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Research Article

# A Multi Objective Offering Inventory Model with time Dependent Demand

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***Abstract***— In this article, I have presented a multi objective offering inventory model with limitation on initial invested money. Any offer on any things always attracts the customers so in this model to increase customer attraction, here purchase cost offering on quantity and demand is time dependent. Limitation is considered on set up cost and purchase cost. Costs are not specific so all cost parameters are considered as the generalized triangular fuzzy number. My formulated multi objective fuzzy inventory system has been solved by Fuzzy programming technique with hyperbolic membership function. A numerical example is taken to elaborate the inventory model. Sensitivity analysis and the graphical representations have been displayed to represent the truth of the model.

***Keywords***— Inventory, offering, Multi-item, Fuzzy number, Fuzzy Technique.

## 1. Introduction

An inventory model deals with decisions that minimize the total average cost or maximize the total average profit and delighting customers. In that way to construct a real life mathematical inventory model we use various assumptions and notations and approximations. In the ordinary inventory system inventory cost i.e. set-up cost, holding cost, deterioration cost, etc. are taken fixed amounts but in real life inventory systems these costs are not always fixed. So consideration of fuzzy variables is more realistic and interesting.

Inventory model was first developed by Harris in 1913. Subsequently, various researchers have improved the inventory system in various ways. Arcelus et. al. [1] developed retailer's pricing, credit and inventory policies for deteriorating items in response to temporary price/credit incentives. Sana [2] established a deterministic EOQ model with delay in payments and time varying deterioration rate. Sarkar [3] studied on EOQ model with delay in payments and stock dependent demand in the presence of imperfect production. Mishra and Singh [4] considered computational approach to an inventory model with ramp-type demand and linear deterioration. Sarkar [20] discussed an EOQ model with delay in payments and time varying deterioration Rate. Khanra et al. [5] presented an inventory model with time dependent demand and shortages under trade-credit policy. Sarkar & Sarkar [6] studied variable deterioration and demand-an inventory model. Alfares and Ghaithan [7] established inventory and pricing model with price-dependent demand, time-varying holding cost, and quantity discounts. Liuxin et al [8] developed optimal pricing and replenishment policy for deteriorating inventory under stock-level-dependent, time-varying and price-dependent demand. Pando et al [9] presented optimal lot-size policy for deteriorating items with stock-dependent demand considering profit maximization. Mondal, Garai and Roy [10] considered optimization of generalized order-level inventory system under fully permissible delay in payment.

Any offer on any things always attracts the customers. So keeping the offer in the business system is very important. Tersine and Leon [11] presented a model on temporary price discount and EOQ. Then Baker and Vilcassim [12] developed continuous review price change inventory model. Monahan [13] considered a quantity discount pricing model to increase vendor profits. Davis and Gaither [14] studied optimal ordering policies under conditions of extended payment privileges Manage. Lee & Rosenblatt [15] discussed generalized quantity discount pricing model to increase supplier's profits. Goyal [16] established economic ordering policy during special discount periods for dynamic inventory problems under certainty. Tersine and Barman [17] presented economic purchasing strategies for temporary price discounts. Wee and Yu [18] developed a deteriorating inventory model with a temporary price discount. Arcelus and Srinivasan [19] discussed ordering policies under one time only discount and price sensitive demand. Chu et al. [20] studied on supplier-restricted order quantity under temporary price discounts. Sarker and Kindi [21] considered optimal ordering policies in response to a discount offer. Lin [22] discussed minimax distribution free procedure with backorder price discount. Cárdenas-Barrón [23] developed optimal ordering policies in response to a discount offer. Giri & Roy [24] studied vendor–buyer integrated production–inventory model with quantity discount and unequal sized shipments. Mandal et al [25] discussed two-warehouse integrated inventory model with imperfect production process under stock-dependent demand and quantity discount offer. Shaikh et al [26] established price discount facility in an EOQ model for deteriorating items with stock-dependent demand and partial backlogging.

