Inventory Control with Fuzzy Inflation and Volume Flexibility under Random Planning Horizon

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ABSTRACT

The objective of this paper is to develop an inventory model with fuzzy inflation and multi variant demand rate. A new demand rate introduced which depends on price, quality and time. Planning horizon is random in nature for manufacturing company. Production rate is taken to be flexible in nature which depends on the technology frequency, capital investment and its elasticity and number of labour. Model is developed for both crisp and fuzzy environment. Numerical example is cited to illustrate the results and its significant features. Finally, to study the effect of changes of quality, inflation and planning horizon sensitivity analysis is carried out.

Key Words: Random planning horizon, fuzzy inflation, Time discounting, Volume flexible environment, price and time dependent demand rate

1. Introduction:

In recent years many research paper have been published assuming that the production rate of a manufacturing system is often assumed to be constant, but in fact production rate is a variable under managerial control. Production rate may be influenced due to demand, on hand inventory and launching new competitive product or with the change in customer's preferences. Many authors have studied problems connected with constant production rate by taking different demand rate and finite planning horizon. However, one of the weaknesses of current inventory models is the unrealistic assumption that planning horizon is taken either finite or infinite. The planning horizon varies over years and may be considered as random with a distribution for seasonal products. There is a quite realistic approach to the model that the demand rate is taken to be multi variant function. In the present paper an attempt has been made to study a more realistic situation, for assuming that production rate is decision variable.

Till now, none has developed inventory models incorporating random planning horizon, price, quality and time dependent demand, imprecise effect due to inflation and discounting with volume flexibility.

Volume flexibility of a manufacturing system is its ability to be operated profitably at different overall output levels. Volume flexibility permits a manufacturing system to adjust production upwards or downwards within wide frontier period to the start of production of a lot. It helps to reduce the rate of production to avoid rapid accrual of inventories.

2. LITERATURE REVIEW

It is commonly observed that the demand for an item declines over time because of the continuous introduction of competing products, loss of appeal, and change in trend or perception about the product and so on. For instance, fashion goods grow out of vogue after some time. The demand for new products like a new model of a computer cannot be continuously sustained when newer and more efficient products are introduced into the market. The demand for seasonal products like winter clothing decreases over the season. In such situations, a strategy that is commonly employed by dealers of such goods is to reduce the price to encourage customers to buy the product. This tactic is based on the relationship between the demand for an item and selling price which has been extensively studied in economic theory, and is the basis for the definition of the price elasticity of the demand. Quality of the product also affects the demand of an items .These perceptions form the basis for our study in this paper. Urban and Baker (1997) considered and order level model with selling price and time dependent demand rate over a single period. Datta and Pal (2001) analyzed a multi-period EOQ model with stock dependent and price-sensitive demand rate. Abad and Jaggi (2003) discussed the EOQ model with price sensitive demand rate. Teng and Chang (2005) extended an EPQ (economic production quantity) model for perishable items, considering the demand rate as inversely proportional to the price. You (2005) developed an inventory model with price and time dependent demand. Banerjee and Sharma (2008) considered three phase product-life-cycle type deterministic demand which is price and time dependent. The demand pattern recurs seasonally and successive seasons are separated by random time intervals. They prove concavity of the net profit function with respect to time when demand is linear. Banerjee and Sharma (2009) also considered selling price dependent demand function with an option of alternative market where demand arises in two different markets at different points of time. Banerjee and Sharma (2010) filled up practical lacuna by considering a general price and time dependent deterministic demand function with seasonality.

It is well recognized that inflation in world is a monetary phenomenon. Buzacott (1975) was the first author to include the concept of inflation in inventory modeling. He developed a minimum cost model for a single item inventory with inflation. Misra (1979) simultaneously considered the time-value of money for internal as well as external inflation rate, and analyzed the influence of interest rate and inflation rate on replenishment strategy. Chandra and Bahner (1985) extended the result in Misra's (1979) model to allow for shortages. Hariga (1995) extended the study to analyze the effects of inflation and time-value of money on an inventory model with time-dependent demand rate. Wee and Law (2001) discussed a deteriorating inventory model taking into account the time-value of money is developed for a deterministic inventory system with price-dependent demand. Moon et al. (2005) developed a deterministic inventory lot-size models under inflation with for fluctuating demand. Chern et al. (2008) developed an inventory model with inflation by assuming that the demand function is fluctuating.

