

Chapter 3

Impact of Inflation on Production Inventory Model with Variable Demand and Shortages



Nidhi Handa, S. R. Singh, and Neha Punetha

Abstract The collaboration of inflation or reverse money on the production inventory system is one of the major key factors for successful supply chain management. Here, demand rate of items is increasing with time and decreasing with proportion of selling price which is effective strategy for the market change. The developed model designed for shortages is considered partially backlogged where backlogging rate is decreasing with waiting time. Considering inflation on various costs is providing more reliable result due to real-life problem. This study presents the impact of inflation on production inventory model for deteriorating items with time and selling price-dependent demand under shortages. After that, to illustrate the model, numerical example is provided and solved. At the end, sensitivity analysis is introduced to show the validity and optimality of proposed study in order to analyse the effect of changes of different key parameters.

Keywords Production · Deterioration · Variable demand · Shortage · Partial backlogging · Inflation

3.1 Introduction

In production inventory system, the aim of manufacturer is to calculate the optimal production cost with lowest price of goods. There are many factors such as demand, production, deterioration and backlogging included in the development of inventory models. Hsieh and Dye (2013) addressed the impact of preservation technology on production model having fluctuating demand with time. Majumder et al. (2015) presented a partial delay payment policy on EPQ model under crisp and fuzzy domain with declining market demand. A manufacturing supply chain model with two-level trade credit policies was proposed by Kumar et al. (2015) under the effect of learning

N. Handa · N. Punetha (✉)

Department of Mathematics and Statistics, KGC, Gurukul Kangri Vishwavidyalaya, Haridwar, India

S. R. Singh

Department of Mathematics, CCS University, Meerut, India

and preservation technology. Mishra (2016) investigated order-level inventory model with quadratic demand rate and Weibull deterioration rate under partial backlogging. Panda et al. (2018) studied two-warehouse optimal model of decaying products having variable demand and shortages with permissible delay approach.

In past study, researcher assumed that the demand to be constant or fixed may mislead the result. Now researcher is focusing on variable demand as like stock dependent, price dependent, time dependent, etc. which provides accurate optimum solution. Sometimes, customer compromises with the quality of items they purchase because of high price. Thus, it is very challenging task for production manufacturer to provide good-quality products in a suitable selling price. Generally, high selling price decreases customer's demand. A production model for infinite time horizon with time-dependent deterioration and price-sensitive demand has been investigated by Sharma et al. (2015). An inventory model including non-instantaneous deterioration with learning effect was studied by Shah and Naik (2018) in which assumed demand is price dependent. Also, Singh (2019) developed EPQ model with variable demand and backlogging where backlogging rate depends on waiting time.

For researcher, it is significant to include deterioration into account. In inventory models, deteriorating products are those items which we cannot use for future purpose due to decay, damage or spoilage of items. Wee and Wang (1999) introduced production policy with time-dependent demand for decaying goods. Molamohamandi et al. (2014) investigated optimal replenishment policy of EPQ model with shortages under permissible delay on payment for decaying items. Priyan and Uthayakumar (2015) studied economic manufacturing problem for defective items under imperfect production processes and reworking system. Tiwari et al. (2018) examined vendor and buyer inventory policy of imperfect products taking carbon emission into account. A lifetime decreasing model was studied by Singh and Rana (2020) with variable carrying cost and lost sale.

In the development of production models, inflation plays very important role as it affects the economy. Due to inflation, there is sustainable increase in general price or continuous fall in time value of money. Business organization is affected due to rapid inflation so it cannot be ignored. In production plants, inventories of raw materials and goods are big outlay and should be completed financially. Sarkar and Moon (2011) established manufacturing production model for imperfect items taking inflation into account. Kumar et al. (2013) studied effect of inflation on order quantity model for perishable products with lost sale. The effect of inflationary environment on ordering model under trade credit policy for finite time horizon was examined by Muniappan et al. (2015) in which deterioration is time dependent. Singh and Sharma (2016) extended production quantity model for stochastic demand and over finite time horizon. Pervin et al. (2020) developed EPQ model with collaboration of preservation technology investment to reduce deterioration rate.

