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# A COST ANALYSIS ON MULTI-ITEM INVENTORY MODEL FOR FACTORY OUTLETS WITH TWO CONSTRAINTS UNDER RANKING ASTEROID FUZZY SET

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## ABSTRACT

Inventory for factory outlet problems without shortage is discussed as a special case of conventional inventory problem. The proposed procedure was programmed with MATLAB (R2009a) version software .the output of the model is affected in its input parameters in demand rate. Numerically we ventured to compare the crip model with fuzzy model .A multi-item inventory model for factory outlets in crisp and fuzzy sense are formulated in the fuzzy environment with stowage space and conveyance cost constraints have been considered. In this model, demand is constant and is related to the unit stowage space and conveyance. The asteroid fuzzy set is defined and is properties are given. The parameters involved in this model represented by asteroid fuzzy set. The average total cost is defuzzify by ranking method. The analytical expressions for maximum inventory level and average total cost are derived for the proposed model by using nonlinear programming technique. A numerical example is presented to illustrate the results.

**Keywords:** Factory outlets, Asteroid fuzzy set, Multi items, Stowage space constraint, Conveyance constraint, Maximum conveyance cost, Maximum stowage space, Ranking Asteroid fuzzy set.

## 1. INTRODUCTION

In manufacturing, services, and business operations in general, inventory issues are frequent. In some inventory models, the demand is assumed to be constant in a state environment. Cost parameters, objective functions, and decision makers' constraints are all imprecise in most real-world situations. The classical (EOQ) inventory problem is defined as the problem of determining the optimal order quantity under relatively stable conditions. This EOQ problem with varying variance had been solved for several years and published since 1915 by a number of researchers. F.W.Harries (1913) [1], E.W. Taft (1918) [2], and G.Hadley & T.M. Whitin (1958) [3] discussed two major assumptions in the classical EOQ models: the demand rate is constant and deterministic. Uncertainties are treated as randomness in conversional inventory models, and they're dealt with using probability theory. However, in some cases, uncertainties are caused by fuzziness, and the fuzzy set theory can be used in these situations. The fuzzy inventory model with storage space and budget constraints was discussed by Shuo-yan Chow and Peterson C. Julian (2009)[4]. Kun-Jen Chang (2012)[5] discussed the integrated inventory model with the transportation cost and two – level trade credit in supply chain management.

A factory outlet is outlined as a factory shop and it is a store where manufacturers sell their products directly to the public at steep discounts. Because not all of a company's products are of high quality, they cannot be sold in retail stores. But they are still usable. Moreover, in such a dynamic market, a product that is fashionable today will become obsolete tomorrow, and given the finite space in retail stores, will be undesirable once again. If that's the case, what about all the products that are no longer available, irregular or redundant? The factory sales centres are approaching. All of the above types that are not found in retail stores are very well located in factory sales centers. Instead of rejecting all the products belonging to such category, the factory outlets sell them at high discounts prices and the buyers are willing to pay for the minor problems in these categories. Manufacturers have initiated to produce products specifically for outlet centres in order to avoid competing with their retail outlets, thanks to the industrial development of outlet centres. Adriana F.Gabor,jan-kees van Ommeren , Ondrei Sleptchenko [12] discussed an inventory model for an Omni channel retailer, that is, a retailer that sells items both via brick-and-mortar stores and online.

In the crisp environment, all the parameters related to the model such as consumable cost, employee cost, security cost, wastage cost, admin cost, marketing cost, demand rate are known and have uncertain value. While some trading scenarios apply to such conditions, in fact most scenarios and parameters and variables are very uncertain in fast changing market conditions. These parameters and variables are referred to as ambiguous parameters in such cases. Clarification acknowledges the reliability of the model by allowing ambiguity throughout the system, which brings it closer to reality.

Numerous strategies have been put forth in the literature for sorting obscure numbers. Nirmal Kumar Mandal [11] proposed fuzzy EOQ model with ranking fuzzy number with cost parameters. A.Faritha Asma [7] decribed the fuzzy inventory model subject to constraints has been transformed in to the crisp inventory problem using Robust's ranking indices. P.Kasthuri, P. Vasanthi (2011)[8] developed with three constraints and have been solved by Karush Kuhn tucker conditions. Roy and Maiti [9]. explored existing problems in their solution procedure for Kuhn–Tucker's method . Although there are some comparative studies, it is not yet known whether similar ranking methods are still in use today, and they have the potential to introduce an ambiguous set of ranking asteroids. The obscure inventory sample for factory sales outlets was obtained using the ranking asteroid fuzzy set.

Till now, there is no literature by using Asteroid fuzzy sets. This paper developed the fuzzy inventory model by using Asteroid fuzzy set. In a realistic situation, the total expenditure for an inventory model and the space available to store the inventory may be limited. The inventory costs, consumable cost, employee cost, security cost, wastage cost, admin cost, marketing cost, and temporary stowage space cost, and the maximum conveyance cost may be flexible with some vagueness for their values. The ambiguity of the above parameters necessitates analyzing the inventory problem in a fuzzy environment. The inventory of multiple items for factory outlets is the subject of this article. The Asteroid fuzzy set is used to represent the cost parameters. The model is distorted by the ranking system, which determines the average total cost. There was a stowage space and conveyance cost constraints in this situation. Finally, a numerical example of the sample and sensitivity analysis is given.

## 2. ASSUMPTION AND NOTATIONS

### 2.1 . ASSUMPTIONS:

i. Multi item will be considered.

ii. Demand rate is uniform.

iii. Shortages are not allowed

iv. Time horizon is finite.

v. The production rate is always greater than demand rate.

vi. Wastage items occurring during the cycle.

vii. Stowage space constraint allowed.

viii. Conveyance cost constraint allowed.

