Some Consideration of Inventory, SMED and Shingo

By
William J. Latzko

Inventory costs a lot of money. There are a variety of costs associated with inventory which we will examine later. Some people think that inventory policy is a manufacturing concern rather than a concern for the service environment. This is not the case. There are many types of inventory. Usually one thinks of inventory in terms of materials such as supplies, works in process and finished goods. One can also think of inventory in terms of cash or manpower.

In either case, inventories are a major problem in service management. Running out of vital forms, lack of skilled personnel or equipment can cause substantial damage in a service environment. Of course, the same type of damage can be experienced in any other environment such as manufacturing. Work in process is inventory. Because this type of inventory seems to occur normally, it is often not realized how much it can constitute of the total capital tied up in inventory. One must be particularly aware of the pipeline effect, the maintenance of inventory at all work stations.

A major bank decided that they would deliver supplies every other week and only in bulk quantities. No longer could a secretary order one red pencil; the order now became a dozen red pencils since the packaging was in units of 12. The biweekly delivery and the bulk orders had two effects on the bank. In the supply area they experienced a saving of five people. In the rest of the bank they experienced the purchase of supply cabinets to hold the stock of supplies beyond the previous amount. Every office now had a minor supply center. The impact on the organization was to quadruple the cost of supplies on the books of the bank. The savings of the five people was swamped by the cost of the policy. This is another example of optimizing a sub-component of a system at the expense of the system

Carrying much inventory is not considered desirable in modern management practices. You want to have just enough. There are several attempts at reducing the amount of inventory carried by an organization. Electronic Data Interchange (EDI) is used by supplier/buyer teams to keep inventories at acceptable levels. In practice, it is the author's believe, this method merely transfers the holding costs to the less powerful partner of supplier or buyer.

Why do firms carry inventory at all? There are several reasons. Primarily companies carry inventory to have goods and services available on demand. When a customer orders a product, it can be shipped from stock as soon as it is available. In some firms this is such an important competitive edge that inventory becomes essential. It is particularly important for retailers and manufacturers of consumer and dated goods.

A second reason is to smooth production. Seasonality of the material often requires the production to stock during the slack season so that customer demand can be satisfied when the season peaks. This tends to keep the labor force stable and reduces the setup costs. On the other hand there is a penalty in holding costs.

A third reason is a hedge against long or uncertain lead times. A lead time is the period between ordering and receiving the goods. Volume materials shipped from overseas by boat often require a large inventory position.

It is clear that large inventory positions are associated with risk. There are several risks involved. Among these are obsolescence, shrinkage, damage to goods, fire, theft, etc. These risks relate to costs. Schonberger and Knod divide these costs into three categories: Obvious, semi-obvious and hidden costs[1].

Among the obvious costs are the capital cost and holding costs. Capital costs include all interest and carrying charges, bank fees and opportunity costs. The holding costs include rent or other space costs, equipment such as shelving and/or material handling equipment, insurance, taxes, salaries for warehousing as well as damage or shrinkage.

The semi-obvious costs include obsolescence, physical inventory taking costs, Stock record keeping, and inventory planning and management costs. The hidden costs are more severe. They include the work in process costs of manufacturing process. This includes space costs, data processing services equipment costs such as mail carts to move work from one location to another, conveyor costs and storage facilities which may range from table space to shelves or racks.