In traditional models, it is assumed that shortages are completely backlogged, but it is not necessarily true in real-life scenario. Considering daily-life problems, some customers like to wait especially in shortage period until replenishment, whereas some become restless and head elsewhere. Chang (2004) classified EPQ model for shortages using variable lead time. He also used algebraic method to

find the minimum total average cost. Jain et al. (2007) extended EPQ model of decaying product for price- and stock-sensitive consumption under shortages. A non-instantaneous inventory model was proposed by Sharma and Bansal (2017) with learning effect and backlogging. An economic production quantity model for deteriorating items was studied by Khurana et al. (2018) with linear demand and partial backlogging. Handa et al. (2020) derived EOQ model under the effect of trade credit policy.

3.1.1 Our Contribution

In the present study, a production inventory model for deteriorating goods with time and price sensitive demand over a finite planning horizon under the effect of inflation on costs has been established. Due to tough competition in the market, manufacturer has to provide good-quality items to the customers at lowest reasonable rate. Shortages are permitted and partially backlogged with waiting time-dependent rate. To minimize the optimal cost of the proposed model, it has been solved numerically. Furthermore, to examine the stability of this problem, sensitivity analysis has been done for different parameters. The findings suggested that the production model may reduce the total average cost by taking inflation on account.

3.2 Assumptions

The model is supported by the following assumptions:

1. The production cycle is for finite planning horizon.
2. The demand of the items depends on time as well as on price such as

$$D(t, s_1) = \alpha + \beta t - \gamma s_1 \quad \text{where } \alpha > \beta \text{ and } \gamma \ll 1$$

3. The model has allowed constant rate of deterioration σ .
4. Deteriorating items are not repaired during whole cycle.
5. Inflation is allowed, and lead time is zero.
6. Shortages occur and not completely backlogged.
7. Backlogging rate is assumed to be decreasing with waiting time and given by

$$\lambda(\delta) = 1 - \frac{\delta}{T}$$

8. The production cycle is for finite planning horizon.

3.3 Notations

$Q_1(t)$	Positive inventory level.
$Q_2(t)$	Maximum inventory level when shortage occurs.
K	Production rate for manufacturing.
P_1	Production cost per unit.
s_1	Selling price.
A	Acquisition cost per unit.
M	Setup cost per production.
σ	Rate of deterioration.
C_d	Deterioration cost per unit.
C_I	Inventory holding cost per unit.
S	Inventory shortage cost per unit.
l	Cost of lost sale per unit.
α, β	Demand rate parameters where $\alpha > \beta$.
γ	Constant function of selling price.
δ	Backlogging rate (constant).
r	Constant rate of inflation.

3.4 Mathematical Modelling

In Fig. 3.1, production starts from $t = 0$. At $t = 0$, there is no production and demand. Production and consumption jointly continued during $[0, u_1]$, production reaches its maximum size at time $t = u_1$, and it stops at this point. After that, due to combined effect of consumption of inventory and deterioration of items, inventory depletes zero during $[u_1, u_2]$. After that, shortages occur including partial backlogging between $t = u_2$ to $t = T$.

