

A Sustainable Supply Chain Model for Defective Items Under Fuzzy Environment

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Abstract

These days it is very difficult to produce 100% good quality items. Hence, delivered lot may have some defective items in the lot and the process of inspection is must for the improvement of quality of items. We deal a sustainable supply chain model for defective items under centroid method defuzzification fuzzy environment by using of centroid method. Nowadays, the emission of carbon from the storage, various type of gases like carbon dioxide, sulphur dioxide and methane and transportations is more dangerous for the human life and also affects the activities of business. Due to carbon emissions some cities are in more and more problems like Delhi, Noida and Ghaziabad. These gases are more responsible for the damaging of the environment balancing and poisonous for the human style. In the Finally, we minimized the total inventory fuzzy cost with respect to the order quantity for the eco-friendly items and also presented numerical example for the justification of the proposed mode. The sensitivity observation has been presented for the ordering policies as well as decision makers and future scope of this scenario also presented.

Keywords: EOQ, inspection, imperfect quality items, carbon emission.

Abstract:

1. Introduction

Inventory is the complete list of items such as goods in property. Inventory includes the raw material, partially manufactured items, prior to sale and departure from the manufacturing product. Inventory is widely used in public as well as private sector organization. Proposed strategy of Hill (1997) refers to the shipment needs to be delivered to retailer during the production segment of manufacturer cycle. In addition to Hill (1997) transportation cost and emission cost was added by Aljazzar et al. (2017). Where transportation cost & emission through transportation was defined in detail by Gurtu et al. (2015) and manufacturer emission was defined by Jaber et al. (2013). Whenever we purchase any item from the market, we must be inspecting the item because of many defects in between them (Jaggi et al., 2011). Also in

supply chain model it affects the demand when there are imperfect items available in the lot (Yadav et al. 2018). Huang (2007) research tasks have been modified by Teng and Chang (2009) with the help of a two-level credit financing scheme which is helpful for the consumers. Chen and Kang (2010) expand a model for an industrial system with the help of two-level credit policy with price dependent demand along with a satisfaction. Shah et al. (2010) has provided a large amount of articles for the inventory system with the help of a two-level credit financing scheme. That factor affected the cost of airplanes examined by Wright (1936). Mandal and Giri (2017) developed an imperfect quality based inventory model for two warehouse system under supply chain model where demand rate varies with respect to stock of the inventory. Sheikh and Patel (2017) improved a two-warehouse based model by using of the shortages concept for deteriorating items where the rate of demand varies with time. Some authors shown the idea of the fuzzy in the system of two warehouse. The basic idea of the fuzzy theory is suggested by Zadeh (1965). The learning effect on seller's ordering policy for defective items with trade credit financing was suggested by Jayaswal (2019). The total manufacturing of profit-making models for items with defective quality subjected to the effect of learning described by Jaber et al. (2008). Kumar (2021) derived the formula for the EOQ under fuzzy environment. Malik and Garg (2021), Malik et al. (2017), Malik and Sharma (2011) and Vikram et al. (2016) generalized an inventory model for two-warehouse system under fuzzy environment. Yadav et al. (2022) developed a fuzzy based inventory model for deteriorating items under variable demand. Mandal (2023) proposed an inventory model with fuzzy environment for the deterioration demand under the variable demand with respect to the stock and also variable holding cost. The learning effect is a one type of mathematical too which helps to minimize the total fuzzy cost corresponding to the number of shipment. we included some authors who worked on the learning theory, Jayaswal et al. (2019) developed a learning based model with the effect of trade policy for imperfect quality items under inspection. Jayaswal et al. (2021) presented an imperfect based scenario with trade-credit policy for deteriorating items under inspection process. Vikram et al. (2016) and Singh and Malik (2010) and these authors gave an inventory model with different approach for deteriorating items under various. Jayaswal et al. (2021) assumed an inventory model with preservation technology for the perishable items under learning effect. Alamri et al. (2023) explained an inventory model with fuzzy environment for imperfect items under trade credit policy and some other authors gave an inventory model with different approach for deteriorating items under various. The research work of Goyal et al. (1985) has been generalized by Su et al. (2007) with the help of credit financing policy and payment rebate. Teng et al. (2006) arranged a two-level credit financing inventory model and in this model the total order is optimized below the permissible delay in amount. The analysis work of Huang (2003) has been explored by Huang (2006) and upgraded this model with the help of two-level credit financing as well as restricted storage space. Hung and Chung (2003) introduced an inventory model which is the enlarged form of Goyal (1985) describing how to reduce the total cost with the help of credit financing along with payment rebate scheme. Teng and Goyal (2007) introduced a stock model for the buyers when the buyer used the credit policy provided by the customer in the industrial sector. Huang (2007) stabilized the establishment of total

