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Strategy for Deriving Maximum Profits by Inventory Minimization

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Abstract
Inventory has been a hotly debated topic in many organizations. Since inventory is directly visible in company financials, there is a high degree of sensitivity to excessive inventory levels in the management ranks. Many organizations carefully track inventory turn ratios and benchmark themselves against key competitors. For some organizations a focus on "lean supply chains" with their high inventory turns have proven to be of substantial strategic value.

Whenever the topic of inventory reduction surfaces, a discussion around the following tradeoff is bound to erupt: inventory reduction versus potential negative service level implications. This paper provides a fundamental and systematic approach for inventory optimization bringing these seemingly contradictory forces into unison. We will show a framework that can be applied, discuss two fundamental strategies to be used sequentially to reduce inventory and demonstrate the application of the principles in a case study. Reliance on IT solutions is also discussed.

We briefly address the need of cash generation through inventory sell-offs even if doing so jeopardizes profitability. For many managers this seems like foolish executive action, but we will shed some light on the rational and demonstrate that in fact this action may represent sound business activity.

The Financial Purpose of Inventory
Engaging in a rational discussion on inventory optimization, we must first clearly define the purpose of inventory. Inventory, just as any other investment in business, must serve the purpose of profit generation, or better yet, profit maximization. Inventory must be put in place in such a way, that the value of placing the inventory exceeds the cost of placing it. Inventory, if strategically placed, can yield additional revenue, profit and cash flow to the organization. In order for inventory to serve this function it must however be put in place using sound analytical methods. 'Gut feel' inventory methods are bound to get the organization into trouble and result in heated discussions about the appropriate inventory levels. Many times this approach to inventory management results in executive inventory level edicts as a last resort, ultimately impacting customer service and profitability.

The Operational Purpose of Inventory
Inventory has a simple operational purpose. If supply and demand for a product are not synchronous, inventory can be used to buffer the mismatch between demand and supply. Whenever the demand stream is not synchronized with the supply stream we therefore have the choice between three potential actions:

1. Do nothing
2. Place a buffer of product between the supply stream and the demand stream to ensure product availability for the demanding party even though product is not produced at that point in time
3. Synchronize supply and demand

Option one has potential in markets where demand exceeds supply; backorders are acceptable and won't have any negative impact on future revenue streams to the organization. While these situations exist, they are rare and bound to be costly further down the road, once customers have been disgruntled by poor availability.

Option two involves utilizing operations management techniques. These techniques allow for the determination of the most profitable inventory position and replenishment methods. Operations management techniques optimize inventory while treating the operational systems and its performance parameters as a given quantity. Therefore, this technique approaches inventory from a "black box" viewpoint, by optimizing inventory given current operational performance.

Option three requires some fundamental change of the operational systems and potentially the customer behaviors. Techniques like Lean and Six Sigma are most useful to drive the kind of change required to fundamentally improve process performance and alleviate or lessen the need for inventory as a buffering mechanism. From an inventory standpoint, Lean will improve flow thus moving towards production of product just in time. By producing product on demand, the fundamental issue of non-synchronous production is addressed. Six Sigma will aid this process by removing variation form the process, again aiding in the synchronization of supply and demand.

In practice both option two and option three should be executed. In many organizations step one is the implementation of a structured, analytical inventory management method using operations management techniques. Initially this step can result in inventory reductions of up to 50% without any negative impact on service levels. In order to continue along a path of continuous improvement, Lean and Six Sigma techniques should be applied to improve the product delivery system. In some cases technology can also be used to aid in this process.

In recent years IT providers substantially increased their product offering to better 'coordinate' supply chain activity and to improve inventory positions. Some cautions have to be kept in mind for those organizations looking to IT solutions as the primary method to improve inventory positions. In many cases IT solutions do not fundamentally change the business process. If they do, it usually requires modeling the business process around an IT solution, versus implementing an IT solution to support the best possible business process. If not planned carefully, IT solutions can "automate" a fundamentally flawed process – hardly in the best interest of the implementing firm. Secondly, IT solutions assume educated users. While new technology software has the capability of applying a vast number of analytical models, the usefulness of those models will be determined by the correct application. IT providers often supply basic training, however, the workforce must be educated in regards to available models in the context of the existing business. Lastly, IT solutions are time consuming and resource intensive. Initially, substantial gains can often be achieved much faster and cheaper by implementing the framework below.

