Inventory Optimization by Fuzzy Logic for Deteriorating Items in sea food exports companies with Shortages under Fully Backlogged Conditions

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Abstract: Here, a fuzzy inventory model for deteriorating items with shortages under fully backlogged condition is formulated and solved. Deterioration rate and demand are assumed to be constant. Shortages are allowed and assumed to be fully backlogged. Fuzziness is introduced by allowing the cost components, demand rate and the deterioration. In fuzzy environment, all related inventory parameters are assumed to be trapezoidal fuzzy numbers. The purpose of this method is to minimize the total cost function in fuzzy environment. Fuzzy method is used to solve data collected from a company. The convexity of the cost function is shown graphically. Sensitivity analysis is also carried out to detect the most sensitive parameters of the system. From sensitivity analysis, we show that the total cost function is extremely influenced by the holding cost, demand rate and the shortage cost.

Key words: cost, fuzzy, sensitivity analysis

I. INTRODUCTION

1.1 INVENTORY

Inventories occupy the most strategic position in the structure of working capital of most business enterprises. It constitutes the largest component of current asset in most business enterprises. In the sphere of working capital, the efficient control of inventory has passed the most serious problem to the cement mills because about two-third of the current assets of mills are blocked in inventories. The turnover of working capital is largely governed by the turnover of inventory. It is therefore quite natural that inventory which helps in maximize profit occupies the most significant place among current assets.

Inventory is the stock of any item or resource used in an organization. An inventory system is the set of policies and controls that monitor levels of inventory and determine what levels should be maintained, when stock should be replenished, and how large orders should be. By convention, manufacturing inventory generally refers to items that contribute to or become part of a firm’s product output. Manufacturing inventory is typically classified into raw materials, finished products, component parts, supplies, and work-in-process. In distribution, inventory is classified as in-transit, meaning that it is being moved in the system, and warehouse, which is inventory in a warehouse or distribution center. Retail sites carry inventory for immediate sale to customers. In services, inventory generally refers to the tangible goods to be sold and the supplies necessary to administer the service. The basic purpose of inventory analysis, whether in manufacturing, distribution, retail, or services, is to specify

(1) When items should be ordered and

(2) How large the order should be.

Many firms are tending to enter into longer-term relationships with vendors to supply their needs for perhaps the entire year. This changes the "when" and "how many to order" to "when" and "how many to deliver."

The inventory means aggregate of those items of tangible personal property which

(i) Are held for sale in ordinary course of business.

(ii) Are in process of production for such sales.

(iii) They are to be currently consumed in the production of goods or services to be available for sale.

Inventories are expandable physical articles held for resale for use in manufacturing a production or for consumption in carrying on business activity such as merchandise, goods purchased by the business which are ready for sale.

Inventory: The stock of any item or resource used in an organization

Finished Goods: Goods being manufactured for sale by the business which are ready for sale

Materials: Articles such as raw materials, semi-finished goods or finished parts, which the business plans to incorporate physically into the finished production.

Supplies: "Article, which will be consumed by the business in its operation but will not physically as they are a part of the production. The short inventory may be defined as the materials, which are either saleable in the market or usable directly or indirectly in the manufacturing process. It also includes the items which are ready for making finished goods in some other process or by comparing them either by the concern itself and/or by outside parties. In other words, the term inventory means the material having any one of the following characteristics. It may be

1. Saleable in the market,

1. Directly saleable in the manufacturing process of the business

2. Usable directly in the manufacturing process of the undertaking, and

4. Ready to send to the outside parties for making usable and saleable productions out of it.

1.2 INVENTORY COSTS

In making any decision that affects inventory size, the following costs must be considered:

1. Holding (or carrying) costs: This broad category includes the costs for storage facilities, handling, insurance, pilferage, breakage, obsolescence, depreciation, taxes, and the opportunity cost of capital. Obviously, high holding costs tend to favor low inventory levels and frequent replenishment.

1. Setup (or production change) costs: To make each different product involves obtaining the necessary materials, arranging specific equipment setups, filling out the required papers, appropriately charging time and materials, and moving out the previous stock of material. I f there were no costs or loss of time in changing from one product to

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another, many small lots would be produced. This would reduce inventory levels, with a resulting savings in cost. One challenge today is to try to reduce these setup costs to permit smaller lot sizes. (This is the goal of a JIT system.)

