

An EOQ Inventory Model with Greening Environment for Eco-Friendly Items under Carbon Emissions

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ABSTRACT

In this paper, we deal with an EOQ inventory model with greening environment for eco-friendly items under carbon emissions. Now a day a lot of carbon units are emitted from the different sources like factories, firms and some other production factories in the form of poisonous gases and these gases effect the neat and clean environment. Due to the carbon emissions, carbon dioxide, sulphur dioxide, and methane are more responsible for these issues, and some Indian cities like Delhi, Noida, and Ghaziabad are more affected currently on account of this reason. There are more problems related to the environment like air pollution, water pollution and the quality of the eco-friendly foods deteriorate as soon as. The Government tries to control such issues by including of some cost like pollution cost and carbon emission cost. For the development of this study, we conducted additional literature reviews to understand the inventory cost concern in this scenario, and the optimal lot size calculated using the maxima and minima concepts of calculus. The objective of this paper is to minimize the retailer's total inventory cost when customers demand an eco-friendly item from the retailer without any environmental issues. Therefore, we minimized the inventory cost with respect to the order quantity for the eco-friendly foods, and with the help of the numerical example, the model is justified. The sensitivity observation has been presented and also got more results (i) the percentage defective affects the order quantity and retailer's total cost (ii) if the carbon emissions are more from the transportation during deliveries of items then retailer will have to pay more carbon emission cost to the Govt authority(iii) The pollution cost of waste quality items affects the lot size and the retailer's inventory cost during transaction of items and also included more results in the observation and managerial insights for the ordering policies as well as decision makers. The future scope of this scenario is also presented in the conclusion.

Keywords: Eco-Friendly Environment; Pollution; EOQ; Inspection; Carbon Emission.

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1. INTRODUCTION

The environment issues day by day increase due to the impact of the carbon emissions and also effecting the human life style. We should always aware from this environment issues by using of alternate task. The carbon emissions exit due to using of transportation for delivery of inventory items from one place to another place during leading of business. The production companies want to produce 100% good quality eco-friendly food items but in general, it is not true and produced items may be some defective items during the production of items when inspected whole lot. In this scenario, it is supposed that the retailer receives a demanded lot from the seller as assumption. The retailer separates the whole lot at a constant screening rate into two categories one is defective quality items and second is the good quality items which is eco-friendly regarding environment. Waste quality items are sold at low price as compared good quality items and more defective items are responsible for the carbon emission and pollution issues. The retailer included two costs namely carbon emission cost and pollution cost for the controlling of the environmental issues. Finally, we minimized the total inventory cost with respect to order quantity by using of maxima and minima theory of calculus.

2. LITERATURE REVIEW

A lot of authors worked in this direction and we selected some authors who nearly worked in this way. Gurtu et al. (2015) worked on an inventory system to address carbon emissions in supply chain management. Aljazzar et al. (2016) developed an inventory model with the effect of carbon emissions for the good quality items where carbon emissions emit from the transportation of items and included carbon emission cost for the controlling of environment issues. Jaber et al. (2013) considered a manufacturer-based inventory decision model for items with good quality under inspection. Jaggi et al. (2011) designed a supply chain model with different type of the demand rate under discount policy where retailer inspect the whole lot and included the inspection cost for the improvement of quality of the food items. Yadav et al. (2018) generalized the inventory model with the use of game theory for imperfect quality items under carbon emissions. Bazan et al. (2015) proposed a supply chain model for the decision makers of the inventory theory where greenhouse gases emit the carbon units under different inventory polices. Jaber et al. (2013) generalized an inventory model in which they calculated the carbon emission and gave a policy for reducing carbon emissions.

Hill (1997) designed the supply chain model under production system. Bouchery et al. (2012) proposed an inventory model with sustainability criteria under various polices. Chaabane et al. (2012) assumed a sustainability-based supply chain model with an eco-friendly demand rate under a carbon trading policy. Hong et al. (2012) considered an inventory model with the production of green items. Huang and Zhao

(2014) proposed a two-level supply chain model with low carbon emission policy for the retailer and the buyer under environment sustainability. Lindgreen and Hingley (2003) developed a supply chain scenario for the effect of the food factory and welfare policies for the industrial sector under eco-friendly demand rate. Ma et al. (2015) designed a good-based supply chain model with the reduction of the carbon units under stochastic demand rate. Ma et al. (2016) improved the previous model by using the carbon policies and the carbon cap policy under the production system. Mishra (2022) designed an ordering polices model with carbon emissions for deteriorating items under a sustainable environment. Wang (2023) developed an inventory model with the carbon peaking expectation policies under different policies. Lastly, we minimized the total inventory cost for the retailer during ordering polices with respect to order quantity under some realistic situations.