economic order which was increased with the form of Haung (2003) with the help of a two-level credit financing scheme. Huang and Hsu (2008) to expand a two-level credit financing scheme with the help of a partial credit scheme. An economic order quantity formulation has been presented by Jaggi et al. (2008) introducing an economic order quantity formulation with the help of two-level credit policy with credit dependent demand. In this paper we have studied the impact of incorporating the imperfect quality items in the lot to the total cost which includes setup cost, holding cost, transportation cost, production cost, interest earning & emission. If the total cost increases or decreases, it directly impacts the factors included in total cost. So here we have observed the changes in the total lot size and changes in total cost if there are some imperfect qualities in the lot delivered.

2. Notations

The following notations have been given under below with meaning description

Q = Order lot (decision variable) (units)

D = Retailer's demand rate (units/year)

\tilde{D} = Retailer's fuzzy demand rate (units/year)

P = Manufacturer's production rate where ($D < P$)

A_r = Ordering cost for reailer (\$/shipment)

C_r = Item unit cost for reailer (\$/unit)

h_r = Holding cost for reailer (\$/unit/year)

s_r = Storage holding cost for for reailer (\$/unit/year)

A_m = Ordering cost for manufacturer (\$/shipment)

C_m = Item unit cost for manufacturer (in \$)

h_m = Holding cost for manufacturer (\$/unit/year)

s_m = Storage holding cost for for reailer (\$/unit/year)

λ = Shipment lot size multiplier in a vendor cycle

T_m = Manufacturer's cycle time = $\lambda Q/D$ (year)

δ = Percentage of defective items

T_e = Transport emission tax (in \$)

T_{ci} = Emission tax rate (\$/Ton)

T_{cap} = Truck capacity (in integer)

η = Number of trucks per shipment (Q/T_{cap})

E_m = Manufacturing emission (g/unit)

d = Distance traveled in one side (Km)

TAC_R = Rretailer's total annual cost (in \$)

TAC_m = Mmanufacturer's total annual cost (in \$)

$\Psi(Q)$ = Integrated total annual cost (in \$) under crisp model

$\tilde{\Psi}(Q)$ = Total integrated fuzzyfied cost (in \$) under fuzzy environment

$\tilde{\tilde{\Psi}}(Q)$ = Total integrated defuzzified cost (in \$) under fuzzy environment

3. Assumptions

- The rate of demand obeys the effect of fuzzy environment.
- The demand rate is taken as triangular fuzzy number
- Shortages are not permitted in this model.
- The rate of demand is less than the rate of production.
- The capacity of all trucks is same and uses same path for each truck during supply chain.
- Single type of items is used during this supply chain.
- The cost of holding units is included during non-production phase.
- Delivered lot has some defective items.
- Imperfect quality items are sold at low price in another market.
- Manufacturer emission cost will be fixed during supply chain
- The cost related to holding units is termed as financial cost which will be same during supply chain.
- The financial cost for retailer is greater than the financial cost of manufacturer at the retailer's end.

4. Proposed Model

Our proposed model follows the model mythology of Hill (1997) and its inventory representation has been depicted in figure 1. Manufacturer prepared Q units as per demanded retailer. It is suppose that D is the rate of demand for retailer. In this order, we studied the model of Jaber et. al. (2013) which presented for the manufacturer emissions which are equal to $E_m = aP^2 - bP + c$. Gurtu et al. (2015) explained the carbon emission cost associated with transportation and transport with the help of formula $(2d eT_{ci})$.