2. Ordering costs: These costs refer to the managerial and clerical costs to prepare the purchase or production order. Ordering costs include all the details, such as counting items and calculating order quantities. The costs associated with maintaining the system needed to track orders are also included in ordering costs.

4. Shortage costs: When the stock of an item is depleted, an order for that item must either wait until the stock is replenished or be canceled. When the demand is not met and the order is canceled, this is referred to as a stock out. A backorder is when the order is held and filled at a later date when the inventory for the item is replenished. There is a trade-off between carrying stock to satisfy demand and the costs resulting from stock outs and backorders. This balance is sometimes difficult to obtain because it may not be possible to estimate lost profits, the effects of lost customers, or lateness penalties. Frequently, the assumed shortage cost is little more than a guess, although it is usually possible to specify a range of such costs.

II.LITERATURE REVIEW

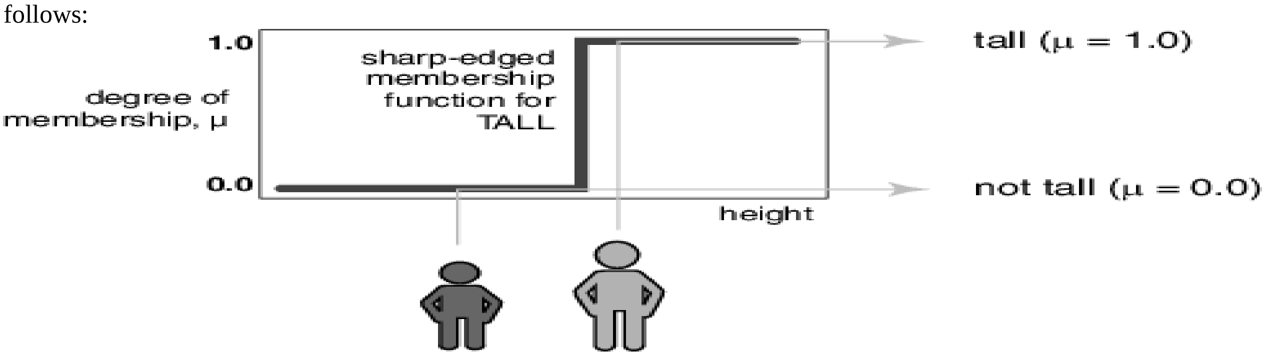
2.1 Fuzzy Logic

Fuzzy logic originates from fuzzy set theory which was proposed by Zadeh and has since found a number of applications as a theory of graded concepts. It provides a mathematical framework where vague, conceptual phenomena can be rigorously studied. Fuzzy logic models human experiential knowledge in any domain. When applied to solve performance measurement or prediction problems, fuzzy logic takes the help of the knowledge from the domain expert and employs fuzzy arithmetic to produce fuzzy inference systems. Fuzzy logic is an application of the fuzzy set theory particularly used in dealing with process imprecise information with a changed membership function. Fuzzy operation is a process of ‘crisp-fuzzy-crisp’ for a real system in which the original input and the terminal output must be crisp variables, but the intermediate process is a fuzzy inference process. Fuzzy inference is a method that interprets the values in the input vector and assigns values to the output by means of some set of fuzzy rules. In a classical set, an element either belongs to or does not belong to a set. Since fuzzy sets describe vague concepts based on the premise that the elements used are not numbers but belong to words or the value of a linguistic variable, an element of a fuzzy set naturally belongs to the set with membership values from the interval [0, 1]. The shape of the membership function of fuzzy sets can be either linear (trapezoidal or triangular) or various forms of non-linear, depending on the nature of the system being studied. The output of a fuzzy logic system is based on different membership functions, which can be considered as a range of inputs. The first step involves fuzzification which implies the conversion of classical data or crisp data into fuzzy data or membership functions. This information is then fed to the decision logic or fuzzy inference process which combines membership functions with the control rules to derive the fuzzy output. The next step involves the defuzzification process which converts a fuzzy output into a non-fuzzy one by using different methods to calculate each associated output. Finally, the knowledge base system comprises experts’ knowledge of the application domain as well as the decision rules which depict the relationship between the inputs and outputs.

