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Inventory Model of Deteriorating Items with Investment Constraint in Fuzzy Environment

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ABSTRACT: In this paper a multi item EOQ model with stock dependent demand for deteriorating items under the investment constraint is considered in fuzzy environment. Different inventory costs and the amount of investment are represented as triangular fuzzy numbers. The model has been solved by Robust ranking method, fuzzy optimization technique (FOT) and intuitionistic fuzzy optimization technique (IFOT). Nearest interval approximation method is used in FOT and IFOT. Pareto optimality test is done for fuzzy optimization and intuitionistic fuzzy optimization techniques. The methods are illustrated with a numerical example.

KEYWORDS: Fuzzy inventory, Deteriorating items, Nearest interval approximation, Robust's ranking, Fuzzy Optimization, Intuitionistic fuzzy optimization.

I. INTRODUCTION

Inventory problems are common in manufacturing, maintenance service and business operations in general. Often uncertainties may be associated with demand, various relevant costs. Generally demand rate is considered to be constant, time dependent, ramp type and selling price dependent. However in present competitive market stock-dependent demand plays an important role in increase its demand. Deterioration is one of the important factor in inventory system. Some items like food grains, vegetables, milk, eggs etc. deteriorating during their storage time and retailer suffers loss. In an inventory system available storage space, budget, number of orders etc. are always limited hence multi-item classical inventory models under these constraints have great importance.

In conventional inventory models, uncertainties are treated as randomness and are handled by probability theory. However in certain situations, uncertainties are due to fuzziness and in such cases the fuzzy set theory introduced by Zadeh [18] is applicable. Many researches introduced the concept of ranking function [14] for fuzzy parameter which gives a representative value for it. Using ranking function fuzzy parameters can be easily changed into crisp one.

The fuzzy parameters changing into appropriate interval numbers are introduced by Gregorzwshi [5],Susovan chakrabortly et.al [15,16] proposed a method to solve an EOQ model using the concept of interval arithmetic. In fuzzy optimization the degree of acceptance of objectives and constraints are considered here. Now a days different modification and generalized form of fuzzy set theory have appeared, intuitionistic fuzzy set (IFS) is one among them. The concept of an IFS can be viewed as an alternative approach to define a fuzzy set in case where available information is not sufficient for the definition of an imprecise concept by means of a conventional fuzzy sets.

In this paper, under limited investment, a multi-item inventory model of deteriorating item with stock-dependent demand is formulated in crisp and fuzzy environment. Here the objective is to find an EOQ to maximize the profit under the investment constraint. The problem is solved by

- (i) Robust's ranking technique
- (ii) Fuzzy optimization technique
- (iii) Intuitionistic fuzzy optimization technique

The model is illustrated numerically and the results are obtained from different methods.



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II. PRELIMINARIES

Definition(1): Atanassov [20],Let X={ x_1, x_2, \dots, x_n } be a finite universal set. An Atanassov's intuitionistic fuzzy set (IFS) in a given universal set X is an expression \hat{A} is given by $\hat{A} = \{\langle x_i, \mu_{\hat{A}}(x_i), v_{\hat{A}}(x_i) \rangle : x_i \in X\}$ Where the functions $\mu_{\hat{A}} : X \to [0,1]$ i.e. $x_i \in X \to \mu_{\hat{A}}(x_i) :\in [0,1]$ and $v_{\hat{A}} : X \to [0,1]$ i.e. $x_i \in X \to v_{\hat{A}}(x_i) \in [0,1]$ define the degree of membership and the degree of non-membership respectively of an element $x_i \in X$ satisfy the condition: for every $x_i \in X$, $0 \le \mu_{\hat{A}}(x) + v_{\hat{A}}(x) \le 1$.

Definition(2): Let \hat{A} and \hat{B} be two Atanassov's IFSs in the set X. The intersection of \hat{A} and \hat{B} is defined as follows: $\hat{A} \cap \hat{B} = \left\{ \left\langle x_i, \min\left(\mu_{\hat{A}}(x_i), \mu_{\hat{B}}(x_i)\right), \max\left(v_{\hat{A}}(x_i), v_{\hat{B}}(x_i)\right) \right\rangle | x_i \in X \right\}$.

