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Do you have too much overall inventory while experiencing stock-out situations? One culprit may be your system EOQ setting

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Abstract

Optimal EOQ determination is a classic case of a compromise between a set of conflicting elements. When used properly, EOQ makes the proper balance between the costs associated with processing orders (which provides motivation to order large quantities at a time) and the inventory holding costs (which in contrast provides motivation to order as little as possible at a time). In this article, practical and real-life considerations are presented to highlight common mistakes in applying the EOQ formula found in text books.

Keywords: Operations improvement, Lean, Inventory Management, EOQ (Economic Order Quantity)

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Introduction

Although the EOQ (Economic Order Quantity) formula has been in existence and in use for quite some time, misunderstandings and mistakes are still common. Ironically, the advancements in computer systems may be at least in part to blame. Almost all ERP/APS (Enterprise Resource Planning / Advanced Planning & Scheduling) packages come with built in calculations for EOQ, often leaving the users unaware of how it is calculated. As an unfortunate consequence, the data inputs and system setup which control the output are left unquestioned. Some organizations lack the rigor and/or regular process of reviewing these inputs. Even when the system spits out an unreasonable figure, it may be difficult to detect as there are so many SKUs (Stock Keeping Units). A structured review and modifications to the inputs often lead to significant improvement in both inventory levels and stock-out situations.

We find many of these default EOQ calculations are too generic and inadequate – in some cases, the initial values had been set by the system implementers during rushed implementation phase rather than operation experts. If the initial inputs were set many years ago, they may need to be modified to reflect the latest business situation.

Corporate goals and strategies can also be inconsistent with the EOQ. Measuring performance by inventory turns alone is a common mistake made in the name of inventory management. Many companies have achieved aggressive inventory turns goals only to find their bottom line dwindle due to increased operational costs. EOQ should help in finding the right balance to minimize the combination of order costs and inventory holding costs. In purchasing this is referred to as the order quantity; in manufacturing, this is the production batch size.

EOQ Formula

The EOQ formula, found in just about any supply chain related textbooks and manuals, is very sound and practical for most real life situations. Nevertheless, a thorough understanding of the equation is crucial to ensure proper inputs into the equation. In this article, we will first derive the EOQ formula and by doing so, better understand the assumptions and limitations that are inherent in it. We will then explain each of the components in detail and offer suggestions on what specific factors should be included/excluded. We will conclude with some more considerations that will allow a successful implementation in real life situations.

1. Derivation of the EOQ Formula

Below is the equation for calculating the economic order quantity:

$$EOQ = \sqrt{\frac{2 * N * p}{i * C}} \qquad (1)$$

where: N = total annual usage in units

p = cost to process each order

i = inventory holding cost (as a percentage of per unit cost)

C = cost per unit

While the calculation itself is fairly straightforward, the task of determining the proper input into the equation can be a challenge. Based on our experiences, exaggeration of order costs and misunderstanding of holding costs are common, consequently leading to improper decisions.

One way to better understand this formula is to go over a few numerical examples. The following are the three proposed scenarios, which includes two extreme cases. We will derive the general formula immediately after the three numerical examples.

Scenario 1 order the entire annual quantity all at once (to minimize order processing cost)

Scenario 2 order one unit at a time (to minimize inventory holding costs)

Scenario 3 order 200 units at a time

For our scenarios, let's assume the following for a hypothetical SKU

2,000 units	annual usage (N)
$ 10 / order	cost to process each order (p)
15%	annual inventory holding cost percentage (i)
$ 50 / unit	cost per unit (C)

Scenario 1:

We will incur order processing cost of $ 10 ($10/order * 1 order) and an inventory holding cost of $ 7,500 ($50/unit * 15% * 2,000 units / 2). Hence, the total cost under scenario 1 is **$ 7,510**.

Scenario 2:

We will incur order processing cost of $ 20,000 ($10/order * 2,000 orders) and an inventory holding cost of $ 4 ($50/unit * 15% * 1 unit / 2). Hence, the total cost under scenario 2 is **$ 20,004**.