Fuzzy logic’s primary aim is to provide a formal, computationally-oriented system of concepts and techniques for dealing with modes of reasoning which are approximate rather than exact. Thus, in fuzzy logic, exact (crisp) reasoning is considered to be the limiting case of approximate reasoning. According to Jain *et al*., the primary goal of fuzzy systems is to formulate a theoretical foundation for reasoning about imprecise propositions, which is termed approximate reasoning in fuzzy logic technological systems. Fuzzy logic incorporates a simple ‘IF X and Y, then Z’ approach in solving problems rather than using a systematic mathematical model, thus fuzzy logic is used to mimic normal human reasoning but in a rather faster way. Fuzzy logic is an empirical based model which relies on the experience of the operator and provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise or missing input information. Although the approaches in fuzzy logic are quite descriptive, they are capable of mimicking normal human reasoning at a very high rate. It is very robust and forgiving of operator’s data input and often works when first implemented with little or no tuning. It is inherently robust as it doesn't require precise data inputs and the output and/or feedback is a smooth function despite a wide range of input variation. The application of fuzzy is not limited to a few feedback inputs and one or two outputs and neither is it necessary to measure or compute the rate of change of parameters in order for it to be implemented. Based on the rule-based operation any reasonable number of inputs can be processed (1-8 or more) and numerous outputs (1-4 or more) can be generated. The use of fuzzy logic can be applied to measuring the performance of non-linear systems which would be difficult or impossible to model mathematically.

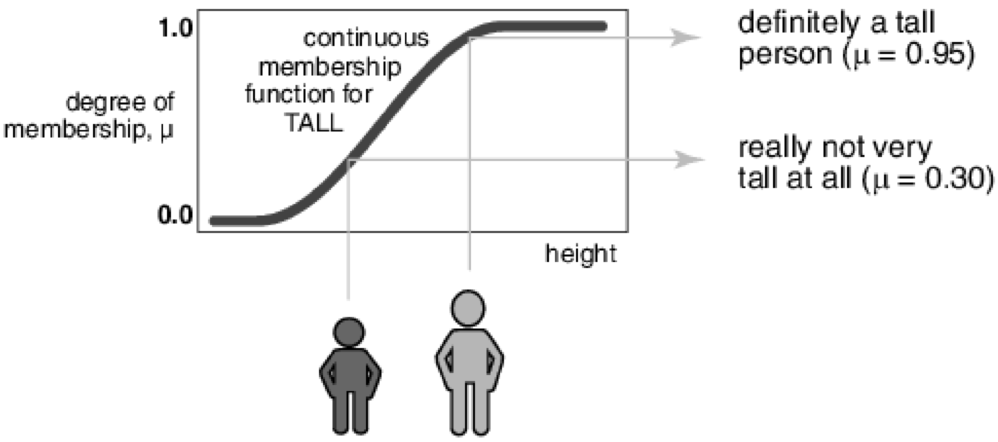
2.2 Fuzzy Set

In mathematics a set, by definition, is a collection of things that belong to some definition. Any item either belongs to that set or does not belong to that set. Let us look at another example; the set of tall men. We shall say that people taller than or equal to 6 feet are tall. This set can be represented graphically as follows:



The function shown above describes the membership of the 'tall' set, you are either in it or you are not in it. This sharp edged membership functions works nicely for binary operations and mathematics, but it does not work as nicely in describing the real world. The membership function makes no distinction between somebody who is 6'1" and someone who is 7'1", they are both simply tall. Clearly there is a significant difference between the two heights. The other side of this lack of distinction is the difference between a 5'11" and 6' man. This is only a difference of one inch; however this membership function just says one is tall and the other is not tall.

The fuzzy set approach to the set of tall men provides a much better representation of the tallness of a person. The set, shown below, is defined by a continuously inclining function.



The membership function defines the fuzzy set for the possible values underneath of it on the horizontal axis. The vertical axis, on a scale of 0 to 1, provides the membership value of the height in the fuzzy set. So for the two people shown above the first person has a membership of 0.3 and so is not very tall. The second person has a membership

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of 0.95 and so he is definitely tall. He does not, however, belong to the set of tall men in the way that bivalent sets work; he has a high degree of membership in the fuzzy set of tall men.

