

## PRODUCTION STRATEGIES FOR EXCEPTIONAL ORDERS MANAGEMENT

M. de Falco, M.E. Nenni, M.M. Schiraldi

### INTRODUCTION

Increase of competitiveness, unpredictable changes in the demand, rise of new trade procedures generated from e-business models; these factors, during last years, had obliged industry to search for significant improvement in supply chain management and production processes. Since year, supply chain efficiency and flexibility constituted major study topics in operations management area; however, while in past times the research mainly focussed on the analysis and optimisation of single phases among the whole processes, the attention have recently converged on the performances and on the design of the supply chain in its entirety (Beamon,1998). Now, more than in past time, the pursuit of profit for an individual firm in the supply chain seems not to be a far-sighted strategy, if compared to the search for efficiency of a global system, where all players may have the opportunity to agree on production planning and operations management, as well as to share logistic and distribution processes, in order to cooperate and defeat competition. With such hypotheses, the design of flexible contractual agreement gains in importance; the negotiation of productive capacity among supply chain players is, indeed, often based on the basis of an indicative value, to which the customer reserves the rights to apply changes within a certain period of time from the delivery of the order. The capability of promptly reacting to the modification of his customer requests clearly becomes a major competitive advantage factor for the supplier. In order to effectively sustain this reaction, the supplier may be forced to speed-up all or some of his internal processes – first at all, the production process – in different ways according to the amount of the order variation; the maximum *flexibility* in the exploitation of the supplier potentialities is though needed, in the sense of “capability of reacting to modification of customers’ needs” (Brandolese *et al.*, 1995). In this way, the supplier faces a number of chance for production strategies: an exceptional order which requires an immediate execution and a quick delivery indeed, may be carried out partly using stock and partly varying the production pace; the *expediting* strategy needs to be considered after the evaluation of lots of decision variables; moreover, the choice of a specific production strategy influences a number of aspects related to the production units itself: the behaviour of finite products and raw materials inventory levels, the overbalance of production rate, the variation in management costs, etc. On the other hand, the increased flexibility of the supplier gives advantage to the downstream units, which can diminish their inventory costs, decreasing in example their safety stock levels. The advantages for the customers coming from the possibility to launch an exceptional order which overcome the planned deliveries require the production unit to invest in flexibility, and this investment must be rewarded through an adequate increase in the supply contractual agreement cost. In this work the *product-based expediting* (Srivastav, 1999) case is taken into consideration; the *expeditor* represents the entity which continuously adds demands on the top of previously stated order specification (Miller, 2001). The attention devoted to these topics is witnessed by the rise of societies and fellowships which consider the study of *expediting* as their mission – first at all, the Expediting Management Association, EMA. The aim is to focus on the customer-supplier relationship and to quantify the increase in the contract cost, due to the opportunity for the customer to launch, in the interval between two planned deliveries, and exceptional order of a variable quantity of products, with *immediate* delivery. The influence of the production strategy choice on this capability will be analysed, and in order to do this, a formalization of the production strategy concept aligned with the main theories of operations management will be proposed.

## PRODUCTION STRATEGIES AND MODEL HYPOTHESES

In this paragraph the concept of production strategy will be described: we will use a generic representation of a production unit in which only the basic functions of storage and processing are modelled. Under the hypothesis of re-order cycle inventory policy, the raw material inventory level may follow a linear emptying function which originates from the production rate  $PR$ , with periodic instantaneous fillings (with period  $T$ ) due to the arrivals of the suppliers loads. Obviously, the finite products inventory level follows a similar but inverse trend, under the hypothesis of periodic (with the same period  $T$ ) shipping of products to the customers. The production rate  $PR$  may be upper bounded by a maximum production rate  $PR_{max}$  determined through the analysis of the overall equipment efficiency in the industrial plant. The production unit may agree with its supplier on the periodic delivery of the quantity  $q$  of raw materials, and the same quantity of finite products may be provided by the production unit to its customers (the processing ratio between raw materials units and finite product units in this case should be 1:1). Now, if we define as *production strategy* a sequence of couples  $(PR_i ; \Delta t_i)$  of certain production rates  $PR_i$  maintained for certain time intervals  $\Delta t_i$ , in the described case we can pursue the simple production strategy

$$(PR_{avg} ; T) \quad [A]$$

so that

$$PR_{avg} \times T = q \quad \text{and of course} \quad q \leq PR_{max} \times T, \quad \forall q \geq 0$$

Clearly, the strategy  $(PR_{avg} ; T)$  is only one among the infinite choices. One could chose, in example, the sequence

$$(PR_1 ; \Delta t_1) ; (PR_2 ; \Delta t_2) ; (PR_3 ; \Delta t_3)$$

where it stands

$$PR_1 \times \Delta t_1 + PR_2 \times \Delta t_2 + PR_3 \times \Delta t_3 = q \quad \text{and} \quad \Delta t_1 + \Delta t_2 + \Delta t_3 = T$$

In general, a *levelled* production strategy may be preferred to a production strategy in which different production rates are chosen in sequence; the possibility to keep an unique production rate for all the period  $T$  allows the minimization of the workforce cost, the optimization of the utilization rate of the resource and the industrial equipments, the simplification of the master production schedule generation. In this work though, the opportunity of choosing a *not-levelled* production strategy will be analysed.