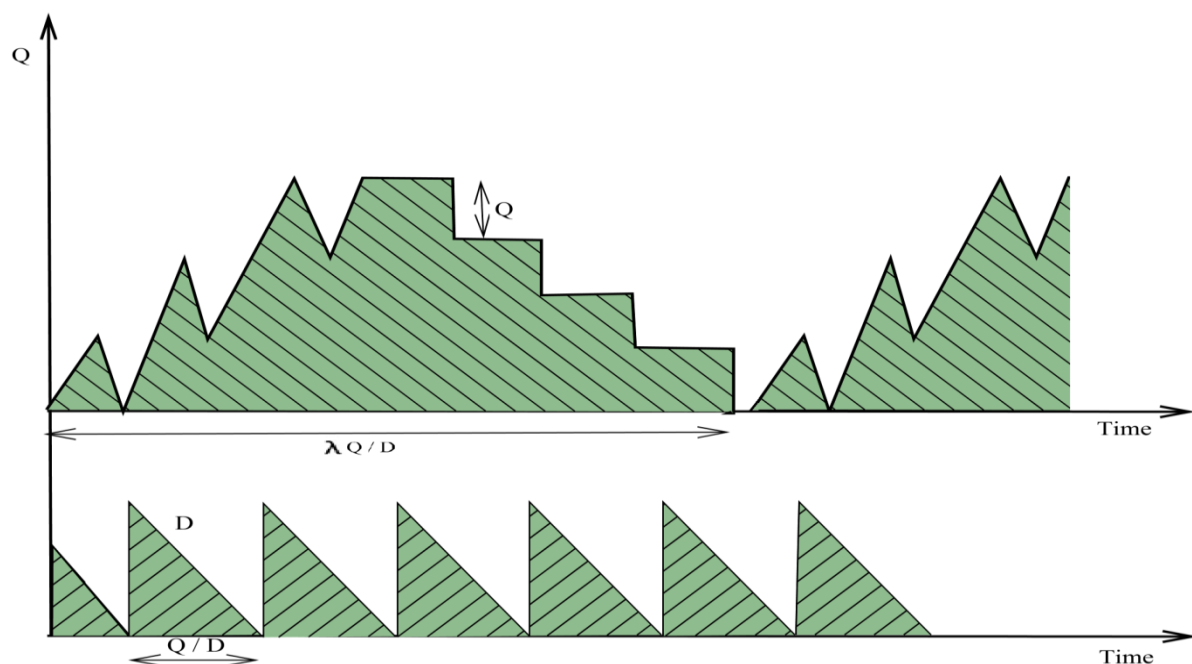


Figure 1: Inventory process with time

4.1 Retailer’s total annual cost

In this section, we calculated the total annual cost for the retailer which is the sum of the setup cost $(SC = \frac{(A_r)D}{Q})$, item cost $(IC = C_r D)$, holding cost $((h_r + S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{17520} \right])$, and transportation cost $(TC = \frac{\eta D A_0}{Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2})$ and emission tax $(ET = \frac{\eta D T_e}{Q})$.

The Retailer’s annual cost(TAC_R) can be defined as given below;

$$TAC_R = SC + IC + IHC + TC + ET$$

$$TAC_R = \frac{(A_r)D}{Q} + C_r D + (h_r + S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{17520} \right] + \frac{\eta D A_0}{Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2} + \frac{\eta D T_e}{Q} \dots(1)$$

4.2 Manufacturer’s total annual cost

In this section, we calculated the total annual cost for the retailer which is the sum of the setup cost $(SC_m = \frac{(A_m)D}{\lambda Q})$, item cost $(IC_m = C_m D)$, holding cost $(IHC_m = (h_m + S_m) \frac{Q}{2} \left[\frac{2D}{P} + \frac{\lambda(P-D)}{P} - 1 \right])$, and transportation cost $(TC_m = \frac{\eta D A_0}{Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2})$ and emission tax $(ET_M = E_m D T_{ci})$.

