A comparative analysis of inventory costs of JIT and EOQ purchasing

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Introduction
Manufacturing companies that use economic order quantity (EOQ) purchasing, either classical EOQ model or a variation thereof, increasingly are faced with the decision of whether or not to switch to the just-in-time (JIT) purchasing policy. This is a complex decision, requiring careful examination of each system and its possible impact on a variety of factors, such as cost, quality, and flexibility of the operations. This creates a need for a comparative analysis of these two popular inventory management practices, and an examination of the many factors that enter in such a decision. Quantifying and comparing the costs of these models should be an integral part of such an analysis.

Just-in-time is one of the most celebrated modern manufacturing techniques and its use has helped many firms in becoming more productive and competitive. JIT is designed to virtually eliminate the need to hold items in inventory. It is defined as: “to produce and deliver finished goods just in time to be sold, sub-assemblies just in time to be assembled into goods, and purchased materials just in time to be transformed into fabricated parts” (Schonberger, 1982). However, the benefits associated with JIT generally surpass the mere savings in inventory holding costs. A well implemented JIT system will also result in improved quality, lower manufacturing costs, lower ordering costs, elimination of waste, streamlining of the production process, and the elimination of production process bottlenecks (Rao and Scheraga, 1988). Most JIT companies view JIT purchasing as a significant component of their JIT implementation and a major factor in their success (Billesbach et al., 1991).

Despite the impressive success of JIT programmes, many companies still use the traditional approach to determine their purchase orders. This is particularly true for small manufacturing firms who cannot effectively implement JIT purchasing (Temponi, 1995). The traditional inventory management practices centre around the economic order quantity model which focuses on minimizing the inventory costs rather than on minimizing the inventory (Johnson and Stice, 1993).

According to the EOQ model, a manufacturer places several orders to its suppliers every year, with the size of each order (order quantity) being enough to satisfy the production demand for a certain period of time. For this model, the most economical order quantity that minimizes the total annual costs can be obtained mathematically. These costs include: the cost of carrying goods in inventory; the transportation and clerical costs of placing the orders; and the...
purchase price of the items. These costs can be further broken down into more specific costs. For instance, carrying cost consists of the cost of physical storage, opportunity cost of the working capital tied up in purchased goods, taxes and insurance paid on inventory items, and inventory spoilage and obsolescence (Gaither, 1996).

There is a large number of studies comparing EOQ and JIT systems (Chyr et al., 1990; Hong et al., 1992; Johnson and Stice, 1993; Jones, 1991; Lee and Ansari, 1985; Ramasesh, 1990; Sauers, 1986). Most of these studies advocate the use of JIT over EOQ. However, in a comparison of JIT and EOQ, Johnson and Stice (1993) conclude that “traditional inventory management techniques may under-emphasize the costs of maintaining large inventories. JIT may under-emphasize the costs of not maintaining inventories, particularly since such costs are often difficult to identify and measure”. In another study, Jones (1991) states that most manufacturers ignore some relevant and important costs associated with carrying inventory, and thus do not calculate EOQ lot sizes correctly. He argues that correct usage of the EOQ model will result in lot sizes that closely approximate JIT lot sizes.

This paper complements the existing literature by developing a mathematical model that evaluates and quantitatively compares the variable costs associated with the EOQ and JIT models in purchasing materials and parts from suppliers. The model examines the impact of different factors on the cost performance of the two systems, allowing for the assessment of the conditions under which a company would be better off using one of these two models.

**Model**

**EOQ costs**

The materials purchased by a company may have a regular consumption pattern or be consumed irregularly. It is the regularly consumed items that account for most of the purchasing and inventory costs. For these items annual demand and consumption patterns can be determined in advance and used as the basis for negotiation with suppliers (Joshi and Campbell, 1991). The economic order quantity model is most suited for determining the order size for such items.

In the classical EOQ model the total annual cost of an item ($T_{CE}$) is the sum of the cost of delivered goods, inventory ordering cost, and carrying cost, or:

$$T_{CE} = \frac{kD}{Q} + \frac{Qh}{2} + P_{E}D$$

(1)

where $D$ is the annual demand for the item, $Q$ is the quantity ordered each time, $k$ is the cost of placing one order, $h$ is the annual inventory carrying cost per unit, and $P_{E}$ is purchase price per unit. The first term on the right hand side is the annual ordering cost, the second term is the annual holding (carrying) cost, and the last term is the annual purchasing cost (Gaither, 1996).
The EOQ model has been a popular method for estimating the most economic order size that would minimize the total cost. The optimum order quantity \( Q^* \) is given by:

\[
Q^* = \sqrt{\frac{2kD}{h}}
\]

and results in an annual total cost of:

\[
TC_E = \sqrt{2kDh} + P_E D
\]