Given the need of producing  $q$  finite products by time  $T$ , the production unit has the possibility to choose any production strategy which stands among the two extremes:

$$(PR_{max} ; \Delta t_A) ; (0 ; T - \Delta t_A) \quad [B]$$

$$(0 ; T - \Delta t_A) ; (PR_{max} ; \Delta t_A) \quad [C]$$

where it stands

$$PR_{max} \times \Delta t_A = q = PR_{avg} \times T$$

In comparison to C strategy, B strategy is clearly more robust to unexpected occurrences which may slow down or stop the production process. On the contrary, the average inventory level of finite products increases. A production strategies area (*PSA*) can be identified, which comprises all the feasible production strategies in period  $T$ . This area is depicted in Fig.1.

Now the costs related to the choice of a certain production strategy will be analysed.

In general, we will find:

- storage costs, because the choice of a production strategy influences the raw material and finite products inventory levels;
- production costs, because the choice of a production strategy determines the acceleration or deceleration of the production rate and different production rates are associated to different costs.

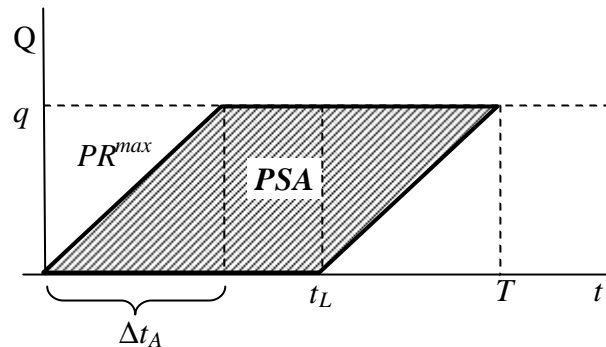


Fig. 1 – Production strategies area

Storage cost is calculated on raw materials (*RM*) and finite products (*FP*) average inventory levels. It is noticeable that *RM* and *FP* average inventory level are equal, on period *T*, in case strategy *A* is applied, while are complementary when strategies *B* and *C* are applied. The *stockholding cost (SC)* – related to cycle cost, thus excluding safety stock – can be derived computing the storage cost as a percentage *t* of the material value.

As far as the production cost is concerned, in compliance to the more classic theories of project management, we can state that the production cost of one unit  $C_{unit}$  of finite product follows the function

$$C_{unit} = C_{min} + k \cdot \frac{q_i}{\Delta t_i} \quad [1]$$

where  $C_{min}$  represents a fixed minimum cost,  $k$  a constant which originates from the specific typology of production process, while  $PR_i = q_i/\Delta t_i$  represents the production rate chosen for the processing of the selected finite product in the lot  $q_i$ . The *production costs (PC)* borne in period *T* is then equal to

$$PC = \sum_i \left[ q_i \cdot C_{min} + k \cdot \left( \frac{q_i^2}{\Delta t_i} \right) \right] \quad [2]$$

where it stands

$$T = \sum_i \Delta t_i \quad \text{and} \quad q = \sum_i q_i$$

Hence the total cost (*TC*) associated with each production strategy, being  $TC = SC + PC$ , can be expressed as follow:

$$TC_A = q \cdot t \cdot \left[ \left( \frac{V_{FP} + V_{MP}}{2} \right) \right] + q \cdot \left[ C_{min} + k \cdot \left( \frac{q}{T} \right) \right] \quad [3a]$$

$$TC_B = q \cdot t \cdot \left[ V_{FP} \left( 1 - \frac{\Delta t_A}{2 \cdot T} \right) + V_{MP} \left( \frac{\Delta t_A}{2 \cdot T} \right) \right] + q \cdot \left[ C_{min} + k \left( \frac{q}{\Delta t_A} \right) \right] \quad [3b]$$

$$TC_C = q \cdot t \cdot \left[ V_{MP} \left( 1 - \frac{\Delta t_A}{2 \cdot T} \right) + V_{FP} \left( \frac{\Delta t_A}{2 \cdot T} \right) \right] + q \cdot \left[ C_{\min} + k \left( \frac{q}{\Delta t_A} \right) \right] \quad [3c]$$

