high it is not reasonable to use MTS policies since this would mean carrying excessive safety stock inventory. *RDV* has also been prescribed by D’Alessandro and Baveja (2000) for MTO-MTS classification. They use *RDV* and average demand volume to categorise products into MTO and MTS. The products with high volume, low variability are MTS products; while products with low volume and high variability are MTO products.

From the above description and discussion of the literature we can draw a number of conclusions. The concepts discussed above help us understand the complex trade-offs involved in MTO or MTS decision and provide guidelines for it, but there is no easily available, ready-made instrument that will achieve the same in practice. Moreover, the capacity considerations are ignored in these concepts since each product is considered in isolation during the decision process.

The above also clearly indicates what are the key factors that need to be taken into account in developing a decision aid for MTO or MTS decision: service delivery requirement, demand variability, cost considerations etc. and process constraints, mainly in the form of limited available capacity. The next section develops such a decision aid.

DECISION AID

All manufacturers want to meet the service requirements at minimum cost. Therefore, in deciding MTO or MTS partition, we concentrate on two important aspects: (i) inventories are held to attend delivery service requirements, or (ii) inventories are held to provide cost savings. In order to do this, we start analysing, first, if service considerations force us to keep the item in stock, regardless of the cost considerations and if this is not the case we do cost calculations to arrive at the decision. The procedure followed is thus sequential. We start with the delivery service requirement analysis, followed by the demand and cost analysis, finally capacity requirement analysis is done to check and achieve the feasibility of the MTO-MTS classification. Figure 1 shows the architecture of this procedural tool. Recipe (product) master and the order book are the main input for the system. One can assume that getting this data for any company is achievable. Since recipe data is the core of food industries and all the orders are recorded, these should always exist in MRP/ERP systems. We now explain each step in the sequential procedure.

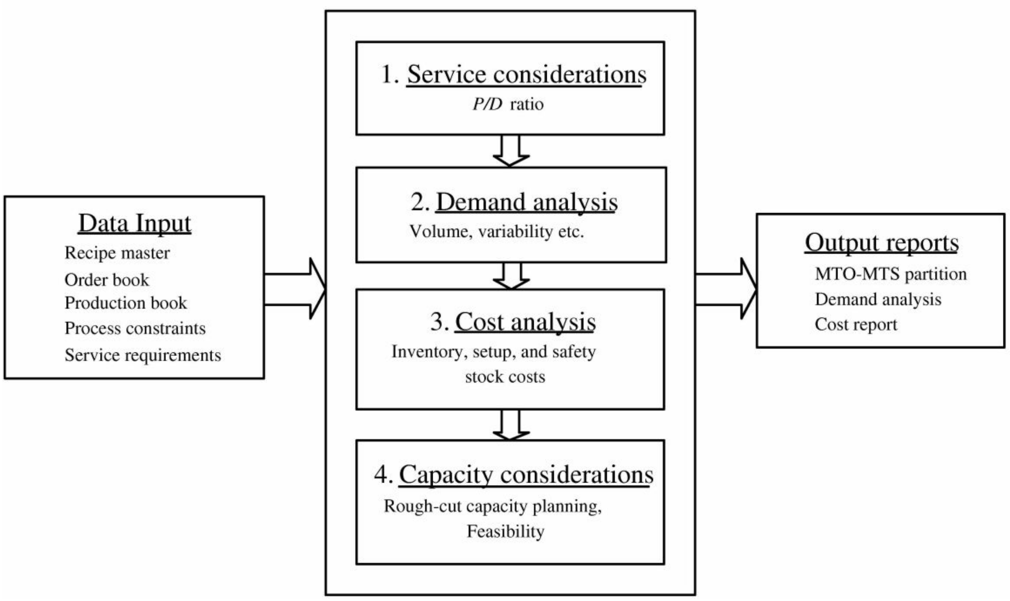


Figure 1 - Architecture of MTO-MTS decision aid

Service considerations

For each recipe one can associate a desired maximum customer delivery lead-time that is acceptable to the customer. This delivery lead-time can be determined by taking into account the delivery history of the product (available from the order book) and the market benchmarks. Similarly, manufacturing lead-time can be computed for each recipe from previous production order book history or by estimates provided by shop supervisors. This can also be computed using the discussion and procedures provided in Van Donk et al. (2003).

