Tactical and Operational Issues in a Hybrid MTO-MTS Production Environment: The Case of Food Production

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Abstract. Hybrid production environments that combine MTO and MTS strategies have emerged to enable production systems to better respond to changes in consumer and market demand. This paper discusses some of the tactical and operational production planning and control (PPC) issues involved in such hybrid production environments, using the food industry as an illustrative case. The discussion identifies MRP combined with WLC as a promising approach for incorporating MTO items into an MRP planning environment on the tactical and operational levels. Additional techniques are required to incorporate uncertainty and provide flexibility in this particular context and these should be further investigated taking different food supply chain characteristics into consideration.

Keywords: planning, control, hybrid, MTS, MTO, food.

1 Introduction

Food production is similar to process manufacturing, showing a higher complexity than discrete manufacturing (Crama et al., 2001). In addition to great attention to quality and food safety, food producers have traditionally focused on economies of scale to keep costs and prices down (van Donk et al., 2008, Verdouw and Wolfert, 2010). However, a production system as a whole should not only focus on costs but also show high flexibility in reacting to changing market conditions, fluctuating demand forecasts and actual demand (Bertrand et al., 1990). Over the past decades the food sector has therefore attempted to become more responsive by shifting from the traditional make-to-stock (MTS) approach towards applying more make-to-order (MTO) and combined MTO-MTS approaches (Crama et al., 2001, Soman et al., 2004).

The need for differentiating products and managing them differently is well recognised in literature (see e.g. Fisher, 1997, Christopher et al., 2006). However, such hybrid systems complicate the task of **production planning and control (PPC)** considerably since combining MTO and MTS in the same production system impacts on a number of tactical and operational issues and decisions - requiring companies to deal with complex trade-offs between inventory policies, number of set-ups, machine utilisation, production lead times, needs for cycle and safety stock, etc. (Soman et al.,

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2004). The purpose of this paper is therefore to **highlight and discuss some of the tactical and operational PPC issues and decisions involved in a hybrid production environment**. Particular emphasis is put on how to handle the demand uncertainty caused by the application of both MTS and MTO in the same production system.

The paper starts with a description of the study's research methodology, followed by an introduction to the empirical background. Next, PPC is defined, while the two subsequent chapters outline and discuss issues on the tactical and operational planning levels respectively. The conclusion outlines the paper's contributions and some suggestions for further research.

2 Methodology

This conceptual paper is a theoretical discussion of the tactical and operational implications of a concept involving hybrid MTO-MTS production approaches. Research on these more operational aspects of hybrid production situations is scarce since the majority of research focuses on a single type of production environment. The aim of the paper is therefore not to provide solutions to these highly complex issues, but rather to highlight and discuss some of the most critical decisions based on existing literature and the authors' experiences from industry.

The paper's theoretical base is within operations strategy, planning and control, and scheduling, and the discussion exploits and combines the advances of related production environments to provide new insights. The study focuses on the food sector as this is one of the sectors where hybrid production environments are becoming more common.

3 Food Sector Characteristics

Food supply chains deal with highly perishable goods, where rapid product and raw material deterioration significantly impacts on product quality and the amount of waste both within the supply chain and in consumer households. In addition, demand and price variability of food products is increasing, making food supply chains more complex and harder to manage than other supply chains (Ahumada and Villalobos, 2009). Food supply chain actors are faced with the challenge of supplying an ever broader variety of these perishable products to increasingly demanding customers, while at the same time moving products quickly through the supply chain and keeping costs as low as possible. Table 1 summarises some of the supply chain and logistics characteristics which are particular to the food sector.

Food production can be classified as a process industry where production of standard products is mainly continuous, with large production series, and raw materials and intermediates are accumulated and processed together in batches. The typical steps are receipt of inputs (raw materials, ingredients, packaging materials, etc.), processing, packing (where bulks are transformed to discrete products through sizing and labelling), and delivery. Typically there are three stock positions; raw materials, unpacked bulk products, and packed end products (Méndez and Cerdá, 2002, van Dam et al., 1993).