Where  $V_{FP}$  and  $V_{RM}$  indicate respectively the value of the unit finite product and that of raw material. It is noticeable that, from [3a, 3b], the choice of *A* strategy rather than *B* strategy allows a cost saving of:

$$TC_B - TC_A = [t(V_{FP} - V_{MP}) + 2k \cdot PR_{\max}] \cdot \frac{q}{2} \cdot \left( 1 - \frac{PR_{avg}}{PR_{\max}} \right) \quad [4]$$

While, from [3a, 3c], the choice of *A* strategy becomes more convenient than *C* strategy when the value of a finite product is “not so higher” than the value of the correspondent raw material, quantitatively when:

$$t(V_{FP} - V_{MP}) < 2k \cdot PR_{\max} \quad [5]$$

### EXCEPTIONAL ORDERS MANAGEMENT

We will now analyse the case in which the production unit allows its customer to launch one exceptional supply order before the end of the period  $T$ . This order will request an additional amount of finite products  $q_s$ , on top of the quantity  $q$ , to be delivered within a certain time interval (*delivery time*,  $DT$ ). In general, in dependence from the moment in which the exceptional order is received, the production unit will need to increase its production rate, and eventually to use some stock in case  $PR_{\max} \times DT < q_s$ . If the customer asks for immediate delivery (*delivery time* = 0), the production unit has the only possibility to satisfy the order with the stock already present in the finite product warehouse; and the inventory build-up function depends on production strategy which has been chosen at the beginning of  $T$ .

By the way of an example, the choice of strategy *C* will determine that the production unit will not be able to accept any exceptional order after time  $t_L$  (because starting from time  $t_L$ , the entire production capacity is devoted to the processing of the quantity  $q$ ), while if the exceptional order is received before time  $t_L$ , the production unit will not be able to satisfy it if  $q_s > PR_{\max} \times \Delta t_L$ , where  $\Delta t_L$  indicates the time interval between  $t_L$  and the moment in which the exceptional order is received.

Let's now consider the frequency distribution of the exceptional order receipt time: in general, the distribution will reach higher values in the middle of the period  $T$  while the probability of the receipt of an exceptional order near the beginning or the end of period  $T$  will be lower, due to the fact that the standard order has been just launched or is about to be launched; the frequency distribution of exceptional orders may be easily derived from the analysis of historical data. For our purposes, we can make the hypothesis of a generic frequency distribution whose probability of the order receipt for time  $t < t_A$  and  $t > t_L$  is actually little, (i.e.  $\sim 5\%$ ). Then, in order to compare the results of the production strategies, we will restrict our analysis in the time interval  $[t_A \div t_L]$  in which the probability of the order receipt is higher. In this way, the choice of strategy *B* will determine that an exceptional order of amount  $q_s = q$  can be satisfied with  $\sim 95\%$  of probability, as shown in Fig. 2.

On the contrary, the choice of strategy *A* will determine that the size of the exceptional order that can be satisfied varies on the time in which the order is receipt, but if we require the same service level as in case *B* before (95%), the maximum size of the exceptional order becomes  $q_s = PR_{avg} \cdot \Delta t_A$ , as shown in Fig. 3 below.