The decision rule is straight forward– if the manufacturing lead time is larger than the desired maximum customer delivery lead time, i.e. if the *P/D* ratio is greater than one, the recipe is classified as MTS otherwise there is no need to stock it based on service requirements. The demand and cost analysis has to be taken up in that case. It should be clear that in all these type of discussions and decisions cost and profitability considerations of the product-customer should be considered as well.

Demand analysis

The demand analysis forms the core of the model. The classical ABC analysis can be easily carried out from the input. However, it is felt that this categorisation is too simplistic and does not account for differences in uncertainty that exists in the demand among various products. Instead, a demand variability analysis, in the form of *RDV*, as suggested in D'Alessandro and Baveja (2000) is followed. Figure 2, shows a plot of average weekly demand on the x-axis and demand variability (coefficient of variance) on the y-axis. It is possible to categorise products into 4 groups– (a) High volume, low variability, (b) High volume, high variability, (c) Low volume, low variability and (d) Low volume, high variability. The products in the high-volume, low variability are candidates for MTS production. Most of the product recipes belonging to the low volume, high variability category should be produced on MTO basis. Many recipes belong to the high volume, high variability category and may be produced on MTS basis. However, more safety stock levels would be required for such recipes and economic considerations discussed in the next sections come into the picture. It is also recommended that closer ties should be sought with the customers in order to reduce their variability.

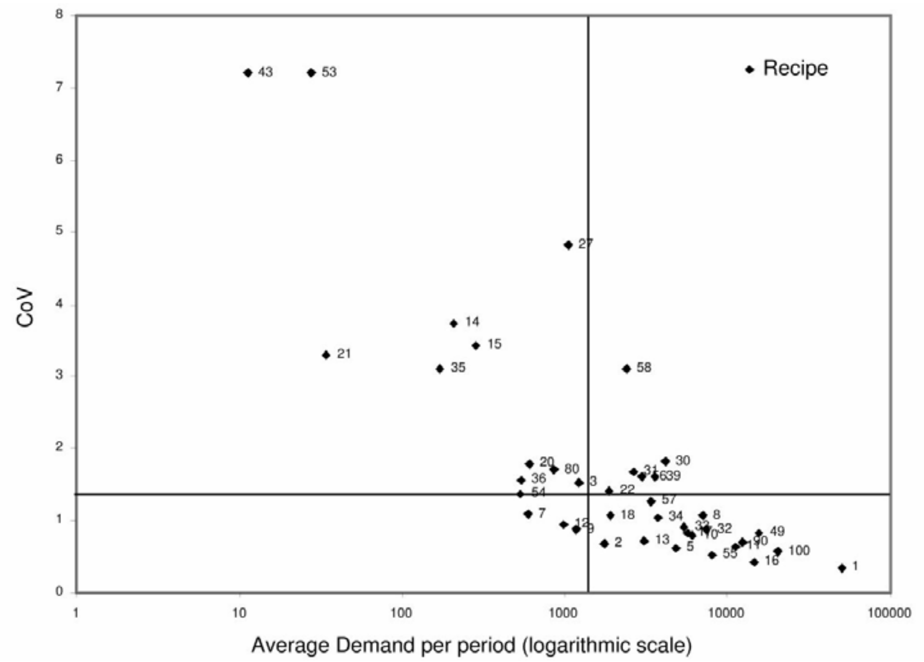


Figure 2 - Output report: Demand variability analysis. Period indicates a week in the example shown.

While doing this analysis, some difficulty might arise 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. These are the likely areas of conflicts as well as 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, fewer inventories, more set-up time but this also allows differentiated service for different customer classes. Sales and production departments should jointly decide on ‘what is high demand’ and ‘what is high variability’. Some simple rules can be defined, e.g. a vertical partition to take place at a certain percentage of total demand. This type of discussion between sales/marketing and production/planning, based on the above data is hardly present in companies, but truly valuable to arrive at sound decisions.

Economic considerations

In this section, the costs of producing a recipe to stock and to order are compared. This model is adapted from chapter 4 of Magee and Boodman (1967). The assumptions and the data of the problem are as follows:

- The annual expected demand for the recipe is D units/year, a number of N orders are received annually from the customer.
- There is a fixed charge of A euros/order for the manufacturing set-up.
- It costs PC euros/time unit of machine usage (production and set-up time)
- The production rate is P units per time unit and the average set-up time for the item is S time units.
- If the recipe is stocked, it is ordered in economic order quantities Q; also, to protect against uncertainty a safety stock (SS) is held. In some cases it may be necessary to change these using order quantity modifiers on account of technological constraints like shelf life, minimum batch size etc. These can be easily brought in but are ignored in this paper.
- It costs C_{MTS} euros/unit to produce the recipe for stock; it costs C_{MTO} when it is on order; the two costs are established by assuming that in MTO case the expected order size is D/N units and in the MTS case it is Q units. In some cases, it may be possible to combine MTO orders into one

production order but here we will assume that it is not done because of the large product variety and shorter lead-time requirements. The combining of orders may lead to long and varying lead times.