Definition (3):Let \mathfrak{R} be the set of all real numbers. An interval, moore[9], may be expressed as $\overline{a} = [a_L, a_R] = \{x : a_L \le x \le a_R, a_L \in \mathfrak{R}, a_R \in \mathfrak{R}\}$ (1)

where a L and a R are called the lower and upper limits of the interval \overline{a} , respectively.

If $a_L = a_R$ then $\overline{a} = [a_L, a_R]$ is reduced to a real number a, where $a = a_L = a_R$. alternatively an interval \overline{a} can be expressed in mean-width or centre-radius form as $\overline{a} = \langle m(\overline{a}), w(\overline{a}) \rangle$, where $m(\overline{a}) = \frac{1}{2}(a_L + a_R)$ and

 $w(\overline{a}) = \frac{1}{2}(a_R - a_L)$ are respectively the mid-point and half-width of the interval \overline{a} . The set of all interval numbers in \Re is denoted by I(\Re).

Definition (4): (Triangular fuzzy number)

For a triangular fuzzy number A(x), it can be represented by A(a,b,c:1) with membership function $\mu_A(x)$ given by

$$\mu_{A}(x) = \begin{cases} \frac{(x-a)}{(b-a)}; a \le x \le b\\ 1 & ; x = b\\ \frac{(c-x)}{(c-b)}; b \le x \le c\\ 0 & ; o therw is e \end{cases}$$

Definition (5): (α-cut of a fuzzy number)

The α -cut of a fuzzy number A(x) is defined as A(α)={x: $\mu(x) \ge \alpha, \alpha \in [0,1]$ }

Definition(6): Nearest interval approximation

According to Gregorzewski [5] we determine the interval approximation of a fuzzy number as: Let $A = (a_1, a_2, a_3)$ be an arbitrary triangular fuzzy number with a α -cut $[A_L(\alpha), A_R(\alpha)]$

Then by nearest interval approximation method, the lower limit C_L and upper limit C_R of the interval are

$$C_{L} = \int_{0}^{1} A_{L}(\alpha) d\alpha = \int_{0}^{1} \left[a_{1} + (a_{2} - a_{1}) \alpha \right] d\alpha = \frac{a_{1} + a_{2}}{2}$$

$$C_{R} = \int_{0}^{1} A_{R}(\alpha) d\alpha = \int_{0}^{1} \left[a_{3} - (a_{3} - a_{2}) \alpha \right] d\alpha = \frac{a_{2} + a_{3}}{2}$$
(2)

Therefore, the interval number considering \tilde{A} as triangular fuzzy number is $\left[\frac{a_1 + a_2}{2}, \frac{a_2 + a_3}{2}\right]$.



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Definition(7):Pareto-optimality

 $x^0 \in X$ is said to be a Pareto optimal solution if there does not exist another $x \in X$ such that $f_k(x^0) \le f_k(x)$ for all P = 1,2,...,p and $f_j(x^0) < f_j(x)$ for at least one $j \in \{1, 2, ..., p\}$

III. ASSUMPTION

- (i) The scheduling period is constant and no lead time.
- (ii) Replenishment rate is infinite.
- (iii) Selling price is known and constant.
- (iv) Demand rate is stock dependent.
- (v) Shortages are not allowed.
- (vi) Deteriorating rate is age specific failure rate.

IV. NOTATIONS

- T_i : Time period for each cycle for the ith item.
- R_i : Demand rate per unit time of i^{th} item. $[R_i = a_i + b_i q_i]$
- θ_i :Deteriorating rate of ith item.
- $Q_i(t)$: inventory level at time t of ith item.
- C_H : Total Holding cost.
- C_{1i} :Holding cost per unit of ith item.
- C_{3i} :Setup cost for ith item.
- S_{di} :Total deteriorating units of ith item.
- P_i :Selling price per unit of ith item.
- Q_i :Initial stock level of i^{th} item.
- $PF(Q_i)$: Total profit of ith item.

N :Number of items.

