PURCHASING AND INVENTORY MANAGEMENT IN SCIENCE-BASED INDUSTRIES

by

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ABSTRACT

Inventory Management has been widely discussed in the literature. Recently, the so called "Just in Time" method received extensive publicity and was claimed to be one of the major factors of the Japanese industrial success. This, in turn, promoted a large campaign in the rest of the industrialized world, to adopt and imitate the "Just in Time" (JIT) policy. Corporate and plant managers focused attention and set up goals as to reach as closely as possible the Japanese inventory levels. Quite often, adoption of JIT disregarded the totally different nature of the business their companies engaged in,relative to Japanese industry.

This paper clarifies the differences between two different industrial models: The "Assembly Line" model versus the Hi-Tech Job Shop "Science Based" model and prescribes the inventory strategy appropriate for each of those models. It is shown that a fully automated Assembly Line type factory requires a "Just in Time" (minimal holding costs) inventory strategy, while the Science Based type should follow a more elaborate "optimal penalty" type of policy.

1. Introduction

Inventory Management has been widely discussed as one of the main issues that contribute to the success of manufacturing companies. It is popular today to imitate the Japanese "Just in Time" (hereafter JIT) methods in Western companies. Corporate and plant managers focused attention and set up goals to reach as closely as possible the Japanese inventory levels, quite often disregarding the totally different nature of the business their companies engaged in.

Most of the literature done in managing inventory discusses the benefits gained by using the Just in Time methods (for example, Schonberger, [1982], [1986]). Others compare it to the traditional MRP systems or the OPT concepts (for example, see Fox, [1983a], [1983b], or Plenert and Best, [1986]). No alternative models were suggested for the Science Based Industry (hereafter SBI).

This paper discusses the nature and problems of the high research and development job shop oriented industry designated as SBI. The paper suggests that many of the Japanese "Just in Time" methods are not appropriate for this type of industry. It is shown that these Japanese Just in Time methods are good only for assembly line type industries. While managing purchasing and inventories in the "Science Based" industry, a different inventory strategy should be implemented. This strategy is developed in this paper, using a mathematical optimization model. It is shown that the "Just in Time" model can be viewed as a special case of the more general model proposed here.

Section 2 of this paper defines and discusses the nature and behavior of the SBI. Section 3 specifies the characteristics of the Assembly Line industry, and shows why the JIT methods work well in that type of process. In section 4 we demonstrate that JIT is inappropriate for Science Based industries. We present and apply an alternative model for purchasing items in the "Science Based" industry. Examples of applying the model, and sensitivity analysis are carried out. Section 5 draws the conclusions.

2. The "Science Based" Industry

In order to clarify what is meant in this paper by the term "Science Based" industry it is important to characterize and define the major attributes that distinguish such industry.

First, and probably most important characteristics of such industry is the high research and development (R & D) content associated with its product line. Products are often sold on the basis of innovation and superior performance, rather than on pure price competition. Examples are Aerospace Industries, Industrial and Professional Electronics, the high end of the Computer Industry etc.

The second important characteristic is the strong sensitivity of such industry to the timely availability of its products. "Time to Market" is a crucial element and failure to meet the appropriate R & D Production cycle time can result in large penalties to the company, and might put its survival in question. There is an ongoing pressure for shorter cycle times in the R & D stage as well as during production (see, for example, Goldratt and Fox, [1986]).

As a result of the above characteristics, the SBI usually employs a relatively large amount of highly qualified people, most of which has high technical skills and hold academic degrees. This contributes to the high labor content of the total product cost.

With respect to the purchased parts and materials, the following characteristics are typical in the SBI:

a) The raw material percentage out of the total development cost is relatively low (usually less than 20%).

b) The raw material cost increases during production, (usually no more than 40%).

c) The technological life cycle of some of the components is relatively short. The competitive race forces engineering to use state of the art components, and change standards of items frequently.

d) The lead time of the non-standard component is long, uncertain, and may vary from item to item and with time.

To summarize, the need to achieve state of the art performance requires the frequent use of non standard, state of the art components, which increase the uncertainty in terms of their availability in time.

3. The Assembly Line Process

The traditional classification of types of processes divide into four major categories: Project, Continuous processes, Repetitive processes, and intermittent processes (Chase and Aquilano, [1985]). A project refers to a one time mission divided into defined tasks, having managerial and/or technology connection. The Continuous processes are typified by process industries such as steel, plastics or chemicals. In the repetitive processes items are produced in large lots following the same series of operations as the previous items. These are typified by mass production using production lines in such industries as automotive, appliances, and so on.

