◆ Application Paper

Capacity Reservation for Due Date Promising : A Conceptual Framework

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Abstract

In make-to-order manufacturing, if orders are processed and promised in first-come first-served base, then the urgent orders from important customers my be lost. Consequently, in practice, orders are not confirmed upon receipt; and delayed as necessary. Such uncertainty of due date causes significant waste of cost and time. In this paper we propose a new concept of reserved capacity as an alternative to accommodate the urgent orders from important customers, while the due date of all orders are confirmed at its arrival; and suggest a few operational policies.

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1. Introduction

On-time delivery(OTD) rate is one of the most important success factors in MTO(make-to-order) based manufacturing environment. The OTD rate depends not only on production flexibility but order acceptance policy. Especially in the process industry, production lines have relatively lower flexibility because of longer setup times between production lots. This forces production lot sizes to be larger in order to maintain the productivity, which in turn conflict with the goal of achieving higher OTD rate. That is, productivity and OTD rate are in trade-off relation. When urgent orders are accepted from important customers while all lines are temporarily saturated, then either the urgent order has to be delayed, or existing orders already in schedule have to be delayed. If so, the due date customers asked cannot be met.

To avoid such a situation, we need to consider a new order acceptance policy which can promise the due dates for all orders that have been accepted, including at least some portion of the urgent orders. For confirming possible completion date of an order, ATP(Available-To-Promise) logic is widely used. However, ATP considers only the available inventory stock over a certain period of time and examines fixed production schedule to reply the expected due date of a job[1]. For this reason, ATP cannot properly cope with the uncertainty in the future demand.

We propose a new conceptual framework of "reserved capacity" scheme which allows rooms available beforehand for ungent orders to come in to the production schedule. We also present a order acceptance policy which can effectively handle various orders including urgent orders: the CTP(Capable-To- Promise). CTP can be viewed as a revised version of ATP in which we consider not only the stock level and existing production schedule but also the earliest possible slot in the production schedule. With the framework of CTP along with "revised capacity" concept, one can confirm and promise due dates for most of all regular and urgent cusotmer orders.

In the following sections, we will survey the related literature; define the concept of reserved capacity; suggest a few ways to operate the reserved capacity; and efficient order acceptance policies for urgent orders.

2. Related Literature

Due date setting and promising is a difficult task and requires efficient capacity and lead time management (Ozdamar, 1997). Available-to-promise (ATP) logic is widely used to confirm delivery dates by examining all finished and in-process goods (Kise, 1978). In the MTO based manufacturing environment, however, suppliers usually have few standard products and volatile difficult-to-predict demands on a variety of end items. This makes it very hard to confirm due dates for incoming work orders solely by available inventory along with ATP logic. Especially when orders have short lead times and production facilities are highly congested, decisions on whether or not to accept an order becomes very important to in the context of due date promising for existing and incoming orders.

Researches regarding the due dates can be classified into two categories: order acceptance and shop floor scheduling. Easton and Moodie (1999) addressed a problem of lead time uncertainty caused by dual bids using the same resources in order to hedge against the possible capacity loss, and presented an optimal pricing and lead time decision technique for MTO firms with contingent orders. Kingsman et. al.(1996) addressed a process of dealing with customer enquiries so as to attract a sufficient load of profitable work, and presented a decision support and expert system approach to help MTO firms achieve more profitable operations. Hendry et. al.(1998) addressed a workload control(WLC) problem for MTO firms; and presented a simulation model to test the effectiveness of one of the WLC concepts. Bertrand and Sridharan (2001) addressed a problem of determining, for MTO firms with greater order arrival rate than the service rate, when and which orders should be subcontracted; and investigated the robustness of the policies against the error in parameter estimates. Okubo (1996) addressed nonlinear single-item two-stage periodic review production inventory system in which the production capacity is restricted by both the production capacity and inventory level of semi-finished product stock, and proposed a rule of production ordering for finished and semi-finished products. Ozdamar and Yazgac (1997) addressed the due date setting problem for MTO firms, and presented a formal due date assignment procedure to minimize the total backorder and overtime costs.

One important issue that has not received enough attention in the literature is the fact that many suppliers have their own group of important customers which are significantly distinguished from other customers in terms of sales volume and/or strategic value, and whose requested due date must be met. If the due dates of such important customers are long enough, then it does not cause any problem. But in practices, those important customers usually place orders with very short due dates. Therefore, the objective of the suppliers is to establish a well-defined order receiving and scheduling policy which can both confirm the due dates of all accepted orders and maintain a room to accept urgent orders with short due dates from important customers.