(wavy bar (~) represents the fuzzification of the parameters)

V. MATHEMATICAL FORMULATION

5.1 Crisp model:

As $Q_i(t)$ is the inventory level at time t of i^{th} item, then the differential equation describing the state of inventory is given by

$$\frac{d}{dt}Q_i(t) + \theta_i Q_i(t) = -(a_i + b_i Q_i(t)) \qquad 0 \le t \le T_i$$

Solving the above differential equation using boundary condition Q_i(t)= Q_i at t=0, we get

$$Q_i(t) = -\frac{a_i}{(\theta_i + b_i)} + \left[Q_i + \frac{a_i}{(\theta_i + b_i)} \right] e^{-(\theta_i + b_i)t}$$
(3)

And using boundary condition $Q_i(t)=0$ at $t=T_i$

$$\dot{T}_{i} = \frac{1}{\left(\theta_{i} + b_{i}\right)} \log\left\{1 + \frac{\left(\theta_{i} + b_{i}\right)Q_{i}}{a_{i}}\right\}$$
(4)

The holding cost of ith item in each cycle is

$$C_{\rm H} = C_{1i} G_i (Q_i)$$
(5)

Where,



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$$G_i(Q_i) = \int_0^{Q_i} \frac{q_i dq_i}{a_i + (\theta_i + b_i)q_i}$$
$$= \frac{Q_i}{(\theta_i + b_i)} + \frac{a_i}{(\theta_i + b_i)^2} \log\left\{1 + \frac{(\theta_i + b_i)Q_i}{a_i}\right\}$$

By neglecting the higher power terms, we get

$$G_{i}(Q_{i}) = \frac{Q_{i}^{2}}{2a_{i}} \left\{ 1 - 2 \frac{(\theta_{i} + b_{i})Q_{i}}{3a_{i}} \right\}$$

The total number of deteriorating units of the ith item is (0) = AC(0)

$$S_{di}(Q_{i}) = \theta_{i}G_{i}(Q_{i})$$
The net revenue for the ith item is

$$N(Q_{i}) = (P_{i} - C_{i})Q_{i} - P_{i}S_{di}(Q_{i})$$
(6)

$$N(Q_{i}) = (P_{i} - C_{i})Q_{i} - P_{i}\theta_{i}G_{i}(Q_{i})$$
The profit of ith item is

$$PF(Q_{i}) = N(Q_{i}) - C_{1i}G_{i}(Q_{i}) - C_{3i}, \qquad i=1,2,....n.$$

$$PF(Q_{i}) = (P_{i} - C_{i})Q_{i} - P_{i}\theta_{i}G_{i}(Q_{i}) - C_{1i}G_{i}(Q_{i}) - C_{3i} \qquad i=1,2,....n.$$
(7)

$$PF(Q_{i}) = (P_{i} - C_{i})Q_{i} - (C_{1i} + P_{i}\theta_{i})G_{i}(Q_{i}) - C_{3i}, \qquad i=1,2,....n.$$
Hence the problem is

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Max
$$PF = \sum_{i=1}^{n} \left[(P_i - C_i)Q_i - (C_{1i} + P_i\theta_i)G_i(Q_i) - C_{3i} \right]$$
 (8)

Subject to : $\sum_{i=1}^{n} C_i O_i \leq B$

$$Q_i \ge 0, i=1,2,....n.$$

5.2. Fuzzy model:

When above profit, cost, selling price, deteriorating rate and total budget become fuzzy, the said crisp model is transform to

$$M \quad \tilde{a} \times PF = \sum_{i=1}^{n} \left[(\tilde{P}_{i} - \tilde{C}_{i})Q_{i} - (\tilde{C}_{1i} + \tilde{P}_{i}\tilde{\theta}_{i})G_{i}(Q_{i}) - \tilde{C}_{3i} \right]$$

$$Subject \text{ to: } \sum_{i=1}^{n} \tilde{C}_{i}Q_{i} \leq \tilde{B}$$

$$Q_{i} \geq 0, \qquad i=1,2,\dots,n$$

$$M = M = THEM = TICAL \text{ ANALYSIS}$$

VI. MATHEMATICAL ANALYSIS

A. Robust ranking technique:

Given a convex fuzzy number \tilde{a} , the Robust's ranking index is defined by

$$R(\tilde{a}) = \int_{0}^{1} 0.5(a_{\alpha}^{L}, a_{\alpha}^{U}) d\alpha$$

where $\left(a_{\alpha}^{L}, a_{\alpha}^{U}\right)$ is the α -level cut of the fuzzy number \tilde{a} .

In this paper we use this method of ranking for the fuzzy numbers. The Robust's ranking index $R(\tilde{a})$ gives the representative value of the fuzzy number \tilde{a} . Hence using this we can defuzzify into crisp one.



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Robust's ranking technique [10,14] which satisfies compensation, linearity and additivity properties and provides results which are consistent with human intuition.

