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ON INTUITIONISTIC FUZZY INVENTORY MODELS WITHOUT ALLOWING STORAGE CONSTRAINT

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ABSTRACT

This paper deals with the problem of determining the economic order quantity (EOQ), as a function of the setup cost and the holding cost in the interval sense. Practically vagueness caused by the variation in fixing these costs is inevitable. Intuitionistic fuzzy inventory model with instantaneous replenishment and no shortages is analyzed to compute the economic order quantity and the total annual cost by assigning fuzzy quantity and intuitionistic fuzzy quantity instead of real quantity to these costs. Parametric programming technique is applied and the results are compared numerically both in fuzzy optimization and intuitionistic fuzzy optimization techniques. Necessary graphical presentations are also given besides numerical illustrations.

KEYWORDS: Inventory, Economical Order Quantity (EOQ), Fuzzy Optimizations, Intuitionistic Fuzzy Optimization, Parametric Programming Technique

AMS Code: 03E72, 90B05

1 INTRODUCTION

Inventory problems are common in manufacturing, maintenance cost and business activities in general. Recently much attention has been focused on EOQ models with fuzzy carrying cost, fuzzy shortage cost, fuzzy setup cost, fuzzy demand etc; this means that elements of carrying cost, shortage cost, setup costs and demand are fuzzy members [10],[20],[23]. Zimmerman [28,29,30] showed the classical algorithms can be used in few inventory models.

Inventory model such as instantaneous stock replenishment and no shortages is analyzed by assigning fuzzy quantities to the setup costs (C_S) and holding cost (C_1) instead of crisp values.

Recently fuzzy concept is introduced in the inventory problems by several researchers. Park [21], Vujosevic[27] et.al, Chang[5,7] et.al, Liu[19] et.al are proposed the EOQ model in the fuzzy sense where inventory parameters are triangular fuzzy concept in decision.

An early work using fuzzy concept in decision making has been performed by Bellman and Zadeh[4], through introducing fuzzy goals, costs and constraints. Lee et.al[18] introduced the application of fuzzy set theory to lot sizing in material requirements planning. In their paper uncertainty in demand is modeled by using triangular fuzzy numbers.

One of the interesting generalization of the theory of fuzzy sets is the theory of intuitionistic fuzzy sets introduced by Atanassov[1,16,17] and seems to be applicable to real world problems. The concept of intuitionistic fuzzy sets can be viewed as an available information is not sufficient for the definition of an imprecise. Intuitionistic fuzzy sets are fuzzy sets described by two functions; a membership function and a non-membership function that are loosely related.

Intuitionistic fuzzy set can be used to simulate human decision-making process and any activities requiring human expertise and knowledge that are inevitably imprecise or totally reliable. An interval valued intuitionistic fuzzy sets are analyzed by Atanassov and Gargov[11,12,13] Atanassov and Kreinorich[16,17] implemented intuitionistic fuzzy interpretation of interval data. The crisp values are compared numerically both in fuzzy optimization and intuitionistic fuzzy optimization techniques. Objective of this paper is to find Q^0 and TC^0 in both intuitionistic fuzzy optimization method and fuzzy optimization method. Necessary graphical presentations and numerical illustrations are also given.

2 FORMULATION OF PARAMETRIC PROGRAMMING PROBLEM FOR SOME BASIC INVENTORY MODELS

The setup cost $\tilde{X}$, holding cost $\tilde{Y}_1$, and shortage cost $\tilde{Y}_2$ are approximately known and are represented by the following intuitionistic fuzzy sets:

$$\tilde{X} = \{(x, \mu_{\tilde{X}}(x), \nu_{\tilde{X}}(x)) | \, x \in X\} \tag{2.1}$$

$$\tilde{Y}_i = \{\left(y_i, \mu_{\tilde{Y}_i}(y_i), \nu_{\tilde{Y}_i}(y_i)\right) \mid y_i \in Y_i\}, (i = 1,2) \tag{2.2}$$

where X, Y_1 and Y_2 are crisp universal sets of setup cost, holding cost and shortage cost respectively and $\mu_{\tilde{X}}(x)$ and $\mu_{\tilde{Y}_i}(y_i), (i = 1,2)$ are the respective membership functions.