Multi item is more profitable in business. Multi item helps to increase the customer and also helps to increase the sales. So multi item is most impotent in business world. Roy and Maiti [27] considered multi-bjective inventory models of deteriorating items with some constraints in a fuzzy environment. Garai et al [28] presented a multi-item inventory model with fuzzy rough coefficients via fuzzy rough expectation. Garai et al [29] developed multi-objective inventory model with both stock-dependent demand rate and holding cost rate under fuzzy random environment. Malik and Sarkar [30] studied disruption management in a constrained multi-product imperfect production system. Chakraborty et al [31] discussed multi-warehouse partial backlogging inventory system with inflation for non-instantaneous deteriorating multi-item under imprecise environment. Das [32] established multi item inventory model include lead time with demand dependent production cost and set-up-cost in fuzzy environment. Das [33] also explained fuzzy multi objective inventory model of demand dependent deterioration including lead time.

Fuzzy number and fuzzy techniques are most importance in business world. Fuzzy idea was first established by Zadeh in 1965. Application of fuzzy was developed by Zimmermann in 1985. Garai, Chakraborty and Roy [34] considered expected value of exponential fuzzy number and its application to multi-item deterministic inventory model for deteriorating items. Soni and Suthar [35] presented EOQ model of deteriorating items for fuzzy demand and learning in fuzziness with finite horizon. Poswal et al [37] expressed investigation and analysis of fuzzy EOQ model for price sensitive and stock dependent demand under shortages. Roy & Maity [38] established a fuzzy inventory model with constraints. Maity [39] also considered fuzzy inventory model with two ware house under possibility measure in fuzzy goal. Sarkar [40] discussed EOQ model with delay in payments and time varying deterioration Rate. Bhosale and Umap [43] presented evaluation and selection of supplier in a healthcare supply chain using TOPSI. Zulqarnain, Saeed, Ahmad, Dayan and Ahmad [44] studied application of TOPSIS Method for Decision Making. Alqatqat, Feng and Solanki, discussed fuzzy topsis multiple-attribute decision making for production electric upon future data.

As a last paragraph of the introduction should provide organization of the paper/article (Rest of the paper is organized as follows, Section 1 contains the introduction of the article. Section 2 presents notation, assumption, and formulation of the inventory model as a nonlinear optimization problem. Section 3 develops the fuzzy model since costs are not specific. Section 4 for the solution procedure for solves the proposed model. Section 5 solves a numerical example to clarify the proposed model. In section 6, sensitivity analysis and the graphical portrayals have been displayed to illustrate the model. Finally, Section 7 provides conclusions and some opportunities for future research.

## 2. Necessary part of the inventory model

### 2.1 Notation

$S_i$: Set-up cost per order for i^th item.
$h_i$: Holding cost per unit and per unit time for i^th item.
$M$: Total expected set-up-cost and purchase cost.
$T_i$: The length of cycle time for $i^{th}$ item, $T_i > 0$.
$I_i(t)$: Inventory level for the i^th item at time *t*.
$Q_i$: The order quantity for the duration of a cycle of length $T_i$ for i^th item.
$TAC_i(Q_i, D_i)$: Total average cost for the i^th item.
$\widetilde{TAC}_i(Q_i, D_i)$: Fuzzy total average cost for the i^th item.
$\tilde{h}_i$: Generalized triangular fuzzy number of the parameter $h_i$
$\tilde{a}_i$: Generalized triangular fuzzy number of the parameter $a_i$
$\tilde{b}_i$: Generalized triangular fuzzy number of the parameter $b_i$
$\tilde{s}_i$: Generalized triangular fuzzy number of the parameter $s_i$

### 2.2 Assumptions

1. The inventory system has considered multi item.
2. The replenishment occurs instantaneously at infinite rate.
3. Demand rate is time dependent.
4. Purchase cost offering on quantity so purchase cost taking as $P_i = a_i Q_i^{-b_i}$ where $a_i > 0$, and $0 < b_i << 1$ are constant real numbers.
5. Shortages are not considered.

