Cost concepts and EOQ

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Inventory Control In Power Utilities: Key Issues In Cost Concepts And EOQ

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Abstract:
This study explores the cost concepts, their implications and application of Economic Order Quantity (EOQ) models in the context of power generation facilities and other industries. EOQ serves as a fundamental tool for determining the optimal order quantity that minimizes total inventory costs, balancing the expenses associated with ordering and carrying inventory. The paper examines practical considerations and deviations from EOQ calculations in power plant settings, such as seasonal variations in fuel demand, shelf-life constraints of spare parts and various chemicals and other consumables, and the impact of bulk purchasing discounts from suppliers. These factors necessitate strategic decision-making to adjust order quantities and align inventory levels with fluctuating operational demands while ensuring cost efficiency and reliability.
Key Word: *Cost concepts, EOQ, inventory management, power plants, operational efficiency, cost-effectiveness.*

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I. Introduction

Inventory management is crucial for ensuring operational efficiency and cost-effectiveness in power generation facilities and various other industries. Central to this discipline are cost concepts that provide a framework for making informed decisions about inventory levels and procurement strategies. Understanding and managing these costs are essential for optimizing inventory management. The EOQ model, a fundamental tool in this domain, assists in determining the optimal order size that minimizes total inventory costs by balancing the expenses associated with ordering and holding inventory [1]. However, real-world applications often require adjustments/departures to theoretical models to account for practical considerations such as demand variability, shelf-life constraints, and supplier discounts [2]. This study explores these cost concepts in detail, highlighting their implications for inventory management and demonstrating how strategic adaptations of EOQ models can lead to significant cost savings as well enhanced operational efficiency.

II. Inventory Cost

Effective inventory management hinges on a thorough understanding of the associated costs, which directly influence inventory policies and decision-making. The three primary costs in inventory management that significantly impact inventory policies are as follows.

Inventory Carrying Cost

Inventory is liquid asset like money, but it is not as liquid as money in the bank. Money in the bank earns interest while it actually cost to maintain inventories. The main elements of inventory carrying cost are:

(a) Capital cost: This normally is the interest charges, which are to be paid to the bank and may be 8-12%. Interest rate, however, are variable and regulated/guided by monetary policy of Central Bank of the country, in India Reserve Bank of India or Federal Reserve or Fed in USA viz CRR (Cash Reserve Ratio), Repo Rate, Reverse Repo Rate, SLR (Statutory Liquidity Ratio) Marginal Standing Facility rate. If not paying interest for working capital than losing interest if the funds are deposited with bank which is known as Out-of-Pocket Cost. But it will be more realistic to consider opportunity cost of money (by opportunity cost is meant cost that is incurred in withdrawing funds from a productive activity to invest them in inventories. Opportunity cost of capital is rate of return earned by the company on its total investment. If this is considered then capital cost may be around 16-18% (in India)).

(b) Storage and handling cost: Most obvious inventory carrying cost & includes rent of storage facilities or depreciation if owned by the organization, salaries of personnel, Materials handling (this includes depreciation of handling equipments, fuel and maintenance cost and associated cost of manpower for operating equipments or hiring charges of equipment if outsourcing is done) and insurance; security and preservation of materials etc. Storage costs vary widely with type of material stored/storage facilities used and may be 2-5% of the value of the materials stored per year.

(c) Deterioration and obsolescence cost: Usage of every material cannot be judged very accurately and some material gets stored for a longer time than what is generally desirable. This results in deterioration of materials, which is very high for certain type of material such as paints, rubber goods, electrodes etc. Obsolescence is one of prices paid for industrial & technological advancements. With rapid changes in design and engineering, obsolescence becomes a very alarming problem. Obsolescence cost is high regarding store and spares required for maintenance of plants subject to rapid technological changes such as control & instrument, computer hardwires and other electronic items and low in regard to stabilized items of stores and raw materials [3]. Larger accumulation of inventory and higher is the risk of wastage and obsolescence, which may be 2-5%.