Table 1. Food supply chain characteristics (based on Romsdal et al., 2011)

Area	Characteristics
Product	• High perishability (raw materials, intermediate and finished products) • High and increasing product variety, particularly for promotions, decreasing product life cycle, high percentage of slow-moving items
Market	• Varying and increasing demand uncertainty, fairly predictable annual demand, high variation in periodic demand • Customers demand frequent deliveries and short response times
Supply	• Some supply uncertainty and variable raw material yield
Production system	• Capital-intensive technology, long set-up times, high set-up costs • Long production lead times, processes adapted to high volume, low variety, with raw materials and intermediates processed in batches

The characteristics in Table 1 show that there is increasing product variety and demand uncertainty in the food sector – which significantly increases the complexity of PPC for food producers. A **differentiation strategy** according to demand uncertainty has been suggested as a way to reduce this complexity. Kittipanya-ngam (2010) and Romsdal et al. (2012) suggest that the products that are the most difficult to plan and control should be given most focus in PPC. In this way, products with high demand uncertainty are within the "focus box" and controlled using an MTO strategy, while the remaining products are associated with an MTS strategy. This means that producers may find themselves in a situation where they need to **combine MTS and MTO approaches** within the same production system – thereby significantly complicating PPC on the tactical and operational level.

4 Introduction to Production Planning and Control (PPC)

Planning and control refers to the task of defining the structures and information upon which managers within a production system make effective decisions (Vollmann et al., 2005), and the design of the PPC system should be based on company- and industry-specific needs and characteristics (Stevenson et al., 2005).

At the highest planning level, the PPC approach is determined. The most common approaches include MTS, MTO, engineer-to-order (ETO), assemble-to-order (ATO) and mass customisation (MC). In the food sector, production systems are commonly classified as following either an MTS or an MTO strategy. In addition, ATO can be relevant in cases where the processing and packaging processes can be decoupled (Romsdal et al., 2012). However, in food processing, neither a pure MTO nor a pure MTS strategy is practical and food is therefore one of the sectors where a combined MTO-MTS approach is quite common.

At the strategic PPC level product families are formed in order to group items which can be planned and controlled using the same strategy. In addition, target service levels are set against which the performance of the production system is later evaluated. This level should also ensure that the operational capabilities meet the total load of aggregated demand for products and resources in the long run.

Operating a hybrid MTO-MTS approach brings about a number of issues involving complex trade-offs which must be thoroughly evaluated and incorporated into the lower PPC levels. The key issue is **how to deal with MTO items in the MTS schedule** – and some of the tactical and operational decision and alternative methods for dealing with these in hybrid production situations are discussed in the following chapters.

5 Tactical Level Issues

At the tactical level, the production volumes for MTS items are planned and the material planning is performed to determine the quantity and timing for components needed to produce these end-items. In a hybrid environment this level must also accommodate the uncertainty associated with the **quantity and timing** of future demand for MTO items into the material plans.

The literature contains several studies that discuss methods appropriate for tactical PPC decisions. Jonsson and Mattsson (2003) argue that the re-order point system, runout-time planning, and **material requirements planning (MRP)** methods seem to work well for making detailed materials planning decisions in an MTS environment with standardised product components produced in a batch production process. Further, they suggest a good match between MRP and the MTO environment. However, Stevenson et al. (2005) argue that MRP does not fully address the key decision support in an MTO environment since **capacity is not considered at the point of order/job entry and order release**. At the operational level, order acceptance and due date assignment are other key decisions in an MTO environment which must consider capacity. Based on the above requirements, **Workload Control (WLC)** can be appropriate since it ensures high due date adherence and considers capacity simultaneously. WLC uses a pre-shop pool of orders consisting of a series of short queues, where jobs are released if workload levels will not exceed pre-set maximum limits. Simultaneously, WLC ensures jobs do not stay in the pool too long, thereby reducing work in progress (WIP) and lead times (Stevenson et al., 2005).

However, before these methods can be applied in a hybrid MTO-MTS environment, the differences in the **production rates** in MTS and MTO environments need to be considered. The differentiation strategy described in chapter 3 is based on the majority of production being run using the MTS strategy (i.e. for products with low demand uncertainty), thus requiring a standardised method like MRP to reduce **operating costs**. In addition, MTO orders are received occasionally, requiring a focus on strict adherence to **specified due dates**. Based on this, a possible solution for the hybrid environment is to **combine the MRP method with WLC**. MRP can be used as the backbone of the system – but must be tailored and supported with some **additional techniques** so that the WLC method can be applied at the point of new MTO order entry.

In addition to the issue of dealing with MTO orders, **other potential disruptions** to schedules can occur which must be handled at the operational short-term level. Consequently, in order to ensure consistency between the tactical and operational levels, as well as to enable the combination of MRP and WLC methods, the tactical level must contain some approaches which consider such uncertainties and provide the required flexibility. Although some studies have been conducted on how to incorporate MTO products into an MTS planning environment (see e.g. Federgruen and Katalan, 1999, Soman et al., 2006), the studied approaches only considered a narrow selection of food supply chain characteristics. There is therefore a need to investigate a **broader set of techniques** that consider more of the food sector characteristics.