Let α denotes the minimal acceptable degree of objectives and constraints and β denotes the maximal degree of rejection of objectives and constraints. Then the (α, β)-level of $\tilde{X}, \tilde{Y}_i, (i = 1,2)$, [6,10,11], are

$$X_\alpha = \{(x \in X | \mu_{\tilde{X}} \geq \alpha)\}, \tag{2.3}$$

$$Y_{i_\alpha} = \{(y_i \in Y_i | \mu_{\tilde{Y}_i} \geq \alpha)\}, (i = 1,2) \tag{2.4}$$

$$X^\beta = \{(x \in X | \nu_{\tilde{X}} \leq \beta)\} \tag{2.5}$$

$$Y_i^\beta = \{(y_i \in Y_i | \nu_{\tilde{Y}_i} \leq \beta)\}, (i = 1,2) \tag{2.6}$$

where $\alpha \geq \beta;\ \alpha + \beta \leq 1 \ and \ \alpha, \beta \geq 0$.

The quantities $X_\alpha, Y_{i_\alpha}\ (i = 1,2), X^\beta \ and \ Y_i^\beta, (i = 1,2)$ are crisp sets. Using (α, β)-level the setup cost, holding cost and shortage cost can be represented by different levels of confidence intervals [16,17,25,26]. Hence an intuitionistic fuzzy inventory models can be reduced to a family of crisp inventory models, with different (α, β)-level cuts

$\{X_\alpha \mid 0 < \alpha \leq 1\}, \{Y_{i_\alpha} | \, 0 < \alpha \leq 1\}, (i = 1,2),$

$\{X^\beta | 0 < \beta \leq 1\} \ and \ \{Y_i^\beta | 0 < \beta \leq 1\} (i = 1,2)$

The above sets represent sets of movable boundaries and they form nested structure for expressing the relationship between the crisp sets and intuitionistic fuzzy sets.

Let the confidence intervals of the intuitionistic fuzzy sets $\tilde{X}$ and $\tilde{Y}_i, (i = 1,2)$ be $[l_{x_\alpha}, u_{x_\alpha}]$ and $[l_{y_{i_\alpha}}, u_{y_{i_\alpha}}]$, $(i = 1,2)$, $[u_{x^\beta}, l_{x^\beta}]$ and $[u_{y_i{}^\beta}, l_{y_i{}^\beta}]$, $(i = 1,2)$ respectively. Since the set-up cost, holding cost and shortage cost are intuitionistic fuzzy numbers, using Atanassov's extension principle [16,17,25], the membership and non-membership functions of the performance measure $p(\tilde{X}$ and $\tilde{Y}_i)$, $(i = 1,2)$ are defined as

$$\mu_{p(\tilde{X},\tilde{Y}_i)}(z) = \sup_{x\in\tilde{X},y_i\in\tilde{Y}_i} \min \ \{\mu_{\tilde{X}}(x), \mu_{\tilde{Y}_i}(y_i)/z = p(x,y_i)\}, (i = 1,2) \tag{2.7}$$

and

$$\nu_{p(\tilde{X},\tilde{Y}_i)}(z) = \inf_{x\in\tilde{X},y_i\in\tilde{Y}_i} \max \ \{\nu_{\tilde{X}}(x), \nu_{\tilde{Y}_i}(y_i)/z = p(x,y_i)\}, (i = 1,2) \tag{2.8}$$

Construction of the membership function $\mu_{p(\tilde{X},\tilde{Y}_i)}(z)$, $(i = 1,2)$ and $\nu_{p(\tilde{X},\tilde{Y}_i)}(z) (i = 1,2)$, are respectively equivalent to say that derivation of (α, β) - levels of $\mu_{p(\tilde{X},\tilde{Y}_i)}(z)$, $(i = 1,2)$ and $\nu_{p(\tilde{X},\tilde{Y}_i)}(z)$

$(i = 1,2)$,

From the equation (2.7) the equations $\mu_{p(\tilde{X},\tilde{Y}_i)}(z) = \alpha$, $(i = 1,2)$ is true only when $\mu_{\tilde{X}}(x) = \alpha$,

$\mu_{\tilde{Y}_i}(y_i) \geq \alpha$ or $\mu_{\tilde{X}}(x) \geq \alpha$, $\mu_{\tilde{Y}_i}(y_i) = \alpha$ are true.