The manufacturer’s annual cost(TAC_m) can be defined as given below;

$$TAC_m = SC_m + IC_m + IHC_m + TC_m + ET_m$$

$$TAC_m = \frac{(A_m)D}{\lambda Q} + C_m D + (h_m + S_m) \frac{Q}{2} \left[\frac{2D}{P} + \frac{\lambda(P-D)}{P} - 1 \right] + \frac{\eta D A_0}{Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2} + E_m D T_{ci} \dots(2)$$

4.3 Integrated total annual cost for supply chain system

In this section, we have calculated total joint cost for supply chain which is the sum of retailer’s annual cost and manufacturer’s cost. From the equations (1) and (2), we get

$$\Psi(Q) = \frac{(A_m + \lambda A_r)D}{\lambda Q} + D(C_r + C_m) + (h_r + S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{17520} \right] + \frac{(h_m + S_m)Q}{2} \left\{ \frac{2D}{P} + \frac{\lambda(P-D)}{P} - 1 \right\} + \frac{\eta D A_0}{Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2} + \frac{\eta D T_e}{Q} + E_m D T_{ci} \dots (3)$$

4.4 Integrated total annual cost for supply chain system under fuzzy environment

Let us suppose that the demand rate is taken as triangular fuzzy number is $\tilde{D} = (d_1, d_2, d_3)$ and its α – cut of \tilde{D} is represented by $D(\alpha)$ and the value of $D(\alpha)$ can be defined as $D(\alpha) = [D_L(\alpha), D_U(\alpha)]$, where $D_L(\alpha) = d_1 + (d_2 - d_1)\alpha$ and $D_U(\alpha) = d_3 - (d_3 - d_2)\alpha$.

The equation (3) fuzzyfied the total integrated cost, we get

$$\tilde{\Psi}(Q) = \frac{(A_m + \lambda A_r)\tilde{D}}{\lambda Q} + \tilde{D}(C_r + C_m) + (h_r + S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{17520} \right] + \frac{(h_m + s_m)Q}{2} \left\{ \frac{2\tilde{D}}{P} + \frac{\lambda(P-\tilde{D})}{P} - 1 \right\} + \frac{\eta\tilde{D}A_0}{Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2} + \frac{\eta\tilde{D}T_e}{Q} + E_m\tilde{D}T_{ci} \quad \dots(4)$$

Now, defuzzified the equation (4) by using of centroid method, we get

Integrated total fuzzy cost for the supply chain,

$$\left(\tilde{\Psi}(Q), \tilde{0} \right) = \frac{(A_m + \lambda A_r)(d_1 + d_2 + d_3)}{3\lambda Q} + \frac{(C_r(d_1 + d_2 + d_3) + C_m(d_1 + d_2 + d_3))}{3} + (h_r + S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{17520} \right] + \frac{(h_m + s_m)Q}{2} \left\{ \frac{2(d_1 + d_2 + d_3)}{3P} + \frac{\lambda(3P - (d_1 + d_2 + d_3))}{3P} - 1 \right\} + \frac{(d_1 + d_2 + d_3)\eta A_0}{3Q} + \frac{\eta A_1(2\lambda n - \lambda - 1)}{2} + \frac{\eta(d_1 + d_2 + d_3)T_e}{3Q} + \frac{E_m(d_1 + d_2 + d_3)T_{ci}}{3} \quad \dots(5)$$

5. Solution procedure

We adopt the property of maxima and minima property for the calculation of integrated fuzzy cost, if $\frac{d\tilde{\Psi}(Q)}{dQ} = 0$, we calculated the value of lot size, (Q) by using of Mathematica 9.0, and

suppose it is $Q = Q^*$ (consider) and now we calculates $\frac{d\tilde{\Psi}(Q)}{dQ}$, and if we get $\frac{d\tilde{\Psi}(Q)}{dQ} \geq 0$, then

$Q = Q^*$ is called optimal value of Q and denoted by Q^* .

The convexity of joint total fuzzy cost for supply has been shown in the figure with help of Mathematica 9.0 software.

6. Numerical example

The input parameters have been taken from the contribution of Jaber et al. (2013) and Gurtu et al. (2015) and presented in the Table 1.

Table 1 Input parameters.