If for capital cost, market rate of interest may be adopted, inventory-carrying cost may lie between 15-20%. On the other hand if opportunity cost of capital is to be considered, it may well lie between 18-22% (in context of Indian industries).

Purchasing or Ordering Costs/Set up Cost

Ordering cost covers cost of originating an indent (Purchase Requisition), calling of offers/tenders (RFQ-Request for Quotations), processing tenders (technical and commercial evaluation of offers) preparing and vetting of comparative statement/quote analysis to find out evaluated lowest offer, preparing purchase proposal and approval from competent authorities in the organization as per Delegation of Power, placing the order, inspection, verifying the invoices and payments to vendors/suppliers. Composition of buying cost can be grouped as under:

(a) Purchase: Cost of inviting tenders (RFQs) and fixing most suitable supplier for item (involving technical and commercial scrutiny/evaluation). It is the cost of preparing and placing order.

(b) Expediting & Miscellaneous costs: includes salary of purchase personnel, administrative and over-head costs, expediting cost, other miscellaneous cost (communication, postage or courier charges, canteen facilities etc).

(c) Receipt & Inspection: includes cost of receiving and handling, cost of inspection (both pre-dispatch inspection at suppliers works and at destination after receipt at stores). This cost may be substantial if for critical materials third party services are utilized for inspection. Cost of delivery from receiving to stores or direct to using department.

(d) Set-up Cost: When inventory control refers to manufactured item, corresponding cost is set up cost. Every time a production run is taken up, there is loss of machine time, operator time etc. which is included in set up cost. Set up cost also includes cost of paper work, inspection, etc. involved with every production run. Set up cost increases when the batch sizes are smaller and the number of batches is large but it is less if batch size is large per unit manufacturing cost will be low. As a result of this in the manufacturing optimum batch size is worked out keeping in view the set-up cost.

Stock-out/ Non-availability Cost

When an item is required and is not available in stock (or requisite quantity not available), it is called "stock-out". As a result, certain consequences follow and there is a certain cost associated with those consequences which is known as stock-out cost or non-availability cost. If consequences are serious such as break down/ shut down of plant and machinery, men idle time, loss of production and profit, failure of customer services and resulted loss of goodwill, stock-out cost is considerable. On the other hand, a stock-out may involve a little more than an effort in expediting, stoppage of work in the area which is insignificant and, in that event, cost would be negligible [4].

Unlike inventory carrying, stock-out cost is highly variable from item to item, place to place and situation and depends upon both intangible and tangible factors so that its determination is much more complicated than that of possession costs i.e. ordering cost and inventory carrying cost.

Each firm has to calculate its own stock-out costs for different items at different times. For example, stock out of a critical spare not readily available in market, may be tremendous. On the other hand, stock-out cost of a supply item of a non-critical nature, readily available (mass production items), may be insignificance

Working out stock-out cost

In case of 'down time' due to stock out of production materials, another product or a change in schedule can also be considered. Alternative may not apply while considering 'down time' due to machinery itself. It is necessary to calculate real stock-out cost which is attributable to stock out of spares and is only cost of additional down time due to such stock-out. Portion of down time directly attributable to necessary maintenance work itself cannot be shown as the stock out cost of spare part. For example, if maintenance work has actually been held up for a day for want of a spare, only one day time is attributed to stock out cost of item. Subsequent maintenance may require another two days before machine is put into operation. These two days down time cost cannot be part of stock out cost of item.

There may be a situation where plant is to shut down for periodical overhaul. But 2 hours before the scheduled shut down a critical spare fails and the same is not available. Even if the spare is available, it shall not be replaced. Suppose overhaul takes 3 weeks time and within this period spare is made available, virtually there is no loss of power generation due to immediate non-availability. It is therefore more realistic to base the stock out cost on the actual loss in production rather than merely on down time. The stock out cost comprises of:

1. **Actual loss of production:** This arises from added down -time or running the plant at lower capacity
2. **Additional set up costs:** These costs are due to changes in schedule (production of another item, if feasible), such as extra setups and associated logistical expenses (such as change of tools and jigs. paper work including issue of work order)
3. **Additional procurement costs (rush purchases):** This includes costs like air freight, deputing personnel to supplier works or far away markets to procure the necessary items and other procurement related expenses.
4. **Higher prices for items:** These include cost due to special pick-up arrangements, procuring higher quality items then actually required, and paying premium prices for quick availability.