From the equation (2.8) the equations $\nu_{p(\tilde{X},\tilde{Y}_i)}(z) = \beta$, $(i = 1,2)$ are true only when $\nu_{\tilde{X}}(x) = \beta$,

$\nu_{\tilde{Y}_i}(y_i) \leq \beta$ or $\nu_{\tilde{X}}(x) \leq \beta$, $\nu_{\tilde{Y}_i}(y_i) = \beta$ are true.

The parametric programming problems have the following form:

$$l_{p_\alpha} = \min p(x, y_i) \tag{2.9}$$

such that

$l_{x_\alpha} \leq x \leq u_{x_\alpha}$,

$l_{y_{i_\alpha}} \leq y_i \leq u_{y_{i_\alpha}}, (i = 1,2)$,

and

$u_{p_\alpha} = \max p(x, y_i)$

such that

$$l_{x_\alpha} \leq x \leq u_{x_\alpha}, \tag{2.10}$$

$l_{y_{i_\alpha}} \leq y_i \leq u_{y_{i_\alpha}}, (i = 1,2)$,

$$u_{p^\beta} = \min p(x, y_i) \tag{2.11}$$

such that

$u_{x^\beta} \leq x \leq l_{x^\beta}$,

$u_{y_i^\beta} \leq y_i \leq l_{y_i^\beta}, (i = 1,2)$,

and

$l_{p^\beta} = \max p(x, y_i)$

such that

$u_{x^\beta} \leq x \leq l_{x^\beta},$ (2.12)

$u_{y_i^\beta} \leq y_i \leq l_{y_i^\beta}, (i = 1,2),$

If both l_{p_α} *and* u_{p_α} are invertible with respect to α then the left shape function

$L(z) = l^{-1}p_\alpha$ and the right shape function $R(z) = u^{-1}p_\alpha$ [2,3,24] can be obtained. From this the membership function $\mu_{p(\tilde{X},\tilde{Y}_i)}(z)$, $(i = 1,2)$ is constructed as

$$\mu_{p(\tilde{X},\tilde{Y}_i)}(z)=\begin{cases} L(z)\ for\ z_1 \leq z \leq z_2 \\ 1\ for\ z_2 \leq z \leq z_3 \\ R(z)\ for\ z_3 \leq z \leq z_4 \end{cases} \quad (2.13)$$

where $z_1 \leq z_2 \leq z_3 \leq z_4$, $L(z_1) = R(z_4) = 0$ *and* $L(z_2) = R(z_3) = 1$.

If both u_{p^β} *and* l_{p^β} are invertible with respect to β then the left shape function

$L(z) = u^{-1}p^\beta$ and the right shape function $R(z) = l^{-1}p^\beta$ [2,3,24] can be obtained. From which the membership function $\nu_{p(\tilde{X},\tilde{Y}_i)}(z)$, $(i = 1,2)$ is constructed as

$$\nu_{p(\tilde{X},\tilde{Y}_i)}(z)=\begin{cases} 1 - L(z)\ for\ z_1 \leq z \leq z_2 \\ 0\ for\ z_2 \leq z \leq z_3 \\ 1 - R(z)\ for\ z_3 \leq z \leq z_4 \end{cases} \quad (2.14)$$

where $z_1 \leq z_2 \leq z_3 \leq z_4$, $L(z_1) = R(z_4) = 1$ *and* $L(z_2) = R(z_3) = 0$.