Most of the models deal with finite or infinite planning horizon. But for seasonal products, the planning horizon varies over years and must be consider as random with some suitable distribution function. There are some models (cf. Bhunia and Maiti (1997), Yang et al. (2010)), etc.) in which time horizon has been considered as finite. For seasonal products, the planning horizon varies over years and may be considered as random with a distribution. Moon and Yun (1993) developed an EOQ model with a random planning horizon. Moon and Lee (2000) presented an EOQ model under inflation and discounting with a random product life cycle.

When some inventory parameters are fuzzy in nature, the resultant objective function also becomes fuzzy. Roy and Maiti (2000) have solved the classical order level inventory models in fuzzy environment. Yao and Wu (1999) and Dey, J.K. et al. (2005) have considered the production model with fuzzy environment. Always, inflation is not being crisp in nature. So, fuzzy inflation is realistic factor. Roy et al. (2008) have developed an inventory model with stock dependent demand when rates of inflation and time discounting are fuzzy in nature. The particular case, when resultant effect of inflation and time value is crisp in nature, is also analyzed. Maity, K. and Maiti, M. (2008) developed the optimal production policy for an inventory control system of deteriorating items with fuzzy inflation.

It is difficult for firm to forecast demand for new product and services even for existing one given the socioeconomic uncertainties underlying consumer's purchase decisions. The reality of uncertain demand is never going to disappears. In response to the demand uncertainties, a firm may develop capabilities in the firm's resources and infrastructure to deploy volume flexibility. It is the ability to be operated profitably at different output level. Flexible production rate is an authentic approach over constant rate. Khouja (2005) developed a production model with a flexible production rate. Sana and Chaudhari (2003), Sana et al. (2004) discussed the effect of flexible production rate with different conditions. Sana et al. (2007) and Sana and Chaudhuri (2007) extended the EPLS model which accounts for a production system producing items of perfect as well as imperfect quality with volume FMS.

Table1: Major characteristics of inventory models on selected articles

Authors and Published years	Demand	Inflation	Fuzzy	Volume flexibility	Random planning horizon
Urban **and** Baker (1997)	selling price and time dependent	No	No	No	No
Datta **and** Pal (2001)	stock and price sensitive	No	No	No	No
Abad **and** Jaggi (2003)	price sensitive	No	No	No	No
Teng **and** Chang (2005)	price sensitive	No	No	No	No
You (2005)	selling price and time dependent	No	No	No	No
Banerjee **and** Sharma (2008)	selling price and time dependent	No	No	No	No
Banerjee **and** Sharma (2009)	Price dependent	No	No	No	No
Banerjee **and** Sharma (**2010**)	selling price and time dependent	No	No	No	No
Buzacott (1975)	Constant	Yes	No	No	No
Hariga (1995)	Time dependent	Yes	No	No	No
Wee **and** Law (2001)	price-dependent	Yes	No	No	No
Moon ***et al*** (2005)	Time varying	Yes	No	No	No
Chern ***et al.*** (2008)	Time varying	Yes	No	No	No
Moon **and** Lee (2000)		Yes	No	No	Yes
Roy **and** Maiti (2000)	Stock dependent		Yes	No	No
Roy ***et al***. (2008)	Stock dependent	Yes	Yes	No	Yes

Maiti **and** Maiti (2008)	Stock dependent	Yes	yes	No	No
Dey ***et al***. (2005)	Varying	No	yes	No	No
Yao **and** Wu (1999)	Constant	No	Yes	No	No
Misra (1979)	Constant	Yes		No	No
Chandra **and** Bahner (1985)	Constant	Yes	No	No	No
Bhunia **and** Maiti (1997)	Time dependent	No	No	No	No
Yang ***et al.*** (2010)	Stock dependent	Yes	No	No	No
Sana **and** Chaudhari (2003)	Stock dependent	No	No	Yes	No
Sana **et al.** (2004)	Time varying	No	No	Yes	No
Sana ***et al.*** (2007)	Reduced selling price dependent	No	No	Yes	No
Sana **and** Chaudhari (2007)	Reduced selling price dependent	No	No	Yes	No
Khouja **and** Meharaj (2005)	Constant	No	No	Yes	No
Present Paper	Price, Time and Quality dependent	Yes	Yes	Yes	Yes

In the existing literature, it is observed that there is almost a huge vacuum in the inventory models which is based on flexible manufacturing system models. Few researchers have considered the same but they have not considered the random planning horizon with fuzzy inflation. In the present study considering realistic approaches, production rate as decision variable which depends on the technology frequency, labour cost and capital investment. The goal of this work is to develop a production inventory model with volume flexibility, in which the demand rate is declining due to time and selling price, over a random planning horizon.