FUZZY Model

We consider the model in fuzzy environment. Due to fuzziness, it is not easy to define all the parameters precisely. Let, $c_h=(c_{h1}, c_{h2}, c_{h3}, c_{h4})$, $c_p=(c_{p1}, c_{p2}, c_{p3}, c_{p4})$

$c_s=(c_{s1}, c_{s2}, c_{s3}, c_{s4})$, $\acute{r}=(r_1, r_2, r_3, r_4)$, $\theta=(\theta_1, \theta_2, \theta_3, \theta_4)$

be trapezoidal fuzzy numbers in LR form. Then, the total cost of the system per unit time in fuzzy sense is given by

$$\tilde{C}(t_1, T) = \frac{1}{T}[C_o + \tilde{r}\tilde{C}_h(\frac{1}{2}t_1^2 + \frac{1}{3}\tilde{\theta}t_1^3) + \tilde{r}\tilde{C}_p(\tilde{\theta}t_1^2) + \frac{r}{2}\tilde{C}_s(T-t_1)^2]$$

$$= \frac{1}{T}[C_o + (r_1C_{h1}, r_2C_{h2}, r_3C_{h3}, r_4C_{h4})(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}, \frac{t_1^2}{2} + \frac{\theta_2 t_1^3}{3}, \frac{t_1^2}{2} + \frac{\theta_3 t_1^3}{3}, \frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3}) + (r_1C_{p1}, r_2C_{p2}, r_3C_{p3}, r_4C_{p4})(\theta_1 t_1^2, \theta_2 t_1^2, \theta_3 t_1^2, \theta_4 t_1^2) + (r_1C_{s1}, r_2C_{s2}, r_3C_{s3}, r_4C_{s4})\frac{(T-t_1)^2}{2}]$$

$$= \frac{1}{T}[C_o + (r_1C_{h1}(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}), r_2C_{h2}(\frac{t_1^2}{2} + \frac{\theta_2 t_1^3}{3}), r_3C_{h3}(\frac{t_1^2}{2} + \frac{\theta_3 t_1^3}{3}), r_4C_{h4}(\frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3})) + (r_1C_{p1}\theta_1 t_1^2, r_2C_{p2}\theta_2 t_1^2, r_3C_{p3}\theta_3 t_1^2, r_4C_{p4}\theta_4 t_1^2) + (r_1C_{s1}\frac{(T-t_1)^2}{2}, r_2C_{s2}\frac{(T-t_1)^2}{2}, r_3C_{s3}\frac{(T-t_1)^2}{2}, r_4C_{s4}\frac{(T-t_1)^2}{2})]$$

$$= (W, X, Y, Z). \quad (15)$$

where $W = \frac{1}{T}(C_o + r_1C_{h1}(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}) + r_1C_{p1}\theta_1 t_1^2 + r_1C_{s1}\frac{(T-t_1)^2}{2})$,

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$$X = \frac{1}{T}(C_o + r_2 C_{h2}(\frac{t_1^2}{2} + \frac{\theta_2 t_1^3}{3}) + r_2 C_{p2}\theta_2 t_1^2 + r_2 C_{s2}\frac{(T-t_1)^2}{2}),$$
$$Y = \frac{1}{T}(C_o + r_3 C_{h3}(\frac{t_1^2}{2} + \frac{\theta_3 t_1^3}{3}) + r_3 C_{p3}\theta_3 t_1^2 + r_3 C_{s3}\frac{(T-t_1)^2}{2}),$$
$$Z = \frac{1}{T}(C_o + r_4 C_{h4}(\frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3}) + r_4 C_{p4}\theta_4 t_1^2 + r_4 C_{s4}\frac{(T-t_1)^2}{2}).$$

The $\alpha -$ cuts, $C_L(\alpha)$ and $C_R(\alpha)$, of trapezoidal fuzzy number $\tilde{C}(t_1, T)$, are given

$$C_L(\alpha) = W + (X - W)\alpha = \frac{1}{T}(C_o + r_1 C_{h1}(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}) + r_1 C_{p1}\theta_1 t_1^2 + r_1 C_{s1}\frac{(T-t_1)^2}{2}) + \frac{1}{T}[r_2 C_{h2}\left(\frac{t_1^2}{2} + \frac{\theta_2 t_1^3}{3}\right) - r_1 C_{h1}(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}) + r_2 C_{p2}\theta_2 t_1^2 - r_1 C_{p1}\theta_1 t_1^2 + r_2 C_{s2}\frac{(T-t_1)^2}{2} - r_1 C_{s1}\frac{(T-t_1)^2}{2}]\alpha,$$