3. MODEL - EOQ PROBLEMS WITH INSTANTANEOUS REPLENISHMENT AND NO SHORTAGES

Assumptions

3.1. The inventory system pertains to a single item.

3.2 Annual Demand (D) is deterministic.

3.3 The inventory is replenished in a single delivery for each order.

3.4 Replenishment is instantaneous.

3.5 There is no lead time.

3.6 Shortages are not allowed.

Using the concept of α, β level, the above intuitionistic fuzzy inventory models can be reduced as EOQ model with instantaneous replenishment and no shortage [9,14,15,22] for which

$$Q^0 = \left[\frac{2DC_s}{C_1}\right]^{\frac{1}{2}} \quad (3.1)$$

and

$$TC^0 = \left[\frac{Q^0 C_1}{2}\right] + \left[\frac{DC_s}{Q^0}\right] = [2DC_sC_1]^{\frac{1}{2}} \quad (3.2)$$

where C_s *and* C_1 represent the set-up cost and the holding cost respectively.

4. ILLUSTRATIONS

Consider an EOQ problem with instantaneous replenishment, without shortages. The setup cost and holding cost are fuzzy numbers represented by $\overline{X}$ =[400,450,550,600] and $\overline{Y}_1$=[0.7,0.8,1.1,1.1]. The α level of the membership functions $\mu_{\overline{X}}(x)$, $\mu_{\overline{Yi}}(yi)$)are [400+50α,600-50α] and [0.7+0.1α,1.1-0.1 α] respectively. The β level of the non membership functions $\nu_{\overline{X}}(x)$, $\nu_{\overline{Yi}}(yi)$ are [450-50β, 550+50β] and [0.8-0.1 β,1+0.1 β] respectively.

From the equation (2.9), (2.10), (2.11) and (2.12), the parametric programming problems are formulated to derive the membership function for $\overline{Q}$

They are of the form

$$l_{Q_\alpha^0} = \min\left\{\frac{2Dx}{y_1}\right\}^{1/2} \tag{3.3}$$

with $400+50\alpha \le x \le 600-50\alpha$

$0.7+0.1\alpha \le y_1 \le 1.1-0.1\alpha$

and $$u_{Q_\alpha^0} = \max\left\{\frac{2Dx}{y_1}\right\}^{1/2} \tag{3.4}$$

with $400+50\alpha \le x \le 600-50\alpha$

$0.7+0.1\alpha \le y_1 \le 1.1-0.1\alpha$

Where $0<\alpha\le 1$

$$l_{Q^{0\beta}} = \max\left\{\frac{2Dx}{y_1}\right\}^{1/2} \tag{3.5}$$

with $450-50\beta \le x \le 550+50\beta$

$0.8 - 0.1\beta \le y_1 \le 1 + 0.1\beta$

and $$u_{Q^{0\beta}} = \min\left\{\frac{2Dx}{y_1}\right\}^{1/2} \tag{3.6}$$

with $450-50\beta \le x \le 550+50\beta$

$0.8 - 0.1\beta \le y_1 \le 1 + 0.1\beta$

Where $0 < \beta \le 1$

$l_{Q_\alpha^0}$ is found when x and y_1 approach their lower and higher bound respectively. Taking D=10,000 units, the optimal solution for (3.3) is

$$l_{Q_\alpha^0} = \left[\frac{20\times10^4\times(400+50\alpha)}{11-\alpha}\right]^{1/2} \tag{3.7}$$

Also $u_{Q_\alpha^0}$ is found when x and y_1 approach their upper bound and lower bound respectively. In this case the optimal solution for (3.4) is

$$u_{Q_\alpha^0} = \left[\frac{20\times10^4\times(600-50\alpha)}{7+\alpha}\right]^{1/2} \tag{3.8}$$

$l_{Q^{0\beta}}$ is found when x and y_1 approach their higher and lower bound respectively. Taking D=10,000 units, the optimal solution for (3.5) is

$$l_{Q^{0\beta}} = \left[\frac{20\times10^4\times(450-50\beta)}{10+\beta}\right]^{1/2} \tag{3.9}$$

Also $u_{Q^{0\beta}}$ is found when x and y_1 approach their lower bound and higher bound respectively. In this case the optimal solution for (3.6) is

$$u_{Q^{0\beta}} = \left[\frac{20\times10^4\times(550+50\beta)}{8-\beta}\right]^{1/2} \tag{3.10}$$

The membership function $\mu_{\overline{Q^o}}(z)$ is obtained and given by

$$\mu_{\overline{Q^o}}(z) = \begin{cases} \dfrac{11z^2-8\times10^7}{z^2+10^7} & for\ 2696.7995 \le z \le 3000 \\ 1 & for\ 3000 \le z \le 3708.0992 \\ \dfrac{12\times10^7-7z^2}{10^7+z^2} & for\ 3708.0992 \le z \le 4140.3934 \end{cases} \tag{3.11}$$

The graph of $\mu_{\overline{Q^o}}(z)$ is depicted in Figure 1.