Salameh and Jaber (2000) developed an inventory model with the method of inspection process for the imperfect quality items were delivered lot has some defective items. in this direction, Wee et al. (2007) improved the model of Salameh and Jaber (2000) by the using of the shortages policy and also presented the shortages quantity and lot size for the ordering policy as well as derived the profit formula for the retailer. Eroglu and Ozdemir (2007) worked on the theory of the inspection process of the defective items with shortages under some realistic situation. Roy et al. (2011) generalized an inventory model with screening process for deteriorating items under different situation.

Hua et al. (2011) proposed an inventory model with carbon footprint under some realistic situation. In this direction, Howitt et al. (2011) worked on the carbon emissions under different issues. Gupta et al. (2013) studied the optimal decision-making strategy for an inventory-based demand-driven inventory model with non-perishable items. Kumar et al. (2016) studied an inventory model with fixed holding costs and inventory-dependent demand for non-perishable items. Malik et al. (2017) identified an inventory model with secondary requirements based on dual warehouse management. Singh et al. (2011) studied two warehouse models for non-perishable products with stock dependent demand. Singh et al. (2014) studied inventory management using computational software. Malik et al. (2017) developed a second-order demand-based inventory model that includes supply shortages and two storage capacities. Sharma et al. (2022) studied product flexibility to identify manufacturing defects and inflation. Sharma and Malik (2022) developed a product model to achieve the best results with inventory dependent requirements. Singh and Malik (2011) discuss the inventory model with two storage capacities for demand-driven inventory and non-changing inventory.

Guereca et al. (2013) developed an inventory model for cleaner research under carbon emissions specially for institute of Mexico. Sarkar et al. (2016) proposed a sustainable supply chain model with the effect of carbon emissions under transportation environment. Tiwari et al. (2018) designed an

inventory model with carbon emissions under shipment delivery. Gautam and Khanna (2021) generalized an inventory model with the effect of the inspection process for the defective items under returning policies. Jaggi et al. (2016) developed an inventory model with screening cost under inspection theory, where the demand rate is less than the screening rate.

Tyagi et. Al. (2022) investigates a novel neural optimization technique to build inventory models. Vashisth et al. (2016) proposed two warehouse inventory models in which demand decays quadratically and holding prices change over time. Verma et al. (2022) provided a comprehensive review and survey of particle swarm optimization techniques and products. Yadav and Malik (2014) provide a comprehensive overview of commodity theory, types, and applications. Kumar et al. (2023) presented a fuzzy product model for transportation efficiency. Sharma et al. (2023) studied the inventory structure of the retail investment loan market. Tyagi et al. (2023) examined and studies the pharmaceutical and cosmetic products in the context of fuzzy inventory systems.

3. RESEARCH GAP AND PROPOSED WORK

In this section, we discussed only the literature review, which is closely related to this research study, and presented its contribution. The proposed work of this scenario is presented at bottom of Table 1

Table 1: author's contribution and proposed work of this scenario

Author's name	Imperfect items	Carbon emission	Transportation emission cost	Pollution control cost	Inspection
Salameh & Jaber (2000)	✓				
Lindgreen and Hingley (2003)		✓			
Huang and Zhao (2014).		✓			
Ma et al. (2015).		✓			
Aljazzar et al. (2016).		✓			
Tiwari et al. (2018)	✓	✓			
Marchi et al. (2019b)	✓	✓			
Giri & Masanta (2020)	✓				✓
Singh et al. (2021)		✓			
Masanta & Giri (2022)	✓				

Sharma et al. (2022)	✓				✓
Jayaswal et al. (2022)	✓				✓
Kumar et al. (2023)			✓		
Our paper	✓	✓	✓	✓	✓

MOTIVATION FOR THE PROPOSED WORK

To the best of our knowledge, not much research has been done on the inventory model that incorporates eco-friendly polluted free demand rate, impact of percentage defective items, impact of carbon emission cost and pollution control cost for imperfect quality items. Additionally, it is evident that eco-friendly polluted free demand of food items policies will be very helpful in increasing sales, which will increase profit as well as carbon emission cost and pollution control cost also included in this study. The aforementioned details inspired us to suggest the current study and the fruitful outcomes are detailed in the numerical example, observation and managerial insights.

