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OPTIMIZATION OF STOCK MANAGEMENT SYSTEM WITH DEFICIENCIES THROUGH FUZZY RATIONALE WITH SIGNED DISTANCE METHOD IN SEABORN PROGRAMING TOOL

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Abstract. This study proposes a fuzzy inventory model for managing large-scale production, incorporating cost considerations. The model accounts for two types of expenditure scenarios—parametric and exponential. Uncertainty surrounds holding costs, setup costs, and demand rates. The approach considers a supply chain system with a complex manufacturing process, factoring in transportation costs based on the quantity of goods and distance between the supplier and retailer. The initial crisp model is then transformed into a fuzzy simulation, incorporating specific fuzzy variables affecting inventory costs. The proposed method significantly reduces overall inventory costs for the entire supply chain. Retailer demand is linked to inventory levels, and vendor/distributor storage deteriorates over time. The fuzzy condition assumes hexagonal variables for all associated factors. The study employs the signed distance method for defuzzification to determine the optimal order quantity with hexagonal fuzzy numbers. Mathematical examples are provided to illustrate the practicality of the proposed approach.

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1. Introduction

The most fundamental promotional commodity-based is inventory, which consists although it travels throughout the curriculum of organisation, there certainly are several techniques associated. The majority of inventory simulations were developed so as to minimise a businessman's inventory costs while they are

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just partially participating in an organization's execution. The business procedure involves every stockist. The overwhelming majority of dissertations which simulate single-item or multiple-item systems of inventory endeavour towards decreasing the cost of the inventory management system for either merchants, vendors or manufacturers. For equally the difficulties we confront in everyday existence and the problems we face in theoretical research, inventory control is important. In characteristic inventory models, uncertainties are managed by applying probability theory and are treated as randomness. Economic order quantity (EOQ) is the inventory model that is predominantly utilised. Harris and Wilson produced this representation of reality. Hadley investigated multiple inventory techniques subsequently. Nevertheless, Zadeh is principally responsible for the fuzziness that originated. A number of approaches to making decisions in fuzzy regards were examined out by Zadeh. The investigators have determined that it takes consideration into account an assortment of different factors which influence an inventory system or supply chain network, particularly cost parameters, which are the most crucial variables to be modelled in a way that eliminates the total stock cost or expenses associated with the supply chain structure and, as a consequence, enhances profitability for the firm. Particular models for inventory taking into consideration consumption that was exponentially increasing, dependent upon time, a constant, and stock-dependent. Nevertheless, they seldom end up in an inventory system that is streamlined. Merchandise can be manufactured or produced at numerous phases within the marketing method in an organisation, and then packaged products are supplied with the marketplace to be devoured by recipients. Certain goods produced in the procedure have become deteriorating while others are in good enough condition to be used until they reach the end individuals, depending on the condition of the production process, stock holding process, or merchandise in transportation system. Deterioration is an occurrence that ends up resulting in material biochemical losses or physiological deterioration of goods throughout the supply chain as a whole, both of which result in financial loss for the merchant. Deterioration consequently constitutes the crucial factor in influencing the expense of inventory during its duration in storage and during the transportation. Uncertainty in the marketplace contributes to valuing along with manufacturing system hyperinflation during the company's operating process. With characteristics having an established and fixed significance, the marketplace's unpredictability cannot be maintained. Prediction is unsuitable to use as an ideal indicator of necessity considering that it is susceptible to fluctuation at any moment as the consequence of numerous unknowable factors in the nation. In a comparable way, cost component escalation is additionally unpredictability and contingent upon the current scenario and disasters. subsequently is crucial to investigate the potential for predictability and model the system correspondingly, which permits the observation of the market's unpredictable in immediate proximity to the crisp quantity of substances. Numerous study articles are currently published in this domain designed to tackle the amount and insecure circumstances. A stock management model had been suggested for the supply chain system encompassing suppliers and distributor that optimises the the average overall inventory cost of individuals jointly responsible for the manufacturing process. The approach has been influenced by numerous papers on inventory illustrating and describing a supply chain system of transportation involving commodities. In order to interact with the arbitrary scenario involving production rate, consumption rate, decomposition rate, and procurement rate, a crisp model initially was implemented under the influence inventory level consumption rate. A combining fuzzy modelling has then been established. It is predicated that there are inadequate of merchandise and that supply and manufacturing are essentially immediate. The aforementioned works merely take consideration of the inventory-related modelling of a system of inventories in a fuzzy environment; mostly of them neglect the expenses associated with transport and operations. A number of investigators are now concentrating on the development of supply chain models that take into account the distribution system of materials, but just a minority of the proposals incorporate the fuzzy environment into take into consideration in order to accommodate subsequent unpredictable circumstances that could not be precisely but could look extremely comparable to the circumstances prevailing at that moment.