The Value of Placing Inventory

As stated previously, the value of placing inventory is to have product on hand when it is required. The requirement for product can originate at a customer seeking product as well as an internal need for product, such as the requirement for piece parts at the assembly line. As such, the value of inventory can be found in the following:

1. Making a sale immediately, preventing either a lost sale or a delay in cash flow (in the case of backorders being acceptable)
2. Ability to produce product as planned

Instead of listing the value of inventory, we can also express the value as a cost of not having inventory. Since this inverse view of the value of inventory will prove to be advantageous in the derivation of inventory models later, we will continue considering the cost of not having inventory. In detail they are:

1. Cost of a lost sale
2. Cost of capital in the case of a delayed sale
3. Cost of a line shutdown, line changeover, etc., due to parts unavailability etc.
4. Delivery penalties
5. Overtime charges

The Cost of Placing Inventory

Placing inventory is costly and is a cash flow drain, which is the reason for the attention it usually gets. The following is a brief list of the type of costs that should be considered when deciding on the appropriate amount of inventory to be held:

1. Cost of capital. Any cash used to purchase inventory is not returned to shareholders or reinvested in economic value added (EVA) activities. Therefore there is a real cost to the firm of placing inventory for purposes of supply and demand synchronization. A good indicator for the cost of capital is the weighted average cost of capital (WACC).
2. Cost of obsolescence. In markets with high rates of product innovation and customer expectations for product innovation, product placed as inventory can become obsolete. At best this inventory can be sold at a discount once it has become obsolete, however, in some cases it must be removed and written off entirely. If it is sold as obsolete product the firm may encounter an additional cost if cannibalization of its own product portfolio occurs.
3. Cost of management. Managing inventory requires resources in the form of individuals managing the administrative and physical aspects. Additionally IT resources are consumed in the process of managing the inventory.
4. Cost of physical storage.
5. Cost of ordering. The order process typically requires administrative resources to complete the ordering transactions. Even in highly automated B2B situations, auditing personnel will be required.
6. Cost of setup. The physical setup of production should be considered in cases where batch manufacturing is still applicable. This cost can be substantial in those organizations with large equipment, such as injection molding etc.
7. Shipping cost.

Inventory in Distress Situations

In addition to the costs mentioned above, inventory may also play a vital role for a firm in distress. If the inventory is saleable, management may decide to utilize the inventory as a cash generator regardless of the impact on some of the costs stated above. While non-profitable sell-offs may seem irrational to some, it in fact can represent very sound business action. If the firm is close to default and the continuing operation is in the shareholders interest, the unprofitable liquidation of inventory may generate sufficient cash to implement other changes for survival. The potential cost incurred in this situation, the cost of default, may also be incorporated, but is beyond the scope of the discussions of this paper. The methods discussed here are useful primarily for those organizations with sufficient cash flow to sustain operations. Along the similar lines, inventory can be useful during the initial stages of an economic downturn. During this stage, the company has a fixed cost structure to support strong product demand. As demand drops in the economic downturn, the associated fixed cost structure of the firm lags behind in adjustment, thus creating serious cash flow drains. Inventory sell-offs may be used to bridge this transition period.

Inventory for Profit Maximization

The goal of any inventory policy is quite easy to state: Minimize the sum of all costs associated with inventory. The question of the 'correct' amount of inventory can now be expressed as a cost minimization problem that needs to be solved. We will demonstrate the mechanics of this shortly.

The Operations Management Approach

To implement an operations management approach to inventory optimization, we must first and foremost understand the cost structure associated with the parts under scrutiny. Depending on the primary players contributing to the overall cost of having and not having inventory available, the application of different inventory models and management methods will be appropriate.

Furthermore, since the operational purpose of inventory is to buffer a mismatch of supply and demand, we must understand the supply and demand behavior we are attempting to buffer.

Typically we need to understand supply lead-time from order placement to receipt into inventory along the following parameters:

1. Average lead time
2. Variation of lead time
3. Stability of lead time

With regard to product demand, we subsequently need to understand:

1. Average demand (daily, if available)
2. Variation of demand (daily, if available)
3. Stability of demand

In order to characterize the supply lead-time and demand, statistical tools such as Statistical Process Control (SPC) have proven to be quite useful.

Once all these elements have been determined, it is most useful to collect the information in a matrix to get a quick overview of all the primary cost drivers as well as the supply and demand behavior. From the matrix a standard model can either be chosen, or a custom model can be derived.

Example Situation

A high inventory of internally produced piece parts is receiving management attention. The parts are manufactured on older equipment only capable of producing in batches. This type of equipment is not designed and cannot be re-designed to manufacture in single piece flow. Replacement of the equipment is out of the question, as it would require major capital expenditures not justified by the improvements it would provide.

Once the parts are produced they are stored in inventory. The assembly line requests these parts from the warehouse whenever an assembly run needing the parts is scheduled. Historically, the assembly line has also been stopped due to unavailability of these piece parts.