INNOVATION OF THIS PROPOSED WORK

The retailer's total is minimized with respect to order quantity in this paper for the eco-friendly imperfect quality items under carbon emissions and pollution environment. In relation to cycle time. Observation and analysis are also done on how the carbon emissions and pollution environment, as well as some related cost functions, affect the inventory model under such circumstances. The following outlines this paper's distinctiveness and contribution;

- i. Under carbon emissions, pollution environment, and eco-friendly, pollution-free goods, an inventory model with a pollution-free demand rate for eco-friendly items under a carbon emissions environment has been established.
- ii. It is considered that the delivered lot to the retailer has some percentage defective.
- iii. To create a more realistic scenario, transportation cost and pollution control cost are also taken into account in the suggested model.
- iv. Eco-friendly polluted free demand rate policies are utilized to increase sales, which raises profits and minimizes the retailer's total inventory cost.
- v. The findings presented that under the inspection of items, pollution control cost, transportation cost and percentage defective items, retailer 's total inventory cost will be minimized with eco-friendly demand rate under no shortages.
- vi. To comprehend the robustness of the model, a numerical example with a study inquiry is shown, along with an algorithm for minimizing the retailer's total cost with respect to lot size.
- vii. Sensitivity analysis is given at the end to determine how reliable the inventory model is.

3.1 NOTATIONS

For the proposed inventory model, here we procedure the succeeding notations and assumptions:

D	Polluted free demand rate (units per year)
Q	Lot size for the ordering of the business system(units)
A_r	The retailer's ordering cost for the system (\$ per shipment)
C_r	The cost for unit items for the retailer (\$ per items)
h_r	Retailer's holding cost (\$ per unit per year)
s_r	Retailer's storage holding cost (\$ per unit per year)
λ	The multiplier for the shipment for order quantity
δ	The percentage defective in the lot size.
T_e	Taxation cost for the controlling the carbon emission (in \$)
γ	Screening rate
T_{ci}	The tax rate for the emissions (\$ per Ton)
T_{cap}	Truck capacity (in integer)
η	Number of trucks for the transportation ($\frac{Q}{T_{cap}}$)
ω	The pollution factor
P_c	The cost for the pollution
TAC_R	The total inventory cost for the retailer (in \$)

3.2 ASSUMPTIONS

- The retailer demanded pollution free eco-friendly items from the seller to save the environment.
- The concept of shortages is not assumed in this model.

- The carbon emissions are assumed due to transportation
- The carbon emission cost included.
- The pollution cost is included to prevent the pollution of the environment.
- It is considering that retailer received a lot which has some defective items.
- Waste items are sold at low price.

4. FORMULATION OF THE PROPOSED MODEL

The development of this model is followed with the theory of Hill (1997). In the initial, the manufacture supplied Q units as per demanded the pollution free items from the manufacturer. It is considered that D is the pollution free demand rate of the eco-friendly items. When retailer received demanded lot after that he inspected the whole lot at screening rate γ . The retailer classified whole lot after inspection, one is defective and other is non defective items. The defective quality items sold at low price in another market. The cost function of this model for the retailer and model Figure 1 is also presented below;