2. PRELIMINARIES

2.1. Fuzzy Number. A fuzzy set $[a_\alpha, b_\alpha]$, where $0 \leq \alpha \leq 1$ and $a < b$ defined on $\mathbb{R}$, is called a fuzzy interval if its membership function is given by:

$$\mu_{[a_\alpha, b_\alpha]} = \begin{cases} \alpha, & \text{if } a \leq x \leq b \\ 0, & \text{otherwise} \end{cases}$$

2.2 Hexagonal Fuzzy Number. A hexagonal fuzzy number $A = (a, b, c, d, e, f)$ is represented with the membership functions:

$$L^{-1}(\alpha) = \frac{L_1^{-1}(\alpha) + L_2^{-1}(\alpha)}{2} = \frac{a + b + (c - a)\alpha}{2}$$
$$R^{-1}(\alpha) = \frac{R_1^{-1}(\alpha) + R_2^{-1}(\alpha)}{2} = \frac{e + f + (d - f)\alpha}{2}$$

2.3 Signed Distance Method. If $A = (a, b, c, d, e, f)$ is a hexagonal fuzzy number, then the signed distance method of A is defined as:

$$d(A, 0) = \int_0^1 d([A_L(\alpha), A_R(\alpha)], 0)\, d\alpha = \frac{1}{8}(a + 2b + c + d + 2e + f)$$

2.4 Seaborn Plotting in Python. Seaborn is a terrific Python visualization toolkit for data visualization and graphing. It provides delightful default styles and color schemes to make statistical charts visually appealing. Seaborn depends on the matplotlib software and is intimately linked with pandas' data structures. The intention of Seaborn is to make visualization the primary means of analyzing and comprehending data. It contains dataset-oriented APIs that allow switching between various graphical representations for identical attributes to gain a better understanding of the dataset.

3. Notations

Notation	Description
$G(t)$	Inventory available promptly.
$K + lt$	Rate of demand at a specific point in time.
ε	Consistent rate of decay.
F	Inventory quantity manufactured.
J	Continuity of a cycle.
IC	The cost of holding each unit of inventory.
E	Units in deteriorated condition.
EC	Crumbling cost.
VC	Cost of scarcity.
V	Inventory subsequent standby fulfillment.
$Y[B, D]$	Estimated total cost.

Table 1. Notations and Descriptions

3.1. Assumptions.

- It has no indication of lead time.
- Shortages are permissible and entirely backlogged.
- The restocking rate is inexhaustible but its quantity is constrained.
- The stock-dependent inflation rate is taken into contemplation.
- If time is restricted, the time perspective.
- During the cycle of operation, there is no repair of deteriorated components.