As an alternative to handle the urgent orders, overtime can absorb certain portion of urgent orders, but its capacity is limited, and it still causes delay in the delivery of the scheduled orders. In some assembly industry, expediting manual operations can create some extra capacity. However, such expedition is not applicable to process industry. In today's business environment, due to the increasing use business solutions such as ERP and SCM, the confirmation of due date becomes more and more important. Especially in the electronic commerce where sales, quotation, bidding, and contract are all processed by software automatically, confirming the due dates of orders will become mandatory. For these reasons, we propose a new order acceptance and scheduling scheme, called a reserved capacity policy, which can effectively cope with urgent orders while meeting the due dates of existing and some portion of incoming urgent orders.

3. Due Date Related Problems

3.1 Terminology

Conceptual ambiguity in the term 'due date' often confuses industry practitioners and academic researchers in due dates. We define the terms as follows.

<u>due date</u>: the date customer wants to receive final products. Customers and the supplier usually confirm the actual due date through negotiation

<u>lead time</u>: due date - order receiving date

<u>due date overcharge</u>: the cases where production is completed before the confirmed due date, but the first shipping takes place after the due date

Overcharged due date: first shipping date - due date
Shipment delay: first shipping date - production completion date
Planned order: orders that are listed in the sales forecast, but not yet placed by customers
Urgent order: orders that are from important customers and whose due date are relatively short.

3.2 Causes of Due Date Related Problems

The reasons suppliers fail to meet the due date can be viewed as follows. First, Customers tend to ask earlier due dates than they actually need. This causes unnecessary final product inventory in manufacturers' warehouse. This also sacrifice the customer service level since some really urgent orders are often delayed by such orders. Likewise, customers tend to place larger order quantity. And when the production is completed, they ship out the small portion of the completed order over many times, leaving the remaining volume to the manufacturers warehouse. Very often the customers begin to ship out the products after the due date they asked. Such a unnecessarily early due dates will increases inventory at the manufacturers warehouse, occupying the production lines too early and delaying other existing orders with confirmed due date.

Second, from the sales viewpoint, only a limited information of customers production plan and inventory is available. Ambiguous definition and concept of due date confuses related personnel in the firm. There exist no consistent order receiving and production policies to meet the due dates. For example, the production schedule is frequently changed as the urgent orders arrive, which shifts the due dates of already scheduled orders. Customers who overcharges due date to occupy the production lines early make other orders to miss their due dates.

Third, from the viewpoint of production and purchasing departments, changes in production schedule is restricted due to physical constraints imposed to the lines. Since larger orders are preferred for higher productivity, many smaller orders are often delayed. Furthermore, identical orders with different due dates are often combined into single larger production lot to improve productivity. These make it difficult for the suppliers to promise the due date to the customers. Lack of information exchange or integration between production and purchase plan often makes on-time production harder.

Fourth, from the management side, lack of synchronization between monthly sales plan, production plan, and scheduling, along with ambiguity to lay a charge, often amplifies the delay of due dates.

On-time delivery rate can be improved by the following rough cut suggestions. First, due date-related terms and strategic order policies need to be clearly defined in such a way that due date is taken to be the same as the shipping date to the customer in order to avoid the due date overcharge. In doing so, suppliers complete the production by the due date, under the agreement that customers accept the shipping on the same due date. Second, various efforts must be made to improve internal efficiency of the company. Higher accuracy in sales forecast must be maintained. To this end, key performance indicator (KPI)s must be established and managed according to the global objective of the firm. Production division must operate the production capacity efficiently by producing, during the low demand season, excessive items that are expected to be sold in the peak season. Optimal realtime scheduling system and KPIs for production are necessary for achieving both higher on-time delivery rate and productivity simultaneously. Third, information system that enables sharing real time data between sales and production is necessary. For this, internal information flow and transmission system must be established, which often requires redesign of planning system. External efforts to establish the partnership with customers to share demand and production information is also necessary, which often includes the implementation of strategic supply chain management (SCM) system and customer relationship management(CRM) system.

3.3 Due Date Promising System

As we described in the previous section, many problems occur regarding the due date in MTO based manufacturing environment. Currently customers tend to overcharge the due date; suppliers spend a lot of efforts to adjust due dates, with no guaranteed shipping date. Such processes impose significant loss in time and cost to both parties. To avoid such losses, we suggest an order and production policy in which each order is replied a promised due date, or more precisely, shipping date. In many supply chain solutions, such function is called Capable-To-Promise(CTP). CTP can be defined as a business process in which, for a customer order, possible shipping date is identified, considering current production schedule; adjust and fix the due date by negotiation with the customer when necessary.