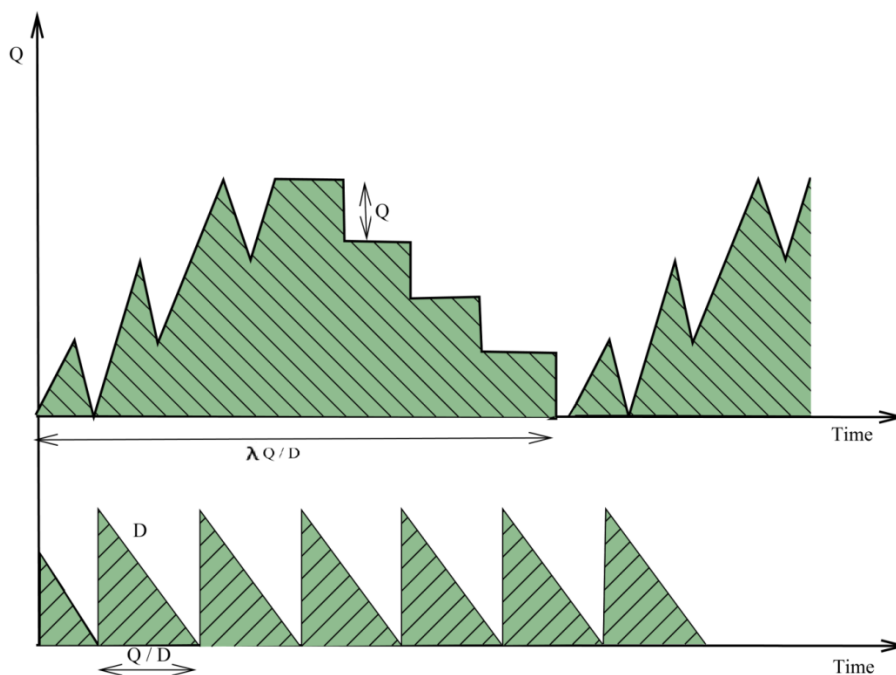


Figure 1: Representation of inventory system for the retailer

4.1. RETAILER'S TOTAL ANNUAL COST

In this part, we are discussing the retailer's total cost which is the sum of pollution control cost, ordering cost, unit items cost, holding cost, storage cost, transportation cost and carbon taxation cost.

Retailer's total cost

$$(TC_R) = \text{Pollution control cost} + \text{Ordering cost} + \text{Unit items cost} + \text{Holding cost} + \text{Storage cost} + \text{Transportation cost} + \text{Carbon taxation cost} \quad (1)$$

The all-cost function can be written as

$$(i) \text{Pollution control cost}(PC) = wP_c Q \tag{2}$$

$$(ii) \text{Ordering cost (OC)} = \frac{(A_r)D}{Q} \tag{3}$$

$$(iii) \text{Unit items cost}(IC) = C_r D \tag{4}$$

$$(iv) \text{Holding cost (IHC)} = (h_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{\gamma} \right] \tag{5}$$

$$(v) \text{Storage cost (SHC)} = (S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{\gamma} \right] \tag{6}$$

$$(vi) \text{Transportation cost}(TC) = \frac{\eta D A_0}{Q} + \frac{\eta A_1 (2\lambda n - \lambda - 1)}{2} \tag{7}$$

$$(vii) \text{Carbon taxation cost (TX)} = \frac{\eta D T_e}{Q} \tag{8}$$

The values of the cost function from the equations (2) to (8) replaced in the equation (1), we get the total cost function for the retailer

$$TAC_R = wP_c Q + \frac{(A_r)D}{Q} + C_r D + (h_r + S_r) \left[\frac{(1-\delta)Q}{2} + \frac{\delta Q^2}{\gamma} \right] + \frac{\eta D A_0}{Q} + \frac{\eta A_1 (2\lambda n - \lambda - 1)}{2} + \frac{\eta D T_e}{Q} \tag{9}$$

5. SOLUTION PROCEDURE

We have taken some steps for the calculation of lot size and minimized the total inventory cost for the system and used the concept of maxima and minima method

Step 1: First, we find out the value of $\frac{d\Psi(Q)}{dQ}$ and put equal to zero i.e. $\frac{d\Psi(Q)}{dQ} = 0$, calculates the minimum

value of Q . We move to next step;

Step 2: After that we calculates $\frac{d^2\Psi(Q)}{dQ^2}$ and put the value of the Q from the first step;

Step 3: If got $\frac{d^2\Psi(Q^*)}{dQ^2} \geq 0$, then $Q = Q^*$ is minimum with respect to Q .