**3.2 NOTATIONS:**

The following are for the $i^{th}$ item (i= 1,2,3,....N)

N - No. of items

$Q_i$ - Outlet quantity (Decision variable)
$q_i$ - Sales quantity (Decision variable)
$R_i$ - Demand is constant
$C_{c_i}$ - Consumable cost per unit per unit time
$S_{c_i}$ - Security cost per unit per unit time
$E_{c_i}$ - Employee cost per unit per unit time
$A_{c_i}$ - Admin cost per unit per unit time
$M_{c_i}$ - Marketing cost per unit per unit time
$W_{c_i}$ - Wastage cost per unit per unit time
$P_{c_i}$ - Conveyance cost per unit item
$s_i$ - Stowage space required by each unit (in sq.mt)
$F_c$ - Maximum amount for convenience per unit per unit time
$S_m$ - Maximum available stowage space for factory out let (in sq.mt)
$T_c$(or) C ($q_i$,$Q_i$)-Total cost per unit time
$\tilde{C}_{c_i}$ - Fuzzy Consumable cost per unit per unit time
$\tilde{S}_{c_i}$ - Fuzzy Security cost per unit per unit time
$\tilde{E}_{c_i}$ - Fuzzy Employee cost per unit per unit time
$\tilde{A}_{c_i}$ - Fuzzy Admin cost per unit per unit time
$\widetilde{M}_{c_i}$ - Fuzzy Marketing cost per unit per unit time
$\widetilde{W}_{c_i}$ - Fuzzy Wastage cost per unit per unit time
$\tilde{s}_i$ - Fuzzy Stowage space required by each unit (in sq.mt)
$\tilde{s}_m$ - Fuzzy maximum available stowage space for factory out let (in sq.mt)
$\tilde{F}_c$ - Fuzzy maximum amount for conveyance per unit per unit time
$\widetilde{T}_c$ (or) $\widetilde{C}(q_i, Q_i)$- Fuzzy Total cost per unit time

The factory outlet model is constructed by using the above assumptions and notations.

## 4. MATHEMATICALMODELINCRISPENVIRONMENT

Total cost = $\sum_{i=1}^{n}$ [Consumable cost + Security cost + Employee cost + Admin cost + Marketing cost + Wastage cost]

$$T_C\,(or)C(q_i\,,Q_i\,)=\sum_{i=1}^{n}\left(\frac{1}{2}C_{C_i}\,\frac{q_i^{\,2}}{Q_i}+\frac{1}{2}S_{C_i}\,\frac{q_i^{\,2}}{Q_i}+\frac{E_{C_i}R_i}{Q_i}+\frac{A_{C_i}R_i}{Q_i}+\frac{M_{C_i}R_i}{Q_i}+\frac{P_{C_i}R_i}{Q_i}+\frac{1}{2}W_{C_i}\,\frac{(Q_i-q_i\,)^2}{Q_i}\right)$$

4.1

The problem is stated that minimize the total cost (TC), subject to constraint

$$\sum_{i=1}^{n}s_iQ_i\leq S_m$$

Minimize TC

$$\sum_{i=1}^{n}s_iQ_i\leq S_m$$

4.2

$$\sum_{i=1}^{n}Pc_iQ_i\leq F_c$$

4.3

Using Lagrange multipliers method, the Lagrange function is

$$L(q_i,Q_i,\lambda_1,\lambda_2)=\sum_{i=1}^{N}\left(\frac{1}{2}C_{C_i}\frac{q_i^{\,2}}{Q_i}+\frac{1}{2}S_{C_i}\frac{q_i^{\,2}}{Q_i}+\frac{E_{C_i}R_i}{Q_i}+\frac{A_{C_i}R_i}{Q_i}+\frac{M_{C_i}R_i}{Q_i}+\frac{P_{C_i}R_i}{Q_i}+\frac{1}{2}W_{C_i}\frac{(Q_i-q_i)^2}{Q_i}\right)-\lambda_1(\sum_{i-1}^{N}s_iQ_i-S_m)-\lambda_2(\sum_{i-1}^{N}Pc_iQ_i-Fc)$$

4.4

By using Kuhn-Tucker necessary condition in (4.4)

Differentiate the equation 4.4 with respect to $q_i$ and equal to zero

ie) $$\frac{\partial L(q_i\,,Q_i\,,\lambda_1,\lambda_2\,)}{\partial q_i}=0$$

$$\sum_{i=1}^{n}\left[C_{C_i}\,\frac{q_i}{Q_i}+S_{C_i}\,\frac{q_i}{Q_i}+0+0+0+0-W_{C_i}\,\frac{(Q_i-q_i\,)}{Q_i}\right]=0$$

$$q_i=\left(\frac{W_{C_i}}{C_{C_i}+S_{C_i}+W_{C_i}}Q_i\right)\quad,\qquad i=1,2,3\ldots N$$

4.5

Differentiate the equation 4.4 with respect to $Q_i$ and equal to zero ie) $$\frac{\partial L(q_i, Q_i, \lambda_1, \lambda_2)}{\partial Q_i} = 0$$

$$\sum_{i=1}^{N}\left(-\frac{1}{2}C_{C_i}\frac{q_i^{\,2}}{Q_i^{\,2}} - \frac{1}{2}S_{C_i}\frac{q_i^{\,2}}{Q_i^{\,2}} - \frac{E_{C_i}R_i}{Q_i^{\,2}} - \frac{A_{C_i}R_i}{Q_i^{\,2}} - \frac{M_{C_i}R_i}{Q_i^{\,2}} + \frac{P_{C_i}R_i}{Q_i} + \frac{1}{2}W_{C_i}\left[\frac{2Q_i(Q_i - q_i) - (Q_i - q_i)^2}{Q_i^{\,2}}\right]\right)$$
$$-\lambda_1(\sum_{i-1}^{N} s_i \;{}_i) - \lambda_2(\sum_{i-1}^{N} P_{c_i}) = 0$$

$$W_{C_i}Q_i^{\,2} - 2(\lambda_1 s_i + \lambda_2 P_{c_i})Q_i^{\,2} = (C_{C_i} + S_{C_i} + W_{C_i})q_i^{\,2} + 2R_i(E_{C_i} + A_{C_i} + M_{c_i} + P_{c_i}) \quad 4.6$$