And
$$C_R(\alpha) = Z - (Z - Y)\alpha = \frac{1}{T}(C_o + r_4 C_{h4}(\frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3}) + r_4 C_{p4}\theta_4 t_1^2 + r_4 C_{s4}\frac{(T-t_1)^2}{2}) - \frac{1}{T}[r_4 C_{h4}(\frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3}) - r_3 C_{h3}(\frac{t_1^2}{2} + \frac{\theta_3 t_1^3}{3}) + r_4 C_{p4}\theta_4 t_1^2 - r_3 C_{p3}\theta_3 t_1^2 + r_4 C_{s4}\frac{(T-t_1)^2}{2} - r_3 C_{s3}\frac{(T-t_1)^2}{2}]\alpha$$

By using signed distance method, the defuzzified value of fuzzy number $\tilde{C}(t_1, T)$, is given by

$$C_{dS}(t_1, T) = \frac{1}{2}\int_0^1 [C_L(\alpha) + C_R(\alpha)]d\alpha$$
$$= \frac{1}{2T}[C_o + r_1 C_{h1}(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}) + r_1 C_{p1}\theta_1 t_1^2 + r_1 C_{s1}\frac{(T-t_1)^2}{2}] + \frac{1}{4T}[r_2 C_{h2}\left(\frac{t_1^2}{2} + \frac{\theta_2 t_1^3}{3}\right) - r_1 C_{h1}(\frac{t_1^2}{2} + \frac{\theta_1 t_1^3}{3}) + r_2 C_{p2}\theta_2 t_1^2 - r_1 C_{p1}\theta_1 t_1^2 + r_2 C_{s2}\frac{(T-t_1)^2}{2} - r_1 C_{s1}\frac{(T-t_1)^2}{2}] + \frac{1}{2T}[C_o + r_4 C_{h4}(\frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3}) + r_4 C_{p4}\theta_4 t_1^2 + r_4 C_{s4}\frac{(T-t_1)^2}{2}] - \frac{1}{4T}[r_4 C_{h4}(\frac{t_1^2}{2} + \frac{\theta_4 t_1^3}{3}) - r_3 C_{h3}(\frac{t_1^2}{2} + \frac{\theta_3 t_1^3}{3}) + r_4 C_{p4}\theta_4 t_1^2 - r_3 C_{p3}\theta_3 t_1^2 + r_4 C_{s4}\frac{(T-t_1)^2}{2} - r_3 C_{s3}\frac{(T-t_1)^2}{2}] \quad (16)$$

III. ASSUMPTIONS

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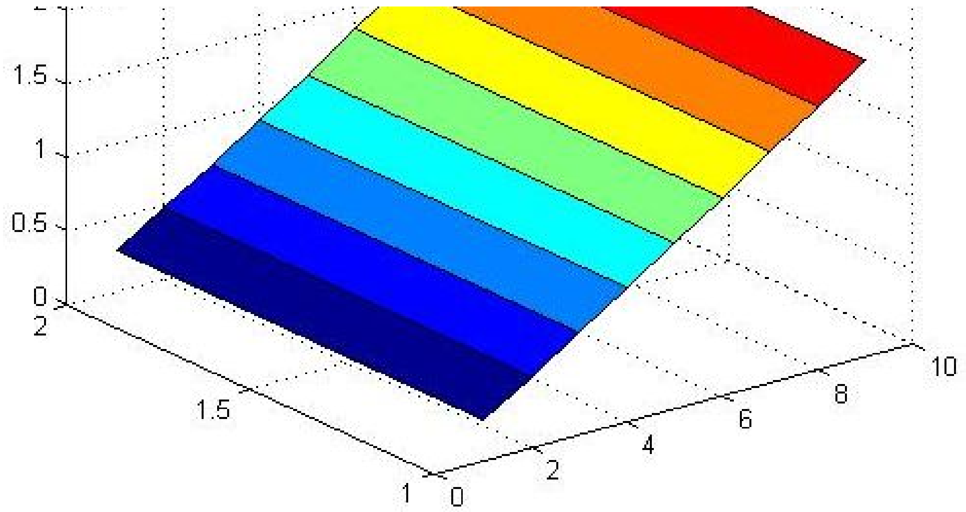

