Aggregate Production Planning with Stochastic Demands in MTS/MTO Environments

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Abstract

One of the growing production strategies is hybrid Make-To-Stock (MTS)/Make-To-Order (MTO), since this strategy benefits from the both well-know strategies MTS and MTO. Among handful research papers in the field of hybrid production context, no researches have been devoted to aggregate production planning level. Therefore, this paper addresses aggregate production planning from a tactical point of view. Finally, a sample test is used to validate the feasibility and applicability of the proposed model.

Keywords: Make to stock; Make to order; Aggregate production planning; Stochastic demand; Mathematical programming

1 Introduction

Hybrid Make-To-Stock (MTS)/Make-To-Order (MTO) deals with a combination of two extreme production contexts; MTS and MTO. MTS production environments are planned and implemented based upon forecasts of demands and coming orders. Hence, products are accomplished before entrance of any order and with respect to forecasted specifications from customers. In contrary to MTS, products are manufactured exactly as dictated by actual orders in MTO production context. MTO production environments require special forms of layouts, where machines are arranged into manufacturing cells by specific design conditions (Semancok all, 2011). Moreover, in MTO context, processing of no products are triggered without existence of any actual orders received from customers. Two above production strategies have some corresponding benefits and drawbacks. For instance, in MTS production contexts, considerable holding costs or stock-out costs are inevitable in contexts with highly fluctuating demands. Also, no customization can be performed on MTS-based produced goods, as orders occur while goods are fully processed and stockedin storage locations of the firm (Mu, 2001).

Tab. 1 Different production strategies; before and after OPP represent forecast-driven and customer-order-driven activities, respectively (Olhager, 2003).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Design</th>
<th>Fabrication</th>
<th>Assembly</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make-to-Order</td>
<td>OPP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble-to-Order</td>
<td>OPP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make-to-Stock</td>
<td></td>
<td></td>
<td></td>
<td>OPP</td>
</tr>
</tbody>
</table>

Furthermore, in highly competitive industries, products have limited shelf life; therefore, finished products in a pure MTS system are subjected to risk of obsolescence. The issues and measures involved in MTS environment are usually higher fill rate, demand forecasting, lot sizing, average inventory levels etc. (Soman et al., 2004). Furthermore, since finished-goods inventories are eliminated and firm’s exposure to financial risk is reduced, it usually results in long customer lead times and large order backlogs (Zaerpour et al., 2008). Important issues involved in MTO systems are average response time, average order delay, shorter delivery lead time, due date setting etc. (Soman et al., 2004). Details of four main production strategies are depicted in Tab. 1, including MTS and MTO covered in this paper. The above mentioned conflicting aspects involved in pure MTS and pure MTO manufacturing contexts inspired the combination of two above. In hybrid MTS/MTO environment, two distinct production stages are considered; the first relates to the activities common in both kinds of products processed upon MTS and MTO, the second stage is distinguished for each product for which are performed with respect to specific received orders. Different aspects involved in hybrid MTS/MTO emerges the application of Hierarchical Production Planning (HPP) which includes distinct stages with diverse nature and horizon of planning; strategic, tactical, and operational. This paper addresses tactical aspect of HPP in hybrid MTS/MTO in which amounts and production times of aggregate products are determined. To the best of our knowledge, there are only a handful of research papers considering production planning and control in hybrid systems. This matter that research regarding MTS/MTO systems is still in its infant stages was taken to consideration in (Soman et al., 2004) as well. The most thorough work in this regard is carried out in (Soman et al., 2004). They proposed a comprehensive hierarchical production planning framework that covers the important production management decisions for MTO/MTS situations in food processing. This framework consists of a three-level decision making structure. At the first level, the decisions relating to determining which products to manufacture to order and which products to manufacture to stock are taken. At the second level, the demand and the capacity are balanced. The relevant decision at this level is allocation of production orders for both MTO and MTS products to planning periods. At the third level, there are scheduling and control decisions in which the production orders are sequenced and scheduled. Moreover, in (Chang et al., 2003), a heuristic production activity control model is developed to schedule and control wafer manufacturing in a hybrid wafer production environment (MTO and MTS). For MTO orders, they developed a rigid order release plan and dispatching control and proposed a method of releasing the orders so as to fill up to an appropriate level. For MTS orders. Reference (Mu, 2001) developed a mathematical model as a decision tool to design hybrid MTS/MTO systems and searched for the economical base stock level and location necessary to meet specified service constraint. Also, he showed how to determine the optimal point separating the MTS and MTO operations for both balanced and unbalanced flow lines.