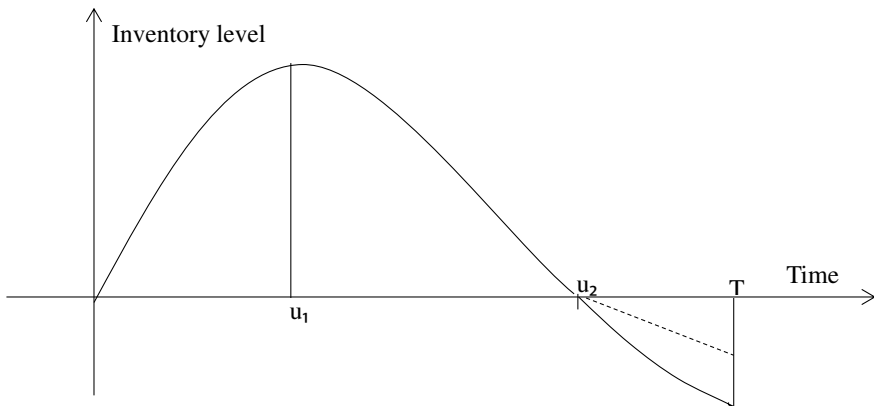


Fig. 3.1 Inventory versus time graph

The behaviour of inventory system with time has been specified by below-given differential equations:

$$\frac{dQ_1(t)}{dt} = K - (\alpha + \beta t - \gamma s_1) - \sigma Q_1(t) \quad 0 \leq t \leq u_1 \quad (3.1)$$

$$\frac{dQ_2(t)}{dt} = K - (\alpha + \beta t - \gamma s_1) - \sigma Q_2(t) \quad u_1 \leq t \leq u_2 \quad (3.2)$$

$$\frac{dQ_3(t)}{dt} = -(\alpha + \beta t - \gamma s_1) \quad u_2 \leq t \leq T \quad (3.3)$$

Boundary conditions are as follows:

$$Q_1(0) = 0, Q_2(u_1) = 0, Q_3(T) = 0$$

Solution of these equations with the help of boundary conditions:

$$Q_1(t) = \left[(K - \alpha + \gamma s_1) \left(t + \frac{\sigma t^2}{2} \right) - \beta \left(\frac{t^2}{2} + \frac{\sigma t^3}{3} \right) e^{-\sigma t} \right] \quad (3.4)$$

$$Q_2(t) = \left[(\alpha - \gamma s_1) \left\{ (u_2 - t) + \frac{\sigma}{2} (u_2^2 + t^2) \right\} + \beta \left\{ \left(\frac{u_2^2 - t^2}{2} \right) + \sigma \left(\frac{u_2^3 - t^3}{3} \right) \right\} \right] e^{-\sigma t} \quad (3.5)$$

$$\text{and } Q_3(t) = \left[(\alpha - \gamma s_1) (u_2 - t) + \frac{\beta}{2} (u_2^2 - t^2) \right] \quad (3.6)$$

Maximum inventory in $[0, u_2]$

$$Q_1(u_1) = Q_m$$

$$Q_m = \left[(K - \alpha + \gamma s_1) \left(u_1 + \sigma \frac{u_1^2}{2} \right) - \beta \left(\frac{u_1^2}{2} + \frac{\sigma u_1^3}{3} \right) \right] e^{-\sigma u_1} \quad (3.7)$$

And maximum inventory in shortage period $[u_2, T]$

$$Q_3(T) = Q_s$$

$$Q_s = \left[(\alpha - \gamma s_1) (u_2 - T) + \frac{\beta}{2} (u_2^2 - T^2) \right] \quad (3.8)$$

Total ordered quantity

$$Q = Q_m + Q_s \quad (3.9)$$

By using boundary condition

$$Q_1(u_1) = Q_2(u_2)$$

$$u_1 = \frac{-1}{\sigma} + \frac{1}{\sigma} \left[1 + \frac{2\sigma}{K} (\alpha - \gamma s_1) \left(u_2 + \frac{\sigma u_2^2}{2} \right) \right]^{1/2} \quad (3.10)$$