The "Just in Time" methods, discussed hereafter, are mainly appropriate for this type of assembly lines and repetitive processes.

The intermittent processes are those in which items are processed in small lots or batches, often to customer's specifications. These are typified by Job Shops, which in turn characterized by individual orders taking different workflow patterns through the plant and requiring frequent starting and stopping. Usually, the Science Based Industries have a Job-Shop / Intermittent process nature.

For better understanding, clear distinction should be made between JIT as a managerial philosophy, and the JIT scheduler. JIT as a managerial way of management consists of three main parts: Total Quality Control (TQC), Total Preventive Maintenance

(TPM), and Just in Time scheduling (JIT).

With respect to scheduling operations and purchased items, just in time, exactly to the time they are needed, the main scheduling mechanism is a "Pull" system (see Schonberger, [1982]).

Manufacturing parts and assemblies using the JIT scheduler results in minimal inventory (raw materials, work in process and finished goods).

While TQC and TPM can be applied to all types of production processes, the JIT scheduler can be applied only to the repetitive assembly lines. In our opinion, the attempt to schedule all the items "Just in Time" does not fit the nature of the Science Based industry. The model shown in the next section demonstrates and explains this issue.

4. A Model for Scheduling Purchased Items

This section briefly reviews a Purchased Items Scheduling model which may be applied and modified for use in the SBI. For further details the reader is referred to Ronen and Trietsch (Ronen and Trietsch, [1986]). First we will introduce the one item model, then show the heuristic solution for the n components project. Then, we will modify the model and apply it in our case.

By way of introduction let us consider the following special case: A project requires one purchased component, which must be on hand at a specific time, t^*. If the item is received earlier, the project will be completed in time, i.e., without penalties, but an inventory holding (carrying) cost C will be incurred for each time unit the item is held in inventory after arrival and until t^*. On the other hand, if the component is late, a penalty P is incurred for each time unit of delay, since the whole project is consequently delayed.

Assume now that the lead time of the component has a given stochastic distribution, and the project manager has to decide when to place the order in such a manner that the total expected cost of the inventory holding cost and the delay penalty will be minimized.

We assume that the project manager is responsible for all the costs associated with the purchasing decision. Therefore, it is in his or her interest and power to minimize the expected total costs. We also assume that the component's lead time is a stationary stochastic variable with a given distribution.

We wish to optimize the scheduling of the order placement, which is the decision variable under the project manager's control.

The objective function is

(4.1) $$\min_{T} \{E(\text{Penalty Cost})+E(\text{Holding Cost})\}$$

Where T is the time the order is placed. Figure 4.1 illustrates the relationship between t^*, T and the lead time distribution. Note that the distribution "starts" at T (the item cannot arrive before being ordered), and consequently the area to the right of t^*, i.e. the penalty probability, increases with T, as expected.

Place Figure 4.1 about here

Expanding the target function (4.1), we may write:

(4.2) $$\min_{T} \left\{ C\int_{T}^{t^*} F(t-T)\,dt + P\int_{t^*}^{\infty} [1-F(t-T)]\,dt \right\}$$

Where:

- t is the current time
- F() is the CDF of the lead time
- C is the holding cost per period
- P is the penalty cost per period

Note that these costs are assumed to be linear.

Solving (4.2) yields an optimal order point T^* , satisfying

(4.3) $F(t^* - T^*) = P / (P + C)$

Let us modify this result now for the special case of Science Based projects:

Let ã be the proportion of the purchased items out of the project cost. This ratio is about 10% to 20% in many of the Science Based projects.

Let C_t be the total project cost.

Let C_h be the holding cost ratio out of the total cost. This ratio is normally between 20% to 30% in most cases.

Let C_p be the penalty cost ratio out of the total cost. This ratio is difficult to determine, and we will cope with this later. Thus,

(4.4) $C = C_t * C_h * \tilde{a}$

(4.5) $P = C_t * C_p$

Incorporating (4.3) with (4.4) and (4.5) will yield

(4.6) $F(t^* - T^*) = C_p / (C_p + C_h * \tilde{a})$ or,

(4.7) $F(t^* - T^*) = 1 / (1 + Ch * \tilde{a} / C^p)$

Sensitivity Analysis

Now, let us make sensitivity analysis of this result:

(A) Sensitivity Analysis for ã:

ã is the ratio between the purchased item and the overall project cost. In projects where ã is small, the purchase order release will approach zero.

