SOME FACTORY ASPECTS OF WAREHOUSING

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In discussing the relationship of manufacturing to distribution systems, I believe that we should use two viewpoints. First, the Materials function has a very vital role to play in carrying out this relationship on a day-to-day basis. In many departments the incoming requisitions are received in Materials; often times the finished goods stock records are under the control of Materials; factory scheduling is a major function of Materials. All of these activities are, of course, closely related to Marketing's responsibilities for product distribution.

The other viewpoint refers to Manufacturing's interest in efficient information processing systems and efficient operating decision rules so as to improve employment stability and maximize machine utilization. The recent Integrated Systems Project work which was conducted with the Instrument Department pointed out quite clearly the critical interdependence among the various business functions. Although the particular product line (Switchboard Instrument) was not stocked in district warehouses, there were a number of models carried at the factory. As part of the design of a total system it was necessary to evolve a plan and a set of decision rules to determine: finished goods factory stock, model ordering intervals, assembly line scheduling and parts and materials control procedures. It was obvious that these critical decisions were mutually interdependent and that it was necessary to have Marketing and Manufacturing work closely together in order to come up with a system that was good for the factory and good for our customers.

To me this is the most important aspect of factory - warehouses relations: we must work together in each department on an integrated team basis when establishing the basic policies and rules which will govern the operation of a business.

Factory Aspects of the Finished Goods Warehousing Plan

In trying to analyze the effect of warehousing policy on factory operations, it is clear that the most important thing that the warehouse can do for us is simply to sell and report. The closer the factory can get to receiving end user information the more stable the system, since there will be less reflected amplification. In this way the ordering policies at the department, whether operated by Marketing or Manufacturing, can be based upon this end user information instead upon someone else's interpretation and modification. This does not predicate against the use of forecasts but it seems rather that they should be submitted independently to be used at this central location for order decision modification. The type of system which the Apparatus Sales Division has put in for warehouse reporting is certainly a major step in the right direction. It provides exact sales data which can then be used effectively in the factory.

This leads into the second major area. To the extent that the communication cycle is minimized and to the extent that reports are submitted frequently reflected usage will be more accurate; hence, the system will operate in a more controlled manner with less oscillation. As a result of servo-theory analysis and various experiments like those of Dr. Jay W. Forrester of MIT, it can be proved that the greater the time lag between system elements the greater the oscillation of the system and the more over-correction is required. A system with large time lags is not responsive and hence is more expensive to operate and does not serve its customers as well.

Key Factory Policies as They Effect Distribution Performance and Inventory

	Factory	Warehouse
1.	**Warehouse Service Level**	
	pre-assembly inventory ("raw")	safety stock in factory warehouse
		end user Customer Service Level
2.	**Production Lead Time**	
	work-in-process inventory	safety stock in factory warehouse
3.	**Ordering Frequency** (per model)	
	set up cost total cost/unit	base stock in factory warehouse
4.	**Degree of Production Smoothing**	
	cost of changing production level unit cost of manufacture	factory warehouse stock

Warehouse Service Level

The manner of measuring warehouse service level is obviously significant to the systems performance. If we use the same measure that has been used for the distribution warehouses for the factory warehouses, then the only special factor that enters into the discussion is the effect of carload requirements. For example, in a 100-point system the relatively low demand per warehouse effectively lengthens the replenishment lead time which will in turn increase the distribution warehouse safety stocks. Of course, the build up of inventory at the factory waiting for carload accumulation will directly add to the finished goods factory inventory.

Another interesting consideration is whether a particular model should be stocked or not. This decision is a function of the production lead time. If production lead time is very short, it is often not necessary to stock many models. For example, it may be necessary to provide three-week service to meet or beat competition. If the factory can assume a three-week or less delivery cycle, there probably won't need to be any finished goods inventory at the distribution points or even at the factory warehouse.

