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Inventory Control Policy with Pricing and Stock Dependent Demand: Latest Trend

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Abstract

Inventory is the physical stock of items held in any business for the purpose of future production or sales. In a production shop, the inventory may be in the form of raw materials. When the items are in production process, we have the inventory as work in-process inventory and at the end of the production cycle: the inventory is in the form of finished goods. An inventory management helps a lot in optimizing the inventory. It helps in maintaining the inventory in adequate quantity and supplying the same at desired timings. As we know that 2/3 of the capital of the organization blocks in the form of Inventory. So, ever manager of the organization try to develop different inventory policies to increase the profit of the organization. Pricing policy and stock dependent demands is the key policies through which manager increases the demand and hence makes the profit for the system. In this paper, latest work in the field of inventory control for pricing policy and stock dependent demand are presented.

Keywords: *Inventory, Pricing Policy, Stock dependent demand*

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1. INTRODUCTION

Operations Research is a discipline that deals with the application of advanced analytical methods to help to make better decisions. The terms management science and analytics are sometimes synonyms for operations research. Operations research overlaps with other disciplines, notably industrial engineering and operations management. It is often concerned with determining a maximum (such as profit, performance) or minimum (such as loss, risk) of the objective functions.

Modelling is an essential and inseparable part of all scientific activity, and many scientific disciplines have their own ideas about specific types of modelling. Modelling is the process of generating abstract, conceptual, graphical or mathematical models. A model is also a way in which the human thought process can be amplified.

Now-a-days modelling created strong links with other sciences and many sectors of the economy. Without it there would be no computers, no software systems, no mobile phones, no design workshops for car and aeronautical manufacturers, no satellite localization systems, signal processing, weather forecasting, cryptography, smart cards or robots. Situation or model where there are multiple possible outcomes, each outcome has varying degrees of certainty or uncertainty of its occurrence.

2. INVENTORY

The goods held by an organization to support production (raw materials, subassemblies, work in process), for support activities (repair, maintenance, consumables), or for sales or customer services (merchandise, finished goods, spare parts) is known as inventory. Inventory is often the largest item in the current assets category, and must be accurately counted and valued at the end of each accounting period to determine a company's profit or loss. Organizations with inventory items of small unit cost generally update their inventory records at the end of an accounting period or when financial statements are prepared (called periodic inventory methods). The value of an inventory depends on the valuation methods used, such as first-in, first-out (FIFO) method or last-in, first-out (LIFO) method. GAAP required that inventory should be valued on the basis of either its cost price or its current market price whichever is lower of the two to prevent over standing of assets and earning due to sharp increase in the inventory's value inflationary periods.

The necessity of having inventory has been balanced against the substantial cost of ordering, carrying and storing inventories. It assumed capital cost, service cost, and storage cost. So it becomes necessary to maintain an inventory because of the following reasons:

- Inventory helps in smooth and efficient running of business.
- Inventory provides service to the customers immediately or at a short notice.
- Due to absence of stock, the company may have to pay high prices because of pieces-wise purchasing. Maintaining of inventory may earn price discount because of bulk-purchasing.
- Inventory also acts a buffer stock when raw materials are received late and so many sale-orders are likely to be rejected.
- Inventory also reduces product costs because there is an additional advantage of batching and long smooth running production runs.
- Inventory helps in maintaining the economy by absorbing some of the fluctuations when the demand for an item fluctuates or is seasonal.

- Pipeline stock (also called process and movement inventories) are necessary where the significant amount of time is consumed in the trans-shipment of items from one location to another.

Inventory control means keeping the overall costs associated with having inventory as low as possible without creating problems. This is also sometimes called stock control. In other words, Inventory control is the process of deciding what and how much of various items are to be kept in stock. It also determines the time and quantity of various items to be procured. The basic objective of inventory control is to reduce investment in inventories and ensuring that production process does not suffer at the same time. It is an important part of any business that must have a stock of products or items on hand. Correctly managing inventory control is a delicate balance at all times between having too much and too little in order to maximize profits. Insufficient inventory means lost sales and costly, time-consuming back orders. Running out of raw materials or parts that are crucial to production process means increased operating costs, too.

3. INVENTORY MODELS FOR PRICING POLICY: LATEST TREND

It has been a commonly known fact that the demand for any products depends upon its selling price. The law of demand says that apart from luxurious commodities, the demand for any product of trade decreases with increases in selling price vice-versa is the case with luxurious items whose demand increases with increasing price. Inventory practitioners have studied the economic order quantity with this theory in mind and came forth with certain interesting facts.