3.5 Cost analysis

Production cost

$$P.C. = P_1 \int_0^{u_1} K e^{-rt} dt$$

$$= P_1 K \left(u_1 - \frac{r u_1^2}{2} \right) \quad (3.11)$$

Acquisition cost

$$A.C. = A \quad (3.12)$$

Setup cost

$$S.C. = M \quad (3.13)$$

Deterioration cost

$$D.C. = c_d \left[\int_0^{u_1} \sigma Q_1(t) e^{-rt} dt + \int_{u_1}^{u_2} \sigma Q_2(t) e^{-rt} dt \right]$$

$$= c_d \sigma \left[(K - \alpha + \gamma s_1) \left(\frac{u_1^2}{2} + \frac{\sigma u_1^3}{6} \right) - \alpha (\alpha - \gamma s_1) \left(\left(\frac{u_2^2}{2} + \frac{\sigma u_2^3}{3} \right) \right. \right.$$

$$\left. \left. - \left(u_2 u_1 - \frac{u_1^2}{2} \right) - \frac{\sigma}{2} \left(u_2^2 u_1 - \frac{u_1^3}{3} \right) \right) + \beta \left(\left(\frac{u_2^3}{3} + \frac{\sigma u_2^4}{4} \right) \right. \right.$$

$$\left. \left. - \frac{1}{2} \left(u_2^2 u_1 - \frac{u_1^3}{3} \right) + \frac{\sigma}{3} \left(u_2^3 u_1 - \frac{u_1^4}{4} \right) - \left(\frac{u_1^3}{6} + \frac{\sigma u_1^4}{12} \right) \right) \right.$$

$$\left. - (r + \sigma) \left((K - \alpha + \gamma s_1) \left(\frac{u_1^3}{3} + \frac{\sigma u_1^4}{8} \right) - \beta \left(\frac{u_1^4}{8} + \frac{\sigma u_1^5}{5} \right) \right) \right]$$

$$\begin{aligned}
& + (\alpha - \gamma s_1) \left(\left(\frac{u_2^3}{6} + \frac{\sigma u_2^4}{8} \right) - \left(\frac{u_2 u_1^2}{2} - \frac{u_1^3}{3} \right) - \frac{\sigma}{2} \left(\frac{u_2^2 u_1^2}{2} - \frac{u_1^4}{4} \right) \right) \\
& + \beta \left(\frac{u_2^4}{8} + \frac{u_2^5}{10} - \frac{1}{2} \left(\frac{u_2^2 u_1^2}{2} - \frac{u_1^4}{4} \right) - \frac{\sigma}{3} \left(\frac{u_2^3 u_1^2}{2} - \frac{u_1^5}{5} \right) \right) \Big] \quad (3.14)
\end{aligned}$$

Holding Cost

$$\begin{aligned}
H.C. &= c_1 \left[\int_0^{u_1} Q_1(t) e^{-rt} dt + \int_{u_1}^{u_2} Q_2(t) e^{-rt} dt \right] \\
&= c_1 \left[(K - \alpha + \gamma s_1) \left(\frac{u_1^2}{2} + \frac{\sigma u_1^3}{6} \right) - \alpha (\alpha - \gamma s_1) \left(\left(\frac{u_2^2}{2} + \frac{\sigma u_2^3}{3} \right) \right. \right. \\
&\quad - \left. \left(u_2 u_1 - \frac{u_1^2}{2} \right) - \frac{\sigma}{2} \left(u_2^2 u_1 - \frac{u_1^3}{3} \right) \right) + \beta \left(\left(\frac{u_2^3}{3} + \frac{\sigma u_2^4}{4} \right) - \frac{1}{2} \left(u_2^2 u_1 - \frac{u_1^3}{3} \right) \right. \\
&\quad + \frac{\sigma}{3} \left(u_2^3 u_1 - \frac{u_1^4}{4} \right) - \left. \left(\frac{u_1^3}{6} + \frac{\sigma u_1^4}{12} \right) \right) - (r + \sigma) \left((K - \alpha + \gamma s_1) \left(\frac{u_1^3}{3} + \frac{\sigma u_1^4}{8} \right) \right. \\
&\quad - \left. \beta \left(\frac{u_1^4}{8} + \frac{\sigma u_1^5}{5} \right) + (\alpha - \gamma s_1) \left(\left(\frac{u_2^3}{6} + \frac{\sigma u_2^4}{8} \right) - \left(\frac{u_2 u_1^2}{2} - \frac{u_1^3}{3} \right) - \frac{\sigma}{2} \left(\frac{u_2^2 u_1^2}{2} - \frac{u_1^4}{4} \right) \right) \right. \\
&\quad \left. \left. + \beta \left(\frac{u_2^4}{8} + \frac{u_2^5}{10} \right) - \frac{1}{2} \left(\frac{u_2^2 u_1^2}{2} - \frac{u_1^4}{4} \right) - \frac{\sigma}{3} \left(\frac{u_2^3 u_1^2}{2} - \frac{u_1^5}{5} \right) \right) \right] \quad (3.15)
\end{aligned}$$