4. INVENTORY MODEL WITH SHORTAGES

Stock models determine the exact moment around which reservations for specific items will have to be implemented as well as a profit of the transaction. The investigation includes strategies for optimum those possibilities, taking into account the cost of obtaining for the goods, the cost of keeping a unit within stock, and the cost of inadequacies. The primary goal of inventories administration is to ensure that that there are enough goods and supplies that can satisfy demand without creating excess inventory, or excess stock. purchasing, holding, transporting, shortfall, and deteriorating costs constitute some of the most common inventory-related expenses. Inventory does not just refer to the things that any organisation produces for sale; it also covers the provisions and components needed for manufacturing. As consequently, it frequently occupies a significant amount of the operational resources. Storage inefficient operations have enormous adverse effects simply because they immediately influence the quantity of objects produced and, as a consequence, revenue generation. Uncertain projections might lead to decisions that are incompatible with the fluctuation of predicted retailing consumption. Demand from consumers constantly evolves. The majority of organisations are reliable. Regardless, with reputable demand projections can determine probable developments, along with significant increases and upticks, utilising beyond information as well as efficiency. A significant number of worldwide manufacturers have been treated as shattered by difficulties with supply chains created by contemporary client behavioural adjustments and rigorous manufacturing practises. A few are remaining unspoiled, but establishments with overseas vendors, as well as manufacturers, have suffered particularly severely impacted.

5. MATHEMATICAL MODEL FOR INVENTORY MANAGEMENT SYSTEM

Mathematical demonstration is a sub-specialty of economic analysis and organization approaching the economically feasible design of production/inventory processes to minimize costs.

5.1. Crisp Function of Inventory Model. It is speculated that the supply chain level at time $t = 0$ is F. The quantity of stock frequently diminishes during the interval due to demand from the marketplace and item impairment $[0, J1)$ and eventually declines to zero at $t = J1$. The restricted supply arises during the span $[J1, J]$ and remains entirely backlogged.

Let $G(t)$ be the inventory available promptly at any time t.

$$\frac{dG(t)}{dt} + \varepsilon G(t) = -(k + lG(t)); \quad 0 \le t \le J1 \quad (1)$$

$$\frac{dG(t)}{dt} = -(k + lG(t)); \quad J1 \le t \le J \quad (2)$$

With the boundary condition solving on equation (1) $G(0) = S$,

$$G(t) = -\frac{k}{\varepsilon + l} + e^{-(\varepsilon+l)t}\left(V + \frac{K}{\varepsilon + l}\right); \quad 0 \le t \le J1 \quad (3)$$

With the boundary condition solving on equation (2) $G(J1) = 0$,

$$G(t) = -\frac{k}{l} + \frac{k}{l}e^{l(J1-t)}; \quad J1 \le t \le J \quad (4)$$

Using $G(J1) = 0$, from equation (3),

$$V = \frac{k}{\varepsilon + l}\left[e^{-(\varepsilon+l)J1} - 1\right] \quad (5)$$

Estimated total average inventory in the period of interval $[0, J1]$,

$$G_1(J1) = \frac{1}{J}\int_0^{J1} G(t)dt = \frac{kJ1^2}{J} \quad (6)$$

Total number of units eliminated during the stocktaking cycle,

$$D = \int_0^{J1} \varepsilon(t)G(t)dt = \frac{\varepsilon kJ1^2}{J} \quad (7)$$

Total average inventory in the interval $[J1, J]$,

$$G_2(J1) = \int_{J1}^{J} G(t)dt = -\frac{k}{lJ}[J - J1 + \frac{1}{l}e^{l(J1-J)} - 1] \quad (8)$$

Using equations (6), (7), (8), the simulation's total average expenditure per unit time,

$$Y[B, D](J1) = IC \cdot G_1(J1) + VC \cdot G_2(J1) + EC \cdot E \quad (9)$$

5.2. Fuzzy Function of Inventory Model. It was predicated that all of the requirements had been determined or could be anticipated with assurance; nevertheless, in real-world scenarios, they will vary slightly from the actual outcomes. As a consequence, the variables associated with the model were unable to be determined to remain constant.