Goyal and **Gunasekaran** (**1995**) developed an integrated production-inventory-making model for determining the economic production quantity and economic order quantity for raw materials in a multi-stage production system. They considered demand function $\left(= KA^{e_a} / P^{e_p}\right)$ as function of selling price (*P*) and frequency of advertisement (*A*).

An Inventory models for perishable items with stock dependent selling rate were established by **Padmanabhan and Vrat (1995)**. The selling rate was assumed to be a function of current inventory level such as the selling rate *D(t)* at time t is assumed to be [α + βI(t)], where a, β are positive constants and *I(t)*is inventory level at time t. The rate of deterioration was taken to be constant with complete, partial backlogging and without backlogging.

Bhunia and **Maiti** (**1997**) developed a deterministic inventory model for deteriorating items considering the demand rate at any instant of time to be a function of selling price, time and frequency of advertisements.

Wee and **Law (1999)** applied the discounted cash-flow approach to a deterministic inventory model of an item with price dependent demand that deteriorated over time at a varying rate.

Wee and **Law (2001)** developed a deteriorating inventory model taking into account the time-value of money for deterministic inventory system with price-dependent demand such as demand rate *d(s) = g – hs*, is a decreasing linear function of selling price where *g-hs > 0* for positive demand.

Kar *et al.* (**2001-a**) developed an optimum inventory model for units which deteriorate continuously with time. Demand of the fresh units was assumed to be a function of both selling price and the level of on-hand inventory. The replenishment rate for the primary shop was infinite. In the primary shop, shortages were allowed and completely backlogged. The secondary shop started with an initial stock of deteriorated units which have been separated initially from the lot. Due to the continuous transfer of deteriorated units from the primary shop, the rate of replenishment at that shop was finite and varied with time. It was assumed that the units deteriorated at a constant rate which was much higher than that in primary shop, shortages were not allowed and demand of the units was a function of selling price only.

Kar ***et al.*** (**2001-b**) again proposed an inventory model for continuously deteriorating items with limitations on investment and total floor-space area. The rate of replenishment was infinite and shortages were not allowed in the primary shop. For secondary shop, the rate of replenishment was finite and varied with time. It was the rate at which the deteriorated units were detected and transported from the primary shop. Shortages were not allowed and demand was a function of selling price only. In the secondary shop, two cases may arise depending upon the rate of replenishment of deteriorated items.

Gor and **Shah (2006)** have also studied the concepts of price dependent demand in an inflation induced environment. They have presented an easy to use algorithm to arrive at the optimal solution. A sensitivity analysis of the optimal solution obtained has been carried out to illustrate the theory.

Pal ***et al.*** **(2007)** investigated the possibilities of defective units in the production process and marketing policy of a manufacturing firm which produces single item with a finite rate. In this study, demand rate was dependent on selling price, marketing cost and quality. The model was developed by formulating constrained maximization problem of marketing department and minimization problem of production department.

Sana ***et al.*** (**2007**) explored the volume flexible model with two different types of demand rates: first for the perfect quality items and second was for defective (imperfect quality) items which were taken as function of reduction in selling price. They considered that unit production cost was the function of finite production rate. Through sensitive analysis, they had shown that profit increases with the increase in the amount of defective items suitable for sale and decision variables were insensitive to change in inspection cost.

Jaggi ***et al.*** (**2010**) presented a two-warehouse inventory model for deteriorating items with price sensitive demand. It was assumed that the units were transported under a bulk release pattern from rented warehouse to own warehouse and the deterioration rates of the items were different in the two warehouses. Further, the model jointly optimized the order quantity and selling price. Depending upon the optimal order quantity, decision was made whether to rent other warehouse. The optimal shipment policy was also provided if indeed the other warehouse is needed.

Sana (2012) discussed a newsboy problem by introducing a price-dependent demand with stochastic selling price. The proposed model analyzed the expected average profit for a general distribution function of p and obtains an optimal order size. Finally, the model was discussed for various appropriate distribution functions of p and at the end Sana illustrated the model with the help of numerical examples.

Panda ***et al.*** **(2013)** developed a dynamic pre-and post-deterioration cumulative discount policy to enhance inventory depletion rate resulting low volume of deterioration cost, holding cost and hence higher profit. They assumed that demand is a price and time dependent ramp-type function and the product starts to deteriorate after certain amount of time.

Alfares ***et al.*** **(2015)** proposed an inventory model by considering demand rate for a specific item which can be affected by many variables such as seasonality, selling price, and availability. They also assumed that unit holding cost tends to be higher for extended storage periods. The objective of that paper is to simultaneously consider the variability of the demand rate, the unit holding cost, and the unit purchase cost.

