Fuzzy Optimal Policy of Some Inventory System

Pabitra Kumar Tripathy, Subhendu Kumar Rath, Sachinandan Mohanty

Abstract: Inventory management is a very important function that determines the health of the supply chain as well as the impacts the financial health of the balance sheet. Each and every organization implements different types of inventory systems to maintain optimum inventory to be able to meet its requirements and avoid over or under inventory that can impact the financial figures. The Inventory system is always dynamic. So with the help of fuzzy system it tries to develop a robust inventory model which will involve trade credit system assuming with cost fuzzy parameters.

I. INTRODUCTION

Inventory refers to those physical stocks which possess economic value but lie idle. These are held in varied forms by the organization waiting for usage, packaging, transformation, processing or sale in future. Though inventory is treated as an idle resource, it serves as an important part for every business organization. It acts as a link between production and distribution processes. No industry can grow without relying on inventory. The necessity for carrying inventory lies in dealing with the anticipated demand because non-availability of materials when required may lead to delays in production or projects or services to be delivered. Organizations which are based on production, trading, consumption and sale store various physical resources to satisfy future needs. The various purpose for carrying inventories include conjectural purposes, functional purposes, physical necessities etc.The success of a business organisation lies in effective inventory management as well as supply chain management. The effective promotion of a product in today's competitive global market depends on capabilities of the organisations. Effective inventory management is one of such capabilities which is necessary to lead the global market. Proper inventory management requires three basic information about (i) forecasted demand (ii) availability of the stock for sale and location of the stock (iii) replenishment lead times. An inventory system furnishes the structural configuration and functioning strategies for retaining and controlling commodities to be stocked. The system controls the ordering and receipt of items. This involves proper time for placement of order, how much and what to be ordered and tracking the goods that already ordered.

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1.2. Types of Inventory

Inventory can be grouped into the following Eight categories:

1.2.1. Raw materials

Raw materials refer to the basic substances usually in natural or semi-finished stage and are converted during the conversion process to produce finished products, components or sub-assemblies. These may be the items purchased by the firm from outside organizations or may be commodities or extracted materials that the firms or its subsidiary has produced or extracted.

1.2.2. Work-in-process

Work-in-process includes the materials in processing stage or are already processed and waiting for final inspection before being included into finished goods. This generally consists of the raw materials under process, parts or components, assemblies or sub-assemblies.

1.2.3. Finished goods

Finished goods inventory consists of the manufactured goods which have been completed through manufacturing process, inspected and are ready to be sent to distribution centres or can be sold to final users or wholesalers or retailers or are awaiting customer order.

1.2.4. Transit inventory

These refer to the inventories which are in transit and yet to reach the destination. Inventory transaction from wholesaler to retailers generally involves significant amount of time for transformation. These are also known as pipeline inventories. Merchandise shipped from a regional whole seller to retail store by rail or truck take many days for transformation. Thus during this time period the goods remain idle.

1.2.5. Buffer inventory

Buffer inventory acts as safeguard against the uncertainty in supply and demand and also protects against poor delivery or poor quality of supplier's product. These also refer to as safety stock or reserve stock. Buffer stock is the stock over and above the inventory currently required to meet the demand. Organizations keep safety stock to avoid the unavoidable situations like stock-outs, loss of goodwill, backordering, etc. Higher level of buffer stock leads a better customer service.

1.2.6. Anticipation Inventory

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Very often firms reserve stocks more than their current requirement in anticipation of a plausible future event such as seasonal fluctuations in demand, price hike, imminent labour strike, etc. Manufacturers employ this strategy and they accumulate the inventory before the demand becomes abnormally high. Manufacturing activities start during the time of low demand so that when demand accelerates, the stocked materials will be exhausted slowly and the firm does not take the risk of enhancing the working hour.

1.2.7. Decoupling Inventory

Decoupling inventory also known as intermediate inventory is the stock accumulated between two interdependent processes to avoid breakdowns or jaggedness in the production rate of the machine and thus enables the reduction in the requirement for output synchronization.

1.2.8. Cycle Inventory

Cycle inventory refers to that part of the inventory which is used to satisfy customers demand during a given time period. This is the most important part of the overall inventory as it satisfies customers' requirements. It is the first place from which customers' order will be met.