To address these stock-out costs, VED analysis (Vital, Essential and Desirable) categorizes items based on their Criticality and related stock-out cost. Items with very heavy down time cost, are categorized as vital items. Due to the significant stock-out costs of critical spares, which attracts immediate adverse attention of management, there is often a tendency to overstock these items. However, when left unchecked, inventories can grow beyond economic limits, leading to excessive carrying costs and inefficiencies [3].

III. Economic Order Quantity (Eoq)

Behavior of inventory carrying cost/ stock holding cost and ordering cost is opposite to each other i.e. if one is increasing the other is decreasing. If we order frequently an item in a year, naturally in small quantities, ordering cost shall increase but inventory carrying cost shall be reduced (it is calculated on half of order quantity/value). As against this if we purchase this item infrequently, naturally order quantity shall be more. As a result, ordering cost shall be reduced but inventory carrying cost shall be increased. Both the cost costs shall be balanced when they are equal and the order quantity that represents this equilibrium is known as Economic Order Quantity (EOQ) [5-7].

In power plant operations and other industries, maintaining an optimal inventory of critical components and spare parts is essential to ensure uninterrupted functionality and prevent costly downtimes. The EOQ model plays a vital role in achieving this balance by determining the ideal order quantity that minimizes total inventory costs. EOQ helps power plants manage the trade-off between ordering costs and holding costs, ensuring that inventory levels are sufficient to meet demand without incurring excessive storage expenses. By applying the EOQ model, power plants can optimize their inventory management practices, reduce Total Incremental Cost (TIC), and enhance overall operational efficiency. The model accounts for Total Ordering Cost (TOC) and Inventory Carrying Cost (ICC)/ Inventory Holding Cost, providing a comprehensive framework for inventory control. These two costs are opposed to each other. If purchases are made infrequently i.e. in large quantities, ordering cost shall small but inventory- carrying cost shall be large. On the contrary, if purchases are made very frequently, i.e. in small quantities, inventory- carrying cost will be less but ordering cost shall be large (Inventory Carrying or Holding Cost is calculated on half of order quantity/value (see Fig.1).

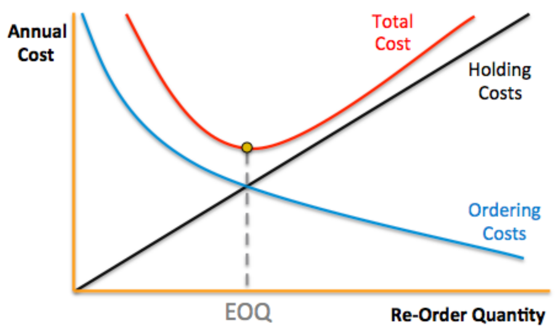

Fig.1: Graphical presentation of Economic Order Quantity

Implementing EOQ allows power plant managers to make rational decisions about when and how much to reorder, thus maintaining a seamless supply chain and supporting continuous power generation. In our analysis we wish to determine the optimal order quantity for a particular time of inventory given, its forecasted usage, ordering cost and carrying cost.