### 2.3 Formation of the model in crisp for $i^{th}$ item

The inventory situation for i^th item has been shown in Figure-1. During the cycle length $[0, T_i]$ the stock reduces due to only demand rate. In that time period the governing differential equation is

$$\frac{dI_i(t)}{dt} = -\frac{C_i^2 t}{(1+t)}, \qquad 0 \le t \le T_i \tag{1}$$

With boundary condition, $I_i(0) = Q_i$, $I_i(T_i) = 0$.
Solving the above differential equation (1), we get

$$I_i(t) = Q_i - C_i^2\big(t - log(1+t)\big),\ 0 \le t \le T_i \tag{2}$$

$$\text{and} \quad Q_i = C_i^2[T_i - log(1 + T_i)]. \tag{3}$$

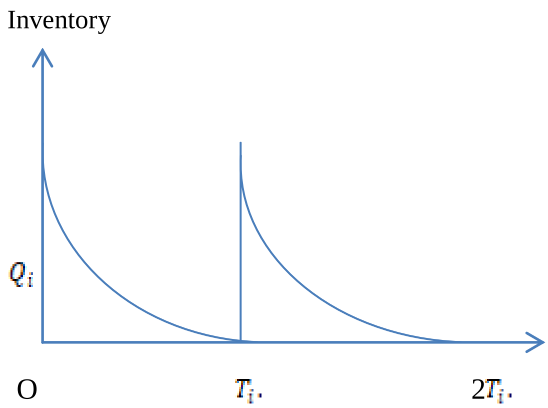


Figure-1 (Inventory level for i^th item)

 

The model related the different expense as following

i) Average holding cost $= \frac{1}{T_i}\int_0^{T_i} h_i I_i(t)dt$

$= \frac{h_i}{T_i}\left\{Q_i(1+T_i) - \frac{c_i^2 T_i^2}{2} - (1+T_i)log(1+T_i)\right\}$

ii) Average set-up-cost $= \frac{S_i}{T_i}$

iii) Average purchase cost $= \frac{a_i Q_i^{1-b_i}}{T_i}$

Total average cost in my proposed model is given by

$$TAC_i(Q_i,T_i) = \frac{h_i}{T_i}\left\{Q_i(1+T_i) - \frac{c_i^2 T_i^2}{2} - (1+T_i)log(1+T_i)\right\} + \frac{S_i}{T_i} + \frac{a_i Q_i^{1-b_i}}{T_i} \quad (4)$$

Therefore the multi objective optimization problem is

Minimize

$$TAC_i(Q_i,T_i) = \frac{h_i}{T_i}\left\{Q_i(1+T_i) - \frac{c_i^2 T_i^2}{2} - (1+T_i)log(1+T_i)\right\} + \frac{S_i}{T_i} + \frac{a_i Q_i^{1-b_i}}{T_i}$$

Subject to, $\sum \frac{S_i}{T_i} + \frac{a_i Q_i^{1-b_i}}{T_i} \le M$ and

$$Q_i = C_i^2[T_i - log(1+T_i)], Q_i > 0, T_i > 0, i = 1,2,\dots\dots\dots.n \quad (5)$$

## 3. Fuzzy Model

Generally the parameters for holding cost, unit production cost, and set-up cost are not particularly known to us. Due to uncertainty, we assume all the parameters $(a_i, b_i, h_i, s_i)$ as generalized triangular fuzzy number (GTFN) $(\tilde{a_i}, \tilde{b_i}, \tilde{h_i}, \tilde{s_i})$ as following

$\tilde{a_i} = (a_i^1, a_i^2, a_i^3; \omega_{a_i}), 0 < \omega_{a_i} \le 1;$

$\tilde{b_i} = (b_i^1, b_i^2, b_i^3; \omega_{b_i}), 0 < \omega_{b_i} \le 1;$

$\tilde{h_i} = (h_i^1, h_i^2, h_i^3; \omega_{h_i}), 0 < \omega_{h_i} \le 1;$

$\tilde{s_i} = (s_i^1, s_i^2, s_i^3; \omega_{s_i}), 0 < \omega_{s_i} \le 1;$

$(i = 1,2, \dots\dots\dots, n).$

Then the fuzzy model is

Minimize

$$\widetilde{TAC_i}(Q_i,T_i) = \frac{\tilde{h_i}}{T_i}\left\{Q_i(1+T_i) - \frac{c_i^2 T_i^2}{2} - (1+T_i)log(1+T_i)\right\} + \frac{\tilde{s_i}}{T_i} + \frac{\tilde{a_i} Q_i^{1-\tilde{b_i}}}{T_i}$$