1.3. Costs involved in Inventory

The costs associated with inventory control are as follows:

1.3.1. Set-up cost

Set up cost is the cost incurred to get machines ready to produce a batch of goods. This is a fixed cost associated to every batch and is spread over the items produced in that batch. It includes:

i. Labour to position tools.
ii. Labour to configure the machine.
iii. Scrap cost of test units run on the machine.

1.3.2. Ordering cost

Ordering costs are associated with the accession of inventory, disregarding the value of the purchased items or the size of the order. It includes costs of a placing order, labour charge for inspection of items, for keeping the items in stock and issuing a supplier's invoice. It is directly proportional to the number of orders placed.

1.3.3. Purchase cost

The purchase cost is the cost paid for procuring a product. It becomes important if quantity discounts are provided. Generally, for the purchase of large quantity of products price discounts are furnished. This induces the firms avail the bulk purchase facility.

1.3.4. Carrying(or holding) cost

Carrying cost is the cost of carrying or holding inventory till it is used or sold. It comprises of the cost of insurance of equipment, cost for maintenance of storage facility, cost for depreciation and interest on the money locked up.

1.3.5. Shortage cost

Shortage cost is associated with shortages. Shortage occurs when the available stock fails to meet the demand. Shortage may lead to backlogging, loss of goodwill, order cancellation, loss of profit, etc.

1.3.6. Salvage cost

The salvage value is the value of a spare product of which no further utility is expected. For the firm the salvage value serves as the disposal value of the product possibly through a discounted sale. The salvage cost is the opposite of the salvage value.

1.4. Factors involved in inventory analysis

1.4.1. Demand

Demand refers to the specific amount of a particular goods and commodities required by a customer during a period of time. Sometimes demand may be known with certainty. It may be completely unknown or uncertain or unpredictable.

1.4.2. Lead Time

Lead time refers to the time period between placement of and order for a product and delivery of the product.

1.4.3. Order cycle

Order cycle time refers to the time period between placing of one order and the next order. It is the time period between two orders that are placed.

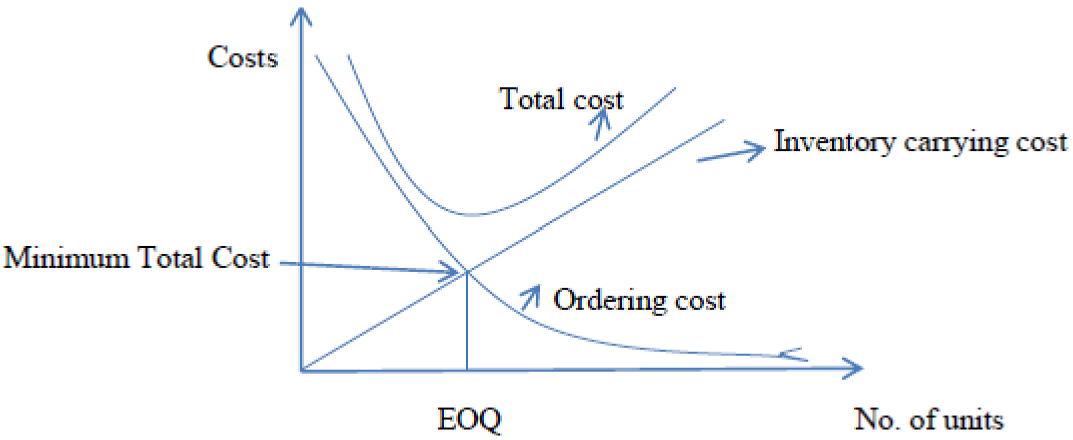
1.4.4. Re-order level

Reorder level is the level which triggers the action to replenish a particular stock of inventory or to start the manufacturing process to avoid stock-out. This level is decided by considering the safety stock and the average lead time demand.

Reorder Level (RL) = Safety Stock (S) + Average Lead Time Demand (DL)

1.5. Economic Order Quantity

Economic order quantity refers to the inventory problems having fixed or completely known demand. As the order size accelerates the ordering cost (cost of purchasing, inspection, etc.) declines but inventory carrying cost (cost of storage, insurance, etc.) increases. Economic order quantity is that size of order which minimizes total annual cost of carrying inventory and cost of ordering.Inventory model aims in representing the inventory problem to ease the decision making process. It enables the decision maker to fix the order size and time of placing order. Two basic techniques are basically applied by the firms to estimate the inventory reserve and they are deterministic and probabilistic models.