3. ASSUMPTIONS AND NOTATIONS

The following assumptions and notations have been adopted for the proposed model to be discussed-

Assumptions:

- Inflation is taken to be fuzzified in nature.
- Demand rate is depends on multi variable. The demand rate D of the produced items is a deterministic function of its selling price s, time and the quality i.e.,D (s, q, t)= $(a-bs)q^{\theta}e^{-\beta t}$ where a, b,θ, β are non negative constants.
- Production rate is considered as a decision variable $K = RI^{\alpha}L^{1-\alpha}$, R is technology frequency, I is invested capital for production expecting technology, (1-α) and α represent labour and capital elasticity of production respectively and L is the no. of labour. .
- Planning horizon is random with distribution.
- Idle time is considered for management of units.
- Shortages are not allowed.
- Lead time is zero.

Notations:

K: Production rate

q: quality of the product

s: Selling price per unit items

γ: Inflation rate

η: Discount rate

r: γ-η, may be crisp or fuzzy

C_h: Holding cost per unit item

C_p: Unit production cost

f (h): p.d.f. of planning horizon

N: Number of fully accommodated cycles to be made during the real time horizon h and time horizon ends during (N + 1)th cycle

H: Total time horizon (a random variable) and h is real time horizon.

C_L: Total cost of last cycle

TC_1: Total cost from j complete cycles

4. FORMULATION OF THE MODEL

Let the producer starts the production with zero inventory level. Initially inventory increases at a finite rate K-D(s,t,q)units per unit time up to time period t_1 at which production is stopped. Thereafter the inventory level depletes due to demand rate for a time period T at which inventory level reaches to zero level again. After that next production cycle starts and this process is continued up to N th cycles.

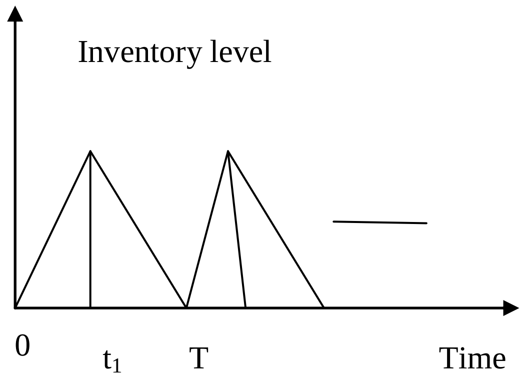


Figure 1: Inventory system

Differential equation of the inventory system of the j-th cyle (1≤j≤N) is

$$Q_1^{'}(t) = K - D(s,t,q) \quad \text{(j-1) T} \le t \le \text{(j-1)T} + t_1 \quad \text{.....(1)}$$

$$Q_2^{'}(t) = -D(s,t,q) \quad \text{(j-1)T} + t_1 \le t \le j\,T \quad \text{.... (2)}$$

With boundary conditions Q{(j-1)T}=0, Q(j T)=0

Solutions of the above equations are

$$Q_1(t) = K\{t-(j-1)T\} + (a-bs)q^{\theta}\left(\frac{e^{-\beta t} - e^{-\beta(j-1)T}}{\beta}\right) \quad \text{.... (3)}$$

$$Q_2(t) = (a-bs)q^{\theta}\left(\frac{e^{-\beta t} - e^{-\beta jT}}{\beta}\right) \quad \text{...... (4)}$$

4.1 Cost function for the system:

Present worth of set up cost : At the beginning of each cycle, setup cost is

$$\text{SUP} = C_0(1 + e^{-r(j-1)T+t_1}) \quad \text{.... (5)}$$

Present worth of Production Cost: Production cost of each item in the jth cycle is

$$\text{P.C.} = C_p \int_{(j-1)T}^{(j-1)T+t_1} Ke^{-rt} dt \quad \text{....(6)}$$

Present worth of Holding Cost: Manufacturer is in possession of holding the inventory during the interval [0,T]. Hence present worth holding cost for the jth cycle is

$$\text{H.C.} = C_h \left[\int_{(j-1)T}^{(j-1)T+t_1} q_1(t)e^{-rt}dt + \int_{(j-1)T+t_1}^{jT} q_2(t)e^{-rt}dt \right] \quad \text{...(7)}$$

Noe total cost of the inventroy system is

$$\text{T.C.} = \sum_{j=1}^{N} [SUP + P.C. + H.C.] \quad \text{....(8)}$$

Now $\sum_{j=1}^{N} e^{-r(j-1)T} = \frac{1-e^{-rNT}}{1-e^{-rT}}$ .... (9)