Different techniques exist to address uncertainties in different contexts. In general, supply chains can **buffer against uncertainty** using **inventory, capacity** and **time**. MTS environments use inventory and capacity as buffers – where safety stock is used to ensure availability when demand is greater than expected, while capacity allows for stock to be duly replenished. In MTO environments, customer orders cannot be delivered instantly and are therefore stored in the order book before they are released as production orders, thus spreading the demand variability out over time (Hedenstierna and Ng, 2011). **Safety lead time** to tackle uncertainty in timing can be a more appropriate technique than safety stocks when demand is stable (Buzacott and Shanthikumar, 1994), thus representing a useful approach for products with low perishability and low demand uncertainty. Further, **hedging** has been suggested as a useful technique for coping with internal uncertainties (Koh et al., 2002), thus representing a useful technique for products with internal error-prone characteristics such as cheese which requires maturation periods as part of the production process.

In summary, MRP in combination with WLC seems to be a promising approach for **material planning** – supported by additional techniques to accommodate uncertainties and provide flexibility. Before these techniques can be applied in practice, further investigation with regards to their ability to handle the characteristics of different product-market combinations and their interactions is needed.

6 Operational Level Issues

The operational level involves determining which product to produce next, when to produce, and how much to produce in the short term, e.g. week or day. The production orders are sequenced and scheduled on machines and other resources within the planning period, determining the set of production orders to be accomplished in the bottleneck, sequence of production orders, and production orders' run length and starting times (Soman et al., 2007).

Developing daily/weekly plans and schedules for production volumes, as well as sequencing orders on the shop floor, is not a substantially challenging task in a stable MTS environment. However, during the execution of the schedules, several types of customised orders for MTO products may be received in a hybrid production environment. Such changes may trigger the **rescheduling** of production orders and **revision of priorities** given to the shop (Jacobs, 2011).

Once required flexibility and uncertainties are accommodated at the intermediate tactical planning level, the **capacity-based WLC method** is an appropriate approach to fit MTO products into the operational schedule, while also incorporating the customer order entry level. At the point of customer order entry, the due date is set depending on the capacity status. This decision is applicable for products with long customer order lead time allowance and negotiable due dates. After the due date is known, the **order release date** is determined by deducting planned workstation lead time from the due date. Workstation lead time can be assumed stable in this highly controlled process-type environment. Depending on the existing and required workload for the new MTO order, the order is added to the sequence of MTS products being released in that period. If the **total workload exceeds the workstation load limit**, there are four available options. The preferred option is to move the order release date to the earlier periods, evaluating the available capacity until the present period. By this approach, the system nervousness and cost of rescheduling can be avoided. Products with low perishability and long customer order lead time allowances are good candidates for such forward scheduling. However, if the product perishability does not allow moving the order to earlier periods, there are three other options; to reschedule the pool of jobs at the point of order release with the aim of reducing setup costs, to increase capacity or to renegotiate the due date.

Orders are normally prioritized and sequenced according to their order release date. This is regarded as one of the advantages of WLC concepts as the performance of order release simplifies the shop floor dispatching process (Stevenson et al., 2005). However, in a food production environment this might lead to high sequence-dependant set up costs, and a sequencing rule that considers the trade-off between order priorities and set-up costs might thus generate considerable benefits.

In summary, we suggest that also at the operational level the combined MRP-WLC approach can improve the **effectiveness of schedules** in hybrid environments. The operational performance of the schedule can then be measured on its ability to meet due dates for MTO products, minimise time jobs spend in the process, reduce WIP inventory for MTS products, and minimise set-up costs and waste.

7 Conclusion

This paper has provided increased **understanding and knowledge** on the tactical and operational implications of hybrid production environments. A number of critical decisions and alternative approaches to balance the requirements of both MTS and MTO items were highlighted and discussed on a material and product level, and a combined MTS-WLC approach seems promising in addressing some of the issues. In terms of **contributions to practice**, the paper provided an overview of critical issues which companies must handle when designing PPC systems for such hybrid environments. However, **further studies** are required to investigate implications for planning and control on a resource level and how the MTS-WLC approach can be applied in practice. In addition, which PPC techniques that are appropriate for what degrees of perishability, demand uncertainty and customer order lead time allowances should be investigated. Relevant aspects to consider include differences in production lead times and maturation times, the point of variant explosion for different product families, and interdependencies between different products for instance in terms of set-up times and costs. The main **limitations** are related to the study's conceptual nature, and further research is required to investigate the appropriateness and applicability of the suggested approaches and techniques in practice.

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