Variable	Value	Variable	Value
(d_1, d_2, d_3)	(995,1000,1020) units per year	T_{cap}	80
P	3200 units per year	δ	0.02
A_m	\$200 per order	T_{ci}	30
C_m	\$15 per unit	T_e	(2)(d)(0.00077344)(30)
h_m	\$ 3 per unit per year	a	0.0000003
s_m	\$ 9 per unit per year	b	0.0012
k_m	0.001	c	1.4
A_r	\$ 30 per order	E_m	$aP^2 - bP + c$
C_r	\$ 20 per unit	η	3
h_r	\$ 4 per unit per year	Q^*	227 units
s_r	\$ 12 per unit per year	$\tilde{\Psi}(Q)$	60407 (\$)

k_r	0.002		
T	5		
d	500		
λ	2		

For the calculation, we used Mathematica software for the optimization of order quantity and total integrated cost for supply chain. The optimal order quantity of this proposed model is $Q^* = 227$ units and the optimal integrated cost with respect to this optimal order quantity is $\Psi(Q^*) = 60407$ \$. The present study is also compared with previous study and has been shown in the Table 2.

Table 2: Comparison of base model with present model

Model	Percentage defective item	Order quantity	Integrated total fuzzy cost
Base Paper	0.02	224	60517.
Proposed Model	0.02	227	60407

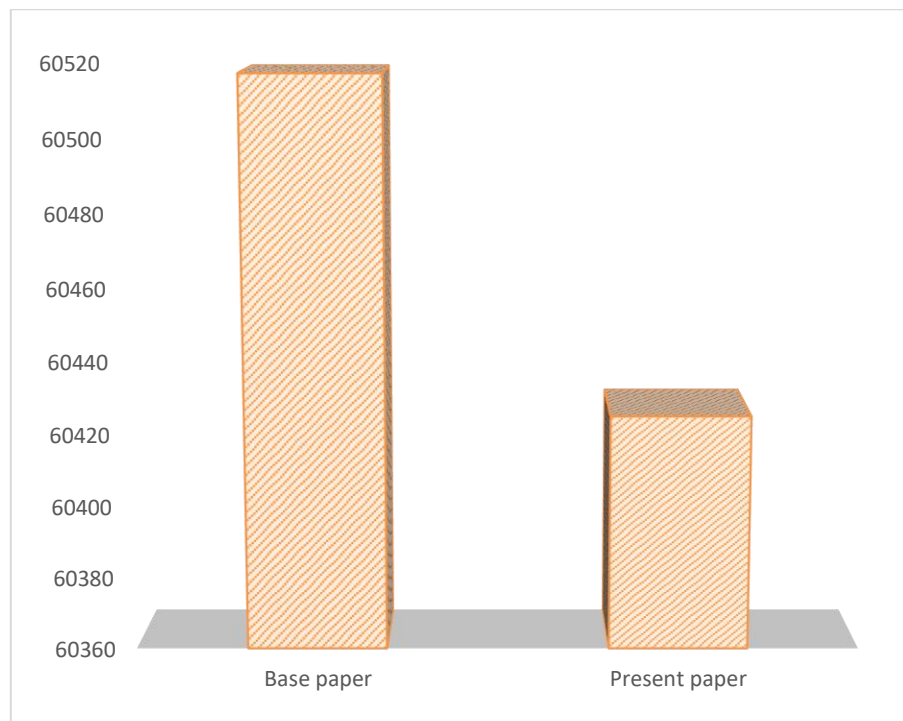


Figure 2: Graphical representation of present model with base model under integrated cost