The line producing the parts suffers from quality problems. Yield is traditionally low.

In summary:

- On average $450K of parts are stored in the warehouse
- Occasionally there is a shortage of product leading to line stoppage and lost sales
- Long setup requires the production in lots
- Low yields result in tampering on the line
- The current process does not cap production

The primary cost player can be summarized as:

- Setup cost
- Holding cost
- Line stoppage and potentially lost sales due to unavailability

Establishing Service Level Goals

In order for the modeling to proceed, we must determine the desire service level for the part. Although counter to popular belief, 100% service levels are usually not desirable for most organizations. In the case of overly high service levels, the cost of holding and managing the inventory far outweighs the benefit of the high service level. On the other hand, low service levels can lead to lost sales or delayed cash flow therefore the cost of placing the inventory can be far lower than the cost associated with a lack of availability.

Service levels can be established using three methods:

Using method one, management sets an arbitrary service level goal based on various opinions or previous 'experience'. Depending on the political landscape of the organization, the party with the strongest influence will tend to bias the inventory position in its favor, tipping the scale to either unbalanced cost extreme mentioned above.

Method two establishes the most appropriate service levels by comparing the service levels of various competitors and positioning the service level such that the entire product offering is appropriately placed in terms of a market value map.

Method three is the utilization of total cost minimization techniques. Using these techniques the costs of holding inventory will be brought into balance with the cost of not holding the inventory. Once these costs are equal for the next marginal unit to be held in inventory, we have determined the economically most appropriate service level and we can subsequently determine the correct inventory position.

Typically method three is the most sensible strategy if the knowledge of detailed cost exists. In new product launches and strategy transitions with subsequent pricing changes, method two may be preferable.

In our example method two is used to establish a service level goal. In the example it is determined that two stock out occurrences per year are permissible at most. In addition it can be noted that demand is random and stable while supply lead times can realistically be modeled as deterministic.

In summary Table 1 helps drive a decision for the most appropriate inventory model.

Table 1 - Table to Display Primary Decision Factors

Model Element Considerations	Detail	Present
Cost of shortage	Lost profit	Potentially
	Line stoppage	Y
	Overtime	Y
	Penalty	NA
	other	NA
Cost of Holding Inventory	Cost of Capital	Y
	Physical Storage	Y
	Management	Y
	Obsolescence	NA
Cost of Setup	PO Generation	NA
	Shipping	NA
	Setup	Y
Production or Acquisition		
Other	SL	Y
Average Demand		Y
Variation of Demand		Y
Average Leadtime		Y
Variation of Leadtime		NA

Model Selection

Reviewing the cost structure using a matrix such as the one presented above can provide some useful guidance for inventory model selection. The field of operations management provides a large number of potential inventory models, such as EOQ, dynamic lot sizing, Newsboy, Base Stock, etc. One key challenge for inventory management professionals is to select the most appropriate model for a given application. Since inventory management is centered on cost minimization given operational conditions, the cost structure and operational conditions are the key decision criteria when selecting models. In order to implement the most effective inventory strategy, all parts in inventory must be defined in terms of these parameters and should be subsequently evaluated for the most appropriate model.

The Q,r Model

In the example situation, the application of a Q,r inventory model is most sensible. In the Q,r model, inventory is produced in lots of Q. The production of a new lot of parts is triggered whenever the actual inventory position reaches a reorder level of r. The quantity remaining in inventory when the order is placed serves the purpose of covering the demand during the lead-time, plus it provides a safety stock to cover any variability of demand to meet the desired service level.

For the purpose of our discussions here, we will derive the optimal order quantity Q and the reorder point r independently. For technical correctness, one total cost equation should be constructed and derived in Q and r. From a practical versus pure technical standpoint the difference in solution is negligible in most cases and for reasons of technical simplicity we will continue on the independent path. (See Figure 1.)

In essence we now need to answer two questions: How much product to manufacture (Q) and at which inventory level (r) we should trigger the manufacture of another lot of material.