JIT costs
Under the JIT system, much of the holding costs and some components of the ordering costs (e.g. preparation of purchase orders for each delivery) can be significantly reduced or eliminated. Other costs such as transportation and inspection costs can be reduced by having the suppliers locate near the buyer's plant or by improving the quality at the suppliers' facilities. The remaining costs associated with holding or ordering items (e.g. storage, inspection, or transportation costs that have not been eliminated) are transferred to suppliers and are in turn charged indirectly to the buyer as a part of the purchase price. Therefore, the annual cost to the buyer under JIT purchasing is the product of the annual demand \( D \) and the unit price \( P_J \), where \( P_J \) includes the portion of holding and ordering costs that are passed on to the buyer.

\[
TC_J = P_J D
\]

Cost difference
Let \( Z \) represent the difference between the costs of EOQ and JIT, then:

\[
Z = \sqrt{2kDh} - (P_J - P_E)D
\]

Rearranging equation (5) by multiplying and dividing the term under the radical by \( P_E \) and factoring out \( P_E \) from the second term leads to:

\[
Z = \sqrt{\frac{2kh}{P_E}} C - \left(\frac{P_J}{P_E} - 1\right) C
\]

where \( C \) is the dollar value of the annual demand \( (C = DP_E) \). The first term on the right hand side of this equation represents the total holding and ordering costs under EOQ, and the second term represents the purchase cost difference between JIT and EOQ.

The indifference point
EOQ will be the less costly alternative for \( Z < 0 \), whereas JIT is the preferred choice for \( Z > 0 \). The root of equation (6) is the indifference point \( (C_{ind}) \) which is
the level of annual demand (in $) at which the total cost of EOQ and JIT are equal. This value is given by:

$$C_{\text{ind}} = \frac{2kh}{D_{\text{ind}} P_E}$$  \(7\)

Note that since by definition $C_{\text{ind}} = D_{\text{ind}} P_E$, where $D_{\text{ind}}$ is the quantity of the annual demand at $Z = 0$, then:

$$D_{\text{ind}} = \frac{2kh}{(P_J - P_E)^2}$$  \(8\)

The analysis is done for demand levels measured both in units and in dollars, since for some manufacturers the information on annual demand for an item is more readily available in the form of total money spent on purchasing the product ($C$), and for others in the form of the units demanded ($D$).

Maximum JIT purchase price

For an item with a given demand, $D$, we can also find the highest price, $P_{J_{\text{max}}}$, that the manufacturer can pay to purchase the item on a JIT basis and still be economically better off than using EOQ purchasing. $P_{J_{\text{max}}}$ is obtained by setting $Z = 0$ in equation (5) and solving for $P_J$, resulting in:

$$P_{J_{\text{max}}} = \sqrt{\frac{2kh}{D}} + P_E$$  \(9\)

For prices higher than $P_{J_{\text{max}}}$, $Z$ will be negative, making EOQ a lower cost alternative.

Discussion of results

Ideally, traditional costs associated with the EOQ model are either eliminated or substantially reduced under the just-in-time philosophy. These costs include storage, capital, insurance, ordering, and transportation costs. Waters-Fuller (1996) and Golhar and Sarker (1992) argue that, under certain conditions, it is also to the economic advantage of a supplier to use JIT production and to frequently deliver small quantities to a JIT manufacturer. This would enable the supplier to pass some of these savings to the manufacturer by offering the items at a lower price.

If a JIT supplier can deliver an item at a price below the EOQ delivery price (i.e. $P_J < P_E$), then both terms on the right hand side of equation (5) will be positive, making $Z$ always positive. Under these ideal circumstances the manufacturer will be economically better off to choose JIT over EOQ for any level of demand since JIT will result in a simultaneous reduction in purchase price, holding costs, and ordering costs.
The author's observations of some major JIT companies, and some of the literature in the field (Chhikara and Weiss, 1995; Waters-Fuller, 1996), indicate that for many companies the reality is different from this ideal situation. In practice, many suppliers of JIT manufacturers produce their products in large batches and respond to the JIT challenge by keeping large quantities of items in their inventories even though they may deliver them in very small quantities (Newman, 1988). Quality control, inspection, and transportation arrangements will also become the responsibility of the JIT supplier, which if not properly managed could add to the supplier's costs. Also, inventory, whether held at the supplier's facility or the buyer's site, will eventually add to the buyer's cost (Chandrashekar, 1994).