An associated problem in the decision to stock or not is the typical usage rates. By the way in which the Hypo department has defined its unit volume (500,000 units per year, 1,000 items) and the use of a fixed unit cost of one hundred dollars, the net result has been a very low usage rate for C & D items. For example, on D items (70% of items, 4% of value; therefore, 4% of usage) the mean usage rate is but thirty units per year across the entire system. It would be very doubtful whether such items would ever be carried on a stock basis.

Similarly, on a typical C item the mean usage per warehouse in a twenty five-point system would only be about one hundred units per year. Again, this might be quite marginal in terms of deciding whether to stock the lower usage C items at some of the smaller warehouses.

The manner in which customer service level has been introduced and applied to the warehouse service level assumes that credit is given for partial order and partial item deliveries. In other words, if a customer wants five items and only three of them can be shipped then we get credit for 60%. Similarly, if he wants five units of a particular item and we can only ship three, we again get 60% credit.

One major factor in operating performance and hence the warehouse service level is the amount of pre-assembly stock that is maintained. To show how this effect is compounded suppose there was an average of five parts per assembly and suppose a service level of 90% was maintained on each of those parts, all the stock items would only be available to support assembly 60% of the time ($.9^5 = .59$). This is obviously too low a percentage for most of our businesses; in some of the larger products where there may often be hundreds or even thousands of items which have to come together at a certain time, it is necessary to maintain in the factory very high service levels on the various parts in order to support a reasonable final assembly level.

Production Lead Time

In determining the production lead time there are numerous elements which must be considered. In a factory, for example, we have to take into account:

a. actual machine processing time

b. "lap" versus "gap" phasing indicates whether a batch will be broken up so that each part will flow to the next machine as it's ready or whether the batch has to move as a package -- in a tray or with a move truck from one station to another.

c. between station buffer stocks make a substantial difference in the lead time. In many of our plants we find that the typical machine processing time is 10% or less of the total in-process time. The rest of the time the item sits in a queue waiting to get on a machine. These between station buffers are necessary however, in order to balance out variable product mixes and to keep the shop operating even while some machine or some man may be temporarily not working.

d. any intermediate stages of stocking of sub-assemblies or major assemblies that go into a final product must also be considered. The more of these intermediate stages there are, the longer the lead time will be since time must be provided for putting the item into the stockroom and taking it out again.

e. The paperwork release frequency is a factor when there is a multi-stage system. For example, suppose there are sub-assembly and final assembly levels. If paperwork is released to the shop once a week, then it is quite likely that the sub-assembly will be done one week and the final assembly the next. This yields a lead time for any particular unit of two weeks.

f. The effective production lead time is also a function of the amount of backlog. As the backlog builds up a new order must simply get in line behind the other orders that have already been released.

g. The data processing time (including stock recordkeeping, scheduling, loading and many other activities) and the paperwork preparation time can both be important factors in lengthening the lead time.

h. The frequency of scheduling the shop can also make a significant difference. No matter how often orders are released if we only examine orders received once a week and schedule the factory at that time, then there is a built-in lag in the response to the actual sales.

One of the techniques which has proven most useful in factory operations in order to reduce production lead time has been the introduction of what is called cycle reduction stocks. This means that instead of starting back say in the raw materials stage each time, important, long cycle assemblies or long cycle parts are carried in stock so that production may start at that stage instead of at the very first operation for the first raw part. This, of course, requires a very careful internal balancing of the costs of carrying inventory as against the marketing needs for a shorter cycle. As an interesting aside, the rule in this area is that we should never carry a cycle reduction stock of any item unless it happens to be the limiting item for the line.

Another factor which can have a major effect upon a production lead time is the impact of variable mix. If each set of orders as they came in was well balanced as to its use of various kinds of machines and personnel skills, the shop would be able to guarantee a relatively short production lead time. However, because this is not true we often get "bottlenecked" operations for a particular mix and therefore start to create additional queues in between station buffers without intending to. In order to be able to regularly meet a given cycle then it is necessary to provide for a planned buffer between stations large enough to take care of the variations in mix that can be expected.

Final Assembly Ordering Frequency

The ordering frequency is a function of what is commonly called the economic lot size. This in turn depends directly upon the annual or periodic usage rate, upon the set up cost and inversely upon the inventory carrying cost and the unit cost of the item.