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IV. DATA SURVEY

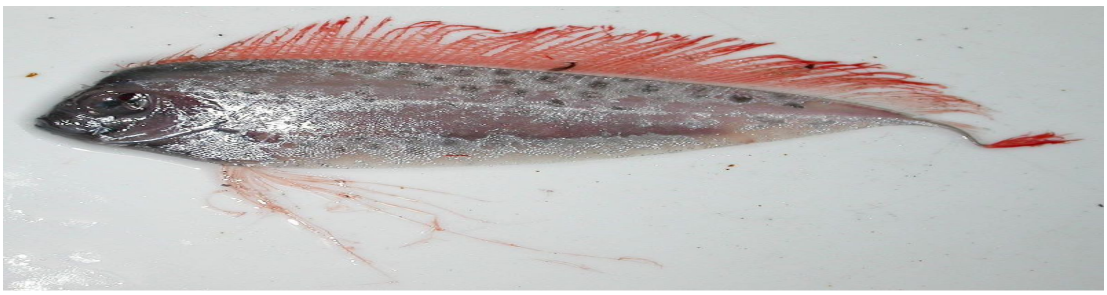
Company: KARTHIKEYA MARINE PRODUCTS

Profile : It is one of the leading sea food exporting companies in Visakhapatnam and was established in the year 2008. It exports sea foods like fish, prawns, shrimps and crabs. The company's inventory can store 300 tons of stock. It primarily exports to countries like Singapore, Taiwan, Malaysia, Sri Lanka, China, Vietnam and Oman.

4.1 Inventory Items:

ITEM	Purchase cost per unit per unit time (C_p) Rs.	Holding cost per unit per unit time (C_h) Rs.	Shortage cost per unit time (C_s) Rs.	Demand Rate (R) Tons
Ribbon Fish	150	400	5	11000
Tuna	95	500	5	11000
Indian Mackerel	70	400	5	11000

Item chosen: Ribbon Fish



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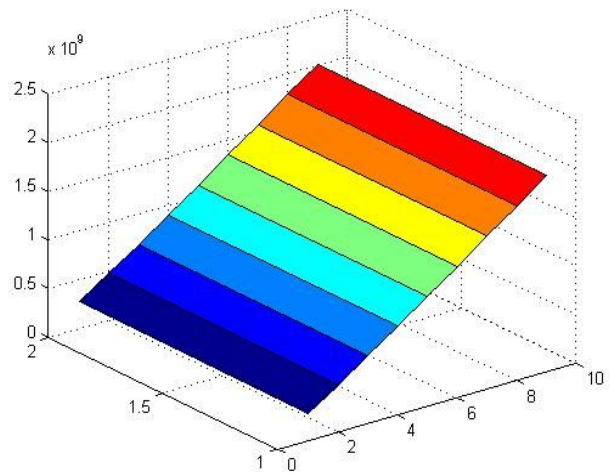
The ribbonfish are any lampriform fishes in the family Trachipteridae. These pelagic fish are named for their slim, ribbon-like appearance. They are rarely seen alive, as they typically live in deep waters, though are not bottom feeders. Specimens have been taken in the Atlantic, the Mediterranean, the Bay of Bengal, at Mauritius, and in the Pacific.

Purchasing cost per unit per unit time (C_p) Rs.	Holding cost per unit per unit time (C_h) Rs.	Shortage cost per unit (C_s) Rs.	Demand Rate (R) Tons	Deteriorating rate (θ)
140	380	5	109	0.001
145	390	5	110	0.002
150	400	5	111	0.003
155	410	5	112	0.004

4.2 Fuzzified values for Ribbon Fish



GRAPHICAL ANALYSIS

V .CONCLUSION

We believe that by using fuzzy logic in inventory management we could determine the optimum reorder time for replenishment of the stock for the inventory in order to reduce the losses due to improper reordering cycle and thereby reducing the overall cost of the inventory

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