Subject to $\sum \frac{\tilde{s_i}}{T_i} + \frac{\tilde{a_i} Q_i^{1-\tilde{b_i}}}{T_i} \le M$ and

$$Q_i = C_i^2[T_i - log(1+T_i)], Q_i > 0, T_i > 0, i = 1,2,\dots\dots\dots.n \quad (6)$$

Using defuzzification technique, if we consider a GTFN $\tilde{A} = (a,b,c;\omega)$, then the total $\lambda$- integer value of $\tilde{A} = (a,b,c;\omega)$ is

$$I_\lambda^w(\tilde{A}) = \lambda\omega\frac{c+b}{2} + (1-\lambda)\omega\frac{a+b}{2}$$

Therefore we get approximated value of a GTFN $\tilde{A} = (a,b,c;\omega)$ is $\omega\left(\frac{a+2b+c}{4}\right)$ by taking $\lambda = 0.5$.

So we have the approximated values $(\widehat{a_i}, \widehat{b_i}, \widehat{h_i}, \widehat{s_i})$ of the GTFN parameters. So the above model (6) reduces to the multi objective inventory model (MOIM) as following

Minimize

$$\widetilde{TAC_i}(Q_i,T_i) = \frac{\widehat{h_i}}{T_i}\left\{Q_i(1+T_i) - \frac{c_i^2 T_i^2}{2} - (1+T_i)log(1+T_i)\right\} + \frac{\widehat{s_i}}{T_i} + \frac{\widehat{a_i} Q_i^{1-\widehat{b_i}}}{T_i}$$

Subject to $\sum \frac{\widehat{s_i}}{T_i} + \frac{\widehat{a_i} Q_i^{1-\widehat{b_i}}}{T_i} \le M$ and

$$Q_i = C_i^2[T_i - log(1+T_i)], Q_i > 0, T_i > 0, i = 1,2,\dots\dots\dots.n \quad (7)$$

## 4. Solution Procedure

### 4.1 Fuzzy programming technique by used hyperbolic membership function for solving MOIM

Solve the MOIM (7) as a single objective NLP using only one objective at a time and ignoring the others. So we get the ideal solutions. Using the ideal solutions the pay-off matrix is defined as follows:

$$\begin{array}{c} \\ (Q_1^1,T_1^1) \\ (Q_2^2,T_2^2) \\ \\ \\ (Q_n^n,T_n^n) \end{array} \begin{array}{cccc} TAC_1(Q_1,T_1) & TAC_2(Q_2,T_2) & \dots\dots & TAC_n(Q_n,T_n) \\ TAC_1^*(Q_1^1,T_1^1) & TAC_2(Q_1^1,T_1^1) & \dots\dots & TAC_n(Q_1^1,T_1^1) \\ TAC_1(Q_2^2,T_2^2) & TAC_2^*(Q_2^2,T_2^2) & \dots\dots\dots\dots & TAC_n(Q_2^2,T_2^2) \\ & \dots\dots & \dots\dots \ \dots\dots & \\ & \dots\dots & \dots\dots \ \dots\dots & \\ TAC_1(Q_n^n,T_n^n) & TAC_2(Q_n^n,T_n^n) & \dots\dots\dots\dots & TAC_n^*(Q_n^n,T_n^n) \end{array}$$

Let

$U^k = \max\{TAC_k(Q_i^i,T_i^i), i = 1,2,\dots,n\}$ for $k = 1,2,\dots,n$

and

$L^k = TAC_k^*(Q_k^k,T_k^k)$ for $k = 1,2,\dots,n.$

Hence $U^k, L^k$ are identified

$$L^k \le TAC_k(Q_i^i,T_i^i) \le U^k$$

$for\ i = 1,2,\dots,n\ ; k = 1,2,\dots,n \quad (8)$

Now objective functions of the problem (7) are considered as fuzzy constraints. Therefore fuzzy non-linear hyperbolic membership functions $\mu_{TAC_k}^H(TAC_k(Q_k,T_k))$ for the k[th] objective functions $TAC_k(Q_k,T_k)$ respectively for $k = 1,2,\dots,n$ are defined as follows:

$$\mu_{TAC_k}^H(TAC_k(Q_k,T_k)) = \frac{1}{2}tanh\left(\left(\frac{U^k+L^k}{2} - TAC_k(Q_k,T_k)\right)\sigma_k\right) + \frac{1}{2} \quad (9)$$

here $\alpha_k$ are the parameters, $\sigma_k = \frac{3}{(U^k-L^k)/2} = \frac{6}{U^k-L^k}$,