Scenario 3:

We will incur order processing cost of $ 100 ($10/order * 10 orders) and an inventory holding cost of $ 750 ($50/unit * 15% * 200 units / 2). Hence, the total cost under scenario 3 is **$ 850**.

Derivation of the formula:

As you have seen the examples above, there are two cost components: 1) cost related to ordering and 2) cost related to holding consequential inventory. The order cost decreases as the order quantity increases (since orders are placed less frequently) whereas the inventory holding costs increases with the increase in order quantity.

The order cost is:

$$p * N/Q \qquad (2)$$

where p = cost tor process each order

N = annual usage

Q = order size

The inventory holding cost is: (cost to hold each unit of inventory) * (average on hand inventory) or equivalently,

$$\frac{1}{2} * Q * i * C \qquad (3)$$

Where Q = order size (5)

i = annual inventory holding cost percentage

C = cost per unit

The total cost of course, is the sum of these two components.

$$\frac{Np}{Q} + \frac{1}{2} Q iC \quad (4)$$

Notice that the only variable in the equation is Q (the order quantity). As you recall from basic calculus principles, to find either the minimum or the maximum value of a given equation, you take the first derivative with respect to the variable (in our case Q) and set it equal to zero. You take the second derivative to determine whether the value is the minimum or the maximum (if it's positive, it's minimum and if it's negative, it's the maximum).

The first derivative gives us:

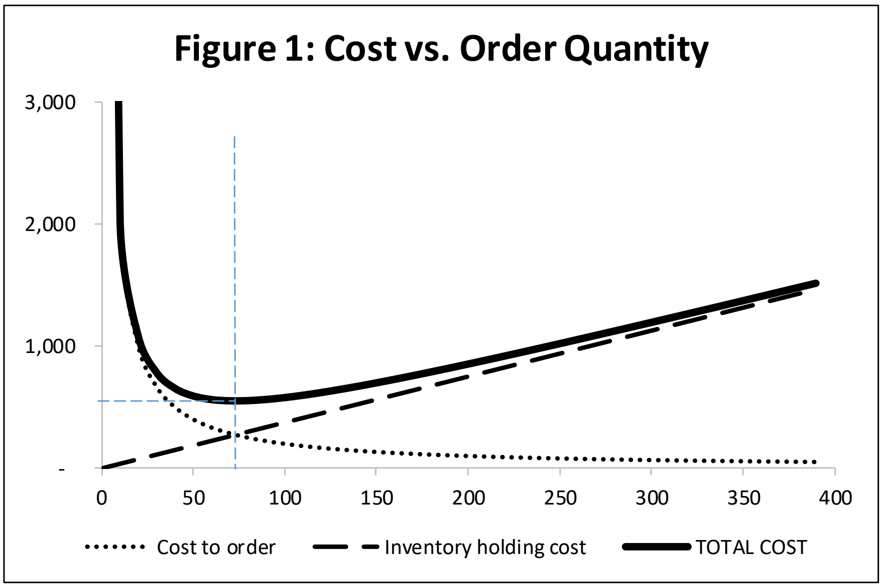
$$-\frac{Np}{Q^2} + \frac{1}{2} iC = 0$$

Solving for Q gives us:

$$Q = \sqrt{\frac{2Np}{iC}} \quad (6)$$

This is the EOQ formula – you will find this in just about all supply chain and inventory management related books.

To see how well this formula (6) works, let's revisit our numerical example above. Based on this text book formula (6), by plugging in N = 2,000 units, p = \$10/order, i = 15% and C = \$50/unit), our EOQ = 73 units. With this, we will incur order processing cost of \$ 274 (\$10/order * 2000 / 73 orders) and an inventory holding cost of \$ 274 (\$50/unit * 15% * 73 units / 2). Hence, our total cost using the EOQ formula is **\$548**. This is indeed the minimum total cost as the chart below illustrates.



2. Explanation of Each Component

Let us now examine each of the EOQ elements and offer some practical suggestions on how best to estimate them.