Fuzzy variables are:

$$\begin{aligned} \epsilon^* &= \text{Fuzzy rate of deterioration}, \\ E_C^* &= \text{Fuzzy cost of deterioration}, \\ I_C^* &= \text{Fuzzy carrying cost}, \\ V_C^* &= \text{Fuzzy shortage cost}, \\ VC^* &= (l_1, l_2, l_3, l_4, l_5, l_6), \\ \epsilon^* &= (\epsilon_1, \epsilon_2, \epsilon_3, \epsilon_4, \epsilon_5, \epsilon_6), \\ IC^* &= (i_1, i_2, i_3, i_4, i_5, i_6), \\ EC^* &= (e_1, e_2, e_3, e_4, e_5, e_6), \end{aligned}$$

which are non-negative Hexagonal Fuzzy Numbers (HFN).

The average standardized consumption per segment of time is estimated as:

$$Y^*[B, D](J1) = (\omega \otimes I_C^*) \oplus (\tau \otimes V_C^*) \oplus (\omega \otimes (E_C^* \otimes \epsilon^*)) \quad (10)$$

where

$$\begin{aligned} \omega &= \frac{kJ_1^2}{J}, \\ \tau &= -\frac{k}{lJ}[J - J_1 + \frac{1}{l}e^{l(J_1-J)} - 1]. \end{aligned}$$

The fuzzy total average cost in the interval $[0, J1]$ is represented as:

$$Y^*[B, D](J_1) = (Y^*[B, D, 1](J_1), Y^*[B, D, 2](J_1), Y^*[B, D, 3](J_1), Y^*[B, D, 4](J_1),$$

$$Y^*[B,D,5](J_1), Y^*[B,D,6](J_1)) \quad (11)$$

where

$$Y^*[B,D,i](J_1) = (\omega i_i + \tau l_i + \omega e_i \epsilon_i), \quad i = 1,2,3,4,5,6.$$

The main functioning of defuzzifying the fuzzy total average cost $Y^*[B,D](J1)$ by using the signed distance method:

$$U(Y^*[B,D](J_1)) = \frac{\omega}{8}\left[i_1 + 2i_2 + i_3 + i_4 + 2i_5 + i_6 + e_1\epsilon_1 + 2e_2\epsilon_2 + e_3\epsilon_3 + e_4\epsilon_4 + 2e_5\epsilon_5 + e_6\epsilon_6\right] + \frac{\tau}{8}\left[l_1 + 2l_2 + l_3 + l_4 + 2l_5 + l_6\right] \quad (12)$$

Minimizing the total average cost for necessary condition:

$$\frac{\partial(U(Y^*[B,D](J_1)))}{\partial J_1} = \frac{2kJ_1}{12}\left[i_1 + 2i_2 + i_3 + i_4 + 2i_5 + i_6 + e_1\epsilon_1 + 2e_2\epsilon_2 + e_3\epsilon_3 + e_4\epsilon_4 + 2e_5\epsilon_5 + e_6\epsilon_6\right] + \frac{k}{lJ}(1 - e^l(J_1 - J))(l_1 + 2l_2 + l_3 + l_4 + 2l_5 + l_6) \quad (13)$$

After satisfying shortages, the optimum quantity of commencing merchandise V^* denoted by $(V^*)^\sim$ is:

$$(V^*)^\sim = kJ_1 + \frac{klJ_1^2}{2} + \frac{k(\epsilon_1 + 2\epsilon_2 + \epsilon_3 + \epsilon_4 + 2\epsilon_5 + \epsilon_6)J_1^2}{16} \quad (14)$$

The optimal quantity of the component that was degraded E^* denoted by $(E^*)^\sim$ is:

$$(E^*)^\sim = \frac{kJ_1^2}{J} + \frac{(\epsilon_1 + 2\epsilon_2 + \epsilon_3 + \epsilon_4 + 2\epsilon_5 + \epsilon_6)}{8} \quad (15)$$