It is therefore reasonable to assume that, in the absence of a holistic system in which both suppliers and manufacturers operate under a perfect JIT system, the supplier would pass some of the costs to the JIT manufacturer in the form of higher prices to at least partially reflect ordering and holding costs that have not been eliminated. This translates into higher per unit purchase (delivery) price for the JIT manufacturer (Willis and Huston, 1990). Under these conditions, JIT will become superior in cost performance only when the annual demand \(C\) or \(D\) of an inventory item is lower than the indifference or break-even point \(C_{\text{ind}}\) or \(D_{\text{ind}}\). As annual demand increases past this point, EOQ becomes the preferred method for controlling inventory orders. That is, for any item there is an annual demand level beyond which JIT becomes the more costly alternative. The cost difference between EOQ and JIT is maximized for a demand level \(C_{\text{max}}\) (or \(D_{\text{max}}\)) at which JIT has the highest cost advantage over EOQ. It can be shown that \(C_{\text{max}} = C_{\text{ind}}/4\) and \(D_{\text{max}} = D_{\text{ind}}/4\).

Impacts of holding and ordering costs
As can be seen in equation (8), the break-even demand is directly proportional to the holding cost, making JIT a better alternative for a wider range of demand for items with high holding cost. This confirms the expectation that when inventory holding cost is high, the JIT system will become more attractive. Holding costs reflect the costs of capital, insurance, obsolescence, damage, etc. These costs are difficult to estimate and the tendency is to under-estimate the real cost of holding inventories. JIT purchasing will prove itself advantageous once the true costs of holding inventories are used in the calculations, making it best suited for items that tend to have higher prices, or higher obsolescence or damage rates as a result of storage. The exception will be when the total inventory held in the supplier-manufacturer system does not decrease, or even increase significantly for the supplier as a result of JIT (Waters-Fuller, 1996), in which case \(P_f\) may increase so much that it would make JIT unattractive.

Equation (8) also shows that items with high ordering costs \(k\) have a wider demand range over which JIT is preferable, consistent with the expectation that under JIT efforts will be made to lower the ordering cost which includes such costs as order processing, inspection, and transportation. Purchasing items from suppliers that are located in the proximity of the manufacturer can significantly lower the transportation costs and is typically associated with JIT practice. Streamlining and modernizing the ordering process and reducing the
cost of receiving the items should also reduce the ordering costs if JIT is to be implemented.

For industries, such as electronics, in which purchased items are expensive but not bulky, transportation cost is a relatively insignificant part of the overall inventory costs, making these industries particularly good candidates for JIT purchasing. For these items holding cost is high and more frequent deliveries will reduce inventory without much increase in $P_J$, leading to a high level of $C_{ind}$ or $D_{ind}$, making JIT preferable even for higher levels of demand. Items with high ordering cost for which significant reduction in ordering cost is not possible or practical are not suitable for JIT purchasing since they will inevitably have high $P_J$. For instance, some items purchased from overseas suppliers have high transportation costs with little prospect of significant reduction in such costs, making JIT delivery of such items cost prohibitive.

Impact of purchase price
As can be seen in equation (8), the larger the premium the manufacturer pays for purchasing items on a JIT basis ($P_J - P_E$), the smaller the range of annual demand for which JIT is preferred. Equation (9) establishes the threshold price level below which the total annual cost under JIT will be lower than EOQ for a given level of demand and other operating conditions. JIT is less costly than EOQ only as long as the JIT purchase price is below $P_{J\max}$. Equation (9) also shows that as the level of demand ($D$) increases, $P_{J\max}$ will decrease, indicating that for an item with a high level of demand JIT will be the superior alternative as long as its price premium is very low. When JIT is implemented correctly and holistically, $P_J$ is expected to be very close to $P_E$ (if not equal to or less than $P_E$), in which case JIT will be preferred even for items with very high levels of demand.

Fixed costs
It should be noted that the preceding analysis focuses on the variable costs associated with JIT and EOQ purchasing (i.e. costs that are dependent on demand and/or order size for each item). A choice between JIT and EOQ will also impact the fixed costs. Certain fixed costs under EOQ, such as the costs associated with operating some storage facilities which include rental, utilities, and personnel salaries of these facilities, may be eliminated under JIT. A JIT purchasing significantly reduces the paperwork volume and saves time for purchasing personnel by using long-term contracts instead of multiple purchase orders and by sharing the buyer's production plans and schedules with trusted suppliers and integrating the suppliers into buyer's purchasing programme (Ansari and Modarress, 1990). Companies that purchase materials based on JIT also make more periodic payments rather than paying for every delivery (Sandras, 1989). These may lead to a reduction in the number of purchasing personnel and a saving in the fixed costs.