We apply Robust's ranking method[10,14] to defuzzify the fuzzy objective and the constraint.

Taking P_i, i=1,2,.....n as fixed in (9) and Using this ranking function the fuzzy model (9) becomes,

$$M \text{ ax } PF^* = \sum_{i=1}^{n} \left[(P_i - R(\tilde{C}_i))Q_i - R(\tilde{C}_{1i})G_i(Q_i) - P_iR(\tilde{\theta}_i)G_i(Q_i) - R(\tilde{C}_{3i}) \right]$$

Subject to: $\sum_{i=1}^{n} R(\tilde{C}_i)Q_i < R(\tilde{B})$.

Subject to: $\sum_{i=1}^{n} R(\tilde{C}_i) Q_i \le R(\tilde{B})$

B. Fuzzy optimization technique:

Using nearest interval approximation [5] to the objective and Robust's ranking [10,14] to the constraint. The proposed model can be stated as

 $\max imize\left\{PF_L(Q_i), PF_R(Q_i)\right\}$

Subject to:
$$\sum_{i=1}^{n} R(\tilde{C}_{i})Q_{i} \le R(\tilde{B})$$
(10)

Here the interval valued problem (10) is represented as

$$\max imize \left\{ PF_L(Q_i), PF_C(Q_i)PF_R(Q_i) \right\}, PF_C = \frac{1}{2} \left[PF_L + PF_R \right]$$

Subject to:
$$\sum_{i=1}^n R(\tilde{C}_i)Q_i \le R(\tilde{B})$$
 (11)

To solve the above multi-objective problem (11) we have used the following fuzzy programming technique.

Step 1: Solve the multi-objective profit function subject to the constraint as a single objective Profit function subject to the constraint using one objective at a time and ignoring all others.

Step 2: From the results of step 1, determine the corresponding values for every objective at each solution derived.

Step 3:From step 2, obtain the lower bounds and upper bounds for each objective functions. Set U_k =max (PF_k) and L_k = min (PF_k), K=L,C,R.

Step 4: Define fuzzy linear membership function $(\mu_{PF_k}; k = L, C, R)$ for each objective function is defined

by

$$\mu_{PF_{k}} = \begin{cases} 0 ; PF_{k} \leq L_{k} \\ \frac{PF_{k} - L_{k}}{d_{k}}; L_{k} \leq PF_{k} \leq U_{k} \\ 1 ; PF_{k} \geq U_{k} \end{cases}$$
(12)

Step 5: After determining the linear membership function defined in(12) for each objective function following the problem (11) can be formulated an equivalent crisp model

Max α,

Subject to:
$$\alpha \leq \mu_{PF_k}(Q); k = L, C, R.$$

$$\sum_{i=1}^{n} R(\tilde{C}_{i})Q_{i} \leq R(\tilde{B}), \ 0 \leq \alpha \leq 1, Q_{i} > 0$$

Step 6: now the above problem can be solved by a non-linear optimization technique and optimal solution of α (say α^*) is obtained.



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Step 7: now after obtaining α^* , the decision maker selects the objective function, from among the objective functions PF_L , PF_C , PF_R . If he selects PF_C

 $\operatorname{Max} PF_{C}$,

 $PF_{L} \leq m_{L}, PF_{C} \leq m_{C}, PF_{R} \leq m_{R}$ Where $m_{L} = U_{L} - \alpha * d_{L}; m_{C} = U_{C} - \alpha * d_{C}; m_{R} = U_{R} - \alpha * d_{R};$ Step8: Pareto-optimal solution
(13)

Now after deriving the optimum decision variables, Pareto-optimality test is performed according to [16], let the decision vectors Q_i^* and the optimum values $PF_L^* = PF_L(Q^*)$, $PF_C^* = PF_C(Q^*)$, $PF_R^* = PF_R(Q^*)$, are obtained from (13). With these values, the following problem is solved using a non-linear optimization technique.

$$\min V = (\epsilon_{L} + \epsilon_{C} + \epsilon_{R})$$
Subject to: $PF_{L} + \epsilon_{L} = PF_{L}^{*}, PF_{C} + \epsilon_{C} = PF_{C}^{*}, PF_{R} + \epsilon_{R} = PF_{R}^{*},$

$$\epsilon_{L}, \epsilon_{C}, \epsilon_{R} \ge 0, Q \ge 0, \alpha \ge \beta$$

$$\alpha + \beta \le 1; \alpha, \beta \ge 0$$

$$(14)$$

The optimal solution of (14), say Q^{**} , PF_L^{**} , PF_C^{**} , PF_R^{**} are called strong Pareto Optimal solution provided V is very small otherwise it is called weak Pareto solution.