Substitute the expression $q_i = \left(\frac{W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}}Q_i\right)$ in the equation 4.6

$$W_{C_i}Q_i^{\,2} - 2(\lambda_1 s_i + \lambda_2 P_{c_i})Q_i^{\,2} = (C_{C_i} + S_{C_i} + W_{C_i})\left(\frac{W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}}\right)^2 Q_i^{\,2} + 2R_i(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})$$

$\Rightarrow$

$$Q_i^{\,2} = 2R_i(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})\left[\frac{C_{C_i} + S_{C_i} + W_{C_i}}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}\right]$$

$\Rightarrow$

$$Q_i = \sqrt{2R_i(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})\left[\frac{C_{C_i} + S_{C_i} + W_{C_i}}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}\right]}$$

ie)

$$Q_i{*} = \sqrt{C_{C_i} + S_{C_i} + W_{C_i}}\sqrt{\frac{2R_i(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}} \quad 4.7$$

Substitute equation 4.7 in 4.5

$$q_i = \left[\frac{W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}}\left[\sqrt{C_{C_i} + S_{C_i} + W_{C_i}}\sqrt{\frac{2R_i(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}}\right]\right]$$

$$q_i{*} = \left[\sqrt{\frac{W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}}}\sqrt{\frac{2R_i(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})W_{C_i}}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}}\right] \quad 4.8$$

Differentiate the equation 4.4 with respect to $\lambda_1$ and equal to zero

ie) $\dfrac{\partial L(q_i, Q_i, \lambda_{1,}, \lambda_2)}{\partial \lambda_1} = 0$

$$\frac{\partial L(q_i, Q_i, \lambda_{1,}, \lambda_2)}{\partial \lambda_1} = \sum_{i=1}^{n} \left( s_i Q_i - S_w \right) = 0$$

$$\left( s_i \sqrt{C_{C_i} + S_{C_i} + W_{C_i}} \sqrt{\frac{2R_i (E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}} \right) = 0$$

4.9

$$\frac{\partial L(q_i, Q_i, \lambda_{1,}, \lambda_2)}{\partial \lambda_2} = \sum_{i=1}^{n} \left( P_{c_i} Q_i - F_c \right) = 0$$

$$\left( P_{c_i} \sqrt{C_{C_i} + S_{C_i} + W_{C_i}} \sqrt{\frac{2R_i (E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})}{W_{C_i}(C_{C_i} + S_{C_i}) - 2(\lambda_1 s_i + \lambda_2 P_{c_i})(C_{C_i} + S_{C_i} + W_{C_i})}} \right) = 0$$

4.10

Substitute the expression of $Q_i$ *and $q_i$ * in equation 4.1, the minimum average cost is derived

$$C(q_i, Q_i) = \sum_{i=1}^{n} \left[ \left( \frac{W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}} \right)^2 \frac{Q_i^{\,2}}{2Q_i} (C_{C_i} + S_{C_i}) + \frac{R_i}{Q_i}(E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i}) + \frac{1}{2} W_{C_i} \left[ Q_i - \left( \frac{W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}} \right) Q_i \right]^2 \right]$$

$$= \sum_{i=1}^{n} \left[ \frac{Q_i}{2} \left( \frac{(C_{C_i} + S_{C_i}) W_{C_i}}{(C_{C_i} + S_{C_i} + W_{C_i})^2} \right) (C_{C_i} + S_{C_i} + W_{C_i}) + \frac{R_i}{Q_i} (E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i}) \right]$$

$\Rightarrow$

$$C(q_i, Q_i) = \sum_{i=1}^{n} \left[ \sqrt{\frac{(C_{C_i} + S_{C_i}) W_{C_i}}{C_{C_i} + S_{C_i} + W_{C_i}}} + \sqrt{2R_i (E_{C_i} + A_{C_i} + M_{C_i} + P_{c_i})} \right]$$

4.11

## 5. ASTEROID FUZZY SET

### 5.1 DEFINITION AND ITS PROPERTIES

An Asteroid fuzzy set $\tilde{A}$ described as a fuzzy subset on the real line R whose membership function $\mu_{\tilde{A}}(x)$ is defined as follows.

$$\mu_{\tilde{A}}(x) = \begin{cases} w\left[1+\left(\dfrac{x-a}{b-a}\right)^{\frac{3}{2}}\right] & a \le x \le b \\ w\left[1+\left(\dfrac{x-c}{b-c}\right)^{\frac{3}{2}}\right] & b \le x \le c \\ \alpha - base & x = w \\ w\left[1-\left(\dfrac{x-c}{b-c}\right)^{\frac{3}{2}}\right] & c \le x \le b \\ w\left[1-\left(\dfrac{x-a}{b-a}\right)^{\frac{3}{2}}\right] & b \le x \le a \end{cases}$$

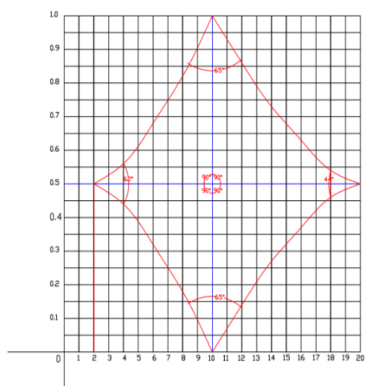


**Figure 5.1 graphical representation of asteroid fuzzy set where w = 0.5**

Where $0.1 \le w \le 0.5$ and a, b, c, are real numbers.