In some cases, instead of making the transportation arrangements the responsibility of the suppliers, JIT buyers ask their suppliers to formulate their quotes for purchase price of the material excluding shipping charges. In this
case the purchase price (\(P_J\)) will be lower but transportation costs will have to be added to the costs of JIT purchasing. Sandras (1989) provides examples of JIT companies who try to minimize their transportation costs by having long-term contracts with transportation companies who would make a circuit through the suppliers and return to the factory on a regular basis. The buyer would then be charged a fixed transportation cost independent of the number of units picked up at each supplier plant, and regardless of whether the truck was full or empty.

The difference in variable costs associated with the two inventory models can be predicted by the analysis presented in this paper. To obtain a more realistic assessment of the overall savings, the difference in pertinent fixed costs for each system should also be estimated and added to the predicted savings in variable costs.

An example

The model presented in this paper is further illustrated by means of an example. Let us assume a manufacturer is considering to switch from EOQ to JIT for purchasing a given item. Purchasing the item according to the EOQ model costs \(P_E = \$40/\text{unit}\). The estimated annual holding cost per unit is \(h = \$12\) (30% per cent of the purchase price), and ordering cost is \(k = \$500/\text{order}\). If he purchases the item on a just-in-time basis the cost will be \(P_J = \$40.4/\text{unit}\). Therefore, from equation (8) \(D_{\text{ind}} = 75,000\) units \(\left(C_{\text{ind}} = \$3,000,000\right)\), and at \(D_{\text{max}} = 18,750\) units \(\left(C_{\text{max}} = \$750,000\right)\) the cost advantage of JIT is at a maximum of \$7,500/year for this item. Figure 1 is a graphical representation of the cost difference between EOQ and JIT as a function of annual demand (equation 8).

Figure 1 indicates that as demand increases, the cost difference between EOQ and JIT widens rapidly until a point where this difference is at its maximum \(\left(D_{\text{max}} = 18,750\right)\). As the annual demand increases beyond this point, the cost advantage of JIT begins to gradually fade, until the two costs become equal at a demand level of 75,000 units. For annual demand above this level, EOQ is the more cost-effective alternative.

On the other hand, for a given demand such as 80,000 units a year, JIT will be preferred to EOQ as long as \(P_J\) is less than \(P_{J_{\text{max}}} = \$40.39\) (equation 9). This is consistent with our earlier observation in Figure 1 that for a higher \(P_J\) \(\left(\$40.4/\text{unit}\right)\), for a demand of 80,000 units a year, EOQ would be less costly.

Conclusion

In this paper, a mathematical model has been developed to compare the annual cost of inventory for JIT and EOQ purchasing. The model establishes an upper limit for the purchase price of any item under JIT, above which JIT will be more costly than EOQ. Determination of this price level provides valuable information for companies when negotiating a delivery price with their JIT suppliers. In addition, the study presents an equation for determining the indifference point between the two systems (level of demand at which the costs are the same), and identifies under what conditions one system is superior to the
other from a cost perspective. The results indicate that the choice of the most appropriate system depends on many parameters.

The break-even demand is a function of EOQ and JIT delivery prices and inventory holding and ordering costs. The analysis of the indifference point formula indicates that EOQ can be expected to remain competitive for items with higher levels of annual demand. Also, the lower the carrying cost or the ordering cost associated with the EOQ model, the lower will be the point of indifference between the JIT and EOQ models, and the wider the range of demand over which EOQ is cost effective. JIT gains in competitiveness as demand for the inventory item or JIT price premium decrease, or the EOQ inventory holding cost or ordering cost increase. This is, however, based on the expectation that with JIT purchasing overall level of inventory in the supplier-manufacturer chain will diminish, and measures will be taken to lower the ordering and transportation costs. Otherwise, the purchase price under JIT might increase so much that would make JIT less attractive for any level of demand.

These results may explain in part the mixed enthusiasm and success among manufacturers in the application of JIT purchasing. Since the parameters establishing the break even point vary from one product to another, the most suitable purchasing policy in a given manufacturing environment may well be a combination of both systems. In fact, a mixed approach is a common practice among manufacturing facilities in which some of their inventory items are purchased according to JIT and some others by EOQ.

It should be noted that these results are based on the analysis of direct and variable inventory costs associated with the two inventory systems. The benefits associated with the proper implementation of a JIT system usually
surpass the mere savings in inventory costs. Thus, the decision to implement a JIT system may be advisable even though inventory cost considerations per se may not justify the choice. The analysis presented in this paper must be complemented with an evaluation of other factors, such as the impact of different purchasing policies on quality and flexibility of the operations, before a final choice is made between EOQ and JIT purchasing.

References