Exhibit 1:

Consider a power plant X that needs to manage its inventory of a critical component efficiently, having annual consumption of the item (A) is Rs.3,60,000, ordering cost per order (S) is Rs.1,000, and inventory carrying cost as a percentage of inventory value (I) is 20%. Given these parameters, if orders are placed in various quantities (Q), the corresponding number of orders, inventory carrying cost, and total cost can be calculated as follows:

Table 1: Analysis of total order cost and inventory carrying cost at different order quantities

Order Quantity (Q)	Number of Orders (A/Q)	Average stock to handle (Q/2)	TOC (A/Q x S)	ICC (Q/2xI)	Total Cost (TOC+ICC)
15,000	24	7,500	24,000	1,500	25,500
22,500	16	11,250	16,000	2,250	18,250
36,000	10	18,000	10,000	3,600	13,600
45,000	8	22,500	8,000	4,500	12,500
60,000	6	30,000	6,000	6,000	12,000
90,000	4	45,000	4,000	9,000	13,000
1,20,000	3	60,000	3,000	12,000	15,000
1,80,000	2	90,000	2,000	18,000	20,000
3,60,000	1	1,80,000	1,000	36,000	37,000

From the Table 1, we can observe the following:

1. **Optimal Order Quantity:** The order quantity of 60,000 units results in the lowest total cost of Rs. 12,000. This is because the TOC (Rs. 6,000) and the ICC (Rs. 6,000) are balanced, minimizing overall expenses.
2. **TOC:** The total order cost decreases as the order quantity increases. This is due to fewer orders being placed, reducing the cumulative ordering cost.
3. **ICC:** The inventory carrying cost increases with larger order quantities because more inventory is held for longer periods.
4. **Trade-Off Analysis:** Smaller order quantities (e.g., 15,000 units) result in higher total costs (Rs. 25,500) due to frequent ordering, while larger quantities (e.g., 3,60,000 units) lead to high carrying costs (Rs. 37,000). The EOQ model helps identify the point where these costs are minimized.

By applying the EOQ model, power plants can determine the optimal order quantity that minimizes total costs, ensuring efficient inventory management and uninterrupted operations. This example demonstrates how varying order quantities impact both ordering and carrying costs, facilitating managers in making rational decisions about inventory control. EOQ can be determined by graphical approach or mathematically.

Graphical Approach

Fig. 2 visually represents the EOQ analysis for power plant operations.

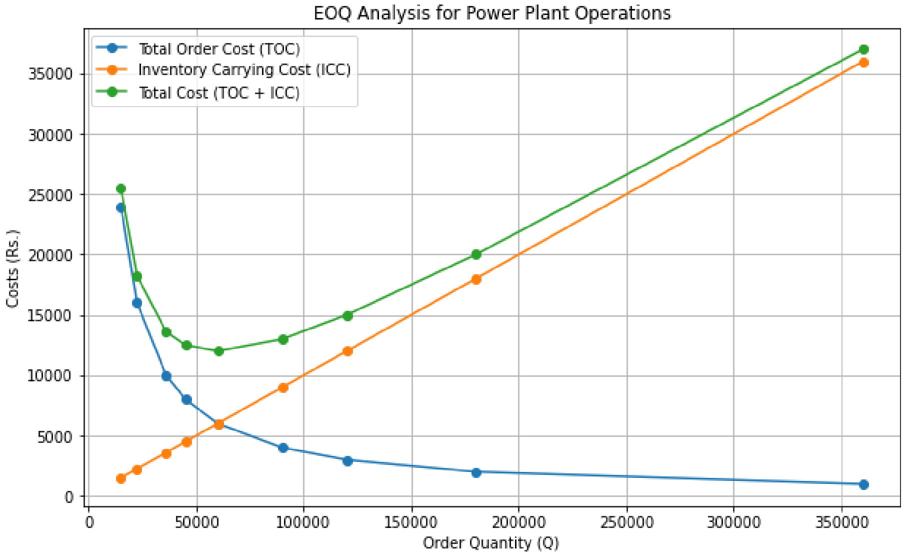

Fig.2: EOQ for Exhibit 1

This graphical representation helps in understanding the trade-offs between ordering and carrying costs and aids in making informed decisions about inventory management.