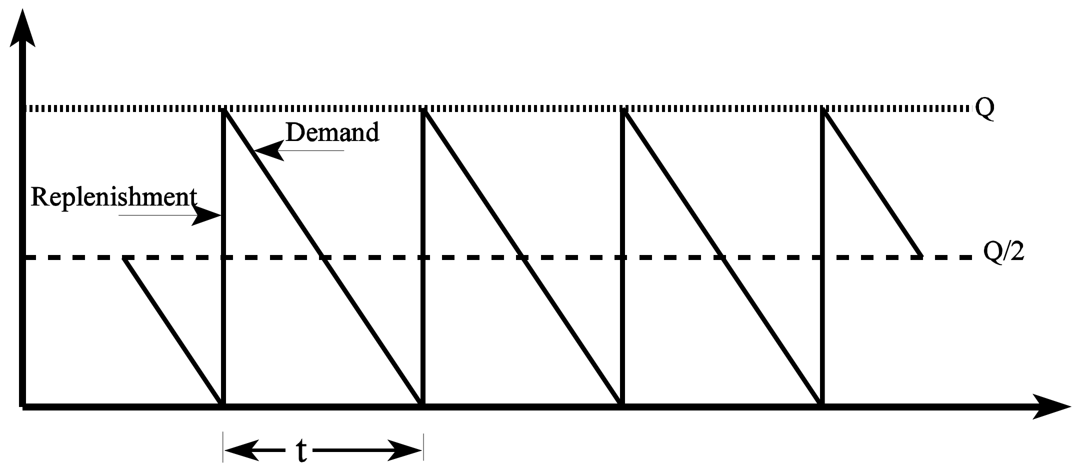
Shigeo Shingo in his book on SMED (Single Minute Exchange of Dies) distinguishes between Excess Inventory and Excess Anticipated Production[2]. Excess inventory comes about because of poor quality. In filling a production order for a certain number of items, A slight overrun is made. The items are inspected and the defective items culled out. The overrun assures that the order will not be short avoiding a rerun. However, if there are more good items left than the customer order called for, the excess items are often put into inventory. These excess items Shingo calls, *Excess Inventory*.

Some manufacturers maintain the right to ship some percentage more (or less) than ordered. Many of these manufacturers overproduce on purpose since the excess inventory will be sold to the customer. In effect, they force the customer to pay for their quality and production inefficiencies. It increases their profits but it is questionable if it makes their customers happy.

Shingo distinguishes the Excess Inventory cost from the *Excess Anticipated Production*. The latter is the deliberate manufacturing for stock. Both types of items are subject to all risks associated with the holding costs. Excess Inventory is totally undesirable and, in most cases, avoidable.

In addition to the holding costs there are ordering costs. The costs include all departments to the extent that they are involved in ordering decisions. Chief among them is the purchasing department. However, other departments can also be involved. For instance, the research department, quality department, inspection department, data processing department, etc. are all involved in the ordering decision. In some cases they are limited to data keeping and analysis, in others it is more.

There are many attempts at balancing the costs of ordering to the cost of holding items. The figure below shows a very simple inventory model. This model has steady withdrawal of the items and an instant replenishment when needed. A more realistic model would show a random withdrawal of items and a replenishment with a lead time. For a more complicated model it is customary to set a Reorder Point (ROP) and allow excess (or buffer or safety) stock to avoid



running out of material while waiting for the reorder to come.

In the simple model shown, the order quantity is “Q”. It is depleted at a constant rate. When it reaches zero, it is instantly replenished. Each cycle takes “t” amount of time. The average amount of inventory held in this model is (0 +Q)/2 = Q/2. There is an annual demand, “D”. The number of order per year is D/Q.

We wish to minimize the total cost “TC”. The annual total cost is the item cost, C_i, times the annual demand, D, plus the product of ordering cost, $C_{o,}$ times the number of orders, D/Q plus the product of the holding cost, C_h, times the average inventory held, Q/2. This becomes the equation $TC = (C_i \times D) + (C_o \times D/Q) + (C_h \times Q/2)$.

To minimize this equation one differentiates with respect to Q. The result is

$$dTC/dQ = 0 + (-1)(C_o \times D/Q^2) + (1/2 \times C_h)$$

Setting dTC/dQ to zero and solving for Q we get the equation

$$Q = \sqrt{\frac{2 \times C_o \times D}{C_h}}$$

This equation minimizes the costs for order quantity Q.

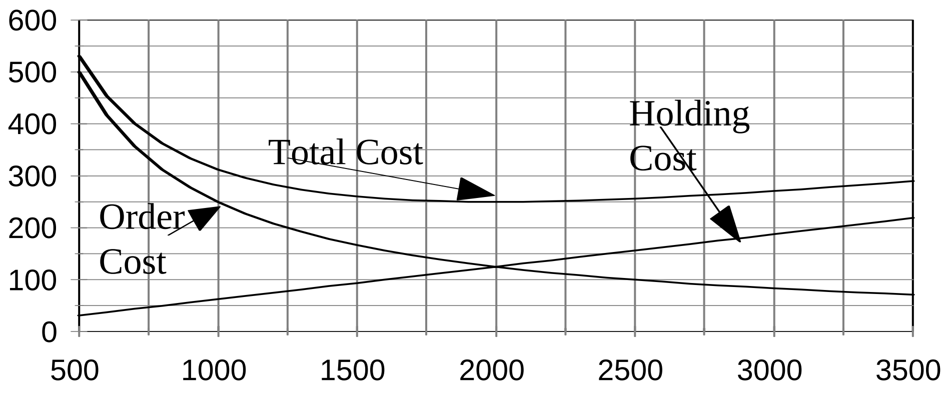
For example for a stock item using the following data:

Factor	Variable	Amount
Annual Demand	D	10,000 items per year
Unit Cost	C_i	$1.00 each
Order Cost	C_o	$25.00 per shipment
Holding Cost	C_h	12.5% of average inventory value
Assumptions		Deterministic demand Constant rate of demand No shortages Constant size of replenishment Zero lead time Infinite replenishment rate Constant inventory cost

Substituting these data into the equation for the Economic Order Quantity (EOQ), Q, we get:

$$Q = \sqrt{\frac{2 \times C_o \times D}{C_h}} = \sqrt{\frac{2 \times 25 \times 10000}{0.125}} = 2000$$

Another way of looking at the equation is with the curve shown below. The total cost is shown on the vertical axis for a variety of possible order quantities on the horizontal axis.

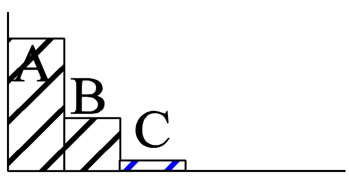


Notice that the Total Cost curve is very shallow in the neighborhood of the best Economic Order Quantity (EOQ). This means that if the EOQ is an odd number, one can round to a nice order number without much loss.

As mentioned above, the model shown here is a simple one. Most inventory situations are far more complex. Demand is often stochastic, not deterministic. Replenishment rate is not instantaneous. There are other EOQ models that take these factors as well as factors such as quantity discount into consideration. For more details on such models see the book by Schonberger and Knod cited above. Other Text on Operations Science or Production and Operations Management give more details.

To handle some of the more complex situations operations people keep buffer stocks. These are stocks that are thought to take care of most of the unpredictable demands and unpredictable replenishment lead times. The more buffer stock is kept, the less likely there will be an outage. However, these stocks cost a lot of money. Companies will try balance the cost of the buffer stock to the occasional outage. “Stock-outs” are those situations where there are orders but no stock to fill them. This could mean lost sales and lost customers. Some companies balance these losses against the inventory costs and permit stock-outs.

In practical terms, of purchasing, it has been noted that relatively few items represent the bulk of the inventory cost. This led purchasing people to the “ABC” concept. Each item is classified as a category from “A” to “C”. The concept is similar to the Parato Principle. Category A constitutes those few inventory items that represent the bulk of inventory costs. Category B is the next group containing more inventory items that account for a significant amount of inventory cost. Category C is the bulk of the items accounting for a very small part of the cost. Good control of category A and B it is said will control inventory costs.



There is a feeling on the part of many managers that if they only had an accurate forecast of demand, they could handle the inventory problem with ease. Unfortunately there is more to the problem than accurate forecasting. Plant and warehouse capacity are factors that influence inventory. The distribution of inventory in multiple shipping points is often a complicating factor.

Companies will try to manufacture in a single or few plants to take advantage of the economies of scale such as shared overhead, support facilities, etc. To serve their customers they often have regional warehouse which they stock from the centralized manufacturing facilities. In theory, these warehouses, near the customer, can supply the customer’s need faster than shipment from a centralized location. In practice, however, this complicates the inventory process. Now demand has to be estimated for each warehouse. Often the error component in the estimation is larger than the estimation for the company as a whole. Consequently, it is often the case that one warehouse experiences shortages while other are overstocked with a particular item.

A concept of Just In Time (JIT) was introduced to the United States in the 1980's. It came from Japanese manufacturing practices where it worked very well. Originally started by Toyota, this concept changes the focus of producing for inventory and in effect pushing orders through the operation, to producing only what is needed when it is needed. The focus of Just In Time is to pull orders through the plant. Toyota made use of cards sent from one station to the preceding station to “order” the items needed at the station. The Japanese word for a card is, “Kanban.” The method soon adopted the name Kanban.

There many advantages to the Just In Time system of manufacturing. The main effect is a substantial reduction of inventory with its associated costs. However, two conditions must be present for this system to work. First the items delivered must all be usable. That is, the quality must be perfect. Second, the items must be available on time.