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Rajagopalan, (2002) proposed a non-linear integer program with service level constraints for MTS/MTO partitioning problem. He developed a heuristic procedure to solve this problem. As a recent work, Zaerpour et al., (2008) presented a novel hybrid methodology in MTS/MTO manufacturing systems for partitioning the MTS/MTO products. They proposed a fuzzy AHP-SWOT methodology in which sixteen criteria were gathered as factors toward partitioning. In their model, criteria are categorized as four classes, namely Strength, Weaknesses, Opportunities, and Threats (SWOT), of which two first classes reflect internal status of firm, while two other classes cover external and environmental affecting factors. The above mentioned papers mostly focused on managerial aspects, especially the more recent ones, while the primary researches had mostly concentrated on operational issues tackled by mathematical techniques, including integer programming and simulation study. Adan and van der Wal (1998) is an instance of the latter. Therefore, the mathematical aspects have been neglected as well as more comprehensive and adaptive solving techniques. Another issue to which must be attended more than before is aggregate planning as the middle-level, tactical planning. On this level are usually applied scheduling algorithms as it is presented for instance by Modrak and Pandian, 2010. Hence, the current proposed model in this paper attempts to compensate the abovementioned drawbacks of previously developed models. Hence, theremainder of the paper is structured as follows; Section 2 elaborates the proposed model, while validation of the model is presented in Section 3. Section 4 provides some concluding remarks.

2 Proposed Model

The paper body may consist of several headings, subheadings, figures, equations, tables etc. This sample manuscript layout is prepared as per the specifications for font types, font styles and font sizes, formatting of title, authors’ information, abstract, headings, numbering of sections, equations, figures, table etc. The paper should not exceed 4 pages, including diagrams, photos etc. The text of the paper should be printed on sheets format A4 DIN/ISO A4 (210x297mm) in two columns. The title of the paper should give clear idea about the work that is present in the paper. It should not be too long. As mentioned in introduction, one of the ignored issues in hybrid MTS/MTO planning is tactical planning; i.e. research papers and case studies in this field mostly concentrate on either operational or strategic-level planning. Therefore, aggregate planning of hybrid MTS/MTO products is challenged by the proposed model in this section. With respect to the nomenclature, the proposed model is followed in Eq. (1)-(14).

Nomenclature

- $b_{it}^h$: backlog cost of product family i during time period t based upon hybrid MTS-MTO
- $h_{it}^f$: holding cost of one unit of product family i at the end of time period t, manufactured upon production strategy MTS
- $h_{it}^b$: holding cost of one unit of product family i in workstation j at the end of time period t, upon hybrid MTS-MTO
- $l_i$: inventory level of product family i at the end of time period t, upon MTS
- $o_{it}^p$: order level for product family i during time period t based upon MTO
- $p_{it}^{d_{l(0)}}$: processing time of unit of product family i in workstation j during time period t based upon MTS (MTO/ hybrid)
- $S_{it}^{s_{l(0)}}$: binary variable indicating if setup is performed for product family i during time period t upon MTS (MTO/ hybrid)
- $SC_{it}^s$: setup cost for product family i during time period t based upon MTS
- $ST_{it}^{s_{l(0)}}$: setup time for product family i during time period t based upon MTS (MTO/ hybrid)
- $WIP_{it}^h$: WIP of product family i before workstation j during time period t based upon hybrid MTS-MTO
- $WIPC_{it}^h$: buffer capacity before workstation j during time period t upon hybrid strategy
- $x_{it}^{l_{a(0)}}$: production volume of product family i in workstation j during time period t based upon MTS (MTO/ hybrid)
- $y_{it}^h$: binary variable indicating if workstation j is after OPP for product family i during time period t upon hybrid MTS-MTO