Shortage cost

$$\begin{aligned}
S.C. &= s \int_{u_2}^T (\alpha + \beta t - \gamma s_1) e^{-rt} dt \\
&= s \left[(\alpha - \gamma s_1)(T - u_2) + \frac{\beta}{2}(T^2 - u_2^2) \right. \\
&\quad \left. - r \left\{ \frac{(\alpha - \gamma s_1)}{2} (T^2 - u_2^2) + \frac{\beta}{3} (T^3 - u_2^3) \right\} \right] \quad (3.16)
\end{aligned}$$

Lost sale cost

$$\begin{aligned}
L.S.C. &= l \int_{u_2}^T (1 - \lambda(\delta)) (\alpha + \beta t - \gamma s_1) e^{-rt} dt \\
&= \frac{l\delta}{T} \left[(\alpha - \gamma s_1)(T - u_2) + \frac{\beta}{2}(T^2 - u_2^2) \right. \\
&\quad \left. - r \left\{ \frac{(\alpha - \gamma s_1)}{2} (T^2 - u_2^2) + \frac{\beta}{3} (T^3 - u_2^3) \right\} \right] \quad (3.17)
\end{aligned}$$

Now, by using Eqs. (3.11)–(3.17), the total average cost (TAC) of the proposed model is

$$\text{TAC}(u_2) = \frac{1}{T} [P.C. + O.C. + A.C. + D.C + H.C. + S.C. + L.S.C.] \tag{3.18}$$

3.5.1 Solution Procedure

The objective of the study is to obtain the optimal value of critical time (u_2) that minimizes the total average cost. Individual optimization method is used to determine the minimum cost per unit time of the proposed model. The value of optimal time will be calculated by using

$$\frac{\partial \text{TAC}}{\partial u_2} = 0 \text{ provided } \frac{\partial^2 \text{TAC}}{\partial u_2^2} > 0$$

3.6 Numerical Example

With the help of numerical aptitudes, the optimal value of time and optimal value of total average cost are calculated. For the calculation, mathematical software Mathematica 11.3 is used, and assigned values for parameters are as follows:

$$\alpha = 1500 \text{ unit}, \beta = 2.5 \text{ unit}, \gamma = 0.02 \text{ unit}, s_1 = 28 \text{ rs/unit},$$

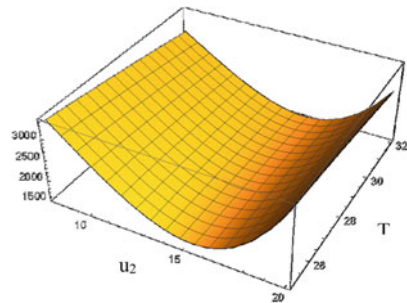
$$M = 1500 \text{ rs}, P_1 = 6 \text{ rs/unit}, K = 1000 \text{ unit}, r = 0.03, A = 10 \text{ rs},$$

$$c_d = 12 \text{ rs/unit}, \sigma = 0.06, C_1 = 0.5 \text{ rs/unit}, l = 7 \text{ rs/unit},$$

$$s = 5 \text{ rs/unit}, \delta = 0.8, T = 30 \text{ days}$$

By considering these values, we obtained (Fig. 3.2).