Here we consider that the planning horizon H is a random variable and follows Exponential distribution with p.d.f. as

$$f(h) = \begin{cases} \lambda e^{-\lambda h}, h \ge 0 \\ 0, otherwise \end{cases} \quad \text{...... (10)}$$

Present value of Expected total cost from N complete cycles is

$$\text{E(TC)} = \sum_{N=0}^{\infty} \int_{NT}^{(N+1)T} T.C.\, f(h)dh \quad \text{...... (11)}$$

From equation (3) and (4) at time t = t_1

$$t_1 = \frac{(a-bs)q^{\theta}T}{RI^{\alpha}L^{1-\alpha}} \quad \text{.... (12)}$$

4.2 Formulation of the last cycle:

The differential equation describing the inventory level q(t) in the interval NT<t are given by

$$Q^{'}(t) = K - D(s,t,q) \quad \text{NT} \le t \le \text{NT} + t_1 \quad \text{..... (13)}$$

$$Q^{'}(t) = -D(s,t,q) \quad \text{NT} + t_1 \le t \quad \text{.... (14)}$$

With boundary conditions Q(NT) = 0, Q(NT+ t_1) = q_0

The solutions of the above equations are

$$Q_1(t) = K\{t-NT\} + (a-bs)q^{\theta}\left(\frac{e^{-\beta t} - e^{-\beta NT}}{\beta}\right) \quad \text{...... (15)}$$

$$Q_2(t) = (a-bs)q^{\theta}\left(\frac{e^{-\beta t} - e^{-\beta(N+1)T}}{\beta}\right) \quad \text{..... (16)}$$

From equation (15) and (16), we have

$$t_1 = \frac{(a-bs)q^{\theta}T}{RI^{\alpha}L^{1-\alpha}} \quad \text{...... (17)}$$

In the last cycle, we consider two cases depending upon the cycle length. Let h be the real value corresponding to the random variable H.

Case I: When NT≤ h ≤NT+ t_1

Present value of the holding cost for the last cycle is given

$$HC_{L_1} = C_h \int_{NT}^{h} Q_1(t)e^{-rt}dt \quad \text{...... (18)}$$

Present value of Setup cost for the last cycle is

$$SA_{L_1} = C_0(1 - e^{-rNT}) \quad \text{....... (19)}$$

Present value of Production cost for the last cycle is

$$PC_{L_1} = C_p K\left(\frac{e^{-rNt} - e^{-r(NT+t_1)}}{r}\right) \quad \text{...... (20)}$$

Case II: When NT + t_1 ≤ h≤(N+1)T

Present value of the holding cost for the last cycle is given

$$HC_{L_2} = C_h[\int_{NT}^{NT+t_1} Q_1(t)dt + \int_{NT+t_1}^{h} Q_2(t)dt] \quad \text{…. (21)}$$

Present value of Setup cost for the last cycle is

$$SAC_{L_2} = C_0(1+e^{-rNT}) \quad \text{…... (22)}$$

Present value of Production cost for the last cycle is

$$PC_{L_2} = C_p K\left(\frac{e^{-rNT} - e^{-r(NT+t_1)}}{r}\right) \quad \text{…..(23)}$$

So, Expected holding cost for the last cycle is

$$\sum_{N=0}^{\infty}\int_{NT}^{(NT+t_1)} HC_L f(h)dh = \sum_{N=0}^{\infty}\int_{NT}^{(NT+t_1)} HC_{L_1} f(h)dh + \sum_{N=0}^{\infty}\int_{(NT+t_1)}^{(N+1)T} HC_{L_2} f(h)dh \quad \text{…….. (24)}$$

So, Expected total cost from last cycle is given by

E $\{TC_L\}$ = Expected Holding cost + Expected Production cost + Set up cost …… (25)

Total cost for the whole system:

Now, total expected cost for the complete time horizon is

E (TC) = $E(TC_1)$ +$E(TC_L)$ …… (26)

4.3 Stochastic Model:

Our problem is to determine T in crisp nature to

Min E (TC) …… (27)

Fuzzy Model:

Model (a): Min z

s.t. $pos\{E(\tilde{TC}) \geq z\} \geq a_1$ …. (28)

Model (b): Min z

s.t. $nes\{E(\tilde{TC}) \geq z\} \geq a_2$ …… (29)

$pos\{E(\tilde{TC}) \leq z\} < 1 - a_2$ ..… (30)

5. SOLUTION METHODOLOGY

To solve the stochastic model (model-1) GA is used. The basic technique to deal problems (28) or (30) is to convert the possibility/necessity constraint to its deterministic equivalent. However, the procedure is usually very hard and successful in some particular cases.