This type of fuzzy set be denoted as $\tilde{A}$ =[a,b,c; $\omega$ ]

**5.2 PROPERTIES OF ASTEROID FUZZY SET**

$\mu_{\tilde{A}}(x)$ satisfies the following conditions:

1. $\mu_{\tilde{A}}(x)$ is a continuous function from R to the closed interval [0,1].
2. $\mu_{\tilde{A}} = 0 \;\; , 0 < x \le a$
3. $\mu_{\tilde{A}} = L(x)$ is strictly increasing and decreasing on (a, b)
4. $\mu_{\tilde{A}} = R(x)$ is strictly decreasing and increasing on (b ,c)
5. $\mu_{\tilde{A}} = 1, x = b$ .
6. Vertical angles are equal.
7. The horizontal and vertical diagonal bisect each other and meet at $90^{o}$.

Remarks:

1. If w > 0.5, then $\tilde{A}$ becomes an improper fuzzy set. (ie., $\mu_{\tilde{A}} > 1$)
2. If w < 0.1, then $\tilde{A}$ becomes a non asteroid fuzzy set.

### 5.3 RANKING ASTEROID FUZZY SET OF COST PARAMETERS WITH BEST APPROXIMATION LEVEL [13]

Let $\tilde{A}$ = (a,b,c) be a Asteroid fuzzy set. The $\alpha$-level interval of $\tilde{A}$ is defined as $A_\propto \in [A_L(\alpha), A_R(\alpha)]$. When $\tilde{A}$ is a fuzzy set , the left and right $\alpha$ cuts are

$$A_L(\alpha) = \begin{cases} a+(b-a)\left(1-\dfrac{\alpha}{w}\right)^{\frac{2}{3}} & if\, 0 \le \alpha \le w \\ a+(b-a)\left(\dfrac{\alpha}{w}-1\right)^{\frac{2}{3}} & if w \le \alpha \le 2w \end{cases}$$

$$C_L(\alpha) = \frac{\int_0^{2w} A_L(\alpha) f(\alpha) d\alpha}{\int_0^{2w} f(\alpha) d\alpha}$$

$$C_L(\alpha) = \frac{\int_0^{w} C_{L_1}(\alpha) f(\alpha) d\alpha + \int_w^{2w} C_{L_2}(\alpha) f(\alpha) d\alpha}{\int_0^{w} f(\alpha) d\alpha + \int_w^{2w} f(\alpha) d\alpha}$$

$$C_L(\alpha) = \frac{\int_0^{w} a+(b-a)\left(1-\dfrac{\alpha}{w}\right)^{\frac{2}{3}} .d\alpha + \int_w^{2w} a+(b-a)\left(\dfrac{\alpha}{w}-1\right)^{\frac{2}{3}} \alpha d\alpha}{\int_0^{w} 1 d\alpha + \int_w^{2w} \alpha d\alpha}$$

$$C_L(\alpha) = \frac{2}{2+3w}\left\{a\left(1+\frac{3}{2}w\right)+\frac{3}{5}(b-a)\left(1+\frac{13}{8}w\right)\right\}$$

5.1

$$A_R(\alpha) = \begin{cases} c+(b-c)\left(1-\dfrac{\alpha}{w}\right)^{\frac{2}{3}} & if\, 0 \le \alpha \le w \\ c+(b-c)\left(\dfrac{\alpha}{w}-1\right)^{\frac{2}{3}} & if w \le \alpha \le 2w \end{cases}$$

$$C_R(\alpha) = \frac{\int_0^{2w} A_R(\alpha) f(\alpha) d\alpha}{\int_0^{2w} f(\alpha) d\alpha}$$

$$C_R(\alpha) = \frac{\int_0^{w} C_{R_1}(\alpha) f(\alpha) d\alpha + \int_w^{2w} C_{R_2}(\alpha) f(\alpha) d\alpha}{\int_0^{w} f(\alpha) d\alpha + \int_w^{2w} f(\alpha) d\alpha}$$

$$C_R(\alpha) = \frac{\int_0^{w} c + (b-c)\left(1 - \frac{\alpha}{w}\right)^{\frac{2}{3}} .d\alpha + \int_w^{2w} c + (b-c)\left(\frac{\alpha}{w} - 1\right)^{\frac{2}{3}} \alpha d\alpha}{\int_0^{w} 1 d\alpha + \int_w^{2w} \alpha d\alpha}$$

$$C_R(\alpha) = \frac{2}{2+3w}\left\{c\left(1+\frac{3}{2}w\right) + \frac{3}{5}(b-c)\left(1+\frac{13}{8}w\right)\right\}$$

5.2

Ranking Asteroid fuzzy set of cost parameters with best approximation level is

$$R_\alpha(\tilde{C}) = \alpha C_L(\alpha) + (1-\alpha) C_R(\alpha)$$

Using the equations 5.1& 5.2

$$R_\alpha(\tilde{C}) = \frac{2}{2+3w}\left\{\left(1+\frac{3}{2}w\right)[\alpha(a-c)+c] - \frac{3}{5}\left(1+\frac{13}{8}w\right)[\alpha(a-c)-(b-c)]\right\}$$

$$\frac{2}{2+3w}\left\{\left(1+\frac{3}{2}w\right)(\alpha a - c\alpha + c) - \frac{3}{5}\left(1+\frac{13}{8}w\right)[\alpha a - \alpha c - b + c]\right\}$$

## 6. INVENTORY MODEL IN FUZZY ENVIRONMENT

The above crisp model (4.1) is fuzzified by asteroid fuzzy set, then

$$\tilde{C}(\tilde{q}_i, \tilde{Q}_i) = \sum_{i=1}^{n}\left(\frac{1}{2}\tilde{C}_{C_i}\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} + \frac{1}{2}\tilde{S}_{C_i}\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} + \frac{\tilde{E}_{C_i}\tilde{R}_i}{\tilde{Q}_i} + \frac{\tilde{A}_{C_i}\tilde{R}_i}{\tilde{Q}_i} + \frac{\tilde{M}_{C_i}\tilde{R}_i}{\tilde{Q}_i} + \frac{\tilde{P}_{C_i}\tilde{R}_i}{\tilde{Q}_i} + \frac{1}{2}\tilde{W}_{C_i}\frac{(\tilde{Q}_i - \tilde{q}_i)^2}{\tilde{Q}_i}\right)$$