\[
\begin{align*}
\text{Min} \sum_{i,t} C_{it} \left( x_{it}^d + x_{it}^b + x_{it}^h \right) + \\
\sum_{i,t} \left[ h_{it}^d \cdot I_i^d + h_{it}^b \cdot B_i^b + S_i^h \cdot SC_i^s \right] + \\
\sum_{i,t} \left[ b_{it}^h \cdot WIP_{it}^h - y_{it}^h \cdot \left( h_{it}^b \cdot WIP_{it}^h + p_{it}^h \right) \right] \\
I_{i,j-1}^d - B_{i,j-1}^b - I_{i,j}^d + B_{i,j}^b = d_{ij}^t & \quad \forall i,t \tag{2} \\
x_{i,j-1,t} - x_{i,j-1,t}^d = 0 & \quad \forall i,j,t \tag{3} \\
x_{i,j,t} - o_{it}^h = 0 & \quad \forall i,j,t \tag{4} \\
WIP_{it}^h \cdot \left( 1 - y_{it}^h \right) - x_{i,j-1,t} + x_{it}^b = 0 & \quad \forall i,j,t \tag{5} \\
\sum_{i} x_{i,j-1,t} + p_{it}^h + S_{it}^{s_{l(0)}} \cdot ST_{it}^{s_{l(0)}} \leq CAP_j & \quad \forall j,t \tag{6} \\
\sum_{i} WIP_{it}^h \leq WIPC_{it}^h & \quad \forall j,t \tag{7} \\
x_{i,j,t} \leq S_i^h \cdot M & \quad \forall i,t \tag{8} \\
x_{i,j,t} \leq S_i^b \cdot M & \quad \forall i,t \tag{9} \\
x_{i,j,t} \leq S_i^d \cdot M & \quad \forall i,t \tag{10} \\
y_{it}^b \leq y_{i,j-1,t} & \quad \forall i,j,t \tag{11}
\end{align*}
\]
\sum y_{i,j}^h \geq 1 \quad \forall i, t \quad (12)

x_{i,n,t} = d_{i,t} \quad \forall i, t \quad (13)

\sum_{i} x_{i,n,t} WIP_{i,t}^h, I_{i,t}, B_{i,t} \geq 0, y_{i,j}^h, S_{i}^h \in [0,1] \quad \forall i, j, t \quad (14)

To conquer the uncertainty involved in Equation (14), three-point estimate approach is adopted (Lockett et al., 1978). In this approach the uncertain parameter is replaced by the estimate calculated as following: Equivalent p\approx (lowest estimate of p + 4 \times most likely estimate of p + highest estimate of p)/6 Using the above approach, the model is converted to a deterministic one which can be easily tackled.

### 3 Test Problem

In order to validate the feasibility and applicability of the proposed model, a sample problem is solved using software package LINGO 9. The hypothetical problem corresponds to a four-station production line which manufactures four products; Product1, Product2, Product3, and Product4 in one period of planning. Since order partitioning is decided before aggregate planning, the products are already divided into three categories; MTS, MTO, and MTS/MTO. The data associated with the products are as the ones in Table 2.

**Tab. 2 Problem data**

![](image)

Moreover, Table 3 indicates the holding cost of the MTS/MTO product at each station. Using the software package, the result optimal solution is presented in Table 4. The results obtained are completely compatible with the initial data given in Table 2. For example, OPP location of MTS/MTO product is determined as Station3, because the holding costs in Station1 and Station2 are definitely less than those of Station3 and Station4. Also, backlog of Product2 is a direct result of its associated backlog cost in Table 2.

**Tab. 3 Holding cost of MTS/MTO product at stations**

<table>
<thead>
<tr>
<th>Station</th>
<th>Station1</th>
<th>Station2</th>
<th>Station3</th>
<th>Station4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>20</td>
<td>25</td>
<td>75</td>
<td>70</td>
</tr>
</tbody>
</table>

**Tab. 4 Solution of the sample problem**

<table>
<thead>
<tr>
<th>Product</th>
<th>OPP location</th>
<th>Inventory</th>
<th>Backlog level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Station1</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Station4</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Station1</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Station3</td>
<td>45</td>
<td>5</td>
</tr>
</tbody>
</table>

### 4 Conclusion and Future Research Directions

Today competitive markets involve high level of customization to satisfy customer requirements. Based upon these facts in the manufacturing contexts, numerous practitioners and academicians have paid great amount of attention to hybrid MTS/MTO issues and its relevant aspects. Although hybrid strategy has an important place in manufacturing context, there are only handful researches among which no papers have focused on aggregate planning. Hence, this paper attempts to tackle aggregate production planning in the field of hybrid MTS/MTO. In the proposed model, uncertainty of hybrid products is expressed by means stochastic variables. Finally, a test problem is used to validate the feasibility and applicability of the proposed model. To continue the current model, the first extension can be spreading the concept herein in this paper to the other levels of hierarchical production planning in order to complete the hierarchy. Second, it is highly recommended to evaluate ability of fuzzy sets theory and stochastic programming in terms of a fuzzy stochastic approach.

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