Fig. 3.2 Convexity of total average cost with respect to u_2 and T



3.7 Sensitivity Analysis

Sensitive analysis is executed for the different parameters by assigning 15%, 10% and 5% decrease or an increase in each of the parameters keeping all other parameters unchanged. The variation in total average cost and critical time with the change in different parameters such as demand rate, deterioration rate, holding cost, backlogging rate and inflation rate is shown in Table 3.1.

Table 3.1 Sensitive analysis with respect to different parameters

Parameter	% variation	Changes in parameter	u_2	TAC
β	-15	2.125	15.5593	1497.9
	-10	2.250	15.4758	1524.64
	-5	2.375	15.3944	1550.76
	0	2.500	15.3151	1576.28
	5	2.625	15.2378	1601.23
	10	2.750	15.1624	1625.64
	15	2.875	15.0887	1649.53
	-15	0.017	15.3159	1575.35
	-10	0.018	15.3156	1575.66
γ	-5	0.019	15.3154	1575.97
	0	0.020	15.3151	1576.28
	5	0.021	15.3149	1576.59
	10	0.022	15.3146	1576.90
	15	0.023	15.3144	1577.21
	-15	0.051	16.9367	1234.63
	-10	0.054	16.3573	1357.96
σ	-5	0.057	15.8182	1471.45
	0	0.060	15.3151	1576.28
	5	0.063	14.8445	1673.43
	10	0.066	14.4032	1763.76
	15	0.069	13.9883	1847.99
	-15	0.425	15.3477	1735.40
	-10	0.450	15.3364	1682.37
C_1	-5	0.475	15.3256	1629.33
	0	0.500	15.3151	1576.28
	5	0.525	15.3051	1523.22
	10	0.550	15.2955	1470.15
	15	0.575	15.2862	1417.07

(continued)

Table 3.1 (continued)

Parameter	% variation	Changes in parameter	u_2	TAC
	-15	0.680	15.3068	1569.46
	-10	0.720	15.3096	1571.74
	-5	0.760	15.3123	1574.01
δ	0	0.800	15.3151	1576.28
	5	0.840	15.3179	1578.55
	10	0.880	15.3207	1580.82
	15	0.920	15.3235	1583.09
	-15	0.0255	15.9151	1885.47
	-10	0.0270	15.7089	1786.17
	-5	0.0285	15.5090	1683.03
r	0	0.0300	15.3151	1576.28
	5	0.0315	15.1270	1466.14
	10	0.0330	14.9443	1352.82
	15	0.0345	14.7670	1236.50

3.8 Observations

1. With the increase in the value of demand parameter beta, critical time and total average cost are decreased.
2. As the coefficient of selling price gamma increases, critical time slightly decreases and total average cost slightly increases.
3. With the increment in deterioration rate, the value of critical time decreases and total average cost quickly increases.
4. On increasing the holding cost, critical time slightly decreases and total average cost decreases.
5. When the value of backloging rate is increasing, then critical time and total average cost slightly increase.
6. When the value of inflation rate is increasing, then critical time and total average cost decrease.

3.9 Conclusion

In this article, the impact of inflation on production inventory model for deteriorating items has been introduced. This study contributes the idea of time- and price-sensitive demand which is a good strategy in today's competitive businesses. Due to fluctuating demand, this demand policy is suitable to fulfil customer requirements. The model follows constant deterioration which is appropriate for high deteriorating units. The organization may only save inventory production cost by proper management of

deteriorating items. In practical environment, considering inflation on cost is a good policy specifically for long-term investment and forecasting. For profitable business, including shortages and backlogging provides more practical results. With the help of numerical examples, total average cost of the system has been concluded. Convexity and sensitivity have been done to check the availability and stability of the model. This approach is appropriate to meet real-life problems. For future, researcher can further extend this model for different rates of deterioration, trade credit policy, two-warehouse and variable holding cost.