Subject to

$$\sum_{i=1}^{n} \tilde{s}_i \tilde{Q}_i \leq \tilde{S}_m$$

$$\sum_{i=1}^{n} \tilde{P}_{c_i} \tilde{Q}_i \leq \tilde{F}_c$$

Minimize TC

$$\sum_{i=1}^{n} \tilde{s}_i \tilde{Q}_i \leq \tilde{S}_m$$

$$\sum_{i=1}^{n} \tilde{P}_{c_i} \tilde{Q}_i \leq \tilde{F}_c$$

The total cost is defuzzified by ranking method

$$R_{\tilde{C}}(\alpha, \tilde{q}_i, \tilde{Q}_i, \lambda_{1,}, \lambda_2) = \sum_{i=1}^{n} \left( \frac{1}{2} R_{\tilde{C}_{C_i}}(\alpha) \frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} + \frac{1}{2} R_{\tilde{S}_{C_i}}(\alpha) \frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} + \frac{R_{\tilde{E}_{C_i}}(\alpha)\tilde{R}_i}{\tilde{Q}_i} + \frac{R_{\tilde{A}_{C_i}}(\alpha)\tilde{R}_i}{\tilde{Q}_i} + \frac{R_{\tilde{M}_{C_i}}(\alpha)\tilde{R}_i}{\tilde{Q}_i} + \frac{1}{2} R_{\tilde{W}_{C_i}}(\alpha) \frac{(\tilde{Q}_i - \tilde{q}_i)^2}{\tilde{Q}_i} \right)$$

$$- \lambda_1 (\sum_{i-1}^{N} \tilde{s}_i \tilde{Q}_i - \tilde{S}_m) - \lambda_2 (\sum_{i-1}^{N} \tilde{P}_{c_i} \tilde{Q}_i - \tilde{F}c)$$

$$R_{\tilde{C}}(\alpha, \tilde{q}_i, \tilde{Q}_i, \lambda_{1,}, \lambda_2) = \sum_{i=1}^{n} \left( \begin{array}{l} \frac{1}{2}\left(\alpha \tilde{C}_{C_{i_L}} + (1-\alpha)\tilde{C}_{C_{i_R}}\right)\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} + \frac{1}{2}\left(\alpha \tilde{S}_{C_{i_L}} + (1-\alpha)\tilde{S}_{C_{i_R}}\right)\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} \\ + \frac{\left(\alpha \tilde{E}_{C_{i_L}} + (1-\alpha)\tilde{E}_{C_{i_R}}\right)\tilde{R}_i}{\tilde{Q}_i} \\ + \frac{\left(\alpha \tilde{A}_{C_{i_L}} + (1-\alpha)\tilde{A}_{C_{i_R}}\right)\tilde{R}_i}{\tilde{Q}_i} + \frac{\left(\alpha \tilde{M}_{C_{i_L}} + (1-\alpha)\tilde{M}_{C_{i_R}}\right)\tilde{R}_i}{\tilde{Q}_i} + \\ \frac{1}{2}\left(\alpha \tilde{W}_{C_{i_L}} + (1-\alpha)\tilde{W}_{C_{i_R}}\right)\frac{(\tilde{Q}_i - \tilde{q}_i)^2}{\tilde{Q}_i} \end{array} \right) - \lambda_1 (\sum_{i-1}^{N} \tilde{s}_i \tilde{Q}_i - \tilde{S}_m) - \lambda_2 (\sum_{i-1}^{N} \tilde{P}_{c_i} \tilde{Q}_i - \tilde{F}c)$$

6.1

Differentiate the equation 6.1 with respect to $\alpha$

$$\frac{\partial R_{\tilde{C}}(\alpha, \tilde{q}_i, \tilde{Q}_i, \lambda_{1,}, \lambda_2)}{\partial \alpha} = \left[ \begin{array}{l} \frac{1}{2}\left(\tilde{C}_{C_{i_L}} - \tilde{C}_{C_{i_R}}\right)\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} + \frac{1}{2}\left(\tilde{S}_{C_{i_L}} - \tilde{S}_{C_{i_R}}\right)\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i} \\ + \left(\tilde{E}_{C_{i_L}} - \tilde{E}_{C_{i_R}}\right)\frac{\tilde{R}_i}{\tilde{Q}_i} + \left(\tilde{A}_{C_{i_L}} - \tilde{A}_{C_{i_R}}\right)\frac{\tilde{R}_i}{\tilde{Q}_i} \\ + \left(\tilde{M}_{C_{i_L}} - \tilde{M}_{C_{i_R}}\right)\frac{\tilde{R}_i}{\tilde{Q}_i} + \frac{1}{2}\left(\tilde{W}_{C_{i_L}} - \tilde{W}_{C_{i_R}}\right)\left(\frac{Q_i - \tilde{R}_i}{\tilde{Q}_i}\right)^2 \end{array} \right]$$

$$\frac{\partial R_{\tilde{C}}(\alpha,\tilde{q}_i,\tilde{Q}_i,\lambda_1,\lambda_2)}{\partial \alpha}=\begin{bmatrix}\left(\tilde{C}_{C_{i_L}}+\tilde{S}_{C_{i_L}}\right)\tilde{q}_i^{\,2}-\left(\tilde{C}_{C_{i_R}}+\tilde{S}_{C_{i_R}}\right)\tilde{q}_i^{\,2}\\ +2\left(\tilde{E}_{C_{i_L}}+\tilde{A}_{C_{i_L}}+\tilde{M}_{C_{i_L}}\right)\tilde{R}_i-2\left(\tilde{E}_{C_{i_R}}+\tilde{A}_{C_{i_R}}+\tilde{M}_{C_{i_R}}\right)\tilde{R}_i+\\ \left(\tilde{W}_{C_{i_L}}-\tilde{W}_{C_{i_R}}\right)\left(\tilde{Q}_i-\tilde{R}_i\right)^2\end{bmatrix}=0$$