A similar concept, called Available-To-Promise(ATP) is, given an order for make-to-stock products, to figure out and answer to the customer the available quantity, time, and its place, including the ones in production schedule. On the contrary, CTP is basically, for make-to-order products, to support the sales by quickly figuring out the possible shipping date if the order is placed in the production schedule according to the scheduling policy. If CTP system is implemented, customers will benefit from guaranteed shipping date, while suppliers will benefit from less uncertainty in production and shipping schedule and higher on-time delivery rate.

4. Reserved Capacity

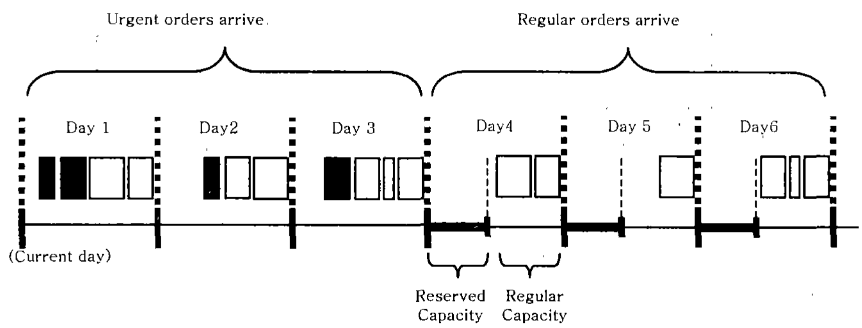
In this paper we present the concept of reserved capacity which is defined as a portion of production capacity that are not assigned to the customer orders in the schedule temporarily. The purpose of reserving a certain portion of capacity in the schedule is that urgent orders with short due date can be assigned in the schedule without delaying the existing orders' due dates, thereby the due dates of all orders are promised and kept.

In the process industry, it is very important to fully utilize expensive facilities at its maximum level in order to minimize the sunk cost. Under the reserved capacity, a certain portion of the capacity (for example, 30%) is reserved for the future scheduling. However, in every "today", 100% of the capacity should be used for production by shifting forward the next scheduled job. Various operational policies can be used for reserved capacity. In this paper, we propose the following policy.

The research is conceptual in nature; for that reason the production system studied has been kept as simple as possible. While in the future we hope to extend our analysis to more complex systems, we start with a simple case of single production line that runs continuously for 24 hours a day; and orders arrive at any time over 24 hours. An example is multi-item continuous production process in a typical petrochemical plant. We consider situations where demand exceeds short-run production capacity so that there are always orders which conflict with existing orders in the production schedule. Otherwise due dates are of no concern.

For the convenience of our discussion, we define an urgent order as one whose due date is within 3 days upon arrival. All other orders are called regular orders. Suppose that an order with due date D arrives when the production line is fully scheduled up to the day D. For this case, either the incoming order has to be rejected with significant loss of potential revenue, or some of the orders already in the schedule have to be postponed with considerable rescheduling effort, and may cause the possible loss of orders. To resolve such dilemma, we present in this paper the *reserved capacity scheme*, which guarantees the due dates of all accepted orders to be met; while allowing certain level of urgent orders from important customers to be accepted in the schedule.

Daily production capacity is divided into two separate time segments, as shown in Figure 1. The term *reserved capacity* is defined as certain portion of daily capacity reserved for urgent order. According to our scheme, regular orders are not allowed to be assigned to the reserved capacity, but only to the regular capacity. Figure 1 shows an example of a six-days schedule in which urgent (shaded) and regular (white) orders are assigned to the reserved (thick-lined) and regular (thin-lined) capacity, respectively. Note that reserved capacity is not distinguished in days 1 through 3. We will explain the reason subsequently in the order acceptance rule.



<Figure 1> An example of a six-days schedule using reserved capacity concept

A validation and measurement of the reserved capacity scheme would require simulation studies. However we will leave this as another research issue. In implementing the reserved capacity scheme, one important issue is to determine when and how a customer is confirmed of the due date of its order. We suggest the following alternatives.

(1) Continuous update

This is to update the schedule whenever a new urgent order arrives. Algorithm is as follows:

Step 1: For the arrived urgent order, identify all production lines (L_i) that can process the ordered item.

Step 2: For all L_i's with nonzero remaining reserved capacity, compute the processing time by dividing the order quantity by hourly capacity of the line. Estimate the setup time at each line considering the preceding job. Find the earliest possible schedule (E_i) for the order at each line.

Step 3: Select the line whose E_i is the earliest and the earliest schedule(E^*)
Step 4: If the customer accepts E^*, fix the schedule. Otherwise the order is rejected.