Chua ***et al.*** **(2015)** developed an inventory model by considering a stocking-factor elasticity approach for pricing newsvendor facing multiplicative demand uncertainty with lost sales. They proved that optimal order quantity decreases in demand uncertainty for zero salvage value.

Feng *et al*. **(2017)** proposed an inventory model that stipulates the demand explicitly in a multivariate function of price, freshness, and displayed stocks. They observed that it is profitable to have a closeout sale at a markdown price, and always keep on-hand displayed stocks fresh and plentiful if the demand is freshness-and-stock dependent. In order to maximize the total profit of the system they considered unit price, cycle time, and ending-inventory level as decision variable.

4. INVENTORY MODELS FOR STOCK-DEPENDENT DEMAND: LATEST TREND

It is usually observed; especially in a supermarket that display of customer goods in large quantities attracts more customers and generates higher demand. This kind of demand rate is getting increasingly common in the real life situations where the market scenario is changing drastically.

A deterministic inventory system with stock dependent demand rate was formulated by **Baker** and **Urban (1988)**.

Inventory model for deteriorating items with stock dependent demand rate was proposed by **Pal** *et al*. **(1993)**.

Vrat ***et al.*** **(1990)** developed a model to determine optimum ordering quantity for stock dependent consumption rate items under inflationary environment with infinite replenishment rate without permitting shortages.

Bhunia and **Maiti (1997)** developed two inventory models assuming that the replenishment rate is finite and dependent on the on-hand inventory and demand simultaneously. The deterioration rate and the demand rate were assumed to be linearly increasing functions of time. The replenishment rate R(t) is dependent on the on-hand inventory level Q(t) and the demand rate D(t) of any time t such that $R(t) = \alpha - \beta Q(t) + rD(t)$, $\alpha > 0$, $r \geq 0$, $0 \leq \beta \leq 1$ and $\theta(t) = \lambda + \mu t$, $0 < \lambda , \mu \leq 1$. $t > 0$

It is common belief that large piles of goods displayed in a supermarket will lead the customers to buy more. Now a day, marketing research also recognizes this relationship. Due to this fact, O.R. scientists recently have concentrated on the inventory problems taking the effect of displayed inventories on demand into account.

Ray ***et al.*** **(1997)** developed a finite time-horizon deterministic economic order quantity (EOQ) inventory model with shortages, where the demand rate at any instant depends on the on-hand inventory (stock-level) at that instant. The effects of inflation and the time value of money were taken into account, considering two separates inflation rates: namely, the internal (company) inflation rate and the external (general economy) inflation rate.

Mandal and **Maiti (1999)** first time proposed a deterministic inventory model of a damageable item with variable replenishment when both demand rates were stock-dependent in polynomial form.

Liao ***et al.*** (**2000**) presented an inventory model for initial-stock-dependent consumption rate when a delay in payment is permissible. In that model, initial-stock-dependent consumption rate was assumed, in which the demand rate depends on the order size and follows the function $\lambda = \alpha + \beta Q^{\tau}$, where α, β and τ are positive constants and Q is order size ($Q \neq 0$). Shortages were not allowed. The effect of the inflation rate and deterioration was also discussed. In that study, mathematical models were also derived under two different circumstances, i.e., case-1: The credit period is less than or equal to the cycle time for settling the account; and case-2: The credit period is greater than the cycle time for settling the account. Besides, expressions for an inventory system total cost were derived for these two cases.

An inventory model with two warehouses and stock-dependent demand rate was proposed by **Zhou** and **Yang** (**2005**). Shortages were not allowed and the transportation cost for transferring items from RW to OW was taken to be dependent on the transported amount. A computational procedure was proposed to obtain the optimal replenishment quantity, the optimal replenishment cycle and the optimal shipment schedule, so that the average total profit of the system should be minimum. In that study, they have provided the theorems as: (i) The optimal order quantity Q^* of the single warehouse system is not less than W if and only if $R \geq 0$, where $R = \alpha (2 - \beta) [\beta (p - c) W + (1 - \beta) A] - h_0 W^{2-\beta}$. (ii) If $R \geq 0$, the two-warehouse model's maximal profit is larger than one of the single-warehouse model.

Hou (**2006**) derived an inventory model for deteriorating items with stock-dependent consumption rate and shortages under inflation and time discounting over a finite planning horizon.

Pal ***et al.*** (**2006**) considered the problem of determining the lot size of a single deteriorating item with the demand rate dependent on displayed stock level (S), selling price (p) of an item and frequency of advertisement (A) in the popular electronic and print media, also through the sales representatives. Shortages, if any allowed, were partially backlogged with a variable rate which depends on the duration of waiting time up to the arrival of next lot.