The membership function $\nu_{\overline{Q^o}}(z)$ is obtained and given by

$$\nu_{\overline{Q^o}}(z) = \begin{cases} \dfrac{-10z^2+9\times10^7}{z^2+10^7} & for\ 2696.7995 \le z \le 3000 \\ 1 & for\ 3000 \le z \le 3708.0992 \\ \dfrac{8z^2-11\times10^7-}{z^2+10^7} & for\ 3708.0992 \le z \le 4140.3934 \end{cases} \quad (3.12)$$

The graph of $\nu_{\overline{Q^o}}(z)$ is depicted in Figure 2.

The parametric programming problem corresponding to the total annual cost TC^o has different only from the (3.3) and (3.4) in the objective function and given below

$$l_{TC^o{}_\alpha} = \min \{2Dxy_1\}^{1/2} \quad (3.13)$$

and $u_{TC^o{}_\alpha}$ =max $\{2Dxy_1\}^{1/2}$ (3.14)

The parametric programming problem corresponding to the total annual cost TC^o has different only from the (3.5) and (3.6) in the objective function and given below

$$l_{TC^{o\beta}} = \max \{2Dxy_1\}^{1/2} \quad (3.15)$$

and $u_{TC^{o\beta}}$ =min $\{2Dxy_1\}^{1/2}$ (3.16)

From the above problems (3.13) & (3.14) $l_{TC^o{}_\alpha}$ is obtained when both x and y_1 approach their lower bound $u_{TC^o{}_\alpha}$ is obtained when both x and y_1 approach their upper bound. Taking D=10,000 units.

$$l_{TC^o{}_\alpha} = [2\times10^4\times(280+75\alpha+5\alpha^2)]^{\frac{1}{2}} \quad (3.17)$$

$$u_{TC^o{}_\alpha} = [2\times10^4\times(660-115\alpha+5\alpha^2)]^{\frac{1}{2}} \quad (3.18)$$

The membership function $\mu_{TC^o}(z)$ is given below

$$\mu_{\overline{TC^o}}(z) = \begin{cases} \dfrac{-150\times10^2+\sqrt{10^6+40z^2}}{2\times10^3} & for\ 2366.4319 \le z \le 2683.2816 \\ 1 & for\ 2683.2816 \le z \le 3316.6248 \\ \dfrac{23\times10^3-\sqrt{10^6+40z^2}}{2\times10^3} & for\ 3316.6248 \le z \le 3633.1804 \end{cases} \quad (3.19)$$

The graph of $\mu_{\overline{TC^o}}(z)$ is given in Figure 3. For the crisp values C_s= ₹ 500, C_1 = ₹ 0.9, D=10,000 units Q^o = 3333.333 units and TC^o = ₹ 3000.

But defuzzification [6,8] of $\mu_{\overline{Q^o}}(z)$ and $\mu_{\overline{TC^o}}(z)$ give Q^o = 3354.05 units and TC^o = ₹ 2999.9532 respectively.

So if definite fluctuation of ₹ 50/- and the maximum possible fluctuation of ₹ 100/- in C_s and definite fluctuation of ₹ 0.1 and the maximum possible fluctuation of ₹ 0.2 in C_1 are identified, then the amount of Q^o to be increase suitably (it can be computed by using the above techniques) so as to maintain the total annual cost.

The graph of $\nu_{\overline{TC^o}}(z)$ is given in Figure 4.

But defuzzification [6,8] of $\nu_{\overline{Q^o}}(z)$ and $\nu_{\overline{TC^o}}(z)$ give Q^o = 3354.05 units and TC^o = ₹ 2999.9532 respectively.