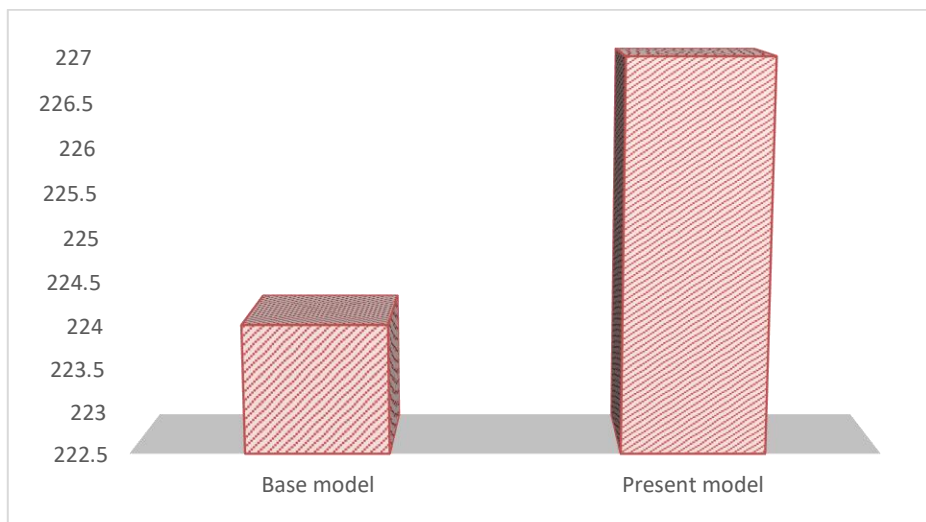


Figure 3: Graphical representation of present model with base model under lot size

7. Sensitivity analysis

Sensitive analysis is a vital constituent of research which analyses the decision which is variable with respect to the model parameters which have been given below:

Table 3: Variable effect of percentage defective items on the lot size and integrated total fuzzy cost

Percentage defective items	Order quantity	Integrated total fuzzy cost
0.01	218	60535
0.02	227	60407
0.03	229	59671
0.04	232	59542
0.05	242	59429
0.08	252	59342

Table 4: Variable effect of fuzzy demand rate on the order quantity and integrated total fuzzy cost

Fuzzy Demand rate	Production rate	Order quantity	Integrated total fuzzy cost
(500,1000,1500)	3200	227	60407
(1500,2000,2500)	4200	432	297654
(2500,3000,3500)	7200	586	627654

Table 5: Variable effect of number of truck on the order quantity and integrated total fuzzy cost

Number of truck	Order quantity	Integrated total fuzzy cost
2	181	59765
3	227	60407
4	264	64321
5	273	65876

Managerial insights

1. From Table-3, we can conclude that the percentage of defective items increase then optimal shipment lot size increase while joint total cost decreases.
2. From Table-4, it can easily be analysed that as the demand rate and production rate increase, initially the order quantity and joint total cost increases.
3. From Table-5, it can easily be analysed that as the number of truck increases with keeping other model parameter constant then order quantity and Joint total cost increases.

8. Conclusion

The purpose of this paper is to analyse the impact of incorporating the imperfect quality items in the lot & we observed that by adding imperfect items it helps to increase the lot size also the total cost is decreasing which includes holding cost, setup cost, item cost, transportation cost, emission tax cost. Findings together with mathematical analysis clearly suggested that the presence carbon emissions and imperfect items had an affirmative impact on retailer ordering policy. This paper can be improved for more sensible positions such as supply reliant and stochastic demand with partial-trade credit, etc.

References

1. Aljazzar, S. M., Jaber, M. Y., & Moussawi-Haidar, L. (2016). Coordination of a three-level supply chain (supplier–manufacturer–retailer) with permissible delay in payments. *Applied Mathematical Modelling*, 40(21-22), 9594-9614.
2. Bazan, E., Jaber, M. Y., & Zanoni, S. (2015). Supply chain models with greenhouse gases emissions, energy usage and different coordination decisions. *Applied Mathematical Modelling*, 39(17), 5131-5151.
3. Gurtu, A., Jaber, M. Y., & Searcy, C. (2015). Impact of fuel price and emissions on inventory policies. *Applied Mathematical Modelling*, 39(3-4), 1202-1216
4. Jaber, M. Y., Glock, C. H., & El Saadany, A. M. (2013). Supply chain coordination with emissions reduction incentives. *International Journal of Production Research*, 51(1), 69-82.