1.6. Inventory Models

Inventory models can be broadly categorised into two groups: Deterministic and Stochastic.

1.6.1. Deterministic Model

In deterministic model the system parameters are known precisely. Deterministic optimisation models presume the state of affairs to be deterministic and consequently render numerical model to optimise on system arguments.

1.6.2. Stochastic Model

Uncertainty and ambiguity in the real world inventory problem are captured by stochastic models. Stochastic model needs more input parameters and requires that some input parameters be defined in probabilistic terms. In stochastic models demand or lead time or both can be expressed by random variables. The construction of mathematical structure for a stochastic inventory model is more complicated as compared to the deterministic model.

1.7. Fuzzy Theory

1.7.1. Fuzzy Set

Fuzzy set refers to a set having an unclear boundary. The objects of the set are assigned a grade of membership lying between the interval 0 and 1.

1.7.2. Membership function

Membership function maps each element of a fuzzy set to a membership function lying between 0 and 1.

1.7.3. ∝-Cut set

The ∝-cut of a fuzzy set is the crisp set that consists of all the elements of the universal set whose membership function is not less than ∝.

1.7.4. Fuzzy number

Fuzzy number is demonstrated by a fuzzy set delineating a fuzzy interval in the real number *R*. Usually a fuzzy interval is represented through two extremities and a peak point. The ∝-cut operation can also be appertained to the fuzzy number. If the ∝-cut interval for fuzzy number *A* is expressed as *A*∝, the obtained interval *A*∝ is defined as

$$A_\alpha = [a_1^\alpha, a_3^\alpha]$$

1.7.5. Triangular fuzzy number

This fuzzy number is demonstrated by three points as A= (a_1,a_2,a_3) and the membership function is represented by

$$\mu_A(x) = \begin{cases} 0, & x < a_1 \\ \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \dfrac{a_3-x}{a_3-a_2}, & a_2 \le x \le a_3 \\ 0, & x > a_3 \end{cases}$$

1.7.6. Trapezoidal fuzzy number

Trapezoidal fuzzy number is expressed by four points as A= (a_1,a_2,a_3,a_4) and the membership function is represented by

$$\mu_A(x) = \begin{cases} 0, & x < a_1 \\ \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \dfrac{a_4-x}{a_4-a_3}, & a_3 \le x \le a_4 \\ 0, & x > a_4 \end{cases}$$

1.7.7. Defuzzification

Defuzzification is the way of transforming a fuzzified outcome into a single crisp value with reference to a fuzzy set.

1.7.8. Methods of Defuzzification:

Signed distance method: If $\tilde{A} = (a, b, c)$ is a triangular fuzzy number then signed distance of $\tilde{A}$ is defined as

$$d(\tilde{A},0) = \frac{1}{2}\int_0^1 d\left([A_L(\alpha)+A_R(\alpha)],\tilde{0}\right)$$
$$= \frac{1}{4}(a+2b+c)$$

If $\tilde{A} = (a, b, c, d)$is a trapezoidal fuzzy number then signed distance of $\tilde{A}$ is defined as

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$$d(\tilde{A},0)=\frac{1}{2}\int_0^1 d([A_L(\alpha)+A_R(\alpha)],\tilde{0})$$

$$=\frac{1}{4}(a+b+c+d)$$

1.7.9 Graded mean integration method:

The graded mean integration of a triangular fuzzy number $\tilde{}$= (a, b, c) is defined as

$$P(\tilde{A})=\frac{\int_0^{w_A} h\left(\frac{L^{-1}(h)+R^{-1}(h)}{2}\right)}{\int_0^{w_A} h\,dh} \quad wih\ \ 0\le h\le w_A \ \ and\ \ 0\le w_A\le 1$$

$$=\frac{(a+4b+c)}{6}$$

The graded mean integration of a trapezoidal fuzzy number $\tilde{A}=(a,b,c,d)$ is defined as

$$P(\tilde{A})=\frac{\int_0^{w_A} h\left(\frac{L^{-1}(h)+R^{-1}(h)}{2}\right)}{\int_0^{w_A} h\,dh} \quad wih\ \ 0\le h\le w_A \ \ and\ \ 0\le w_A\le 1$$

$$=\frac{(a+2b+2c+d)}{6}$$

1.8. Weibull Distribution

The probability density function for a two-parameter Weibull distribution is given by