The Japanese manufacturing concept has, since the 1950's, concentrated on achieving uniformity and quality of products and services. In Japan, manufacturers can rely on supplier quality. Secondly, Japanese suppliers build small plants near their customers, plants dedicated to their customer’s needs. This proximity and partnership of customer and supplier makes it easy to move merchandize to the needed place just in time.

In the United States the use of centrally located large plants (with regional warehousing) creates a dependence on our transportation network. In spite of the quality of this network, its performance has such a high variability that items must be shipped early to be sure that they get there in time. The proximity between customer and supplier is missing. Many U.S. firms also still play an adversarial role vis-a-vis their suppliers. This results in the suppliers not really caring when delivery takes place.

A second problem is the quality of our products. Although vast improvement has been made in the past decade, American products are still not of the best quality. The smart plant manager who is aware of this fact, over orders so that the plant will not have to shut down for lack of good parts. And since time delivery is uncertain, the smart plant manager orders items before they are needed causing excess inventory.

Because of the general conditions in the United States the Just in Time concept is often more a Just In Case policy.

Since the use of Kanban (card) generally only within the plant, this author distinguishes between the general concept of Just In Time and its subset, Kanban. The general concept applies both to the company and its suppliers. The Kanban concept applies only to the company.

Both of these concepts are defeated if we have to make what Shingo calls excess inventory or excess anticipated inventory (see page 2 for definitions.) JIT and/or Kanban require the ability of the supplier--internal or external--to produce only the quantity desired. However, if the setup cost (part of the order cost) is large, then the part may become excessively expensive. Shingo addressed this very important issue.

Shigeo Shingo is an industrial engineer who has specialized in production efficiencies. He in the inventor of the SMED (Single Minute Exchange of Die) System. Apparently, he developed this system in 1950 while studying body-molding presses at the Toyo Kogyo Mazda plant in Hiroshima. There he observed that while the presses were setup, no production could take place. He also observed that the setup engineer would cannibalize other presses if a part was missing. Shingo asked himself why parts should be missing and arrived at the conclusion that the preparation for the setup were haphazard.

This led to the concept of two setup activities: *Internal Setup* and *External Setup.* Internal setup is that portion of the task that can only be performed when the equipment is shut off. External setup is that portion of the task that can be prepared while the equipment is productive. External setup is the laying out of parts or otherwise preparing work for the setup during the production cycle. The more work that can be done as external setup the less the equipment downtime, the greater the production efficiency.

An example of the application of such a principle was observed in a pharmaceutical plant. When tablets are filled into plastic bottles, it is important that there be no foreign matter in the bottles. To be sure that the bottles are empty, the conveyor line of bottles has a station that turns them upside down and blows a blast of clean compressed air into the container. The bottles are then righted and filled. The method of turning the bottles is to use a “twist bar”. This is a set of four rails that literally twist the bottle upside down and then back.

Whenever bottle sizes are changed--several times a day--skilled mechanics had to work for four or more hours to get the four twist bars into alignment. During that time the machine and operators stood idle. The plant engineer following Shingo’s concept solve the problem. He created a set of twist bars for every size used. These bars were in a fixture that slid into place on the line. Using these bar-sets the changeover was reduced from four hours to three minutes. For the plant as a whole this was the equivalent of buying another manned filling line. A tremendous cost savings.

In 1957 Shingo worked on a problem in the Mitsubishi Heavy Industries Shipyard in Hiroshima. There he came across a process where the application of a second equipment paid for itself while the first piece was setup. By having the second piece of equipment, production continued without let-up.

This is similar to another case in the Pharmaceutical industry. In making semi-viscous (slow flowing) material, the plant was required to completely clean all reactors and pipes whenever they changed over to another product. This was a federal requirement under the FDA’s GMP (Good Manufacturing Practices.) It took over eight hours to clean all the items satisfactorily. The reactor could be cleaned in less than an hour but all the pipes and conduits took over eight hours more. It was usually done on Saturdays on overtime to minimize production down time.

The company bought a complete set of extra piping and conduits. Now the cleaning process takes the hour to clean the reactor. While this is going on the rest of the equipment is dismantled and replaced with clean equipment. When the system was running another crew cleaned the parts that were removed and prepared them for the next change over.