C. IF Programming technique

To solve multi-objective maximization problem given by (14), we have used the following IF programming technique. For each of the objective functions $PF_L(Q)$, $PF_C(Q)$, $PF_R(Q)$, we first find the lower bounds L_L , L_C , L_R (best values) and the upper bounds U_L , U_C , U_R (worst values), where L_L , L_C , L_R are the aspired level achievement and U_L , U_C , U_R are the highest acceptable level achievement for the objectives $PF_L(Q)$, $PF_C(Q)$, $PF_R(Q)$ respectively and $d_k = U_k - L_k$ is the degradation allowance for objective $PF_k(Q)$, k=L,C,R. Once the aspiration levels and degradation allowance for each of the objective function has been specified, we formed a fuzzy model and then transform the fuzzy model into a crisp model. The steps of intuitionistic programming technique is given below.

Step 1: Solve the multi-objective profit function a single objective Profit function using one objective at a time and ignoring all others.

Step 2: From the results of step 1, determine the corresponding values for every objective at each solution derived.

Step 3: From step 2, obtain the lower bounds and upper bounds for each objective functions. Set U_k =max (PF_k) and L_k = min (PF_k) K=L,C,R.

Step 4: Define membership function $(\mu_{PF_k}; k = L, C, R)$, and non membership function

 $(v_{PF_{\iota}}; k = L, C, R)$ for each objective function. A linear membership function is defined by



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$$\mu_{PF_{k}} = \begin{cases} 1 & ; PF_{K} \leq L_{k} \\ \left(\frac{PF_{k} - L_{k}}{d_{k}}\right); L_{k} \leq PF_{k} \leq U_{k} \\ 0 & ; PF_{K} \geq U_{K} \end{cases}$$

(15)

A Linear non-membership function is defined by

$$v_{PF_{k}} = \begin{cases} 0 ; PF_{K} \leq L_{k} \\ 1 - \left(\frac{PF_{k} - L_{k}}{d_{k}}\right); L_{k} \leq PF_{k} \leq U_{k} \\ 1 ; PF_{K} \geq U_{K} \end{cases}$$

Step 5: After determining the membership and non-membership function defined in(14) for each objective functions following the problem (13) can be formulated an equivalent crisp model on the basis of definition 2 of this paper as

$$\max \alpha, \min \beta$$

$$\alpha \le \mu_{PF_k}(x) \quad ;k = L, C, R$$

$$\beta \ge v_{PF_k}(x) \quad ;k = L, C, R$$

$$\alpha \ge \beta \quad ;\alpha + \beta \le 1; \alpha, \beta \ge 0$$

$$\sum_{i=1}^n R(\tilde{C}_i)Q_i \le R(\tilde{B}), \ 0 \le \alpha \le 1, Q_i > 0$$

Step 6: Now the above problem can be solved by a non-linear optimization technique and optimal solution of α (say α^*) and β , (say β^*) are obtained.

Step 7: Now after obtaining α^* and β^* , the decision maker selects the objective function, from among the objective functions PF_L , PF_C , PF_R . If he selects PF_C

 $Max PF_{C}$

 $\begin{array}{c} PF_{L} \geq m_{L}, PF_{C} \geq m_{C}, PF_{R} \geq m_{R} \\ PF_{L} \geq n_{L}, PF_{C} \geq n_{C}, PF_{R} \geq n_{R} \\ Q \geq 0, \alpha \geq \beta; \\ \alpha + \beta \leq 1; \alpha, \beta \geq 0 \end{array}$

Where

$$m_{c} = L_{c} + \alpha d_{c}; n_{c} = U_{c} - \beta d_{c}$$
$$m_{R} = L_{R} + \alpha d_{R}; n_{R} = U_{R} - \beta d_{R}$$

 $m_L = L_L + \alpha d_L; n_L = U_L - \beta d_L$

Step8: Pareto-optimal solution

Now after deriving the optimum decision variables, Pareto-optimality test is performed according to [16], let the decision vector Q^* and the optimum values $PF_L^* = PF_L(Q^*)$, $PF_C^* = PF_C(Q^*)$, $PF_R^* = PF_R(Q^*)$, are obtained from (14). With these values, the following problem is solving using a non-linear optimization technique.