Algorithm 1: Algorithm to determine a feasible T to evaluate z for the problem (28):

To determine z for a feasible T, roughly find a point r_0 from fuzzy number $\tilde{r}$, which approximately minimizes z. Let this value be z_0 and set z = z_0 (for simplicity one can take z_0 = 0). Then r_0 is randomly generated in α_1-cut set of $\tilde{r}$ and let z_0 =value of E (TP) for r= r_0 and if z < z_0 replace z with z_0. This step is repeated a finite number of times and final value is taken as the value of z. This phenomenon is used to develop the algorithm.

1. Set z = z_0.

2. Generate r_0 uniformly from the α_1 -cut set of fuzzy number $\tilde{r}$.

3. Set z_0 =value of E (TP) for r= r_0.

4. If z < z_0 then set z = z_0.

5. Repeat steps 2, 3 and 4, N_1 times, where N_1 is a sufficiently large positive integer.

6. Return z.

7. End algorithm.

Algorithm 2: Algorithm to determine a feasible T to evaluate z for the problem (30):

We know that

$$nes\{E(\tilde{TP}) \geq z\} \geq \alpha_2 \Rightarrow pos\{E(\tilde{TP}) < z\} \leq 1-\alpha_2$$

. Now roughly find a point r_0 from fuzzy number $\tilde{r}$, which approximately minimizes E (TP). Let this value be z_0 (for simplicity one can take z_0 = 0 also) and ε be a positive number. Set z = z_0 -ε and if $pos\{E(\tilde{TP}) < z\} \leq 1-\alpha_2$ then increase z withε. Again check $pos\{E(\tilde{TP}) < z\} \leq 1-\alpha_2$ and it continues until $pos\{E(\tilde{TP}) < z\} > 1-\alpha_2$. At this stage decrease value of ε and again try to improve z. When ε becomes sufficiently small then we stop and final value of z is taken as the value of z. Using this criterion, required algorithm is developed as below. In the algorithm the variable F_0 is used to store initial assumed value of z and F is used to store value of z in each iteration.

1. Set, $z = z_0 - \varepsilon, F = z_0 - \varepsilon, F_0 = z_0 - \varepsilon$,tol = 0:0001.

2. Generate r_0 uniformly from the $1-\alpha_2$ cut set of fuzzy number $\tilde{r}$.

3. Set z_0 =value of E (TP) for r= r_0.

4. If z_0 < z.

5. Then go to step 11.

6. End If

7. Repeat step-2 to step-6 N_2 times.

8. Set F = z.

9. Set z = z +ε.

10. Go to step-2.

11. If ($z = F_0$) // In this case optimum value of z < $z_0 - \varepsilon$

12. Set $z = F_0 - \varepsilon, F = F - \varepsilon, F_0 = F_0 - \varepsilon$.

13. Go to step-2

14. End If

15. If (ε< tol)

16. Go to step-21

17. End If

18. $\varepsilon = \dfrac{\varepsilon}{10}$

19. $z = F + \varepsilon$

20. Go to step-2.

21. Output F.

22. End algorithm.

So for a feasible value of T, we determine z using the above algorithms and to optimize z we use GA. GA used to solve model-1 is presented below. When fuzzy simulation algorithm is used to determine z in the algorithm, this GA is named as fuzzy simulation based genetic algorithm (FSGA). This is used to determine fuzzy objective function values.

Algorithm 3: GA/FSGA algorithm

1. Set I = 0, M = 0, M_0 = 50.

2. Initialize $p_{c;}$ p_m.

3. Initialize (P (I)) and let N` is its size.

4. Evaluate (P (I)).

5. While ($M < M_0$)

6. Select N` solutions from P (I) for mating pool using roulette-wheel selection process [32]. Let this set be P_1 (I).

7. Select solutions from P_1 (I) for crossover depending on p_c.

8. Perform crossover on selected solutions to obtain population P_1 (I).

9. Select solutions from P_1 (I) for mutation depending on pm.

10. Perform mutation on selected solutions to obtain new population P (I + 1).

11. Evaluate (P (I + 1)).

12. Set M = M + 1.

13. If average fitness of P (I + 1) > average fitness of P (I) then

14. Set I = I + 1.

15. Set M = 0.

16. End If.

17. End While.

18. Output: Best solution of P (I).

19. End algorithm.

5. NUMERICAL EXAMPLE

5.1 Stochastic model:

To illustrate the performance of the proposed model, the values of the parameters are considered in appropriate units as follows