Differentiate the equation 6.1 with respect to $\tilde{q}_i$

$$\frac{\partial R_{\tilde{C}}(\alpha,\tilde{q}_i,\tilde{Q}_i,\lambda_1,\lambda_2)}{\partial \tilde{q}_i}=\begin{bmatrix}\left(\alpha\tilde{C}_{C_{i_L}}+(1-\alpha)\tilde{C}_{C_{i_R}}\right)\dfrac{\tilde{q}_i}{\tilde{Q}_i}\\ +\left(\alpha\tilde{S}_{C_{i_L}}+(1-\alpha)\tilde{S}_{C_{C_{i_R}}}\right)\dfrac{\tilde{q}_i}{\tilde{Q}_i}\\ -\left(\alpha\tilde{W}_{C_{i_L}}+(1-\alpha)\tilde{W}_{C_{i_R}}\right)\dfrac{(\tilde{Q}_i-\tilde{q}_i)}{\tilde{Q}_i}\end{bmatrix}$$

$$\frac{\partial R_{\tilde{C}}(\alpha,\tilde{q}_i,\tilde{Q}_i,\lambda_1,\lambda_2)}{\partial \tilde{q}_i}=\begin{bmatrix}\left[\alpha\left(\tilde{C}_{C_{i_L}}+\tilde{S}_{C_{i_L}}+\tilde{W}_{C_{i_L}}\right)+(1-\alpha)\left(\tilde{C}_{C_{i_R}}+\tilde{S}_{C_{i_R}}+\tilde{W}_{C_{i_R}}\right)\right]\tilde{q}_i\\ -\left(\alpha\tilde{W}_{C_{i_L}}+(1-\alpha)\tilde{W}_{C_{i_R}}\right)\tilde{Q}_i\end{bmatrix}=0$$

Differentiate the equation 6.1 with respect to $\tilde{Q}_i$

$$\frac{\partial R_{\tilde{C}}(\alpha,\tilde{q}_i,\tilde{Q}_i,\lambda_1,\lambda_2)}{\partial \tilde{Q}_i}=\begin{bmatrix}-\frac{1}{2}\left[\alpha\tilde{C}_{C_{i_L}}+(1-\alpha)\tilde{C}_{C_{i_R}}\right]\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i^{\,2}}-\frac{1}{2}\left[\alpha\tilde{S}_{C_{i_L}}+(1-\alpha)\tilde{S}_{C_{i_R}}\right]\frac{\tilde{q}_i^{\,2}}{\tilde{Q}_i^{\,2}}-\left[\alpha\tilde{E}_{C_{i_L}}+(1-\alpha)\tilde{E}_{C_{i_R}}\right]\frac{\tilde{R}_i}{\tilde{Q}_i^{\,2}}\\ -\left[\alpha\tilde{A}_{C_{i_L}}+(1-\alpha)\tilde{A}_{C_{i_R}}\right]\frac{\tilde{R}_i}{\tilde{Q}_i^{\,2}}-\left[\alpha\tilde{M}_{C_{i_L}}+(1-\alpha)\tilde{M}_{C_{i_R}}\right]\frac{\tilde{R}_i}{\tilde{Q}_i^{\,2}}+\frac{1}{2}\left[\alpha\tilde{W}_{C_{i_L}}+(1-\alpha)\tilde{W}_{C_{i_R}}\right]\\ \left[\dfrac{2\tilde{Q}_i(\tilde{Q}_i-\tilde{q}_i)-(\tilde{Q}_i-\tilde{q}_i)^2}{\tilde{Q}_i^{\,2}}\right]\\ -\lambda_1(\tilde{s}_i-\tilde{S}_m)-\lambda_2(\tilde{P}_{c_i}-\tilde{F}c)\end{bmatrix}$$

$$\frac{\partial R_{\tilde{C}}(\alpha,\tilde{q}_i,\tilde{Q}_i,\lambda_1,\lambda_2)}{\partial \tilde{Q}_i}=\begin{bmatrix}\left[\alpha\left(\tilde{C}_{C_{i_L}}+\tilde{S}_{C_{i_L}}\right)+(1-\alpha)\left(\tilde{C}_{C_{i_R}}+\tilde{S}_{C_{i_R}}\right)\right]\tilde{q}_i^{\,2}+\\ 2\left[\alpha\left(\tilde{E}_{C_{i_L}}+\tilde{A}_{C_{i_L}}+\tilde{M}_{C_{i_L}}\right)+(1-\alpha)\left(\tilde{E}_{C_{i_R}}+\tilde{A}_{C_{i_R}}+\tilde{M}_{C_{i_R}}\right)\right]\tilde{R}_i\\ -\left[\alpha\left(\tilde{W}_{C_{i_L}}\right)+(1-\alpha)\left(\tilde{W}_{C_{i_R}}\right)(\tilde{Q}_i^{\,2}-\tilde{q}_i^{\,2})\right]-\lambda_1(\tilde{s}_i-\tilde{S}_m)-\lambda_2(\tilde{P}_{c_i}-\tilde{F}c)\end{bmatrix}=0$$