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 $\min V = (\epsilon_{L} + \epsilon_{C} + \epsilon_{R})$ Subject to: $PF_{L} + \epsilon_{L} = PF_{L}^{*}, PF_{C} + \epsilon_{C} = PF_{C}^{*}, PF_{R} + \epsilon_{R} = PF_{R}^{*},$ $\epsilon_{L}, \epsilon_{C}, \epsilon_{R} \ge 0, Q \ge 0, \alpha \ge \beta$ $\alpha + \beta \le 1; \alpha, \beta \ge 0$ (16)

The optimal solution of (16), say Q^{**} , PF_L^{**} , PF_C^{**} , PF_R^{**} are called strong Pareto Optimal solution provided V is very small otherwise it is called weak Pareto solution.

VII. NUMERICAL EXAMPLE

For all models let us assume For n=2,

 $P_1=10, C_1=7, a_1=110, b_1=0.5, \theta_1=0.025, P_2=10, C_2=6.75, a_2=100, b_2=0.5, \theta_2=0.03, C_{11}=2, C_{12}=2.2, C_{31}=65, C_{32}=50, B=1800.$

A. Taking $\tilde{C}_{11} = (1.95, 2, 2.05); \ \tilde{C}_{12} = (2.15, 2.20, 2.25); \ \tilde{C}_{31} = (55, 65, 75); \ \tilde{C}_{32} = (40, 50, 60); \ \theta_1 = (0.02, 0.025, 0.03)$ $\theta_2 = (0.025, 0.03, 0.035); \ \tilde{C}_1 = (6.5, 7, 7.5); \ \tilde{C}_2 = (6.25, 6.75, 7.25); \ \tilde{B} = (1700, 1800, 1900)$ m ax $PF^* = 3Q_1 + 3.25Q_2 - 0.010226Q_1^2 - 0.0125Q_2^2 - 115$ $7Q_1 + 6.75Q_2 \le 1800$

The optimum results are

Max PF*	Q_1^*	Q ₂ *
314.98809	138.22278	123.32453
	~	~

B.	Considering all values as sam	e as case (A) and also taking	$P_1 = (9.5, 10, 11); H$	$P_2 = (9.75, 10, 11);$
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	PF_L	PF _C	PF_R
PFL	184.67881	179.22613	179.19743
PF _C	342.71953	358.56453	358.55485
PF _R	500.75962	537.90213	537.91146

The optimum value of α is **0.63690117**

Optimum results when PF_L is chosen as the most important objective function

PF _L *	PF _C *	PF _R *	Q_1^*	Q_2^*
182.68852	353.55546	524.42166	129.09892	120.39850

Pareto optimal solution:

V	PF _L **	PF _C **	PF _R **	Q ₁ **	Q ₂ **
0.75436E-05	182.68852	353.55545	524.42165	129.08873	120.40869



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C. Considering all values as same as case (B) and also taking $\tilde{P}_1 = (9.5, 10, 11); \tilde{P}_2 = (9.75, 10, 11);$ The optimum value of α and β

А	В
0.63690117	0.36309883

Optimum results when PF_L is chosen as the most important objective function

PF _L *	PF _C *	PF _R *	Q ₁ *	Q ₂ *
182.68852	353.55546	524.42166	129.10772	120.38970

Pareto optimal solution:

V	PF_L^{**}	PF _C **	PF _R **	Q1**	Q_2^{**}
0.0000000	182.68851	353.55545	524.42166	129.08487	120.41256

VIII. CONCLUSION

In this paper, a real life inventory problem under the investment constraint environment has been proposed and solved by three different methods namely (i) Robust's ranking (ii) fuzzy optimization (FOT) (iii) intuitionistic fuzzy optimization (IFOT). Different inventory costs and the investment amount are considered as triangular fuzzy numbers nearest interval approximation method is used in FOT and IFOT. Linear membership function is taken for fuzzy objective. Robust's ranking method gives the less profit amount when compared with fuzzy optimization and intuitionistic fuzzy optimization. FOT and IFOT yields better results. Also strong Pareto optimality is obtained for FOT and IFOT.

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