Soni and **Shah** (**2008**) formulated a mathematical model to obtain the optimal ordering policies for the retailer when the demand was of the form R(t)=a+bQ(t) where Q(t) was instantaneous stock level and the supplier offered progressive credit periods to settle the account. They observed that as the value of 'b' increases, demand and procurement quantity increases whereas total cost of the inventory system decreases.

Shah and **Pandey** (**2009**) developed a mathematical model to obtain optimal ordering policy with time dependent deteriorating items. Demand rate was dependent on displayed stock level and frequency of advertisement through media.

Hsieh ***et al.*** (**2010**) developed EOQ model with power-form stock-dependent demand rate followed by a constant demand rate, permitting shortages and time proportional backlogging rate. They considered that backlogging rate (=1/(1+δx)) was a decreasing function of waiting time (x) until the next shipment which was more realistic.

Yang *et al.* (**2010**) developed partial backlogging inventory lot-size model for deteriorating items with stock-dependent demand. They had shown that the optimal replenishment schedule exists uniquely and also shown that the total profit associated with inventory system was a concave function of the number of replenishments. They observed that as the shortage cost increases, profit of the system decreases.

Singh *et al.* (2011) developed inventory models for both non-defective and defective units purchased in a lot and selling separately at two different shops under a single management with the assumption that the demand of the good units was stock dependent whereas the defective ones having price dependent demand only. In primary shop, non-defective units were sold with a profit. And the defective units, which are continuously transferred to the adjacent secondary shop, were sold after some re-work or repair at a reduced price even incurring a loss. Here shortages were allowed in both shops. It was also assumed that the rate of replenishment of units for the primary shop is infinite.

Zhou *et al.* (2012) considered a two-echelon supply chain where a supplier sells a single product through a retailer, who faces an inventory-dependent demand. The supplier hopes to incentive the retailer to order more items by offering trade credit. The retailer places the ordered items on the display shelf (DS) with limited space and stocks the remaining items (if any) that exceed the shelf capacity in his/her backroom/warehouse (BW). From the supplier's perspective, they focused mainly on under which conditions the supplier should offer trade credit and how he/she should design such trade credit policy and corresponding ordering policy to obtain much more benefits.

Zhong and **Zhou (2012)** presented a performance-improving model through trade credit for a two-echelon supply chain, where a supplier sells a single product through a retailer who has limited storage space and faces an inventory-dependent end demand. They considered the non-integrated and integrated optimizing model. They showed that the presented trade credit policy can increase each member's profitability but also the profitability of the whole channel.

Ghaimi *et al.* (2013) investigated a two-echelon supply chain model for deteriorating inventory in which the retailer's warehouse has a limited capacity. The demand rate in retailer is stock-dependent and in case of any shortages, the demand is partially backlogged.

Bhunia *et al.* (2015) developed an inventory problem where initially retailer purchase Q (=P+R) units and after fulfilling the backlogged quantities. They assumed that demand rate of the system is dependent on the on-hand inventory and down to a certain inventory Q_0, it is assumed that demand is constant. It is of the form

$$S(I(t)) = \begin{cases} \alpha(I(t))^{\beta}, 0 \leq I(t) < Q_0 \\ W, I(t) \geq Q_0 \end{cases}$$

They assumed that backlogging rate is the function of the waiting time and is of the form

$$\psi(t) = \frac{1}{1+\delta(t)}.$$

Wang *et al.* (2016) developed a decentralized supply chain inventory model in which a manufacturer supplies a newsvendor-type item to a retailer in a stock-dependent demand market, considering temporary and permanent inventory shrinkages. They also assumed that manufacturer offers a cheaper-wholesale-price, buy-all-back contract to operate the chain as a centralized supply chain.

Lee *et al.* (2017) developed an integrated system in which they considered that vendor manufactures a single product in batches and delivers it in equal-sized to the buyer. They considered that some of the delivered items are presented to the end customers in the buyer's display area, while the rest of the items are kept in the buyer's backroom warehouse. They assumed that demand is positively dependent on the amount of stock displayed. In that paper, they proved that, for any stock-dependent demand, a minimum restocking level at the buyer's sales floor is a more profitable strategy than the traditional run-out replenishment policy.

5. CONCLUSION

Researcher observed that demand rate is affected by the inventory level and pricing policy of the product. So many researchers suggest that retailer may display each of his items in large quantities to generate greater demand. But this arise new problems of space allocation for each item and investment requirements resulting from the increased inventory levels. Viewing this entire problem, **Larson and De Marais** suggested that only those items with high direct product profitability and a high sales volume can be considered for this type of analysis. From the above analysis, model with stock dependent and selling price demand has scope in supermarkets; however, success depends on the correctness of the estimation of the input parameters.

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