6. NUMERICAL EXAMPLE

The input parameters have been taken from Gurtu et al. (2015) and Jaber et al. (2013) for the justification of the proposed model. The values of the input parameters are; $D = 1000$ units per year, $A_r = \$30$ per order, $C_r = \$20$, $h_r, \$4$ per unit per year, $S_r = \$12$ per unit per year, $\delta = 0.02$, $w = 0.3$, $P_c = 40$, $\eta = 4$, $\gamma = 175200$ units per year, $\lambda = 2$, $T_e = 0.0000003$, $A_0 = 0.04$, $A_1 = 0.056$. With the help of the Mathematica

software, we calculated the minimum lot size is $Q^* = 231$ units and the minimum inventory cost (TC_R) for the retailer is 65431 \$.

7. SENSITIVITY ANALYSIS

We analyzed the effect of inventory parameters through sensitivity analysis on the order quantity and retailer's total inventory cost which is given from the Table 1 to Table 4. The graphical presentation of input parameters is also shown from the Figure 2 to Figure 9. The outcomes of this proposed study are shown in the observation and managerial insights which is more beneficial for the ordering policies for the healthy environment.

Table 1: Effect of defective percentage on the lot size and retailer's total cost

Defective percentage	Lot size	Retailer's total cost
0.01	222	65456
0.02	231	65431
0.03	232	65429
0.04	232	65421
0.05	235	65418
0.08	238	65409

Table 2: Impact of demand rate and production on lot size and joint total cost

Demand rate	Lot size	Total Cost
1000	231	65431
2000	343	375442
3000	387	410369

Table 3: Impact of number of trucks on lot size and joint total cost

Number of truck	Lot size	Total Cost
2	190	59491
3	231	65431
4	252	61428
5	277	52258

Table 4: Impact of number of pollution control cost on lot size and total cost

Pollution control cost	Lot size	Total Cost
30	198	59491
40	231	65431
50	245	66428
60	256	67258