- Stock is carried at a charge of *r* euros per unit per year.
- Service level is high enough so as to make the backorder cost negligible.

If we produce the recipe on a MTO basis, the average total processing time, TPT_{MTO}, for each order is:

$$TPT_{MTO} = S + D /(N \times P) \qquad (1)$$

C_{MTO}, the cost per unit is then given by:

$$C_{MTO} = PC \times TPT_{MTO} / (D/N) \qquad (2)$$

The total cost is the sum of ordering cost and the cost of the recipe itself. It can be given by:

$$TC_{MTO} = N \times A + D \times C_{MTO} \qquad (3)$$

When the product is stocked, the average total processing time, TPT_{MTS}, for each batch is:

$$TPT_{MTS} = S + Q/P \qquad (4)$$

C_{MTS}, the cost per unit is then given by:

$$C_{MTS} = PC \times TPT_{MTS} / Q \qquad (5)$$

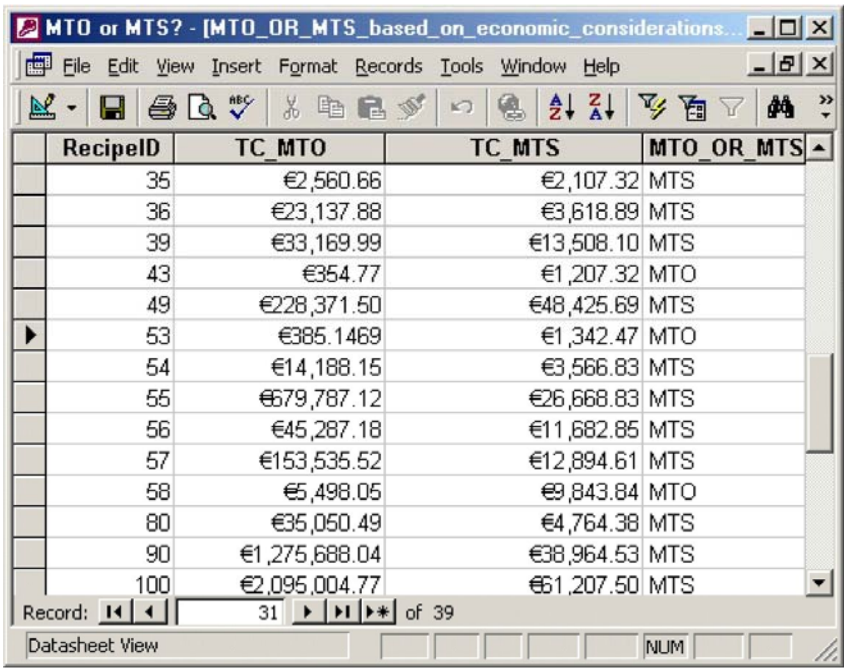
The expected annual cost TC_{MTS} is:

$$TC_{MTS} = (D/Q) A + [Q/2 + (SS)] r + D \times C_{MTS} + C_{syst} \qquad (6)$$

where C_{syst} (euros/year) is the system cost (the recipe's share) of having the item stocked. It is also possible to exclude this, since it can be incorporated in the inventory holding cost rate r. The decision rule be applied is: if $TC_{MTO} < TC_{MTS}$ the recipe is classified as make-to-order; otherwise it is a MTS recipe. Note that in order to compute the total cost we need the estimates of all the parameters involved. Most of them are already available in the recipe master and the order book. The required safety stock can also be taken from historical records, if the recipe was previously stocked; if not, an approximation can be used in the following form:

$$(SS) = k\,(l\,D/12)^{1/2} \qquad (7)$$

where k is the safety factor and l is the lead time, in months. This approximation is used for high variability recipes in RDV analysis and assumes that demand during the lead-time l follows a Poisson distribution. This assumption is rather realistic when we recall that these recipes are the slow-moving items. For fast moving items i.e. low variability recipes, normally distributed demand approximation is used. Figure 3 shows a screenshot of the output of the economic considerations.