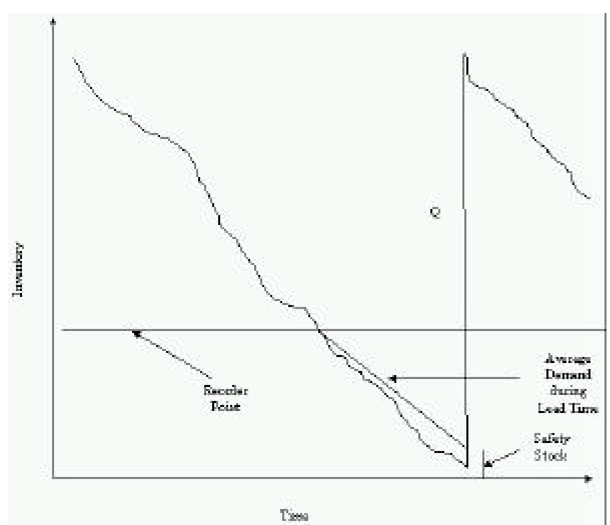

Figure 1 – Inventory Model

To answer the first question, we must consider the following costs:

- Setup cost
- Holding cost

Our goal is to find a production quantity Q such that the sum of the setup costs and the holding cost are minimized. In order to find that quantity we determine the total cost, derive that cost in Q and set the derivative to zero to find the optimal quantity Q, also known as Economic Order Quantity EOQ. We find:

$$TCU = Total\,Cost\;per\,unit$$
$$A = Setup\,and\;Order\;Cost$$
$$D = Average\;Demand$$
$$Q = Lot\;Size$$
$$h = Holding\;Cost$$

$$TCU(Q) = \frac{hQ}{2D} + \frac{A}{Q} + c$$
$$\frac{dTCU(Q)}{dQ} = \frac{h}{2D} - \frac{A}{Q^2} = 0 \implies$$
$$EOQ = \sqrt{\frac{2AD}{h}}$$

The second question we must answer is when to place the order for another lot of parts. The appropriate trigger point r will be the average demand during the lead-time, plus the safety stock required to achieve the desire service level. Accordingly we find:

$$r = reorder\;pnt$$
$$m_{LT} = replenishment\;leadtime(weeks)$$
$$m_{wkly\,dmnd} = average\,weekly\;demand$$
$$s_{wkly\,demand} = std\;dev\,weekly\;demand$$
$$s_{LTD} = std\;dev\,of\;leadtime\,demand$$

$$r = cycle\,stock\;during\;replenishment + safety\,stock$$
$$r = m_{LT} * m_{wkly\,demand} + z * \hat{s}_{LTD}$$

In our specific example we find:

$$EOQ = \sqrt{\frac{2 * \$1605 * 52\,weeks * 1009.7\,units/week}{(0.12 + 0.1) * \$130/unit}} = 2428\,units$$

resulting in

$$Orders\;per\;year = \frac{52504\,units/year}{2428\,units/order} = 21.6\,orders/year$$

Setup requires 9 labor hours at $45/hr and material consumption of $1200, resulting in a setup cost of $1605. The cost of capital is 12% while the inventory storage and management charge is 10%, resulting in an annual holding cost of 22% of part cost.

$$'SL' = 1 - \frac{2\,occurences}{21.6\,order\,cycles/yr} = 0.907 \implies z = 1.325$$
$$s_{LTD} = \sqrt{m_{LT} * \hat{s}^{2}_{wkly\,demand}}$$

$$r = 1wk * 1009.7units + 1.325 * \sqrt{1wk * 528.45^2}$$
$$r = 1009.7units + 700.5units = 1710.2units$$
$$Average\,inventory = 1/2 * EOQ + safety\,stock = 1914.5units$$
$$Average\,inventory\,value = Cost * average\,inventory = \$248{,}885$$

In summary the application of operations management techniques yields the following improvements:

- Increase annual setup costs from $14,926 to $33,700
- Decreased annual inventory management and holding cost from $99,000 to $54,754
- **Realized net savings of $25,000 for this one part number alone**

This example demonstrates the derivation for the determination of inventory levels for an example with a specific cost structure as outlined in Table 1. Models can be derived for other cost structures following a similar process.

Rationalizing the Inventory Portfolio

The Q,r model was specifically chosen given the underlying cost structure and operational reality in this case.

For those organizations seeking to not only optimize the inventory position for individual part numbers but rather the entire inventory, this method is applied across the entire portfolio. A key in the success of this method is of course the model selection itself. Algorithms can be defined to aid in this process, but it must be noted that adequate knowledge in regards to the cost structure and operational realities must be collected. Since many organizations choose not to manage inventory positions to an infinite number of management scenarios and service levels, methods such as cluster analysis can prove to be useful to “bucket” the portfolio into a framework of finite categories. The model should then be revisited periodically to ensure correct ‘bucketing’ of product over time.

The Process Improvement Approach

As stated previously, the process improvement approach to addressing inventory issues focuses on changing those elements driving up inventory levels which the operations management approach to inventory management assumes to be fixed. With this approach, the fundamental costs such as storage, ordering, management, setup etc. are evaluated and lowered.