$k = 1,2,\dots,n.$

Using the membership function (9) the fuzzy non-linear programming problems are as follows:

$Max\ \lambda$

Subject to

$$\frac{1}{2}\tanh\left(\left(\frac{U^k+L^k}{2}-TAC_k(Q_k,T_k)\right)\sigma_k\right)+\frac{1}{2}\geq\lambda\,,\lambda\geq 0 \qquad (10)$$

And same constraints of the problem (7).

The above non-linear programming problem after simplification we can be formulated as

$Max\ y$

Subject to $\quad y+\sigma_k TAC_k(Q_k,T_k)\leq\frac{U^k+L^k}{2}\sigma_k,\ y\geq 0 \qquad (11)$

And same constraints of the problem (7).

The programming problems (11) can be solved by a suitable mathematical programming algorithm and we get the solution of the MOIM (7).

## 5. Numerical Example

Here consider an inventory system which consists three items with $M=Rs.10000$ and c=2.

**Table 1 Input imprecise data for shape parameters**

| Parameters | Items | | |
|---|---|---|---|
| | I | II | III |
| $\tilde{h}_i$ | (6.7.8: 0.9) | (4.5.6: 0.9) | (8.9.10:0.7) |
| $\tilde{s}_i$ | (5000.6000.7000:0.8) | (6500.7500.8000:0.7) | (8000.9000.10000: 0.9) |
| $\tilde{a}_i$ | (7.8.9: 0.8) | (6.7.8: 0.8) | (5.6.7: 0.8) |
| $\tilde{b}_i$ | (0.02.0.03.0.04:0.8) | (0.05.0.06.0.07:0.9) | (0.04.0.05.0.06:0.7) |

Defuzzyfication of the above fuzzy parameters are

**Table 2**

| Items | Parameters | | | |
|---|---|---|---|---|
| | $\hat{h}_i$ | $\hat{s}_i$ | $\hat{a}_i$ | $\hat{b}_i$ |
| I | 6.3 | 4800 | 6.4 | 0.024 |
| II | 4.5 | 5162.5 | 5.6 | 0.054 |
| III | 6.3 | 8100 | 4.8 | 0.035 |

**Table 3** Optimal solution of MOIM

| $T_1^*$ | $Q_1^*$ | $TAC_1^*$ | $T_2^*$ | $Q_2^*$ | $TAC_2^*$ | $T_3^*$ | $Q_3^*$ | $TAC_3^*$ |
|---|---|---|---|---|---|---|---|---|
| 20.53 | 69.85 | 435.94 | 25.02 | 87.05 | 388.57 | 26.43 | 92.49 | 570.76 |

## 6. Sensitivity Analysis

In the sensitivity analysis has been done for all parameters.

**Table 4 Optimal solutions of MOIM for different values of $a_1, a_2, a_3$.**

| $a_1$ | $a_2$ | $a_3$ | $T_1^*$ | $Q_1^*$ | $TAC_1^*$ | $T_2^*$ | $Q_2^*$ | $TAC_2^*$ | $T_3^*$ | $Q_3^*$ | $TAC_3^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -10% | -10% | -10% | 20.54 | 69.88 | 433.98 | 25.02 | 87.06 | 387.03 | 26.43 | 92.50 | 569.32 |
| -5% | -5% | -5% | 20.53 | 69.87 | 434.96 | 25.02 | 87.05 | 387.80 | 26.43 | 92.49 | 570.04 |
| 5% | 5% | 5% | 20.52 | 69.83 | 436.93 | 25.01 | 87.04 | 389.33 | 26.43 | 92.48 | 571.47 |
| 10% | 10% | 10% | 20.52 | 69.82 | 437.91 | 25.01 | 87.03 | 390.09 | 26.43 | 92.47 | 572.19 |