Annual usage

Make sure this value reflects the latest annual volume forecast. It is okay to estimate the expected usage based on the historical values. This is a valid method as long as the past usage is indicative of the future patterns. If any significant upward or downward trend is expected, historical value must first be adjusted before it is plugged into the formula. We have run into instances of companies using annual volume from many years in the past which no longer reflects the current business situation.

Order cost

This represents required time and effort associated with placing an order. This should not be associated with the quantity ordered, but primarily with activities required and directly related to place an order. To help better estimate this cost, the following is a list of what needs to be included and just as important, what should be excluded. To better serve a wide range of audience, we have separated the discussions relevant to purchased items from those relevant to manufactured items.

For purchased items, include costs related to:

- creating/entering/reviewing the purchase order and/or requisition
- approval steps
- receipt process
- incoming inspection
- invoice processing
- vendor payment
- portion of inbound freight if inbound freight is dependent on frequency of the orders and has significant effect on unit cost

This value should exclude those costs related to:

- generating/reviewing forecasts
- sourcing
- getting quotes (unless quoting is done for each order)
- setting up new items in the system
- burden rates or other overhead estimates

Estimate the overall percentage of time the department spends in performing the specific activities for a specific time period (at least a week, preferably a month or a quarter). Then divide this by the line items processed to estimate the cost per order.

For internally manufactured items, include costs related to:

- initiating the work order
- time spent picking and issuing components
- inspection time
- tooling (only if it is discarded after each production run)
- production scrap (only those associated with machine set up)
- machine set up (read the next paragraph)

In certain instances, machine set up costs may have to be adjusted by performing several iterations. This is necessary when the resulting production schedule based on the initial EOQ value exceeds capacity. In such cases, the quantity should be increased incrementally until the capacity limit is no longer violated. On the other hand, if significant excess capacity exists and the set up labor is fixed (i.e. same number of people can perform a wide number of set ups), the incremental set up costs should be close to zero.

In my experience, I find many organizations use a value of $100 (or more) as their order cost. Although this is a nice round number, we often find this value to be way too high. For example, many orders are communicated to the vendors by emails, phone calls or automatically via designated web portal. These activities do not cost $100. Even with all other elements that should be included as a part of order cost, more often than not, we often find over-estimated values. If it really costs more than $100 to place one order, then perhaps a better/simplified ordering process should be designed!

Inventory holding cost

This is the cost associated with having inventory on hand. It is expressed as a percentage of per unit cost. For the purpose of EOQ calculation, if the cost does not depend on inventory quantity, it should be excluded.

The following should be included in estimating this value:

- interest / cost of capital / opportunity cost – if money had to be borrowed to pay for the inventory, then the interest rate is part of the holding cost. If no loan was taken out specifically for the purchase of inventory, then the overall cost of capital must be estimated and included. In case inventory is paid for out of existing cash, then the opportunity cost (i.e. the return you would have gotten if the money was invested instead of spent on inventory) should be included.

- insurance – insurance costs directly related to total inventory value needs to be included.

- taxes - this applies if you are required to pay any taxes on the inventory value.

- risk of obsolescence / damage / theft - this can be highly subjective. Important point is to identify costs directly related to inventory levels. Risk of damage and theft, for example may not be a function of inventory levels, but rather a reflection of the location and/or operating conditions of the organization. A high percentage here is most likely a symptom of a much more serious issue than calculating the proper EOQ!

storage cost – misunderstanding is common in estimating storage costs for EOQ determination. Some companies add up all costs associated with their warehouse and divide it by the average inventory to determine the storage cost percentage. For our EOQ calculation, inventory holding cost should exclude costs that are not directly affected by the inventory levels. In certain cases, the inventory may need to be classified based upon a ratio of storage space requirements. For example, consider a hypothetical environment with only two products with same inventory levels. If product A is much larger in size and hence requires more storage space than B, then A should be assigned proportionally higher percentage for storage cost than B. If either product requires special storage conditions (e.g. cold storage), this factor should also be reflected in storage cost estimate. In instances where there is plenty of excess storage space and special conditions are unnecessary, incremental storage cost is zero. In such instances with excess space, incremental inventory reduction does not provide any actual savings in storage costs. One exception to this rule is when the required heating/cooling of the storage space for unused area is significant and avoidable.