If ã --> 0 then $F(t^* - T^*)$ --> 1

This yields usually toward $T^* = 0$, a result that reflects the behavior of many project managers to release purchase orders as soon as possible. Moreover, in certain cases $\tilde{a} \rightarrow 0$ might yield a negative T^*. In real life situations this is a common feeling of many project managers that they should have released the orders "Yesterday". Thus, the cry to implement the "Just in Time" philosophy in other places should be carefully checked. As shown here, in certain cases of SBI projects, it is much preferred to take the opposite attitude.

Now,

If $\tilde{a} \rightarrow 1$ then $F(t^* - T^*) \rightarrow 1 / (1 + C_h/C_p)$

In this case, the ratio between the holding costs and the penalty cost will result in the optimal timing.

(B) Sensitivity Analysis for C_h and C_p

If $C_h >> C_p$ then $F(t^* - T^*) \rightarrow 0$. This means that better results will be drawn if the purchase orders will be released as late as possible.

If $C_p >> Ch$ then $F(t^* - T^*) \rightarrow 1$, and in that case no chances should be taken for late deliveries, and the purchase orders are released as soon as possible.

Let us now investigate a special case: Suppose we have a high material product, (say $\tilde{a} > .5$) and the penalty costs are a fraction of the product cost ($C_p < C_t$). If the holding costs are relatively high ($C_h > C_p$), then $F() \rightarrow 1$. This leads to a policy of ordering parts "Just In Time". This case is appropriate for Assembly lines, like the automotive industry, and thus, according to this model, the "Just In Time" policy is treated as a special case of our model.

For the Science Based Industry, In many cases the "Just in Time" approach in scheduling orders might yield losses and high penalties, because of the low $\tilde{a}$, high C_p and relatively low C_h.

Example

Let us assume that the component's lead time has an exponential distribution with parameter μ.

Thus, $F(t) = 1 - e^{-t/\mu}$

using the solution of (4.7), for the case of Science Based projects, leads to

(4.8) $T^* = t^* + \mu \ln \{ 1 / (1 + C_h * \tilde{a} / C_p) \}$.

Consider the following special case: We have to assemble a certain item 6 month from now. The item's lead time distribution is exponential with an expected value of 4 months. The carrying cost of this item is 18% per year, and the penalty cost is 5% per month (60% yearly). The purchased parts are 40% of the product cost. Thus,

$t^* = 6$ months

$\mu = 4$ months

$C_h = 18\%$ per year

$C_p = 60\%$ per year

$\tilde{a} = .4$

and following (4.8) yields that $T^* = .07$ month

The following table shows a sensitivity analysis of T^* as a function of $\tilde{a}$:

$\tilde{a}$	T^*
.1	-5.14
.2	-2.49
.3	-0.98
.4	0.07
.2	0.85
.6	1.48
.7	1.99
.8	2.43
.9	2.81
1.0	3.13

The larger $\tilde{a}$ grows, the later the optimal purchasing is going to be and the release of the purchase order is delayed. This might serve as an illustration to the fact that the "Just In Time" methods are appropriate where the components costs are relatively high. In the Science Based industry, where $\tilde{a}$ = .1 to .2 in most cases, it would <u>not</u> be optimal to adopt these methods. Thus, we should be very cautious about the "Just In Time" approach to this industry.

Solving the n item model is much more complicated, as discussed by Ronen and Trietsch [1986]. To solve this difficulty they suggested a good approximation for the optimal scheduling by computing a simple lower bound. This is achieved by treating each item separately. Thus, if we have n items, T_i^* (the optimal time to order item i) will be derived by the solving the following equations, for i=1,...,n:

(4.9) $F_i(t_i^* - T_i^*) = 1 - C_i / S$

where C_i is the holding cost of item i, and S is $P + \hat{\Sigma} C_i$.

In other words, we calculate the T^* for each part independently. By using this policy, the project manager would never have a greater expected penalty than the expected penalty derived by this limit. This might be perceived by managers as a "conservative policy", because the manager takes less penalty risks than at the optimal policy.

Using this method, we can easily calculate the desired time for releasing the purchase orders.

As n, the number of items in the product increases, S increases and $F_i()$ ---> 1. This means releasing the orders as soon as possible. In the case of the SBI, the product complexity creates a need for many items to be assembled together, and thus the optimal policy will not meet the Just in Time approach.