EOQ Formula approach

Using the same information of Exhibit 1, the following deals with the mathematical approach, which is widely used in determining the EOQ in inventory control system. In this we calculate EOQ using the classic EOQ formula,

$$\text{EOQ} = \sqrt{\frac{2AS}{I}} \qquad (1)$$

For the given parameters, $\text{EOQ} = \sqrt{\frac{2\times 360000\times 1000\times 100}{20}} = 60{,}000$

In case, the annual consumption (A) is in units instead of Rs. as above, formula shall be as under:

$$\text{EOQ} = \sqrt{\frac{2AS}{PI}} \qquad (2)$$

where, P is the price per unit.

Derivation of EOQ formula

The EOQ formula helps in determining the optimal order quantity that minimizes the total inventory costs. Here is a step-by-step derivation of the EOQ formula (the terms A, Q, S and I have meanings as already described in the Exhibit 1 data):

(i). Average inventory $= \frac{Q}{2}$ (3)

(ii). Inventory carrying cost ICC $= \frac{Q\times I}{2}$ (4)

(iii). Number of orders per year $= \frac{A}{Q}$ (5)

(iv). Ordering Cost $= \frac{A\times S}{Q}$ (6)

(v). Minimizing total inventory cost: for minimum cost inventory the two costs are equal i.e.,

$$\frac{Q\times I}{2} = \frac{AS}{Q} \qquad (7)$$

(vi). Solving for EOQ

$$Q^2 = \frac{2AS}{I} \text{ i.e., } Q = \sqrt{\frac{2AS}{I}} \qquad (8)$$

This formula is further simplified, when used for a particular organization.

$$\text{EOQ} = \sqrt{\frac{2AS}{I}} = \sqrt{\frac{2S}{I}} \times \sqrt{A} \qquad (9)$$

The above expression is reduced to:

$$\text{EOQ} = K\sqrt{A} \qquad (10)$$

Where, K is constant and its value will be 100 for an organization where ordering cost is Rs. 1000 and carrying cost is 20%

(vii). Calculate optimum number of orders and ordering frequency using the EOQ formula,

$$N = \sqrt{\frac{AI}{2S}} \qquad (11)$$

where, annual consumption has to be in monetary value and not in unit.
Quantity of each optimum order will be EOQ as under:

$$Q = \frac{A}{N} = \frac{A}{\sqrt{\frac{AI}{2S}}} = \sqrt{\frac{2AS}{I}} \quad \text{i.e. formula of EOQ discussed earlier} \qquad (12)$$

IV. Modification Of EOQ Formula

EOQ formula derived in Eq. (9) is based on assumption that with increase or decrease in number of orders, ordering and carrying costs also increases or decreases proportionately. Both costs have some non-variable elements [8], [9]. For example, with an increase of 20% in the inventory, salary of store personnel is not going to increase by 20%. Similarly, if number of orders is reduced by 10%, salary of purchasing staff will not be reduced by 10%. However, if we consider that not all costs (carrying and ordering) vary directly with the quantity ordered or held (some costs may have fixed components), the EOQ formula can be modified to include only the variable portion of these costs:

It is, therefore, logical to consider only the variable portion of ordering and carrying costs.

$$EOQ = \sqrt{\frac{2AS_v}{l_v}} \tag{13}$$

where, S_v and l_v represent variable portion of each cost.

V. Practical Aspects Of EOQ

EOQ is a powerful tool in inventory management that helps businesses optimize costs, improve efficiency, and maintain adequate inventory levels to meet customer demand while minimizing the risks and costs associated with holding inventory. Normally, purchases shall be guided by EOQ calculations but practical departure can be made for good and valid reasons. The following practical consideration should be kept into consideration while working out standard order quantity which suggest to buy different quantities than EOQ:

(a) Shelf life of items (items like cement, refractory, paints, rubber items, laboratory chemicals, bulk chemical etc.).
(b) Seasonal availability of items.
(c) Liberal discounts offered by vendors for bulk purchases (each such case shall be thoroughly analyzed to workout saving due to discounts and additional inventory cost due to higher ordered quantities)
(d) Economy in transportation cost (keeping in view the carrying capacity of transport vehicle like trucks, trailers, railway wagons, containers etc)
(e) Ordering in economic trade packing (items like lubricants, paints etc)
(f) Simplification of routine- i.e. placing 2 orders in a year as against 3 as per EOQ calculations.