Conclusion, Discussion and Recommendations

Now that we have a better understanding of each of the components in the EOQ formula, let's discuss common modifications/ considerations necessary in making this generic formula meaningful and practical.

- Per unit cost may not be static.

The EOQ formula assumes constant per unit cost, which may be an incorrect assumption. For example, vendor contracts sometimes require minimum order size for price discount. This volume discount logic can be programmed to work in conjunction with the EOQ formula. Instead of having a constant per unit cost, have it as a function of the quantity.

- Holding cost may not be static.

The EOQ formula assumes a constant holding cost percentage. Cost of capital, obsolescence risk and storage cost are all topics deserving discussions of their own. More often than not, these costs are not constant. For example, the interest rate a bank will charge is a function of several factors, including prevailing current economic conditions (which you have no control), the credit worthiness of your organization (which doesn't always stay the same), the amount of liability your organization already has, how risky the lender determines this project to be, etc. The matter is further complicated by the fact that it is quite impossible (especially in large organizations) to trace the amount spent on inventory back to specific funding source.

The best way to account for this is to perform a sensitivity analysis around the estimated holding cost percentage. First calculate the EOQ using the best estimate of holding cost and re-calculate the EOQ by varying the holding cost percentage by ± 1% point. As long as the results do not vary significantly, avoid dwelling on this topic for too long, as exact holding cost calculation is impractical to do.

- The consumption (or demand) may not be perfectly linear.

The EOQ formula assumes the consumption is perfectly linear. And based on this assumption, the average inventory during between the two orders is half the order size. This is rarely the case in real life. The demand comes in unpredictable pattern, often in large lumps followed by a period of much lower and/or infrequent consumption. Although over a long run, this may prove to be an acceptable assumption, review the actual patterns for your specific items. Significant seasonality effect needs to be factored in.

● Timing period does not have to be one year.

In almost all cases we encounter, the time period is one year. Proper time period should be chosen based on the demand characteristics of the specific item. Items with relatively short life spans (e.g. IT accessories) should use a much shorter time period in the EOQ calculation. Be careful of period longer than one year since it is more difficult to forecast demand over a longer term. If a time period other than one year is used, the usage and carrying costs must also be based on the same period.

● You may want to impose a maximum quantity.

Additional logic can be built into the generic EOQ formula to set maximum order quantity. This may be due to the vendor's capability (in case of purchased items) or your internal manufacturing capacity/scheduling constraints. Other reasons for imposing a maximum quantity may be to limit your exposure to obsolescence, to account for an item nearing the end of its life cycle or inherent short shelf life, etc.

● The inputs should be reviewed at least once a quarter.

The EOQ calculation is an on-going task. Business environment is in constant change, and the EOQ inputs should reflect the latest situation. For example, significant swings in demand forecast need to be reflected in the usage component of the EOQ calculation. Similarly, the cost per unit used in the equation must reflect any price changes as a result of negotiations or new vendors. To reflect the latest information and to ensure proper inputs, establish a regular review process.

● Determine how to implement.

Once all the inputs have been estimated, you can either calculate the EOQ in a spreadsheet and manually input them into your inventory system or program the refined EOQ formula directly into the existing system. An organization with less than a thousand or so SKUs can get by manually inputting the spreadsheet results into the system. For all other organizations, we recommend either changing the system or uploading the spreadsheet calculated values via a batch program. Regardless of how you decide to implement, remember to perform a sanity check on the results!

- Make further improvements, challenge / improve the environment.

If the generic formula has been properly modified and accurate inputs are used, the EOQ provides the most cost-effective quantity to order based on current operational environment. For further improvements, the environment must also be challenged. E-procurement, vendor-managed inventory, bar-coding and process re-engineering (e.g. set-up time reduction via lean techniques) are examples that can reduce ordering costs. More accurate forecasts, shorter lead/cycle times, equipment upgrades, preventive maintenance, etc. can also be used to reduce costs. EOQ calculation needs to be reviewed and revised to reflect the latest improved environment.

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