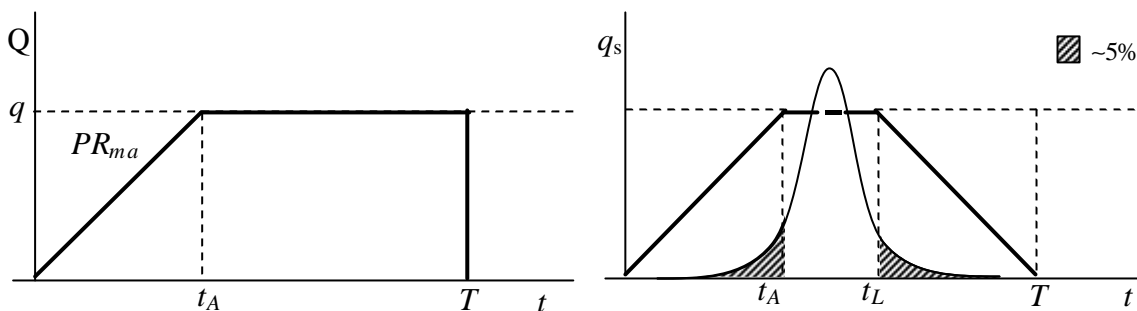


Fig. 2 – Inventory build-up diagram and exceptional order amount in B strategy

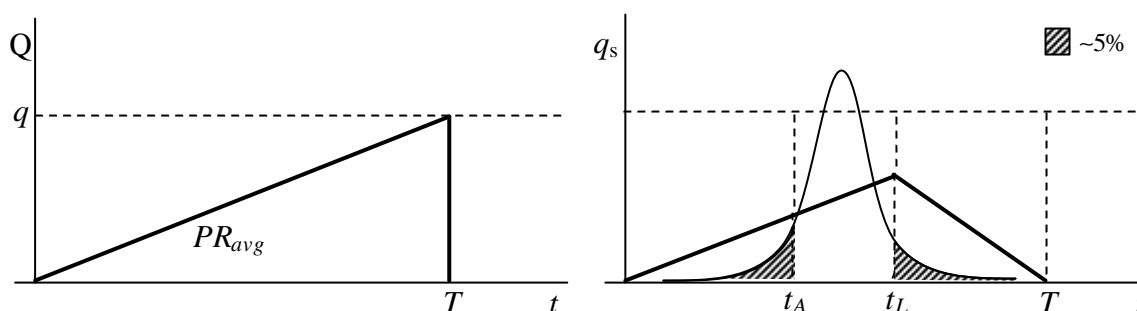


Fig. 3 – Inventory build-up diagram and exceptional order amount in A strategy

This means that the production strategy choice deeply influence the maximum size of the exceptional order that can be satisfied by the production unit: the customer may ask for the possibility of launching an exceptional order of size  $q_s = PR_{avg} \cdot \Delta t_A$ . In this case the production unit can adopt the simpler production strategy A; on the contrary, the customer may ask for the possibility of launching an exceptional order of size  $q_s = q$ . In this case the production unit must adopt the production strategy B.

### DETERMINATION OF THE SUPPLY CONTRACT COST

On top of the cost related to production strategy, in order to manage the exceptional request by the customer, two more cost components shall be considered, which have the same value independently from the choice of the production strategy:

- the increase of production cost related to the exceptional order acceptance ( $PC_{order}$ ): once an order is received, the chosen production strategy maintains a constant production rate until the quantity  $q$  is replenished by the end of period  $T$ . In the worst case in which the order is received at time  $t_L$ , the needed production rate will be  $PR_{max}$ . In this way, according to [1], the  $PC_{order}$  is upper bounded by

$$PC_{order} = q_s (C_{min} + k \times PR_{max}) \tag{6}$$

- the increase of raw material storage cost devoted to exceptional order satisfaction ( $SC_{order}$ ). In general, given the *supplier delivery time* ( $DT_S$ ), the additional cost can be evaluated with

$$SC_{order} = q_s \cdot \left( \frac{DT_S}{\Delta t_A} \right) \cdot V_{MP} \cdot t \quad \text{if } DT_S = \Delta t_A \tag{7}$$

Otherwise, the  $SC_{order}$  is upper bounded by

$$SC_{order} = q_s \times V_{MP} \times t \quad [7b]$$

Now, focussing on the customer-supplier relationship, the increase in the contract cost, due to the opportunity for the customer to launch, in the interval between two planned deliveries, and exceptional order of a variable quantity of products, with *immediate* delivery, will be quantified. The supply contract shall be indeed modified including:

- a fixed cost  $SC_{order}$ , related to the overstock of raw materials, evaluated through [6];
- a variable cost  $PC_{order}$ , borne only if the exceptional order is actually launched, related to the processing of the replenishment of the finite product inventory after the order satisfaction, evaluated through [7] or [7b].
- a fixed cost  $TC_{strategy}$ , related to the choice of a certain production strategy and related to the maximum size of the order that the customer wants to be able to request.

This latter cost, being valid [5], can be configured as follows:

- if the customer asks for the possibility of launching an exceptional order of size  $q_s$  so that  $q_s = PR_{avg} \cdot \Delta t_A$  the production unit can adopt the simpler production strategy A; in this case we have that the total cost ( $TC$ ) related to the production strategy becomes:  
 $TC_{strategy} = 0$ ;
- if the customer asks for the possibility of launching an exceptional order of size  $q_s$  so that  $q_s = q$  the production unit must adopt the production strategy B; in this case we have that the total cost ( $TC$ ) related to the production strategy becomes:  
 $TC_{strategy} = TC_B - TC_A$   
according to [4].

The design of such flexible contractual agreement, in which the customer reserves the rights to apply changes within a certain period from the delivery of the order – pretending however high service levels and special requirements such as immediate deliveries – may become in the next future one of the key drivers of supply chain management. For this reason is of critical importance to deepen the research towards the quantification of the costs of the speed-up of the supplier production processes – which changes in accordance to the amount of the order variation – and towards the design of flexible supply contracts which go beyond the simple concept of Service Level Agreement; the opportunity for the customer to deal with his supplier as he would have dealt with an internal unit, prompt to react to any request which arises from the market, should be considered in these agreements. In this sense, this paper wants to represent a little step in this direction.

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