$$f(t)=\alpha\beta t^{\beta-1}e^{-\alpha t^{\beta}}, \quad t>0$$

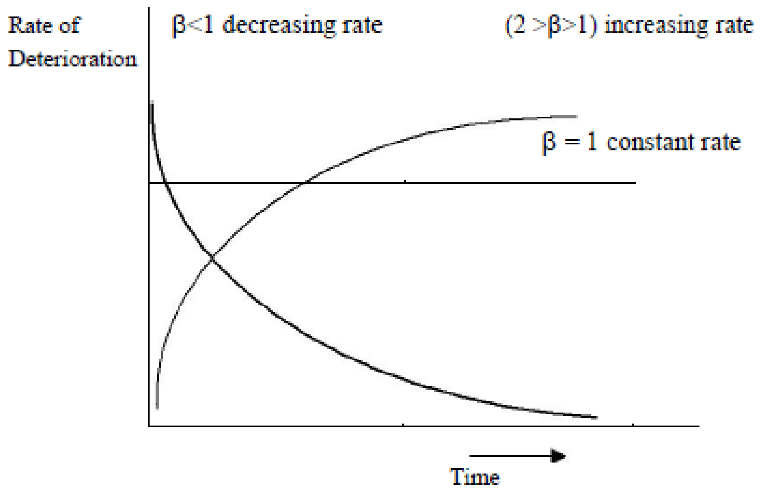
where $\propto > 0$ is the scale parameter and $\beta > 0$ is the shape parameter and t is the time of deterioration.The probability distribution function is

$$F(t)=1-e^{-\alpha\beta t^{\beta}},\ t>0$$

The instantaneous rate of deterioration of the on-hand inventory is given by

$$\theta(t)=\frac{f(t)}{1-F(t)}=\alpha\beta t^{\beta-1}, \quad t>0$$

Two parameter Weibull distribution is applicable for a product having diminishing rate of deterioration only if the deterioration rate at the beginning is immensely high and with increasing rate of deterioration only if the deterioration rate initially is approximately zero.



These drawbacks can be discarded by considering the time of deterioration as three-parameter Weibull distribution whose density function is represented as

$$f(t) = \alpha\beta(t-\gamma)^{\beta-1} e^{-\alpha(t-\gamma)^{\beta}}$$

where $\propto > 0$ is the scale parameter and $\beta > 0$ is the shape parameter, $\gamma (t \geq \gamma)$is the location parameter and t is the time of deterioration.

The instant deterioration rate of the non-deteriorated inventory at time t, (t) can be expressed by employing the relation

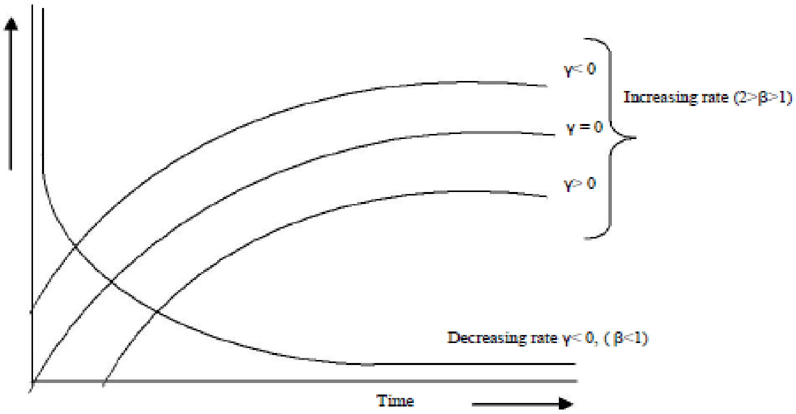
$$Z(t) = \frac{f(t)}{1-F(t)} \qquad (1.2)$$

where F(t) is the cumulative distribution function for the three-parameter Weibull distribution and is given by

$$F(t) = 1 - e^{-\alpha\beta(t-\gamma)^{\beta}} \qquad (1.3)$$

Substituting the values of $f(t)$ and $F(t)$ from (1.1) and (1.3) in (1.2) and simplifying, we obtain

$$Z(t) = \alpha\beta(t-\gamma)^{\beta-1}$$



The above figure clearly specifies that the three parameter Weibull distribution is applicable for products having any rate of deterioration at the beginning and also for the products which start deteriorating only after a certain period of time.

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