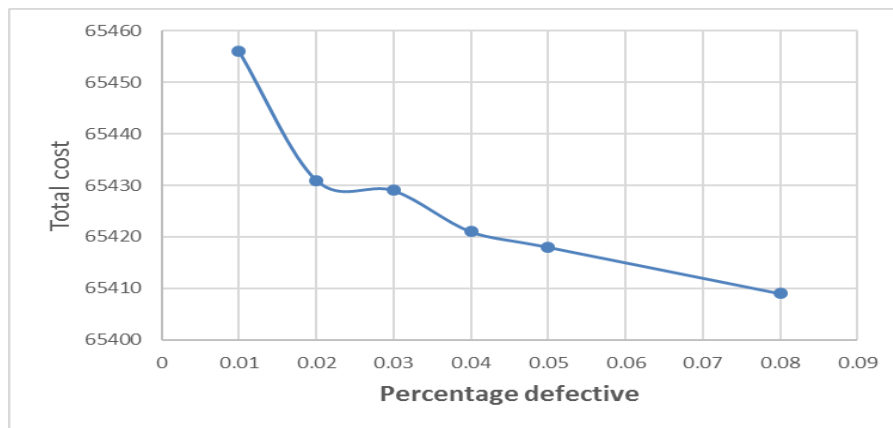


Figure 2: Impact of percentage of defective items on total cost

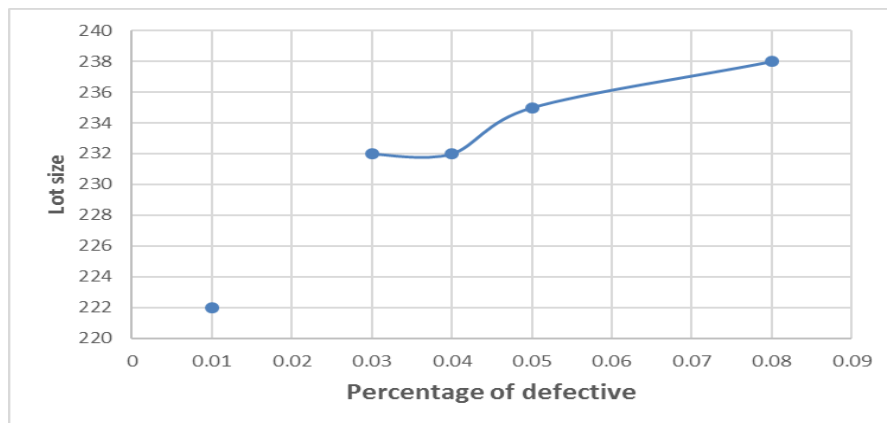


Figure 3: Impact of percentage of defective items on order size

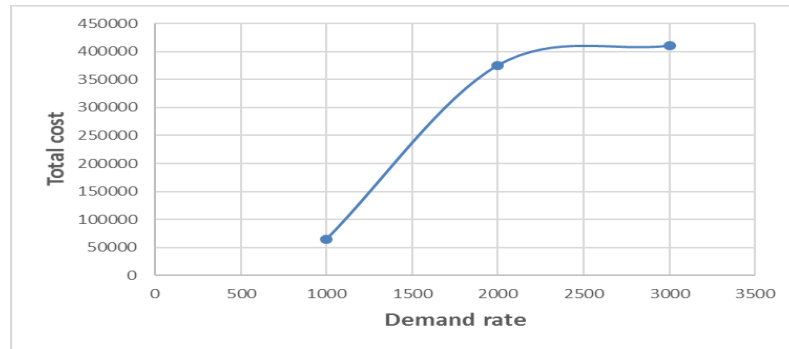


Figure 4: Impact of demand rate on the total cost

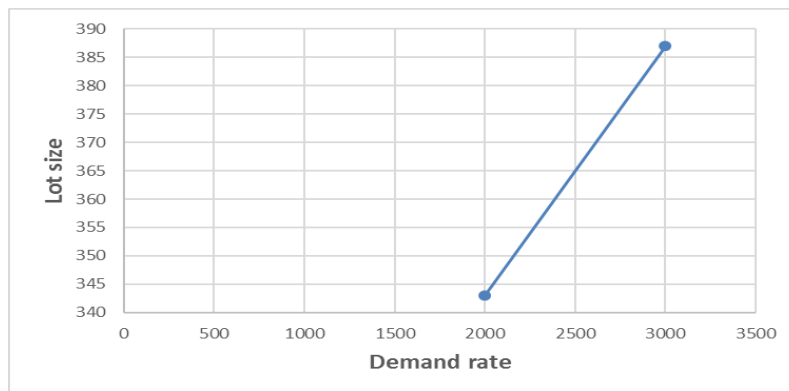


Figure 5: Impact of demand rate on the lot size

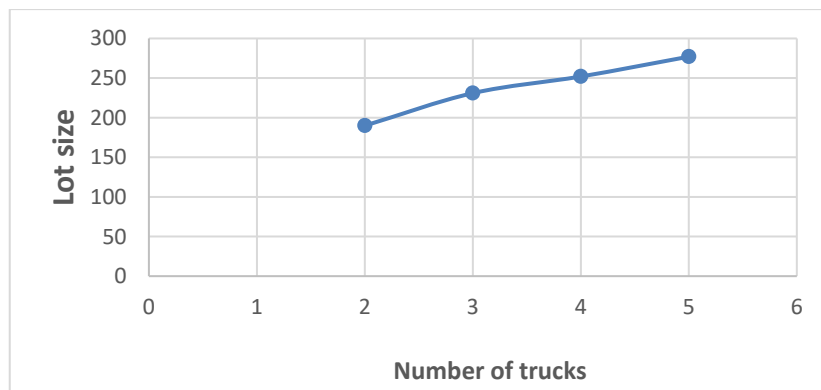


Figure 6: Impact of number of trucks on the lot size

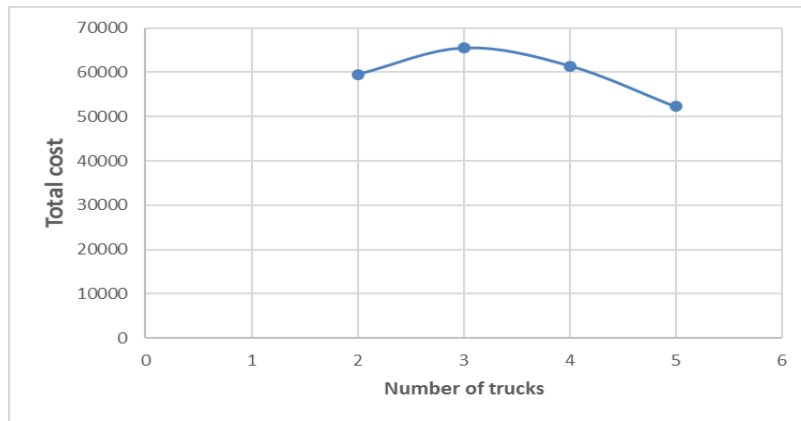


Figure 7: Impact of number of trucks on the total cost

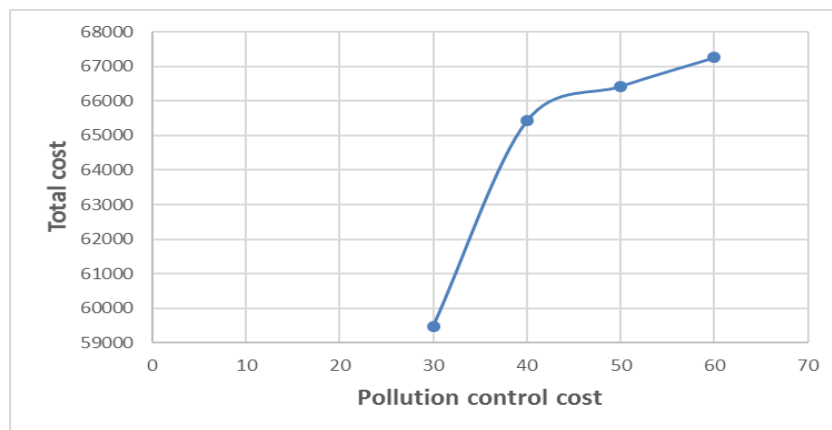


Figure 8: Impact of pollution control cost on the total cost

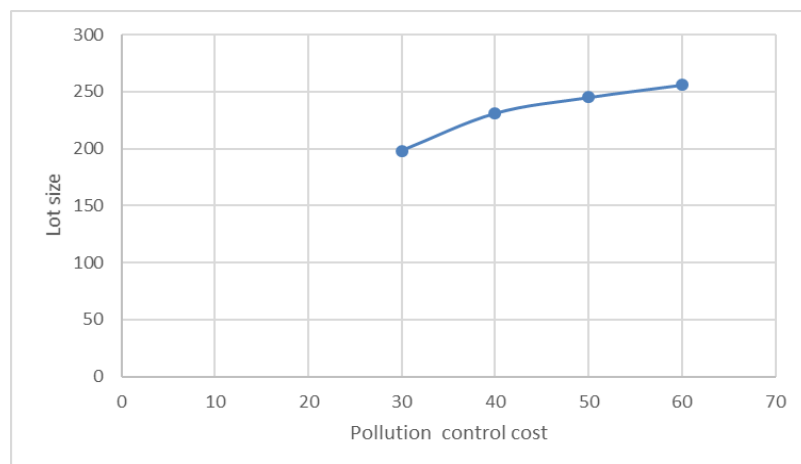


Figure 9: Impact of pollution control cost on the order lot size

8. OBSERVATION AND MANAGERIAL INSIGHTS

I. Effect of defective percentage

We observed the Table 1, if the values of the defective percentage increases from 0.01 to 0.08 up to then the value of the retailer's cost corresponding value of the defective percentage decreases from 65456 \$ to 65409\$ and also analysed that the value of the order quantity increases from 222 units to 238 units corresponding to each value of percentage of defective items. It means that defective percentage gave positive and negative effect on the order quantity and retailer's total cost.

II. Interpretation of Figures 2 and 3. The retailer's total cost fastly decreases when the value of percentage defective lies between 0.01 and 0.02. After that the value of retailer's cost decreases slowly when the value of percentage defective lies between 0.02 to 0.08. Similarly, we can easily have seen that when the value of percentage defective lies between 0.03 and 0.04 then the value of retailer's order quantity increases very slowly and fastly increases between 0.04 to 0.08. This analysis suggests to the decision maker the percentage defective items affect the order quantity and retailer's total cost. It gave negative effect on the total retailer's cost and positive effect on the order quantity. From this analysis, decision makers should be aware during the deliveries of the items when lot has some defective items.