α = 0.1, λ = 0.05, θ =0.05, β = 0.05, r = 0.5, R = 25000, L= 10, j = 10 cycles, C_h = \$10, C_0 = \$10000, s = \$40, a= 350, b= 0.5, q= 0.80, C_p =5

Using the data, we got the optimal value of I and T i.e., I^* and T^* which minimize the total cost and these are

I^* = 0.001, T^* = 75.54 days, C (P^*) = \$257.51, Production cost (PC^*) =\$305745, $E(TC)^*$ = \$ 6972510.

5.2. Fuzzy stochastic model

Here, the resultant inflationary effect is considered as a triangular fuzzy number i.e. r= {0.55, 0.5, 0.6} and all other data remain same as in stochastic model. The maximum optimistic/pessimistic return from expression (28) and (30) has been calculated for different θ and β, and results are displayed in Table 2.

6. SENSITIVITY ANALYSIS

From the sensitivity analysis of the Examples (see Tables 1); it is observed that the optimal Time T^*, Technology Frequency I^* and total expected cost per unit time ($E(TC)^*$) are fairly sensitive with changes of the key parameters (α,θ,λ,a,r, C_h, q,b). The optimal production cost of unit item PC^*) is fairly sensitive with changes in the parameters α , λ,q and r . From the sensitivity analysis of the above example (see Tables 1 and Figs. 2–7), the following facts occur:

Total cost is slightly sensitive to changes in the values of some parameter and highly sensitive to changes in the values of some parameters such as

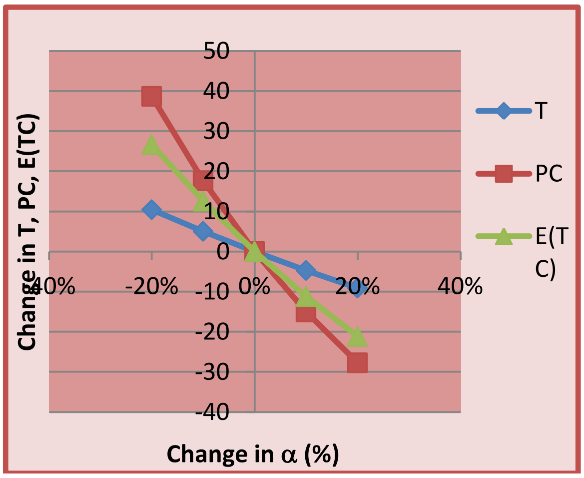
(i) Total cost is slightly sensitive to the changes in the values of parameters a, b, q, θ and highly sensitive to change in r and it is affected to the change inλ.

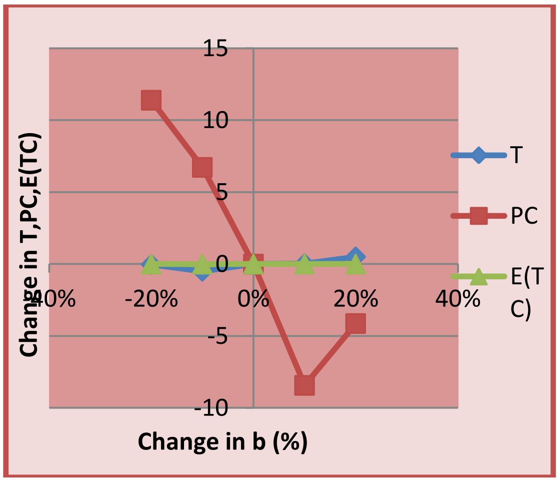
(ii) Unit production cost is slightly sensitive to the change inλ, a, b, q. But it is well sensitive to the change in α.

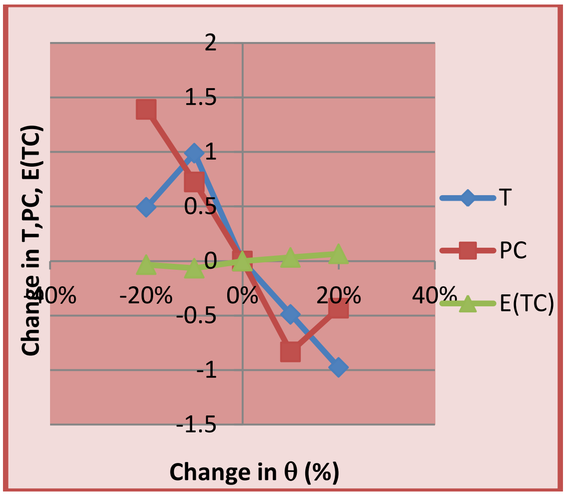
(iii) Planning time is moderately sensitive to change in b, q,θ, λ and little higher sensitive to change in r,α, a.