5. Jayaswal, M., Sangal, I., Mittal, M. & Malik, S. (2019). Effects of learning on retailer ordering policy for imperfect quality items with trade credit financing. *Uncertain Supply Chain Management*, Vol. 7, No. 1, pp.49-62.
6. Jayaswal, M., Sangal, I., Mittal, M. & Malik, S. (2019). Learning effects on stock policies with imperfect quality and deteriorating items under trade credit. *Amity International Conference on Artificial Intelligence (AICAI)*, pp.499-506.
7. Malik, A. K., & Singh, Y. (2013). A fuzzy mixture two warehouse inventory model with linear demand. *International Journal of Application or Innovation in Engineering and Management*, 2(2), 180-186.
8. Malik, A. K., Chakraborty, D., Bansal, K. K., & Kumar, S. (2017). Inventory model with quadratic demand under the two warehouse management system. *International Journal of Engineering and Technology*, 9(3), 2299-2303.
9. Malik, A. K., Kumar, S., & Kumar, S. (2017). Two warehouses inventory model with stock-dependent demand and maximum life time. *Int. J. Phys. Sci*, 29, 309-318.
10. Malik, A. K., & Sharma, A. (2011). A Two Warehouses Inventory Model for Linear Deterioration with Exponentially Demand Rate. *TC*, 2, 1.
11. Vikram, V., Ajay, T., Chandra, S., & Malik, A. K. (2016). A trade credit inventory model with multivariate demand for non-instantaneous decaying products. *Indian Journal of Science and Technology*, 9(15), 1-6.
12. Singh, S. R., & Malik, A. K. (2010). Inventory system for decaying items with variable holding cost and two shops. *International Journal of Mathematical Sciences*, 9(3-4), 489-511.
13. Yadav V, Chaturvedi B. K. and Malik A. K. (2022): Development of fuzzy inventory mode under decreasing demand and increasing deterioration rate, *Int. J. on Future Revolution in Comp. Sc & Communication Eng.*, 8(4), pp. 1-7.
14. Biswaranjan Mandal (2023): Optimization of Fuzzy Inventory Model for Deteriorating Items under Stock Dependent Linear Trended Demand with Variable Holding Cost Function, *Strad Research*, <https://doi.org/10.37896/sr10.5/030> ISSN: 0039-2049, 17(5), 250-261.
15. Yadav A S, Sharma Sand Swami A, (2017): A fuzzy based two-warehouse inventory model for non-instantaneous deteriorating items with conditionally permissible delay in payment, *Int Journal of Control Theory Application*, 10(10), 107-123.
16. Indrajitsingha S K, Samanta P N and Misra U K, (2019): A fuzzy two warehouse inventory model for deteriorating items with selling price dependent demand and shortage under partial backlogged condition, *Int. Journal Applied Mathematics*, 14, 511- 536.
17. Malik A K and Garg H, (2021): An improved fuzzy inventory model under two warehouses, *Journal of Artificial Intelligence and Systems*, 3, 115-129.
18. Ritchie E. (1984): The EOQ for linear increasing demand- A simple optimal solution, *Journal of Operational Research Society*, 35, 949-952.
19. Donaldson W.A. (1977): Inventory replenishment policy for a linear trend in demand- an analytical solution. *Operational Research Quarterly*, 28, 663-670.