Differentiate the equation 6.1 with respect to $\lambda_1$

$$\frac{\partial R_{\tilde{C}}(\alpha,\tilde{q}_i,\tilde{Q}_i,\lambda_1,\lambda_2)}{\partial \lambda_1}=-(\tilde{s}_iQ_i-\tilde{S}_m)$$

$$(\tilde{s}_iQ_i-\tilde{S}_m)=0$$

Differentiate the equation 6.1 with respect to $\lambda_2$

$$\frac{\partial R_{\tilde{C}}(\alpha, \tilde{q}_i, \tilde{Q}_i, \lambda_{1,}, \lambda_2)}{\partial \lambda_2} = -(\tilde{P}_{c_i} Q_i - \tilde{F}_c)$$

$$(\tilde{P}_{c_i} Q_i - \tilde{F}_c) = 0$$

## 7. NUMERICAL EXAMPLE

Develop a mathematical program to minimize the average total cost. Consider a factory outlet shop which produces three type of items. The three items are readymade, carpets and suits. The items are produced in lots. The shop has only 3000 sq. feet's of stowage space and the maximum conveyance cost is Rs.7500. The demand ratio for each item is constant. The appropriate data given,

| Items | 1 | 2 | 3 |
|---|---|---|---|
| $\tilde{S}_{C_i}$ | (25, 30, 35) | (40, 42, 44) | (51, 54, 57) |
| $\tilde{C}_{C_i}$ | (10, 11, 12) | (13, 14, 15) | (16, 17, 18) |
| $\tilde{A}_{C_i}$ | (100, 130, 160) | (140, 150, 170) | (170, 180, 190) |
| $\tilde{E}_{C_i}$ | (140, 145, 150) | (150,170,190) | (200,220,240) |
| $\tilde{M}_{C_i}$ | (110, 115, 120) | (112, 120, 128) | (130, 136, 142) |
| $\tilde{W}_{C_i}$ | (5, 5.5 ,6) | (7, 7.5, 8) | (9, 9.2, 9.4) |
| $P_{c_i}$ | (10,15,20) | (15,20,25) | (20,25,30) |
| $\tilde{s}_i$ | 0.6 | 0.7 | 0.8 (per sq. feet) |
| $\tilde{R}_i$ | 200 | 250 | 300 |

$w$ = 0.5, i = 1,2,3.

Using MATLAB software, the optimal values Q*,q*,α*, $\lambda_1$*, $\lambda_2$* and $T_c$* are tabulated.

Table 7.1 **Optimal Solution**

| Model | It | $C_c$ | $S_c$ | $A_c$ | $E_c$ | $M_c$ | $W_c$ | $P_c$ | S | R | Q* | q* | α* | $T_c$* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crisp 1 | 1 | 25 | 10 | 100 | 140 | 110 | 5 | 10 | 0.6 | 200 | 178.9391 | 63.2645 | - | 26777.32 |
| | 2 | 40 | 13 | 140 | 150 | 112 | 7 | 15 | 0.7 | 250 | 180.3894 | 61.6147 | - | |
| | 3 | 51 | 16 | 170 | 200 | 130 | 9 | 20 | 0.8 | 300 | 194.5754 | 66.9580 | - | |
| Crisp 2 | 1 | 30 | 11 | 130 | 145 | 115 | 5.5 | 15 | 0.6 | 200 | 179.4180 | 61.7051 | - | 34614.2 |
| | 2 | 42 | 14 | 150 | 170 | 120 | 7.5 | 20 | 0.7 | 250 | 181.5789 | 60.9595 | - | |
| | 3 | 54 | 17 | 180 | 220 | 136 | 9.2 | 25 | 0.8 | 300 | 198.5311 | 66.4181 | - | |
| Crisp 3 | 1 | 35 | 12 | 160 | 150 | 120 | 6 | 20 | 0.6 | 200 | 179.8657 | 60.5182 | - | 42450 |
| | 2 | 44 | 15 | 170 | 190 | 128 | 8 | 25 | 0.7 | 250 | 182.5158 | 60.4205 | ` | |
| | 3 | 57 | 18 | 190 | 240 | 142 | 9.4 | 30 | 0.8 | 300 | 202.2660 | 65.9570 | | |

| Fuzzy | $\tilde{C}_{C_L}$ | $\tilde{C}_{C_R}$ | $\tilde{S}_{C_L}$ | $\tilde{S}_{C_R}$ | $\tilde{A}_{C_L}$ | $\tilde{A}_{C_R}$ | $\tilde{E}_{C_L}$ | $\tilde{E}_{C_R}$ | $\tilde{M}_{C_L}$ | $\tilde{M}_{C_R}$ | $\tilde{W}_{C_L}$ | $\tilde{W}_{C_R}$ | $\tilde{P}_{C_L}$ | $\tilde{P}_{C_R}$ | $S$ | R | $Q^*$ | $q^*$ | $\lambda_1$ | $\lambda_2$ | $\alpha^*$ | $T_c$* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item 1 | 28.1071 | 31.8929 | 10.6214 | 11.3786 | 118.6429 | 141.3571 | 143.1071 | 146.8929 | 113.1071 | 116.8929 | 5.3107 | 5.6893 | 13.1071 | 16.8929 | 0.6 | 200 | 197.8569 | 54.7167 | 0.547 | 0.7567 | 0.6659 | 23 |
| Item 2 | 41.2429 | 42.7571 | 13.6214 | 14.3786 | 146.2143 | 153.7857 | 162.4286 | 177.5714 | 116.9714 | 123.0286 | 7.3104 | 7.6893 | 18.1071 | 21.8929 | 0.7 | 250 | 209.2192 | 64.6965 | | | | |
| Item 3 | 52.8643 | 55.1357 | 16.6214 | 17.3786 | 176.2143 | 183.7857 | 212.4286 | 227.5714 | 133.7286 | 138.2714 | 9.1243 | 9.2757 | 23.1071 | 26.8929 | 0.8 | 300 | 237.0731 | 78.8288 | | | | |