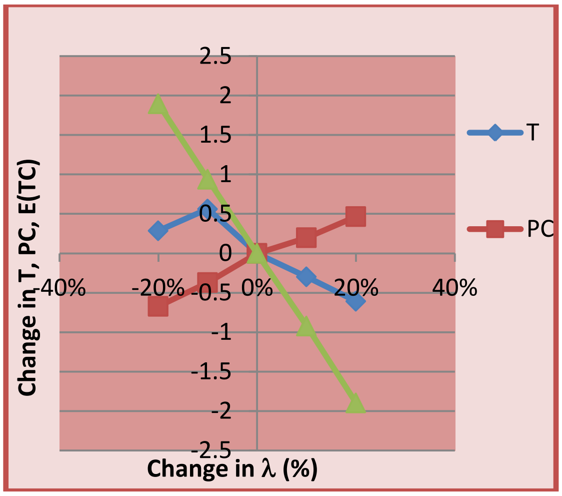
Table 1: Sensitivity analysis for stochastic model

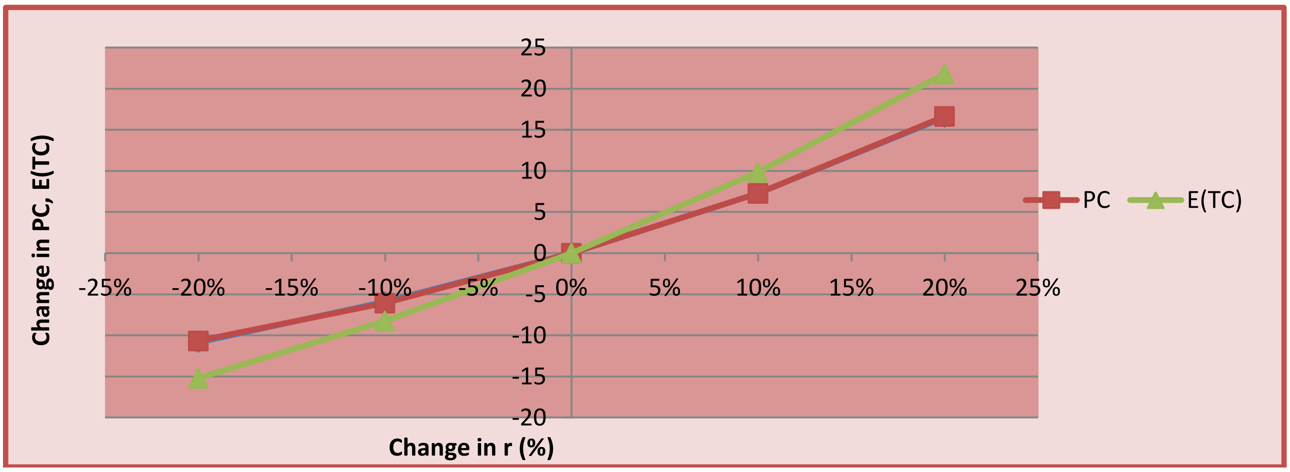
Parameters changes (in %)		T	PC	E(TC)
a	-20%	+10.60886	+10.39035	-0.59964
	-10%	+4.82307	+4.7245	-0.29745
	+10%	-4.0900	-7.4329	+0.29889
	+20%	-7.6058	-4.1227	+0.59964
b	-20%	-0.02528	+11.39	-0.00172
	-10%	-0.5056	+6.7245	-0.0034
	+10%	+0.02528	-8.4329	+0.00346
	+20%	+0.50596	-4.1324	+0.00176
α	-20%	+10.4384	+38.68	+26.66
	-10%	+5.0456	+17.6424	+12.56
	+10%	-4.71916	-15.0669	-11.195
	+20%	-9.09153	-27.723	-21.1722
θ	-20%	+0.4927	+1.39	-0.03284
	-10%	+0.98879	+0.7245	-0.06539
	+10%	-0.4892	-0.8329	+0.0333
	+20%	-0.97489	-0.4324	+0.0668
q	-20%	-2.0653	-3.9036	+0.3138
	-10%	-3.89637	-2.10672	+0.1523
	+10%	+2.3569	+2.2533	-0.14456
	+20%	+5.0856	+2.2503	-0.2823
λ	-20%	+0.2863	-0.67192	+1.89727
	-10%	+0.561635	-0.37031	+0.9394
	+10%	-0.2978	+0.19857	-0.9218
	+20%	-0.60783	+0.46649	-1.89727
r	-20%	-10.84064	-10.6725	-15.223
	-10%	-5.90571	-6.0623	-8.23448
	+10%	+7.2631	+7.2757	+9.8402
	+20%	+16.5184	+16.6421	+21.7956