VI. Cost Impact Of Deviations From EOQ

If changes in order quantity are made ranging from 65% to 155% of theoretically calculated EOQ, total cost increase will be less than 10%.

The formula $\frac{C-Co}{Co} = \frac{(r-1)^2}{2r}$ quantifies the cost impact of ordering a quantity q instead of q_0(EOQ).

Where, $r = \frac{q}{qo}$, Co is the cost associated with EOQ, C is the cost associated with any quantity other than EOQ.

If changes in order quantity are made ranging from 65% to 155% of theoretically calculated EOQ i.e., ranges from 0.65 t0 1.55, the total cost increase will be less than 10%.

These exceptions reveal that the quantitative aspect of EOQ has to be supplemented by executive decisions. The formula takes into consideration the ordinary cost factors but executive decision takes into consideration extra-ordinary limiting factors and compelling situations. While EOQ provides a structured approach to minimize inventory costs, executive decisions play a pivotal role in addressing exceptional circumstances and making strategic adjustments. By balancing quantitative analysis with qualitative insights and situational awareness, organizations can optimize their inventory management practices effectively. This approach not only ensures operational efficiency but also enhances responsiveness to dynamic market conditions and customer expectations. Thus, while EOQ sets a baseline, executive decisions add the necessary flexibility and strategic foresight to maximize overall organizational performance. While large deviations from EOQ should be scrutinized, ordering the nearest practical quantity to EOQ is a pragmatic approach to balance efficiency with flexibility [10].

VII. Assumptions In EOQ Calculations

The assumptions on which EOQ calculations are based shall be summarized as under:

(a) By and large uniformity of demand i.e. continuous and at a constant rate i.e., by and large stable consumption pattern.
(b) Absence of any limitations imposed by stores capacity.
(c) Order and delivery quantities are equal (no phased or staggered deliveries).
(d) There shall be no loss in value other than allowed for in computing possession costs arising from deterioration and obsolescence.
(e) The prices of materials are stable and no discount available.
(f) Lead- time is fixed and not variable.

Even if all the above assumptions do not hold exactly, EOQ shall give us a good indication as to whether the current ordered quantities are reasonable.

In view of these assumptions and limiting factors, formula of EOQ shall be of little use in dealing with materials whose price or usage fluctuates rapidly or the materials whose usage cannot be predicted with a reasonable degree of accuracy. Under such circumstances an EOQ, which is correct today may not be valid for tomorrow.

VIII. Conclusion

The cost concepts and the EOQ approach may be applicable to every type of business and industry. It is typically used in a manufacturing, maintenance and distribution environment where the ordering of stock is constant and repetitive. This paper provides a comprehensive overview of the EOQ model, a foundational tool for optimizing inventory management in contemporary organizations. It addresses the scarcity of current research focusing on the classic EOQ model compared to its more complex variants. The relevance of EOQ fundamentals, particularly within the context of power utilities, is emphasized. The use of a numerical example illustrates how the EOQ model offers straightforward yet powerful solutions to basic inventory control challenges. This pedagogical approach not only enhances understanding among inventory managers but also underscores the model's practical applicability in real-world scenarios. Furthermore, this paper aims to achieve the following specific objectives:

i. Reviewing Underlying Assumptions: Enhancing the understanding of modern inventory managers by reviewing the foundational assumptions of the basic EOQ model.
ii. Describing Vital Variables and Formula: Describing the essential variables and formula of the EOQ model in its classic format, highlighting their critical role in inventory management.
iii. Identifying Emerging Aspects: Identifying areas where modifications or adaptations of the classic EOQ model may be necessary to accommodate evolving operational environments.

In conclusion, this study underscores the enduring importance of the EOQ model in strategic management education and its potential for further adaptation to meet the evolving needs of modern organizations. By understanding and applying the EOQ model's principles, managers can optimize inventory levels, reduce costs, and enhance operational efficiency effectively.

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