RecipeID	TC_MTO	TC_MTS	MTO_OR_MTS
35	€2,560.66	€2,107.32	MTS
36	€23,137.88	€3,618.89	MTS
39	€33,169.99	€13,508.10	MTS
43	€354.77	€1,207.32	MTO
49	€228,371.50	€48,425.69	MTS
53	€385.1469	€1,342.47	MTO
54	€14,188.15	€3,566.83	MTS
55	€679,787.12	€26,668.83	MTS
56	€45,287.18	€11,682.85	MTS
57	€153,535.52	€12,894.61	MTS
58	€5,498.05	€9,843.84	MTO
80	€35,050.49	€4,764.38	MTS
90	€1,275,688.04	€38,964.53	MTS
100	€2,095,004.77	€61,207.50	MTS

Figure 3 - Output report: Economic considerations

Capacity constraints
Once we follow the sequential procedure described above– service considerations, demand analysis, cost considerations– we get an initial solution to the MTO/MTS partition. However, so far we have considered the recipes one by one and have neglected their interactions with the capacity. We are not yet sure whether we have sufficient capacity to follow the MTO/MTS partition obtained so far. To do this, a rough-cut capacity check (i.e. ignoring congestion effects like machine interference) is performed. It is checked whether we have sufficient capacity to produce the initial MTO/MTS partition solution. This can be accomplished using the following expressions. The annual capacity, X_{MTS}, required by the recipe if it is produced to stock is simply the average total processing time of the batch multiplied by the number of batches per year. It is given by:

$$X_{MTS} = TPT_{MTS} \times D/Q \qquad (8)$$

The annual capacity, X_{MTO}, required by the recipe if it is produced on order is simply the average total processing time of orders multiplied by the number of orders. It is given by:

$$X_{MTO} = TPT_{MTO} \times N \qquad (9)$$

The total capacity needed for the given MTO-MTS partition is then given by the expression:

$$\sum X_{MTO} \times y + X_{MTS} \times z \qquad (10)$$

where, $y = 1$ if a product is produced on MTO basis; 0 otherwise;
$z = 1$ if a product is produced on MTS basis; 0 otherwise;
$y + z = 1$ if the product is offered; 0 otherwise.

In case it is observed that there is a shortage of capacity, i.e. the capacity obtained using the expression (10) is less than the available capacity, an iterative procedure is followed to modify the existing MTO/MTS partition. The procedure starts by changing the category of that recipe where increase in total costs (by moving it from MTO to MTS category or vice versa) is minimal. After each iteration a capacity check is done again for checking the feasibility of the partition. The procedure terminates when a feasible partition is found or when all items have been checked. In the latter case, it is clear that the company has capacity shortage. Then, the company may choose not to offer some recipes with low volume, low variability. Low volume, high variability recipes can be offered on MTO basis, if they have high contribution margins.

Alternatively, it is also possible to use the following formulation for the rough-cut capacity planning instead of the iterative procedure (with feasibility checks) described above.

$min \sum (TC_{MTOi} \times y_i + TC_{MTOi} \times z_i)$: Total cost
$s.t.$
$\sum (X_{MTOi} \times y_i + X_{MTSi} \times z_i) <= X$: Capacity constraint
$y_i + z_i = 1$: Product is offered
$y_i, z_i = 0$ or 1 : MTO or MTS

This integer (binary) linear programming model chooses y_i and z_i (decision variables) in such a way that the total cost is minimised while the capacity constraint is satisfied. The model is solved using the SOLVER available in Microsoft Excel. Few y_i and z_i values will have to be preset using the outcome of the earlier steps, e.g. for a certain recipe, the service requirements may force $z_i = 1$, i.e. product has to be produced on MTS basis irrespective of the cost.

There are various output reports available from the decision aid. The most important report suggests the MTO/MTS partition for each recipe along with the justification of the decision. The justification comes from service level requirements, demand analysis and cost considerations as discussed.

CONCLUSION AND DISCUSSION

In this paper, a decision aid for the MTO or MTS decision is developed. This decision, though strategically oriented and complex, influences the production planning and control function of any company. Such decisions are generally taken once every six months or every year. The tool presented gives a unified treatment of various trade-offs and considerations that go into taking the decision. There are not much data or investment requirements on the part of the company to make use of this tool. The familiar interface of Microsoft Access/Excel makes the use of the tool even more attractive. Here, we must state that this tool has not been fully implemented in a real-life setting but the initial feedback in a test case is satisfactory. One of the positive effects of using this procedure is that a discussion can be started on service and leadtime to different customers, the use of inventories, capacity and batch sizes between production and marketing/sales.