20. Silver E. A. and Meal H. C. (1973): A Heuristic for selecting lot size Quantities for the case of a Deterministic time-varying rate and discrete opportunities for replenishment, *Production and Inventory Management* 14, 64-74.
21. Biswaranjan Mandal (2020): An Inventory Management System for Deteriorating Items with Ramp Type and Quadratic Demand: A Structural Comparative Study, *International Journal on Soft Computing (IJSC)* Vol.11, No.1/2/3/4, 1-8. ISSN: 2229 - 6735 [Online]; 2229 – 7103.
22. Dhivya Lakshmi M. and Pandian P. (2021): Production inventory model with exponential demand rate and exponentially declining deterioration, *Italian Journal of Pure and Applied Mathematics*, 45, 59–71.
23. Alamri, O. A., Jayaswal, M. K., & Mittal, M. (2023). A Supply Chain Model with Learning Effect and Credit Financing Policy for Imperfect Quality Items under Fuzzy Environment. *Axioms*, 12(3), 260.
24. Alsaedi, B. S., Alamri, O. A., Jayaswal, M. K., & Mittal, M. (2023). A sustainable green supply chain model with carbon emissions for defective items under learning in a fuzzy environment. *Mathematics*, 11(2), 301.
25. Jayaswal M., Sangal I., Mittal M. and Malik S. (2019). Effects of learning on retailer ordering policy for imperfect quality items with trade credit financing. *Uncertain Supply Chain Management*, 7, 49-62.
26. Jayaswal, M. K., Mittal, M., & Sangal, I. (2021), Ordering policies for deteriorating imperfect quality items with trade-credit financing under learning effect, *International Journal of System Assurance Engineering and Management*, 12(1), 112-125.
27. Jayaswal, M. K., Mittal, M., & Sangal, I. (2021). Effect of Credit Financing on the Learning Model of Perishable Items in the Preserving Environment. In *Decision Making in Inventory Management* (pp. 49-60). Springer, Singapore.
28. Goyal, S. K., 1985, Economic order quantity under conditions of permissible delay in payments, *Journal of the Operational Research Society*, 36, 35-38.
29. Huang, Y. F. (2003). The deterministic inventory models with shortage and defective items derived without derivatives. *Journal of Statistics and Management Systems*, 6(2), 171-180.
30. Huang, Y. F. (2006). An inventory model under two levels of trade credit and limited storage space derived without derivatives. *Applied Mathematical Modelling*, 30(5), 418-436.
31. Huang, Y. F. (2007). Optimal retailer's replenishment decisions in the EPQ model under two levels of trade credit policy. *European Journal of Operational Research*, 176(3), 1577-1591.
32. Huang, Y. F., & Chung, K. J. (2003). Optimal replenishment and payment policies in the EOQ model under cash discount and trade credit. *Asia Pacific Journal of Operational Research*, 20(2), 177-190.
33. Huang, Y. F., & Hsu, K. H. (2008). An EOQ model under retailer partial trade credit policy in supply chain. *International Journal of Production Economics*, 112(2), 655-664.

34. Jaber M. Y., Goyal S. K. and Imran M. (2008). Economic Production Quantity model for items with imperfect quality subjected to learning effects. *International Journal of Production Economics*, 115, 143-150.
35. Jaggi, C. K., Goyal, S. K., & Goel, S. K. (2008). Retailer's optimal replenishment decisions with credit-linked demand under permissible delay in payments. *European Journal of Operational Research*, 190(1), 130-135.
36. Jayaswal M., Sangal I., Mittal M. and Malik S. (2019). Effects of learning on retailer ordering policy for imperfect quality items with trade credit financing. *Uncertain Supply Chain Management*, 7, 49-62.
37. Luo, J. (2007). Buyer-vendor inventory coordination with credit period incentives. *International Journal of Production Economics*, 108(1-2), 143-152.
38. Sarmah, S. P., Acharya, D., & Goyal, S. K. (2007). Coordination and profit sharing between a manufacturer and a buyer with target profit under credit option. *European Journal of Operational Research*, 182(3), 1469-147
39. Shah, N. H., Gor, A. S., & Wee, H. M. (2010). An integrated approach for optimal unit price and credit period for deteriorating inventory system when the buyer's demand is price sensitive. *American Journal of Mathematical and Management Sciences*, 30(3-4), 317-330.
40. Shinn S. W. and Hwang H. (2003). Optimal pricing and ordering policies for retailers under order-size-dependent delay in payments. *Computers and Operations Research*, 30, 35-50.
41. Su, C. H., Ouyang, L. Y., Ho, C. H., & Chang, C. T. (2007). Retailer's inventory policy and supplier's delivery policy under two-level trade credit strategy. *Asia-Pacific Journal of Operational Research*, 24(05), 613-630.
42. Teng, J. T., & Chang, C. T. (2009). Optimal manufacturer's replenishment policies in the EPQ model under two levels of trade credit policy. *European Journal of Operational Research*, 195(2), 358-363.
43. Teng, J. T., & Goyal, S. K. (2007). Optimal ordering policies for a retailer in a supply chain with up-stream and down-stream trade credits. *Journal of the Operational Research Society*, 58(9), 1252-1255.
44. Wright, T. P. (1936). Factors affecting the cost of airplanes. *Journal of Aeronautical Science*, 3, 122-128.
45. Pakkala T P and Acharya K K (1992) : A deterministic inventory model for deteriorating items with two warehouses and finite replenishment rate, *European Journal of Operational research*, 57, 71-76.