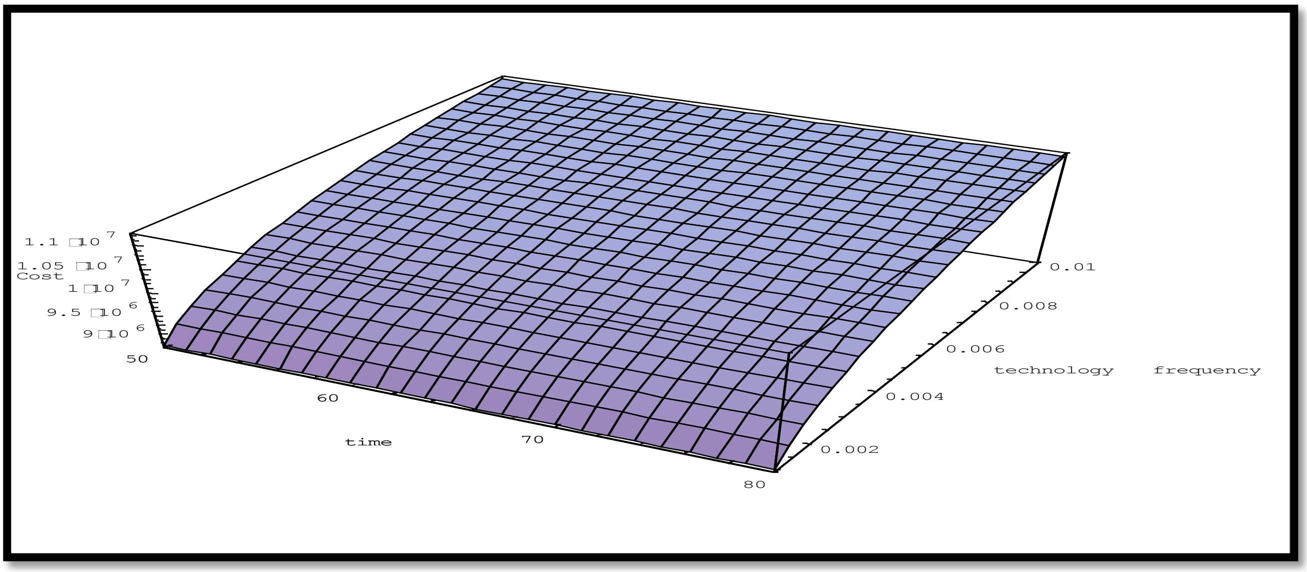












Graphical representation of convexity of the system

Table 2: Results for fuzzy stochastic model

β	θ	Optimistic(a_1=0.9)	Pessimistic(a_2=0.5)
0.50	0.04	6621.71	6145.35
0.55	0.045	6694.51	6211.06
0.60	0.05	6777.61	6286.71
0.65	0.04	6445.28	5980.66
0.70	0.045	6527.22	6055.19
0.75	0.05	6617.18	6137.41
0.80	0.04	6302.54	5847.76
0.85	0.045	6389.36	5927.00
0.90	0.50	6482.83	6012.61

6. CONCLUSION:

In this study, PIPM model is developed for determining selling price, marketing expenditure, production rate, and demand and cycle length with a single product. The decisions regarding marketing as well as production are taken separately by formulating maximization problem for marketing department and minimization problem for production department. Model developed under inflation and time discounting over a stochastic time horizon. For seasonal goods where time horizon is finite but imprecise in nature, it can be estimated as a fuzzy or stochastic parameter. A methodology is suggested for optimization of a fuzzy objective, where instead of the objective function, the optimistic/pessimistic return of the objective is optimized. The methodology presented here is quite general and can be applied to the inventory problems with dynamic demand, allowing shortages, etc. Finally model is illustrated with numerical example.

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