The decision aid presented in this paper is an attempt at developing a structured approach that is converted into a tool for the MTO/MTS decision in food processing industries. There are obviously certain limitations with the presented approach. The tool considers only service delivery time requirements, demand variability and cost considerations. The logical extension of the aid presented in this paper should include other factors that impact the MTO-MTS decision. Shelf life, for example, can be easily brought into the cost considerations. The cost model used in this paper while useful has certain drawbacks: we used a deterministic approach with constant demand and infinite capacity assumptions as in classical independent lot size formula (although the capacity constraints were brought in later). Future models should aim at considering multiple products for determining the lot sizes and the MTO versus MTS option simultaneously. Another question is about the selection of the basic unit (recipe or SKU) for doing the analysis similar to the one presented in this paper. In-depth demand analysis; and commonality indices for SKUs and recipes should help in this regard.

A last important question relates to the basic approach taken in Figure 1. While the underlying logic is to start with demand and service requirements (the external factors) and then bring in cost and capacity considerations (the internal factors) it might be that in some situations either cost or capacity should be considered before entering into service considerations. E.g. under limited capacity it might be better to select high contribution products only irrespective of MTO-MTS. Future research needs to be performed to find if and how market and demand structures and type of production capacities influence the order of decisions. In that we can also further explore if a step-by-step approach has specific disadvantages as copared to an integrated decision model.

REFERENCES

Arreola-Risa, A. and DeCroix, G. A. (1998), “Make-to-order versus make-to-stock in a production-inventory system with general production times,” *IIE Transactions (Institute of Industrial Engineers)*, Vol.30, No.8, pp. 705–713.

Carr, S. A., Güllü, A. R., Jackson, P. L. and Muckstadt, J. A. (1993), “An exact analysis of production-inventory strategy for industrial suppliers,” Working paper, Cornell University.

Christopher, M. (1998), *Logistics and Supply Chain Management: Strategies for reducing cost and improving service*, Second Edition, Prentice Hall, London.

D’Alessandro, A. J. and Baveja, A. (2000), “Divide and conquer: Rohm and Haas’ response to a changing specialty chemicals,” *Interfaces*, Vol.30, No.6, pp. 1–16.

Dennis, D.R. and Meredith, J.R. (2000), “An analysis of process industry production and inventory management systems,” *Journal of Operations Management*, Vol.18, No.6, pp. 683-699.

Hoekstra, S. and Romme, J. E. (1992), *Integral Logistic Structures: Developing Customer-oriented Goods Flow*, McGraw-Hill, London.

Li, L. (1992), “The role of inventory in delivery-time competition,” *Management Science*, Vol.38, No.2, pp. 182–197.

Magee, J. F. and Boodman, D. M. (1967), *Production planning and inventory control*, McGraw Hill, New York.

Olhager, J. (2003), “Strategic positioning of the order penetration point,” *International Journal of Production Economics*, Vol.85, No.3, pp. 319–329.

Soman, C. A., Van Donk, D. P. and Gaalman, G. (2004), “Combined make-to-order and make-to-stock in a food production system,” *International Journal of Production Economics*, Vol.90, No.2, pp. 223–235.

Sox, C. R., Joseph Thomas, L. and McClain, J. O. (1997), “Coordinating production and inventory to improve service,” *Management Science*, Vol.43, No.9, pp. 1189–1197.

Taylor, S.C., S.M. Sewart and Bolander, S.F. (1981), “Why the process industries are different,” *Production and Inventory Management Journal*, Vol.22, No.4, pp. 9-24.

Van Donk, D. P. (2001), “Make to stock or make to order: The decoupling point in the food processing industries,” *International Journal of Production Economics*, Vol.69, No.3, pp. 297–306.

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”, in: *1st joint POMS-EUROMA International Conference*, Como Lake, Italy, Vol. II, pp. 769–778.

Vollman, T. E., Berry, W. L. and Whybark, D. C. (1997), *Manufacturing Planning and Control Systems*, Fourth Edition, Irwin.

Williams, T. M. (1984), “Special products and uncertainty in production/inventory systems,” *European Journal of Operations Research*, Vol.15, pp. 46–54.