References

- Chang H-C (2004) A note on the EPQ model with shortages and variable lead time. *Inf Manag Sci* 15(1):61–67
- Handa N, Singh SR, Punetha N, Tayal S (2020) A trade credit policy in an EOQ model with stock sensitive demand and shortages for deteriorating items. *Int J Serv Oper Inf* 10(4):350–364
- Hsieh TP, Dye CY (2013) A production- inventory model incorporating the effect of preservation technology investment when demand is fluctuating with time. *J Comput Appl Math* 239:25–36
- Jain M, Sharma GC, Rathore S (2007) Economic production quantity model with shortages, price and stock-dependent demand for deteriorating items. *Int J Eng Trans Basics* 20(2):159–168
- Khurana D, Tayal S, Singh SR (2018) An EPQ model for deteriorating items with variable demand rate and allowable shortages. *Int J Math Oper Res* 12(1):117–128
- Kumar S, Handa N, Singh SR (2013) An inventory model for perishable items with partial backlogging under inflation. *Int J Trends Comput Sci* 2(11):551–565
- Kumar S, Handa N, Singh SR, Singh D (2015) Production inventory model for low-level trade credit financing under the effect of preservation technology and learning in supply chain. *Cogent Eng* 2(1). <https://doi.org/10.1080/23311916.2015.1045221>
- Majumder P, Bera UK, Maiti M (2015) An EPQ model of deteriorating items under partial trade credit financing and demand declining market in crisp and fuzzy environment. *Procedia Comput Sci* 45:780–789
- Mishra U (2016) An EOQ model with time dependent weibull deterioration, quadratic demand and partial backlogging. *Int J Appl Comput Math* 2:545–563
- Molamohamadi Z, Arshizadeh R, Tsmail N (2014) An EPQ inventory model with allowable shortages for deteriorating items under trade credit policy. *Discrete Dyn Nat Soc* 2014(6):1–10
- Muniappan P, Uthayakumar R, Vanish S (2015) An EOQ model for deteriorating items with inflation and time value of money considering time- dependent deteriorating rate and delay payments. *Syst Sci Control Eng* 3:427–434
- Panda GC, Khan MA-A, Shaikh A-A (2018) A credit policy approach in a two-warehouse inventory model for deteriorating items with price and stock- dependent demand under partial backlogging. *J Ind Eng Int* 15:147–170
- Pervin M, Roy SK, Weber GW (2020) Deteriorating inventory with preservation technology under price and stock sensitive demand. *J Ind Manage Optim* 16(4):1585–1612
- Priyan S, Uthayakumar R (2015) An EMQ inventory model for defective products involving rework and sales team' s initiatives- dependent demand. *J Ind Eng Int* 11:517–529
- Sarkar B, Moon I (2011) An EPQ model with inflation in an imperfect production system. *Appl Math Comput* 217(13):6159–6167
- Shah NH, Naik MK (2018) Inventory model for non-instantaneous deterioration and price sensitive trended demand with learning effects. *Int J Inventory Res* 2(1):60–77
- Sharma MK, Bansal KK (2017) Inventory model for non-instantaneous decaying items with learning effect under partial backlogging and inflation. *Global J Pure Appl Math* 13(6):1999–2008

- Sharma S, Singh SR, Ram M (2015) An EPQ model for deteriorating items with price sensitive demand and shortages. *Int J Oper Res* 23(2):245–255
- Singh D (2019) Production inventory model of deteriorating items with holding cost, stock and selling price with backlog. *Int J Math Oper Res* 14(2):290–306
- Singh SR, Rana K (2020) Effect of inflation and variable holding cost on life time inventory model with multi variable demand and lost sales. *Int J Recent Technol Eng* 8(5):5513–5519
- Singh SR, Sharma S (2016) A production reliable model for deteriorating products with random demand and inflation. *Int J Syst Sci* 4(4):330–338
- Tiwari S, Daryanto Y, Wee H-M (2018) Sustainable inventory management with deteriorating and imperfect quality items considering carbon emission. *J Cleaner Production* 192:281–292
- Wee HM, Wang WT (1999) A variable production scheduling policy for deteriorating items with time-varying demand. *Comput Oper Res* 26(3):237–254