So if definite fluctuation of ₹ 50/- and the maximum possible fluctuation of ₹ 100/- in C_s and definite fluctuation of ₹ 0.1 and the maximum possible fluctuation of ₹ 0.2 in C_1 are identified, then the amount of Q^o to be increase suitably (it can be computed by using the above technique) so as to maintain the total annual cost.

From the above problem (3.15) & (3.16) $l_{TC^{o\beta}}$ is obtained when both x and y_1 approach their upper bound $u_{TC^{o\beta}}$ is obtained when both x and y_1 approach their lower bond. Taking D=10,000 units,

$$l_{TC^{o\beta}} = [2\times10^4 \times (360 - 85\beta + 5\beta^2)]^{\frac{1}{2}} \tag{3.20}$$

$$u_{TC^{o\beta}} = [2\times10^4 \times (550 + 105\beta + 5\beta^2)]^{\frac{1}{2}}$$

(3.21)

The non membership function $\nu_{\overline{TC^o}(Z)}$ is given below

$$\nu_{\overline{TC^o}(Z)} = \begin{cases} \dfrac{17\times10^3 - \sqrt{10^6 + 40z^2}}{2\times10^3} & for\ 2366.4319 \le z \le 2683.2816 \\ 1 & for\ 2683.2816 \le z \le 3316.6248 \\ \dfrac{-21\times10^3 + \sqrt{10^6 + 40z^2}}{2\times10^3} & for\ 3316.6248 \le z \le 3633.1804 \end{cases} \tag{3.22}$$

CONCLUSIONS

In this paper, the membership functions and the non membership functions for the economic order quantity Q^o and the total cost TC^o are obtained for the elementary intuitionistic fuzzy inventory models.