Thus, the lowest value associated with the total cost indicated by $Y^*[B,D](J1)$ is:

$$Y^*[B,D](J_1) = \frac{1}{8}\left[\omega i_1 + \tau l_1 + \omega e_1\epsilon_1\right] + \frac{1}{4}\left[\omega i_2 + \tau l_2 + \omega e_2\epsilon_2\right] + \frac{1}{8}\left[\omega i_3 + \tau l_3 + \omega e_3\epsilon_3\right] + \frac{1}{8}\left[\omega i_4 + \tau l_4 + \omega e_4\epsilon_4\right] + \frac{1}{4}\left[\omega i_5 + \tau l_5 + \omega e_5\epsilon_5\right] + \frac{1}{8}\left[\omega i_6 + \tau l_6 + \omega e_6\epsilon_6\right] \quad (16)$$

Uncertainty techniques for optimizing these decisions, taking into contemplation the cost of attracting the merchandise, the cost of retaining a unit in inventory counts, and the impact of shortages. An inventory model is associated with initiatives that diminish the total average cost. By using a Fuzzy functioning model, the total cost is optimized.

6. NUMERICAL EXAMPLE

6.1. Crisp Model. Consider $EC = 300$ per order; $IC = 15$ per unit; $VC = 30$ per unit; $\varepsilon = 0.01$ per year; $J1 = 0.5$ year; $J = 1$; $k = 100$; $l = 2$.

$$Y[B, D](J1) = 924.06$$
$$V^* = 86.15$$
$$E^* = 0.25$$

6.2 Fuzzy Model. The hexagonal fuzzy numbers are:

EC^*	VC^*	IC^*	ε^*
100	10	5	0.006
200	20	10	0.008
300	30	15	0.01
400	40	20	0.012
500	50	25	0.014

$J1 = 0.5$ year; $J = 1$; $k = 100$; $l = 2$.

The fuzzy total average expense and fuzzy optimized backordered quantity occur:

$$Y^*[B, D](J1) = 918.02$$
$$(V^*)^{\sim} = 80.05$$
$$(E^*)^{\sim} = 0.15$$

Inventory reduction is an essential component of lowering costs associated with inventory. The strategy is highly significant for minimizing the cost functions because it contributes to attaining the minimal position. Inventory optimization is the approach of diminishing inventory to accomplish to match a drop in demand. This permits the organization to minimize inventory expenses and minimize overstocking. It additionally assists with storage utilization.

7. SEABORN VISUALIZATION: LINE AND BOX PLOT

The Python Seaborn library is a recognized data visualization library. It can perform exploratory data analysis by building on top of the Matplotlib data visualization library. When specifications require data to be contrasted against one another, a multiple plot might be provided. A numerous line plot assists in the differentiation of information so that it can be investigated and interpreted in relation to other data. Each line plot operates on the premise of a single line plot but differs in the manner it appears on the display surface. Each statistical line plot can be personalized by modifying its color, line style, size, or all of the aforementioned, and an indicator is accessible for viewing it.

```
# Import packages
import pandas as pd
import numpy as np

# Create a DataFrame with crisp and fuzzy data
df = pd.DataFrame({
    'crisp': [880, 898, 900, 915, 924],
    'fuzzy': [882, 889, 896, 910, 918],
})

# Plot the DataFrame
df.plot();
```