III. Effect of demand rate of polluted free items

By using of the Table 2, we concluded that, if demand rate of polluted free items increases from 1000 units to 3000 units, then the retailer's cost decreases fastly from 65431 \$ to 410369 \$ and the value of the order lot size also fast increases from 231 units to 287 units.

IV. Interpretation of Figures 4 and 5

The behaviour of demand rate on the retailer's total cost and order quantity can be analyse through graphical representation and also have presented in the Figures 4 and 5. When the value of demand rate lies between 1000 units to 2000 units then the retailer's total cost increases fastly from 65431 \$ to 375442 \$ and lightly increases when the value of the demand rate lies between 2000 units to 3000 units then the value of the retailer's total cost lightly increases from 375442\$ to 410369\$. Similarly, it can be observed that about the variation of values of the order quantity with respect to demand

rate. If the values of the demand rate increase from the 1000 units to 3000 units, then the values of the order quantity also increase linearly from 231 units to 387 units.

It gave positive effect on the total retailer's cost and order quantity. These parameters are more sensitive other than input parameters. It suggests that when customer's demand of polluted free items then retailer or decision maker should be aware about this cost.

V. Effect of number of trucks during transportation

From the table 3, if the number of trucks increases as per requires then the retailer's order quantity fastly increases from 190 units to 277 units and the retailer's total cost also fastly increases from 59491\$ to 65431 \$ and decreases from 65431 \$ to 52258\$.

VI. Interpretation of Figures 6 and 7

The number of trucks affect the retailer's total cost and also order quantity during leading of business. The variation of the retailer's cost and order quantity with respect to the number of trucks are briefly presented in the Figure 6 and 7. It gave positive effect on the total retailer's cost. These results suggest that if firm or industries have low economic then decision maker should be aware about the number of vehicles during ordering polices because number of trucks affect the retailer's total inventory cost.

VII. Effect of pollution control cost due to pollution environment

From the table 4, if the values of the pollution control cost increases from 30 \$ to 60\$, then the value of the retailer's order quantity increases from 198 units to 256 \$ and with the same value of the pollution control cost the retailer's total cost increases from 59491 \$ to 67258 \$.

VIII. Interpretation of Figures 8 and 9

The impact of the pollution control cost on the retailer's total cost and lot size has been shown in the Figures 8 and 9. The variation of the retailer's total inventory cost and order quantity with respect to pollution control cost are shown through graphical representation in respective figures 8 and 9. If the value of the pollution control cost increases numerically from 30\$ to 60\$ then retailer's total cost increases rapidly increases when the pollution control cost lies between 30\$ to 40\$ and slow increases when pollution control cost lies between 30\$ to 60\$. The value of the retailer's order quantity slow increases when the pollution control cost lies between 30\$-60\$. It gave positive effect

on the total retailer's cost and order lot size. During ordering policies, the decision maker should be aware about polluted environment and must include pollution control cost when the Government takes any charge related to environment issues.

9. CONCLUSION

In this paper, we developed a mathematical model with polluted free demand rate under eco-friendly environment where carbon emissions emit from the transportation and carbon emissions as well as pollution of the environment have been controlled by the addition of carbon emission cost and pollution cost. The behaviour of input parameters on the retailer's total cost have been presented in the sensitivity analysis. The aim of the model is analysing the effect of input parameters on the cost and the decision maker can take good during transportation of the eco-friendly food items. This model is specially for the online based market who sales the eco-friendly food items. The present study can be extended with help of waste management cost policy, trade credit and shortages for the supply chain model.

10. APPLICATION OF THE PROPOSED MODEL

The application of the proposed model is more applicable in the food factories or any firm or business industries or big online food factories as well as storage of perishable item or those items which have more deteriorating rate. In such sector retailer or buyer time to time inspects the whole items and classified the whole lot in defective or non-defective items and defective quality items sale at low price because it damages in very short time. Finally, this model is more beneficial for the online based market who sales the eco-friendly food items like burger, pizza and other delivery-based items.

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