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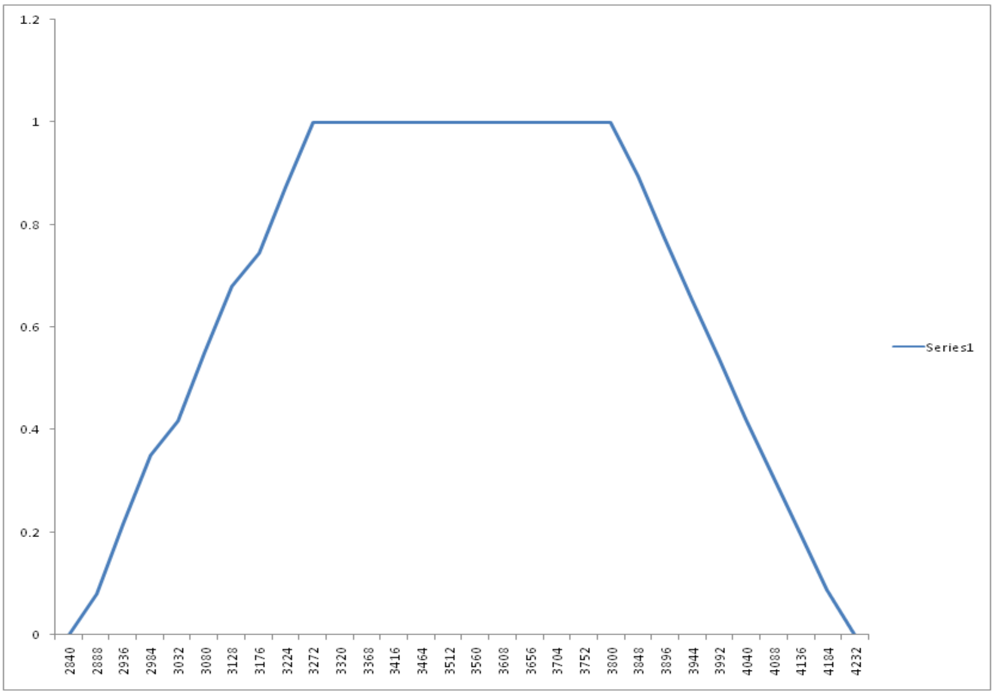
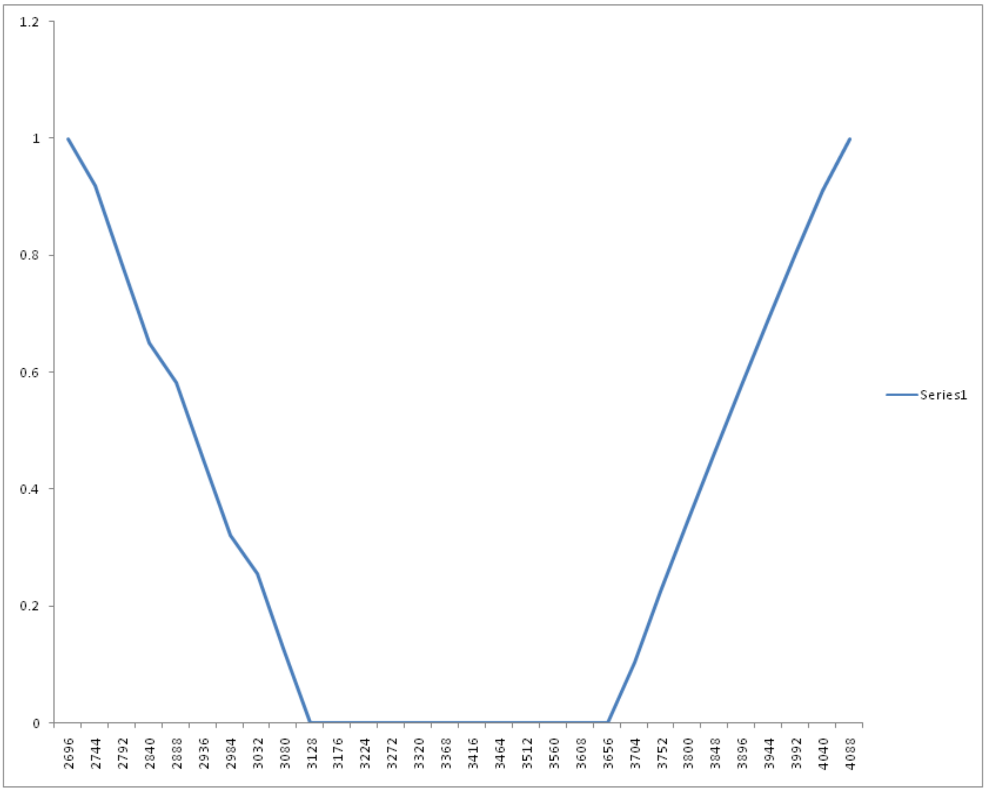
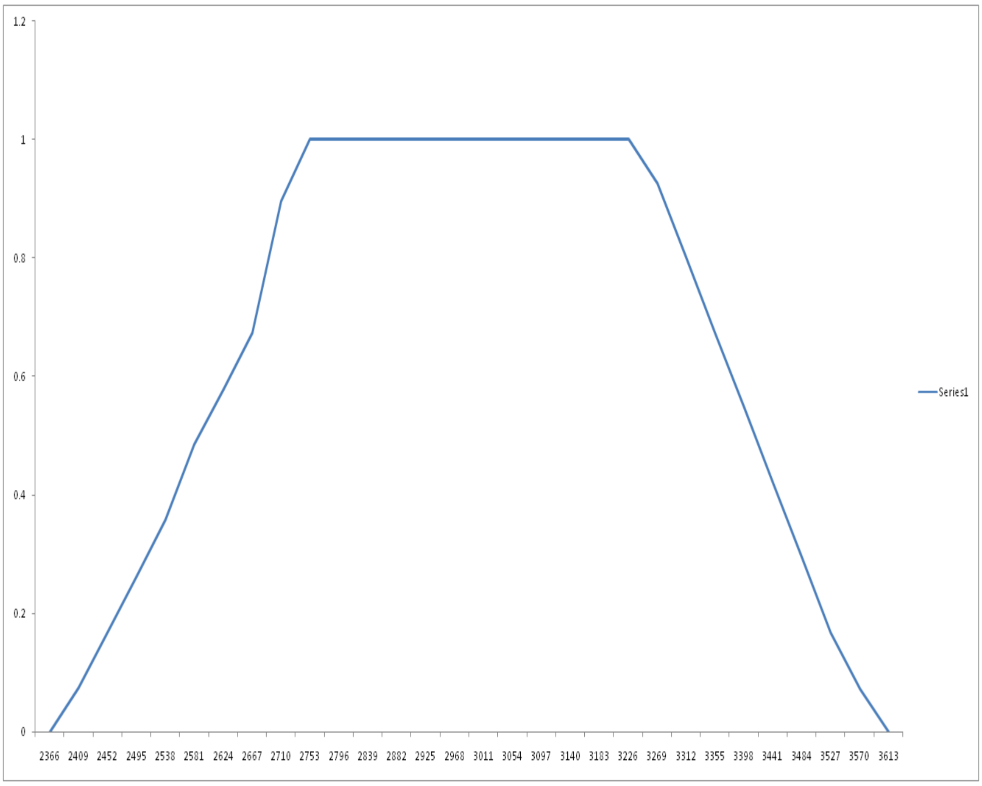
APPENDICES