| Model | Percentage | Item | $\tilde{C}_{C_L}$ | $\tilde{C}_{C_R}$ | $\tilde{S}_{C_L}$ | $\tilde{S}_{C_R}$ | $\tilde{A}_{C_L}$ | $\tilde{A}_{C_R}$ | $\tilde{E}_{C_L}$ | $\tilde{E}_{C_R}$ | $\tilde{M}_{C_L}$ | $\tilde{M}_{C_R}$ | $\tilde{W}_{C_L}$ | $\tilde{W}_{C_R}$ | $\tilde{P}_{C_L}$ | $\tilde{P}_{C_R}$ $\tilde{P}_{C_R}$ | S | R | Q* | q* | α* | $\widetilde{T_c}$ * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuzzy | | 1 | 42.1607 | 47.8394 | 15.9321 | 17.0679 | 177.9644 | 212.0357 | 214.6607 | 220.3394 | 169.6607 | 175.3394 | 7.9661 | 8.5340 | 19.6607 | 25.3394 | 0.9 | 300 | 219.3770 | 26.4220 | 0.9589 | 50413.65 |
| | | 2 | 61.8644 | 64.1357 | 20.4321 | 21.5679 | 219.3215 | 230.6786 | 243.6429 | 266.3571 | 175.4571 | 184.5429 | 10.9661 | 11.5340 | 27.1607 | 32.8394 | 1.05 | 375 | 222.3904 | 26.1625 | | |
| | | 3 | 79.2965 | 83.7965 | 24.9321 | 26.0679 | 264.3215 | 275.6786 | 318.6429 | 341.3571 | 200.5929 | 207.4071 | 13.6865 | 13.9136 | 34.6607 | 40.3394 | 1.2 | 450 | 241.4356 | 28.0235 | | |
| | +25% | 1 | 35.1339 | 39.8662 | 13.2768 | 14.2233 | 148.3036 | 176.6964 | 178.8839 | 183.6161 | 141.3839 | 146.1161 | 6.6384 | 7.1116 | 16.3839 | 21.1161 | 0.75 | 250 | 200.0611 | 24.0049 | 0.8324 | 42011.38 |
| | | 2 | 51.5536 | 53.4464 | 17.0268 | 17.9733 | 182.7679 | 192.2321 | 203.0358 | 221.9643 | 146.2143 | 153.7858 | 9.1384 | 9.6117 | 22.6339 | 27.3661 | 0.875 | 312.5 | 202.828 4 | 23.9065 | | |
| | | 3 | 66.0804 | 69.8304 | 20.7768 | 21.72323 | 220.2679 | 229.7321 | 265.5358 | 284.4643 | 167.1608 | 172.8393 | 11.4054 | 11.5946 | 28.8839 | 33.6161 | 1 | 375 | 220.2965 | 25.5168 | | |
| | -25% | 1 | 21.0803 | 23.9197 | 7.9661 | 8.5334 | 88.9822 | 106.0178 | 107.3303 | 110.1697 | 84.8303 | 87.6697 | 3.9830 | 4.2670 | 9.8303 | 12.6697 | 0.45 | 150 | 154.7037 | 18.4461 | 0.6134 | 25206.83 |
| | | 2 | 30.9322 | 32.0679 | 10.2161 | 10.7840 | 109.6607 | 115.3393 | 121.8215 | 133.1786 | 87.7286 | 92.2715 | 5.48303 | 5.76640 | 13.5803 | 16.4197 | 0.525 | 187.5 | 156.5265 | 18.5919 | | |
| | | 3 | 39.6482 | 41.8982 | 12.4661 | 13.0340 | 132.1607 | 137.8393 | 159.3215 | 170.6786 | 100.2965 | 103.7036 | 6.8432 | 6.9568 | 17.3303 | 20.1697 | 0.6 | 225 | 170.6091 | 19.7449 | | |
| | -50% | 1 | 14.0536 | 15.9465 | 5.3107 | 5.6893 | 59.3215 | 70.6786 | 71.5536 | 73.4465 | 56.5536 | 58.4465 | 2.6554 | 2.8447 | 6.5536 | 8.4465 | 0.3 | 100 | 126.2437 | 15.0219 | 0.5401 | 16804.55 |
| | | 2 | 20.6215 | 21.3786 | 6.8107 | 7.1893 | 73.1072 | 76.8929 | 81.2143 | 88.7857 | 58.4857 | 61.5143 | 3.6554 | 3.8447 | 9.0536 | 10.9465 | 0.35 | 125 | 127.6671 | 15.1975 | | |
| | | 3 | 26.4322 | 27.9322 | 8.3107 | 8.6893 | 88.1072 | 91.8929 | 106.2143 | 113.7857 | 66.8643 | 69.1357 | 4.5622 | 4.6379 | 11.5536 | 13.4465 | 0.4 | 150 | 139.2158 | 16.0681 | | |

**Table 7.2 Sensitivity Analysis (Ranking method**

## 8. OBSERVATION

From the above tables, it should be noted that compared to crisp model, the fuzzy model is very effective method, because of the time consuming in fuzzy analysis and the optimal results are obtained easily.

(i) The average total cost is obtained in fuzzy model is less than the crisp model.

(ii) The outlet quantity Q* in fuzzy model is higher than the crisp model.

## CONCLUSION

In this paper, it developed a fuzzy inventory model formulti-item in our numerical experiments, Ranking Asteroid fuzzy set is considered profitable in small businesses. Here we considered the factory outlet .Also its use is considered to help the small scale entrepreneurs during festival period and pandemic times. The inventory level in the fuzzy environment is high compared to the crisp value, for the fuzzy inventory model with stowage space constraint and conveyance cost constraint. Moreover, the fuzzy inventory model subject to the constraints has been transformed in to crisp inventory problem using ranking indices. Numerical example shows that by this method we can have the optimal total cost. We have demonstrated that the total cost obtained using the ranking fuzzy set method is ideal. Furthermore, one can draw the conclusion that the ranking method can be used successfully to solve fuzzy problems. The minimum total cost in the crisp environment is high compared to the fuzzy value. Finally, conclude that the fuzzy model can be executable in the real work.

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