Lean Manufacturing

The application of lean manufacturing techniques lowers costs while simultaneously lowering the lead-time and lead-time variation. Techniques are used to increase the product flow through the operations. Non-value added operations are removed, further contributing to reduced lead times and lead time variation while lowering the cost structure.

In addition to the traditional lean methods, the implementation of more effective production systems can prove to be of substantial value. Typical changes include the implementation of pull systems from the customer order through the entire activity chain to suppliers. Pull systems can take the form of traditional Kanban systems, but CONWIP or CONCAPACITY or other forms of pull systems may be better choices depending on the operational realities of the organization. The choice of production system proves to be fundamental for the successful implementation of lean on a larger organizational scale and must be cautiously executed.

Lean Manufacturing approaches to process improvement must be carefully orchestrated and receive top-level management support to be successful. The gains generated by these efforts go well beyond the issue of inventory, however it must be clearly understood that lean manufacturing cannot be implemented at a local level, such as the materials management group, but must be implemented with a much larger scope and scale in mind. It will deliver results over and beyond the results possible with pure operations management techniques, but executive support is required.

Six Sigma

The application of Six Sigma techniques will also contribute to lowering the costs while lowering the lead-time and lead-time variation. Six Sigma techniques revolve around the application of statistical techniques to gain fundamental process knowledge. A rigorous application will substantially reduce process variation and as such increase yields and lower manufacturing cost. A clear process understanding will also reduce setup cost by providing the ability to 'dial in' settings after a changeover versus 'tweaking' equipment after each setup.

Six Sigma can be locally applied, however, just as a lean manufacturing effort, top-level management support is required to be truly successful with this effort.

In the example, a reduction of setup cost provided the next largest improvement of inventory levels. Six Sigma techniques were used extensively to fundamentally understand the relationship between process inputs and process output. As a result the 'dial-in' portion of each setup could be shortened, reducing the required labor hours for each setup and reducing the material requirements for each setup. In addition lean techniques, like the implementation of visual workplace methods, further helped in the lowering of setup costs. As an added benefit, the yield issues were addressed.

An Integrated Approach to Inventory Optimization

Integrating the approaches previously outlined will yield a framework of addressing operational efficiency and overall cost structure even beyond pure inventory opportunities. Below is a brief 7 step process that if followed will yield continuous improvement for inventory reduction. Since this framework requires action beyond the typical influence of materials management, the organizational implications of this model must be considered as well as the technical implication. The process of continuously reducing inventory is:

1. Understand process that generates inventory
2. Understand cost structure
3. Understand supply and demand
4. Select inventory model / derive inventory model
5. Determine critical path of optimization
    a. Operations Management
    b. Process improvement
6. Implement change
7. Re-iterate process

In Figure 2, the reduction of setup cost by 50% though the application of lean manufacturing and Six Sigma techniques led to a reapplication of the operations management techniques. After recalculating the lot size and reorder point we find the new total cost of inventory to be $64,819 using the integrated approach. This yields total annual savings of $49,107 for this one part alone.

In summary, the application of an integrated process led to the following results:

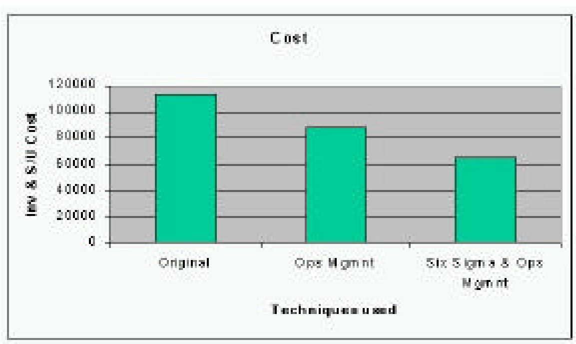

Figure 2 - Cost

Some Practical Thoughts on Implementation in Industry

When following the process we outlined, the largest inventory related gains are typically generated in the initial project phase of applying operations management techniques. In many organizations materials management personnel can quickly be educated to correctly apply these techniques. Typical training can be completed in 3-4 days. Using these methods inventory can be quickly and sensibly reduced without incurring the negative effects of blanked inventory reductions. This framework provides a business approach to determine the 'right' amount of inventory.

Once gains are captured from the initial application, it may be time to evaluate the existing product delivery system, as it often entails the second biggest potential for improvement.

Those organizations most successful in capturing the benefits of inventory optimization choose to specifically designate and educate business analysts in these methods. Their role, unlike those of day-to-day personnel, is to ensure that the inventory models are correctly selected and applied. They have technical responsibility to ensure inventory serves its purpose in maximizing profitability.

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