Note that each line has different remaining reserved capacity in the schedule. Also note that the processing time of the same order can be different at each line because of the unequal hourly capacity of the lines.

(2) Batch update

The customer orders are collected during a certain period of time, for example, one day and the orders are assigned to the schedule according to the priority. By doing so, orders of higher priority can be placed at the earlier slot on the schedule. The confirmed due date of an order is released only at the end of the period of time.

5. Order Acceptance Policies for Reserved Capacity scheme

In this chapter we discuss the advantages and disadvantages of alternative order receiving policies which can promise the due dates.

(1) First-Come-First-Served Policy

This policy does not allow any urgent order but treats all orders as equally important. Customer orders are assigned to the schedule in the order of arrival. For multiple lines case, the order is assigned to the line with earliest possible schedule. The due date of the order is promised at the time the order is received. Although orders are placed on the schedule in the order of arrival, orders with long term due date are scheduled on their due dates even if there are empty spaces in the schedule earlier than the due date.

The advantages of this rule is that the logic is so simple and clear to both customers and the manufacturer. It encourages the longer due dates asking since urgent order is not allowed. On the other hand, the disadvantage is that some important customers who frequently place urgent orders may be dissatisfied. Setup times between consecutive jobs may increase due to random sequence of arrival.

(2) End-of-day confirmation policy

In this policy, orders are collected daily basis until the end of a day. Similar orders can be grouped for line productivity. Once all the customer orders are arranged on the schedule according to the priority rule, then each order is given a due date. If the customer agrees to the due date, then it is fixed. If not, the order is rejected.

(3) Selective confirmation policy

Unlike the policies above in which due dates of all orders are confirmed, selective confirmation policy allows that only a certain group of orders are confirmed of their due dates while other orders are informed of only expected due dates. For important customers, long term orders are confirmed at the time orders are received while short term orders are confirmed at the end of the day. For other customers, long term orders are confirmed at the time orders are received only if item of the orders are already in the schedule as the planned order. Otherwise the order can be accepted if the salesperson submits this order in the sales plan of the following week, in which case this order can be accepted in the following week; or if salesperson substitutes one or more orders that he or she had already placed in the schedule for this new order.

The advantage of the selective confirmation is that they do not accept the short term orders from unimportant customers so that they can process the urgent orders from important customers. Furthermore, unimportant customers are informed of only expected due dates so that they are gradually diverted to other suppliers. Thereby we can focus more on important and higher profit customers. However, this logic is complicated to implement. This may also spoil important customers to habitually request urgent orders. We may lose unimportant customers in such cases.

(4) Grouped confirmation policy

Grouped confirmation policy is that, although all orders are confirmed of their due dates, the due dates are grouped in time according to the priority of the group of orders. For example, orders are grouped to group A, B, and C; and orders in group A, B, and C are given the due dates within three days, four to seven days, and after seven days, respectively. The advantage of this policy is that due dates of all orders are confirmed. But they are reasonably distinguished in that important customers are promised to be scheduled in short period of time while unimportant customers are promised to be scheduled after relatively long time from today. As a result, unimportant customers are gradually diverted to other suppliers. Another advantage is that rescheduling for reducing setup times is possible because there are some empty spaces between the groups in the schedule. However, the logic is also very complicated to implement in the computer. A and due dates of orders in group C may be unnecessarily delayed.

6. Conclusion

As e-commerce rapidly grows in business environment, due date confirmation will become the key competitive factors in order based manufacturing. In order for business firms in a supply chain to synchronize the procurement, production schedule, and shipment, due date confirmation will be a critical requirement between suppliers and customers. Suppliers should not only be capable of meeting all the confirmed due dates, but also focus on the urgent orders from important customers. To this end, suppliers need systematic order acceptance policies as well as the reserved capacity framework to accommodate the urgent orders. On the other hand, manufacturers need to make every effort to maximize the productivity. If the portion of the reserved capacity is too large, then more ordinary orders will be rejected. That means the loss of the profitability of the entire system. Estimating appropriate amount of the reserved capacity using computer simulation is a research issue for further study.

In this paper we explored the due date-related problems that most manufacturers experience. As a viable alternative to resolving such problems, we proposed the concept of reserved capacity and its operational policies. Due date problems can be resolved only when sales and production departments have common objectives and integrated planning and information system. Forecasting, sales plan, production planning and scheduling must be integrated within a consistent framework and logic. Sales personnel must obey the order policies that is inevitable for the system to work. Information must also be shared with the customers. The operation of reserved capacity we propose is generally applicable to any order based manufacturing industry. Detailed implementation may be changed according to the characteristics of specific industry.

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