$\mu_{\overline{Q_0}}(z)$
Figure 1

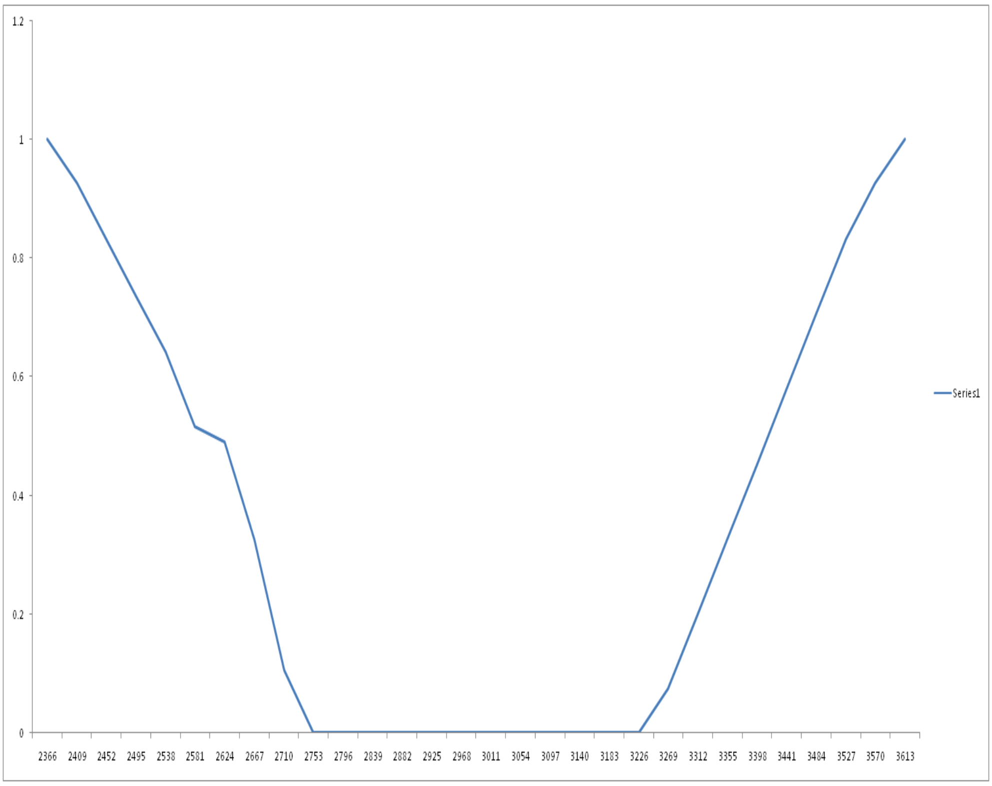


$\nu_{\overline{Q_0}}(z)$
Figure 2



$\mu_{\overline{TC_0}}(z)$

Figure 3



$\nu_{\overline{TC_0}}(z)$

Figure 4