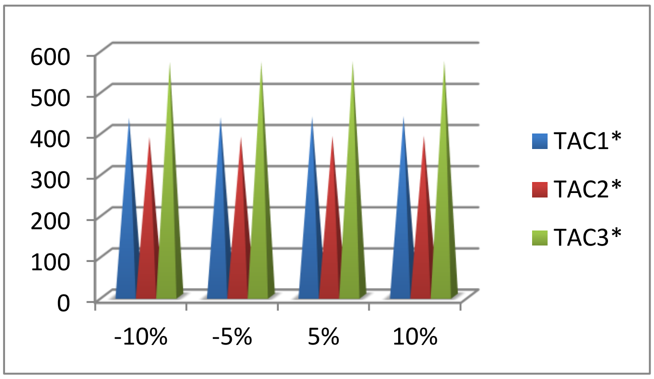


**Fig. 2 optimal cost of three items for different values of $a_1, a_2, a_3$**

From the above Fig. 2 shows that minimum cost of the all items is proportionally to the parameters $a_1, a_2, a_3$.

**Table 5** Optimal solutions of MOIM for different values of $b_1, b_2, b_3$.

| $b_1$ | $b_2$ | $b_3$ | $T_1^*$ | $Q_1^*$ | $TAC_1^*$ | $T_2^*$ | $Q_2^*$ | $TAC_2^*$ | $T_3^*$ | $Q_3^*$ | $TAC_3^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -10% | -10% | -10% | 20.52 | 69.84 | 436.14 | 25.01 | 87.02 | 388.94 | 26.43 | 92.48 | 570.98 |
| -5% | -5% | -5% | 20.53 | 69.85 | 436.04 | 25.02 | 87.04 | 388.72 | 26.44 | 92.48 | 570.91 |
| 5% | 5% | 5% | 20.53 | 69.86 | 435.84 | 25.02 | 87.06 | 388.38 | 26.43 | 92.49 | 570.64 |
| 10% | 10% | 10% | 20.54 | 69.86 | 435.75 | 25.03 | 87.07 | 388.20 | 26.44 | 92.50 | 570.53 |

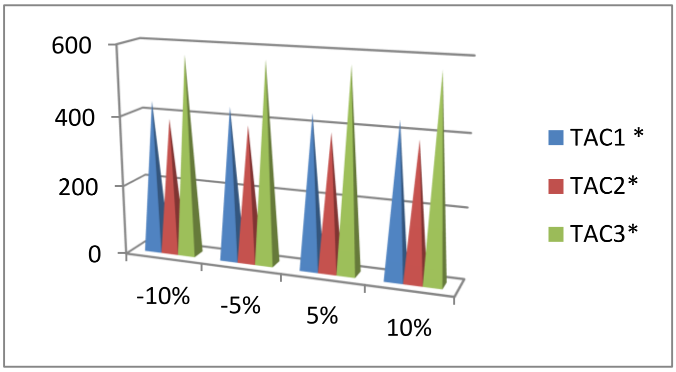


**Fig. 3 minimizing cost of all items for different values of $b_1, b_2, b_3$.**

From the above Fig. 3 shows that minimum cost of the all items is inversely proportional to the parameters $b_1, b_2, b_3$.

**Table 6** Optimal solutions of MOIM for different values of $s_1, s_2, s_3$.

| $s_1$ | $s_2$ | $s_3$ | $T_1^*$ | $Q_1^*$ | $TAC_1^*$ | $T_2^*$ | $Q_2^*$ | $TAC_2^*$ | $T_3^*$ | $Q_3^*$ | $TAC_3^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -10% | -10% | -10% | 19.52 | 66 | 411.98 | 23.78 | 82.29 | 367.41 | 25.13 | 87.45 | 539.34 |
| -5% | -5% | -5% | 20.03 | 67.95 | 424.12 | 24.41 | 84.70 | 378.12 | 25.79 | 90.00 | 555.25 |
| 5% | 5% | 5% | 21.02 | 71.71 | 447.50 | 25.62 | 89.34 | 398.76 | 27.06 | 94.92 | 585.90 |
| 10% | 10% | 10% | 21.49 | 73.52 | 458.79 | 26.19 | 91.54 | 408.57 | 27.68 | 97.29 | 600.69 |