5. Conclusions

This paper deals with the problems of managing inventories and purchasing in the Science Based industry. We have first defined what is meant by the term SBI and described its attributes. The desire to achieve success by innovation and shorter cycle time is one of the most important trends in this industry, thus the penalty for late deliveries is relatively high. For this particular industry, the Science Based model was prescribed.

On the other hand, the assembly line/repetitive process industry has a relatively high material content, and the "Just in Time" approach seems to work well.

The optimization model solve the scheduling and timing problems of the SBI. Sensitivity analysis was carried out, and the Japanese "Just In Time" concept was reviewed as a special case of this model. It was also demonstrated that the "Just In Time" approach is inappropriate for the SBI.

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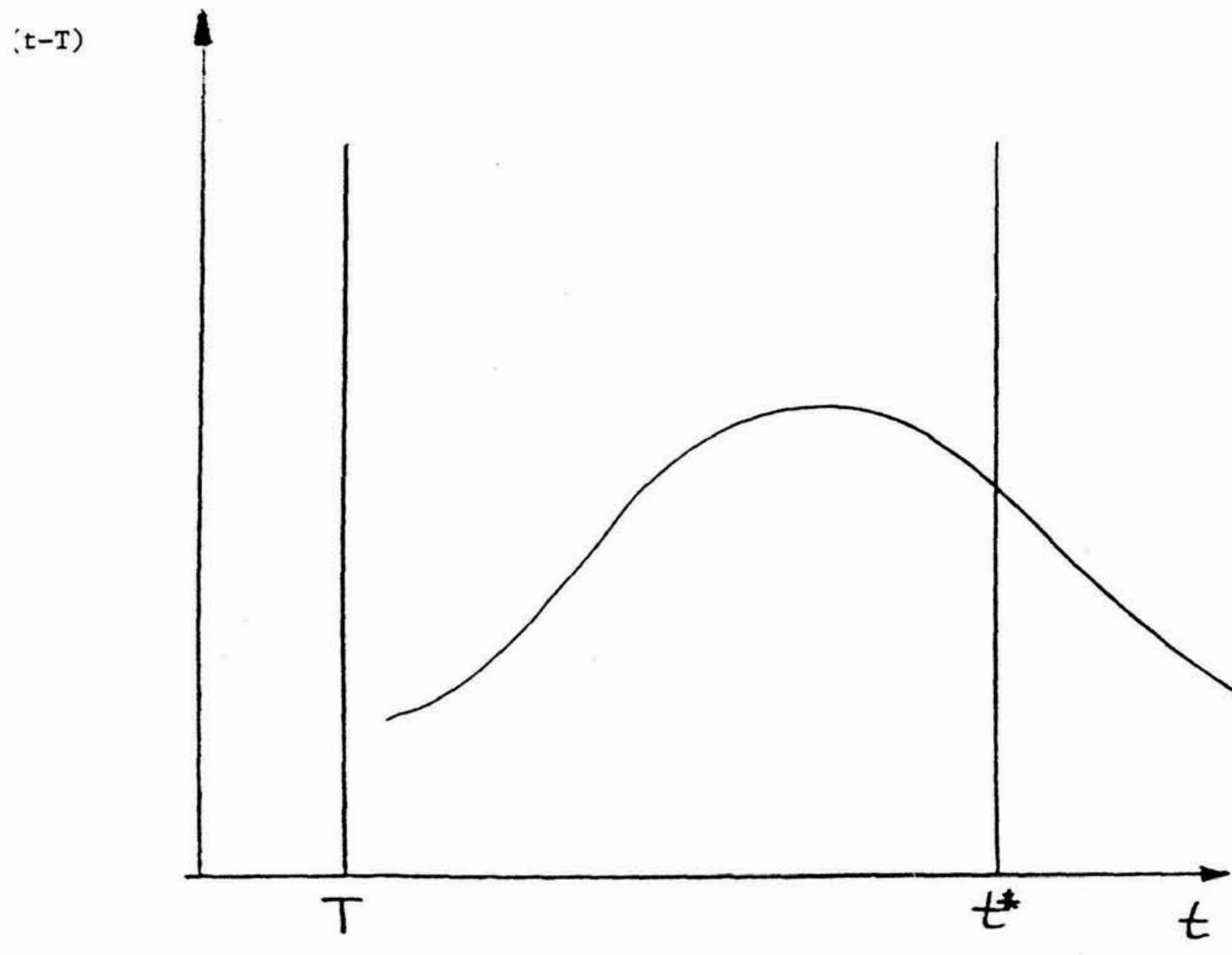

Figure 4.1: The relationship between t*, T and the lead time distribution.