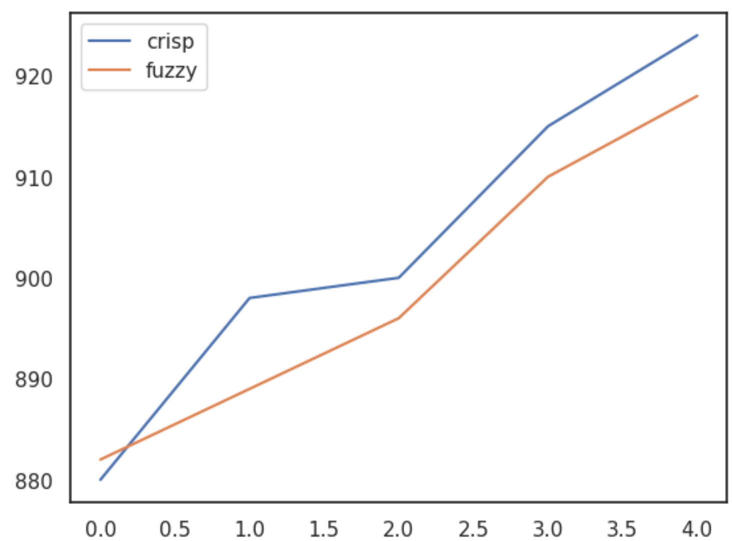

FIGURE 1. Differentiation of total cost in crisp and fuzzy model

A line plot is the illustration which displays data as line marks, indicating the incidence associated with each variable. Figure 1 indicates the minimization of total cost in the crisp value and fuzzy value. Through the line plot it visualizes the differentiation plotting for the values.

7.1. Boxplot in Seaborn Visualization. A box plot participates in preserving the consistency of a quantitative information distribution in such an arrangement that it enables comparability between parameters or across levels of a variable with a category. If allowed, the majority of the portion of the box plot indicates the probability moments for the categories and average. While bristles have downward lines stretching to those most excessive, non-outlier points of information, and regulates are horizontal lines at the ends of the whiskers, their medians have horizontal lines at the level of the median within every box.

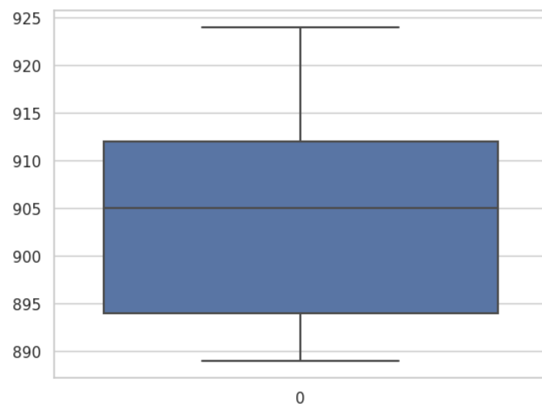

Figure 2. Crisp value of total cost in inventory model

Identification of total cost for the inventory management system, functioning of the maximum value has identified through the solving in the mathematical model. A CSV file is a value-separated by a comma file that allows you to preserve data in a tabulated manner. CSV files resemble conventional spreadsheets but include the .csv extension. CSV files can be accessed in the majority of spreadsheet programs. Figure 2 defines the values of the crisp model in the seaborn box plotting visualizing function.

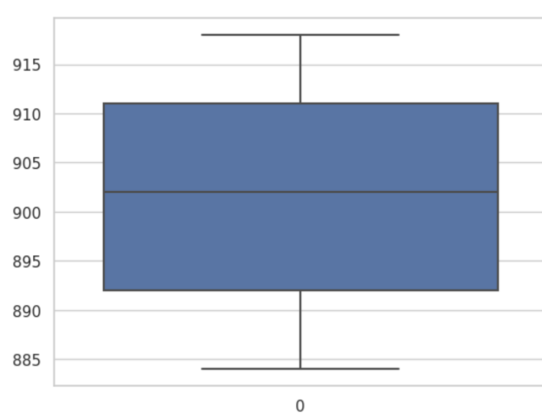

Figure 3. Total cost of Fuzzy model in inventory model

By solving the sign distance method, the fuzzy value of total cost is minimized from the crisp value. Figure 3 indicates the box plot differences from the identified values in the crisp to fuzzy model. Total cost is optimized in the fuzzy model is executed.

8. CONCLUSION

This study introduces a fuzzy management model for handling stock reliability and ongoing inventory shortages. The proposed approach is designed to work well in both clear-cut and fuzzy situations. In the fuzzy setting, all inventory details are represented as hexagonal numbers to add more flexibility. The Signed Distance Method is used to convert fuzzy modelling into more practical aspects. Numerical examples show that the signed distance method is more cost-effective than the clear-cut model. Seaborn Python tools are used to visualize the data for both clear-cut and more flexible numbers.

Conflicts of interest : The authors declare no conflict of interest.

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