The usage rate is simply the expected value of the usage over some period of time. The set up cost is quite a bit more complicated. Probably this should be characterized as the order-oriented costs in contrast to the unit-oriented costs. These are some of the "once-per-order" costs:

- sum of all machine set ups; for purchased parts, the equivalent set up which reflects discount structure
- sum of all the factory or purchasing variable paperwork and handling costs (see reference 1)
- "learning" factors

This set up problem has produced an interesting view of "flexible automation". If you have a truly flexible automatic shop using extensive numerically controlled machines, easily changed work places, etc., we get close to what I call a "zero set up" concept. At zero set up the economic lot size is no longer a function of the internal balancing factors but rather can reflect external needs such as carloading, special marketing requirements, etc. This is in sharp contrast to the "Detroit-type" automation which implicitly raises the set up cost and hence increases the need for larger and larger lot sizes. It seems to me that in most of our General Electric businesses we have to very carefully examine this flexible automation concept. Because of the great variety of products which we have to produce it seems only sensible that we try to provide some way of reducing lot sizes and hence make our shops more responsive to customer demand. Adopting Detroit-type automation will only make our shops less responsive and less flexible.

Inventory carrying cost is usually represented as cost per dollar per time period of holding items in inventory. In general, something in the order of 12% is used to represent the out-of-pocket inventory costs including obsolescence, possession costs and inflation (see reference 2). One key point is that obsolescence factors are typically quite non-linear even though the average might be only 2% or 3%; for items bought in a one to ten-year supply, the obsolescence costs will usually be quite a dominant factor (far more than simply proportional).

The big question mark that I know that you have discussed before is the interest rate or return on investment. There is obviously no simple answer to this complicated financial question. However, since General Electric earned approximately 18% after taxes during 1958 (which implies 36% before taxes) we begin to see that some of the figures that we have used (in the order of say 5% to 10%) may be inadequate in certain situations. One way to resolve this question might be to ask the general manager of a particular business if he would approve investments that won't earn the going rate in that department. We feel in Manufacturing Services that under high growth conditions return on investment that this should really be expressed as an "opportunity cost"; in other words, what could this money earn elsewhere for an investment of equivalent risk.

Another complexity in this analysis is that we have historically dealt just with the expected value of the return on investment. To draw an analogy we might discuss the expected return from a uranium speculation. Suppose we invested in a large number of uranium situations; over the whole span of these we would average a 50% return on our investment but we might have to go through 999 total loss situations before we hit the one bonanza. Certainly this is not equivalent to investing money in General Electric stock.

Out of this has evolved an idea which we call a risk-gain concept. In determining an expected return we should examine a few alternative investment outcomes; for example, what's the chances for losing all of the money? What's the chance of losing 10%? What's the chance of breaking even? What's the chance of making 10%? What's the chance of making 50%? We then find that some potential investments should not be made because they are too risky for the kind of business in which General Electric is engaged. All in all, though return on investment is a very complex subject it strongly influences internal shop decisions.

Another factor is the unit cost itself which, in many businesses, depends upon the production rate. We can think about a production system as having a series of "nodal" points. This is true because people are discrete elements and we can't hire one-half person. In other words, we can balance a production line at ten people or at fifteen people; any other level in between step might be far more costly than the two "nodal" levels. Another consideration in the unit cost area is automated versus non-automated facilities. The calculation of a unit cost with a highly automated facility depends heavily on the equipment investment and the rate at which it is being depreciated. Correspondingly, in a non-automated facility the unit cost is a direct function of the labor content of the product.

If we assume that set up cost is equal to thirty-five dollars per order across the board, then the ordering interval would be one week for A items, up to fifteen weeks for D items (using a cost of carrying inventory of 25%.) There are two major ways in which the factory can express this economic lot size idea. One is through an economic ordering quantity which says that whenever an item reaches a selected reorder point, this given lot size will be ordered. The other is through an economic ordering interval which says to reorder this item once a week or once every two weeks and order that quantity that's been used since the previous time or that quantity that's necessary to bring this model up to a given stock level. One reason that economic ordering intervals work satisfactorily is that the item cost curves are typically quite flat near the optimum so that a swing of thirty or even forty percent in order quantity will not seriously affect the total cost. This is caused by the nature of the square root formula which is used to determine economic lot size.

