Planning of Combined Make-to-Order and Make-to-Stock Production

Beemsterboer, Bartholomeus Jacobus

Chapter 6

Conclusions and discussion

Make-to-order (MTO) and make-to-stock (MTS) are two production approaches that deal with stochastic demand. With MTO production, customers are expected to wait for a limited amount of time, in which the production company is required to deliver the products. With MTS production, the company produces beforehand, so that it is able to absorb demand fluctuations by holding a sufficient amount of inventory.

Combining MTO and MTS production on a facility is known as hybrid production. The planning of hybrid production is particularly challenging, because the planning of the two production systems is so different. For MTO production, an important aim of the planning is to complete as many jobs as possible before their due date. Hence, the focus is on the timing and/or sequencing of jobs. For MTS production, however, we have to balance the delivery performance with the costs of holding inventory. Moreover, producing beforehand allows producing in larger lots, which is more efficient if machines require a setup. Hence, planning methods that are designed for one of the two systems cannot be applied to the other straightforwardly. Hybrid production requires a specific way of planning, in which key characteristics of both MTO and MTS are considered. In this thesis, we explored the potential of specific hybrid production planning approaches and we developed multiple ways of integrating MTS into the planning of an MTO job shop.

6.1 Summary of results

In Chapter 2, we explored the benefits of a specific hybrid production planning approach. We considered a basic, two-product configuration to allow applying Markov Decision Process modeling. Contrary to models researched earlier, we included a lead time of the MTO items in the model with lead times being a key characteristic of MTO, which should not be ignored in a hybrid planning strategy. The results of our analysis showed how production decisions should be based on both inventory level and backlog state of MTO products, and that especially discriminating between states with and without backlog of MTO orders is important. A numerical comparison revealed that taking the state of both product types into account in making production decisions may save up to 60% of the costs compared to reference policies that either prioritize MTO whenever possible, or prioritize MTS when the inventory level drops below an optimally selected base stock.

In Chapter 3, we extended the model of Chapter 2 with machine setups for MTS, so that efficiency considerations came into play. When switching from MTO to MTS requires incurring an additional setup, it becomes beneficial to produce in larger lots. We considered this particularly important for hybrid systems, as the MTO side requires the production system to respond quickly to arriving orders. We therefore studied a flexible lot sizing policy, where the lot size is driven by make-to-order backlogs as well as stock levels. We solved the extended Markov Decision Process to optimality, allowing us to conclude that savings of up to 23% can be achieved with flexible lot sizing, compared to policies that use either completely or partly fixed lot sizes.

The studies of Chapters 2 and 3 considered relatively simple models, allowing the use of a mathematical optimization technique. This provided us with useful insights, which we applied in a more extended and more practically relevant production situation in Chapter 4. Here we considered the case of an MTO job shop to which an MTS item is added as a 'filler'. We extended the model accordingly, by distinguishing six workstations and by considering the variability of MTO order routings, processing times, and due dates. We assumed that shop floor control is organized with a method that is based on the aim to meet MTO due dates. The study focused on integrating the MTS item into the MTO-oriented job shop control mechanism. We proposed four different integration methods that are based on fictitious MTS due dates, so that the regular dispatching method could be applied to MTO and MTS items simultaneously. We showed that for all methods, there is a clear trade-off between the MTO and MTS delivery performance, while this trade-off can be controlled through the use of a single decision parameter. We showed that integration methods which regularly update the fictitious MTS due date based on the inventory level perform better. Although the MTS item may function as a 'filler' item, regarding it as less important and always prioritizing MTO was shown to be far from optimal, despite being popular in both theory and practice. Doing so may result in needless deterioration of MTS performance; we could reduce lost sales by 60% while the MTO delivery performance remained near-perfect by instead using smart integration methods.

In Chapter 5, we considered an inventory model that moves away from the situation of hybrid production. We considered a two-product inventory model with limited storage capacity and we assumed that the capacity is so tight that it allows ignoring the inventory holding costs. We derived closed-form expressions for optimal order quantities and identified circumstances under which it is optimal to vary the order quantity of one of the two products. We showed that this ordering policy can achieve savings up to 25% compared to existing approaches. In doing so, we have shown that not only for hybrid systems, but also for pure MTS systems a flexible approach may very well lead to substantial benefits.