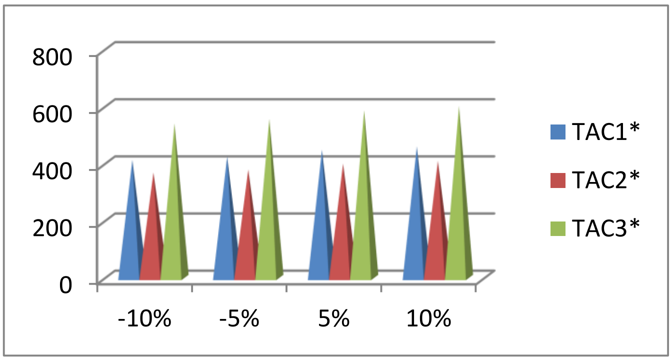


**Fig. 4 minimizing cost of all items for different values of $s_1, s_2, s_3$.**

From the above Fig. 4 shows that minimum cost of the all item is proportional to the parametric values of $s_1, s_2, s_3$.

**Table 7** Optimal solutions of MOIM for different values of $h_1, h_2, h_3$.

| $h_1$ | $h_2$ | $h_3$ | $T_1^*$ | $Q_1^*$ | $TAC_1^*$ | $T_2^*$ | $Q_2^*$ | $TAC_2^*$ | $T_3^*$ | $Q_3^*$ | $TAC_3^*$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -10% | -10% | -10% | 21.59 | 73.88 | 417.11 | 26.32 | 92.05 | 371.35 | 27.81 | 97.79 | 544.98 |
| -5% | -5% | -5% | 21.04 | 71.79 | 426.68 | 25.64 | 89.45 | 380.09 | 27.04 | 95.03 | 558.07 |
| 5% | 5% | 5% | 20.06 | 68.06 | 444.94 | 24.44 | 84.82 | 396.79 | 25.82 | 90.13 | 583.08 |
| 10% | 10% | 10% | 19.62 | 66.39 | 453.67 | 23.90 | 82.75 | 404.79 | 25.25 | 87.94 | 595.06 |

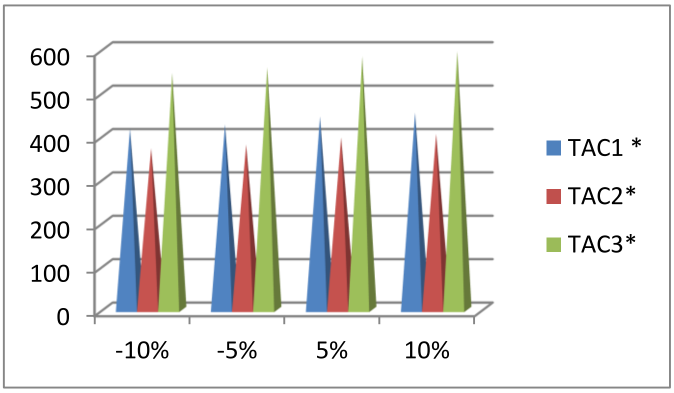


**Fig. 5 minimizing cost of all items for different values of $h_1, h_2, h_3$.**

From the above Fig. 5 shows that minimum cost of the all item is proportional to the parametric values of $h_1, h_2, h_3$.

## 7. Conclusion

In this article, I have presented a multi objective offering inventory model with limitation on initial invested money and demand is time dependent. Any offer on any things always attracts the customers so in this paper to increase customer attraction, here purchase cost offering on quantity. Multi items again help to increase the number of customers. So, multi-item related model is very important nowadays. Limitation is considered on set up cost and purchase cost. Due to uncertainty all the cost parameters are taken as the generalized triangular fuzzy number. Multi objective fuzzy inventory model has been solved by Fuzzy programming technique with hyperbolic membership function. Numerical example is given to illustrate the inventory model. Sensitivity analysis and the graphical representations have been displayed to clarify the reality of the inventory model. Numerical example is solved by using LINGO13 software.

It is hoped to further incorporate the formulated model into more realistic assumptions, such as probabilistic demand, introduce shortages etc. Also hoped that in future inventory problem can be solved in different techniques.

**Conflict of Interest**
The authors declare that they have no conflict of interest.

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**Author Contributions**:
Satya has contributed to the analysis, interpretation of the data, formatting, and editing of the manuscript and approval for publication after reviewing it for significant intellectual content.

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