In 1969 Shingo was asked to work in the Toyota Motor Company main plant. They had a bought a press from Volkswagen. It took Toyota four hours to change the press. Volkswagen apparently used only two hours. Shingo studied this process. By working on converting much of the internal setup to external setups he was able reduce the time to ten minutes. He said, “In the hope that any setup could be performed in under ten minutes, I named this concept, ‘Single Minute Exchange of Die,’ or SMED.”[3]

Shingo’s point is that the EOQ models are ok as far as they go but the do not go far enough. The assumption in these models, he says is that setup time (cost) is fixed. Shingo disagrees and has proved his point.

Shingo shows that the traditional setup requires knowledge and skill. Knowledge of all matters pertaining to the equipment and skill in using this knowledge. In a non-manufacturing sense one could compare this to senior clerks who claim to have a magic all of their own. They mastered the knowledge of the work and through years of practice (or making mistakes) acquire the skills need to perform the work. These clerks often perform editing functions for others less skilled to data enter. Application of Shingo’s concepts could break the hegemony of these workers.

In looking at the reason for the use of large lots (defined by Shingo as over 500 items) Shingo points out that setup costs are a major factor. He shows that as setup time increases large lots gain more and more attraction based on the per unit cost. For instance, if the set up cost in terms of time is four hours (240 minutes) and the production cost is one minute, the following relation occurs:

Setup Time	Lot Size	Operation Time per item	Total Time= Op. Time + Setup Time/Lot Size	Ratio (%)
4 Hours (240 Minutes)	100	1 Minute	1+240/100 = 3.40 Min.	100%
4 Hours (240 Minutes)	1,000	1 Minute	1+240/1000 = 1.24 Min.	36%
4 Hours (240 Minutes)	10,000	1 Minute	1+240/10000= 1.024Min	30%

Setup Time	Lot Size	Operation Time per item	Total Time= Op. Time + Setup Time/Lot Size	Ratio (%)
8 Hours (480 Minutes)	100	1 Minute	1+480/100 = 5.800Min.	100%
8 Hours (480 Minutes)	1,000	1 Minute	1+480/1000 = 1.480Min.	26%
8 Hours (480 Minutes)	10,000	1 Minute	1+480/10000= 1.048Min	18%

Shingo's point is that large lots for a fixed setup period make great gains. The longer the setup time the greater the gains of producing large lots. However there is a large risk as well as the holding costs to be incurred. Shingo makes the point that if the setup time is decreased, the large lot advantage starts to disappear. Suppose he says the setup cost is only three minutes then we have the following result:

Setup Time	Lot Size	Operation Time per item	Total Time= Op. Time + Setup Time/Lot Size	Ratio (%)
3 Minutes	100	1 Minute	1+3/100 = 1.03 Min.	100.00
3 Minutes	1,000	1 Minute	1+3/1000 = 1.003 Min.	97.38
3 Minutes	10,000	1 Minute	1+3/10000= 1.0003 Min	97.12

If we increase the lot size by a factor of ten we save 10-1 or 9 setup times. For the different setup costs Shingo calculates the following savings:

Setup Time	Setup Time Savings	Work Day	Day(s) Saved
3 Minutes	3 Min x 9 = 27 min	8 Hours (480 Min.)	0.06
4 Hours (240 min)	4 Hrs. x 9 = 36 Hrs	8 Hours	4.50
8 Hours (480 min)	8 Hrs. x 9 = 72 Hrs	8 Hours	9.00

The more the setup time the greater are the savings.

How does Shingo reduce the setup time. He studies the internal setup time to see how much of that can be reduced to external setup times. He looks at continual improvement in this area. In the mechanical field, there are many tricks that he gives in his book. For instance the use of fixtures and fast acting locking mechanisms are only a part of this method.

In the service area, it is the author's opinion that similar savings can be effected. For instance in setting up a loan, all the necessary documents could be assembled in advance. Using computers, repetitive information can be carried forward from one screen to the next. The concept of reducing internal setup to external setup is appealing in both manufacturing and service. This reduction of internal setup saves money.

By changing from internal setup to external setup, the setup function can be simplified to eventually use a less skilled and therefore less expensive labor force.

REFERENCES

1. Schonberger, Richard J., and Edward M. Knod, Jr. *Operations Management: Continuous Improvement*, 5th Ed.,Burr Ridge, IL: Irwin, 1994 pps 242-244

2. Shingo, Shigeo, *A Revolution in Manufacturing: The SMED* System, Translated by Andrew P. Dillon from *Shinguru Dandori*. English Ed., Cambridge, MA: Productivity Press, 1985.

3. *Ibid* p. 25