6.2 Conclusion

Overall, our results show that it is important to consider crucial characteristics of both product types in the planning and control of hybrid MTO-MTS production. For MTS , the way to capture the stochasticity of the demand is to hold inventory. MTO deals with stochastic demand by offering delivery within a given lead time. Including these in a hybrid planning approach allows a planner to discriminate between situations with urgent and less urgent MTO backlog. In the latter case MTS can be prioritized when a stock out is imminent. At the same time, the priority of MTS should be based on actual inventory levels. Hence, bringing the two together, a decision on producing either of them should be based on the state of both the MTO backlogs and the MTS inventory. If the machines in a production system require setups, it is important to review regularly how long production runs should continue. If MTS demand is lower than expected and/or more MTO orders than anticipated arrive, then it is important to keep production runs short and switch faster to MTO production. Contrary, if MTS demand is high and MTO demand is low, then long production runs avoid unnecessary setup times, leading to a more efficient capacity usage.

Also when focusing on hybrid job shops, the differences between the two production types favor a hybrid approach. A crucial difference is the strictness of the required completion time of orders. For MTO items, each order has a due date which is strict. For MTS, we can at best define a fictitious due date based on demand forecasts, but as time goes by, the actual demand may be lower or higher.

So the time when we actually need the order to be finished becomes known while it is in production. It is therefore important to adjust the fictitious MTS due dates accordingly. Using MTS items as filler items to fill gaps in utilization left by the stochastics of MTO demand is a commonly accepted approach in job shop practices. However, our study shows that this should not be translated into simple mechanisms of prioritizing MTO orders.

6.3 Future research

We have shown from various perspectives that it is important to take key properties of both MTO and MTS into account when it comes to planning and control of hybrid production. Even with our contributions, the amount of research in the field of hybrid production planning is rather limited, especially when considering that many contributions take a specific MTO or MTS perspective. This provides numerous possibilities for future research.

For instance, we have considered job shop control focused on dispatching methods in Chapter 4, but we have not included the concept of order release. Order release will both provide opportunities and additional complexity. It provides the opportunity to partly centralize the decision whether to prioritize MTO or MTS instead of leaving this to the shop floor control. It also avoids an early commitment of material resources to orders. However complexity also increases since early release of MTS orders will provide extra opportunities to use otherwise idle machines, but disturbs the normally simple prioritization that is common on a shop floor with controlled release of MTO orders. Hence, integrating MTS into the order release of a job shop may be particularly interesting, providing a promising direction for future studies.

Another direction for future research relates to flexibility of lot sizes. We have explored to potential of a planning method that leaves lot sizes flexible in Chapter 3 for a simplified setting. It would be interesting to make this result more concrete by developing MTS lot sizing methods for realistic settings, and to integrate the lot sizing aspect with other aspects in production planning and control, such as job release and dispatching.

When modeling a job shop we have focused at one particular situation, given by a production system that was dominated by MTO and to which a 'filler' MTS item was added. A different situation involving hybrid production emerges when a job shop production environment switches from an MTO to an MTS basis for one or a few of its most demanded products, using the inventory buffer in order to cope with peak demand rather than filling capacity gaps. In this setting, the company could backorder these items in case of a stock-out, i.e. temporarily ‘switch back’ to MTO, because the customers do not require an immediate delivery. Our results on MTS integration in job shop control may not carry over to this setting, as we assumed that sales are lost when there are no items available in inventory. We therefore suggest exploring the planning and control of this setting in future research.

Finally, we have looked at integration of MTS into an MTO planning method. However, because the methods for planning MTO and MTS production systems differ substantially, our results may not be directly applicable to the reverse case of integrating MTO into the planning of an MTS production system. Integrating MTO into an MTS system can involve very different considerations. For instance, having a large amount safety stock at hand gives a production planner the opportunity to delay MTS production when the capacity is needed for a number of MTO orders that have strict due dates, so we conjecture that there is a trade-off between the amount of inventory held and the MTO delivery performance. We suggest exploring these considerations and trade-offs in future studies.

For any of these research suggestions, we recommend using a truly hybrid planning approach that considers key characteristics of both MTO and MTS, as this research has shown for a variety of hybrid production settings that doing so is essential for achieving a good performance for both types of production.