As an analogy to the work that you have done on selective stocking for distribution warehouses, in the factory we often use an ABC classification procedure to classify items based on their dollar sales per year. We often set our ordering policies as a function of this analysis; for example, ordering A items once a month, ordering B items every three months and ordering C items once a year.

In the Hypo example, because each of your products are worth exactly the same amount, you will probably have to use a consistent set up cost for the entire line. This is in contrast to the normal department where set up cost is often reflected in a different unit cost. In some businesses we fortunately find that set up cost tends to be distributed in about the same way as the total yearly cost of an item and hence if we rank them by ABC instead of order quantity, on this basis we don't make out too badly compared to the economic lot size approach.

Production Smoothing of Final Assembly

The percent production variation over a short term should probably best be measured by the change in production rate. We should be careful here not to confuse two different factors though. The fact that the production rate of itself may vary up or down 5% from the stated level does not say that the distribution system can place a plus or minus 5% demand on the factory. The natural variations in output are not under direct shop control; just the week that the distribution system wanted 5% extra the factory might well produce 5% less. The percent variation desired is a direct function of the inventory carrying cost and the back order cost and an inverse function of the cost of changing production level and the variation in unit cost. It is also affected directly by the ratio of the usage variance (over the time interval) divided by the mean demand (over the lead time interval).

Inventory carrying costs have been discussed in the previous section. Back order costs are concerned with lost customers and bad will; it's sometimes called the cost of running out of inventory. This is extremely difficult to measure and about all we can seem to do is to get implicit values by examining what inventories people are willing to carry and implying from this what they apparently feel a back order would cost them. The variance - demand ration, of course, is a measure of the natural variation of the system.

The most important single factor is the cost of changing production level. This is described in references three and four. One must consider the cost of changing production level both upward and downward. The items that are involved here are detailed in the reference papers. However, in general, there are three basic factors which influence how much it will cost to change levels. These are:

1. initial level
2. the rate of change (how soon the change is to be made)
3. the extent of the change (how much of a change will be required)

Variation in unit cost is described on page two of reference five. It simply refers to the fact that you can't change production level at infinitely small steps; there are typically sound levels on which to operate. Even a step further - there is often an optimal operating level in a particular business so that any time you move away from this optimal level a unit cost penalty is incurred as well as the cost of changing level itself.

In discussing change in production rate we have to take into account the personnel impact. A great deal of work has been done by Relations Services people in trying to encourage smoothing out actual demand variations. We are quite proud of the fact that General Electric is considered a good employer and I am sure that this is a major factor in many of our plants which lead them toward maintaining good production stability.

Small production variation can typically be bought by large finished goods inventory or by allowing increased backlogs. Increasing backlogs in turn increase the production lead time which then requires larger distribution inventories.

The use of automated facilities has interesting side effects. In general, the time at which production smoothing must be studied is before the automated facilities are purchased. Of course, at that time we want to minimize capacity and in order to minimize capacity the percentage variations have to be reduced. But once the capacity is already installed then it is a "sunk" cost and we can often be more highly flexible under these conditions.

The real goal that we talk about in smoothing is not just that of personnel. We should also consider smoothing for materials; i.e. what kind of relations we will have with our vendors if we keep driving in emergency orders one week and hold-up and delay delivery the next. In the use of machines (not just in automated plants) we have physical limitations as to just how much a machine can do. Keeping a decently balanced load on the machine gives us adequate time for repair and maintenance.

Conclusion

I would like to leave one major thought:

> The key to an effective distribution-factory system is functional integration. Marketing and Manufacturing must talk to one another and discuss these problems in numerical terms; they must analyze the results and honestly measure

the impact upon our customers and upon our resources. Only this kind of intensive mutual effort on the policies involved will truly optimize our business system performance.

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