An Inventory Model with Price Dependent demand with Partial Backlogging and Preservation Technology

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Abstract— This paper investigates an inventory model that includes partial backlogging, price dependent demand and preservation technology integration. This paper integrates EOQ model for deteriorating items in which demand is determined by selling price, stock, and investment in green technology (or carbon reduction investment), and the rate of deterioration is controlled by investment in preservation technology.

Keywords: Preservation Technology, Partial backlogging, Price dependent demand.

I. INTRODUCTION AND LITERATURE REVIEW

Sustainable inventory management is a critical facet of modern business practices, emphasizing the balance between economic efficiency and environmental responsibility. In the realm of inventory modelling, the consideration of multivariant demand and variable holding costs introduces a layer of complexity that reflects the dynamic nature of real-world supply chains. This complexity is further compounded when partial backlogging is taken into account, allowing for a more nuanced understanding of inventory dynamics. In this context, sustainable inventory models with multivariant demand and variable holding costs under partial backlogging aim to optimize not only economic factors but also environmental and social considerations. These models seek to strike a harmonious equilibrium by minimizing costs, reducing waste, and promoting responsible resource utilization while ensuring customer demand is met effectively. This intricate interplay of variables demands sophisticated mathematical modelling techniques and analytical approaches to develop strategies that are both economically viable and ecologically sustainable. This emerging field represents a forward-looking perspective in inventory management, aligning with the global shift towards sustainable and responsible business practices. Walmart requires its suppliers to take part in clothing projects that use organic cotton (Plambeck, 2007). Ghosh and Shah (2015) investigate customer's sensitivity to greening costs and GPs. Many industries influence consumer's attitudes toward GPs by emphasizing the benefits and necessity of a GSC, nevertheless, consumers must also trust and understand which products are genuinely green (Stindt, 2017). As concerns about environmental protection continue to rise, carbon emission reduction has become increasingly important because carbon dioxide (CO2) is believed to be a major contributor to global warming (Bai et al., 2018). Manupatiet al. (2019) analysed the impact of three carbon policies, namely carbon cap-and-trade, carbon tax and strict carbon cap, on the inventory decisions and the performance of a multi-level supply chain system. Daryanto and Wee (2020) used a carbon tax policy to control the emissions in a three-echelon supply chain consisting of a manufacturer, a buyer and third-party logistics. Sarkar et al. (2021) considered carbon cap-andtrade policy and permissible delay in payments in a vendor-buyer model. Jauhari (2022) explored a sustainable inventory model for a closed-loop supply chain with energy usage and green investment. Gautam et al. (2023) explored the sustainable retail model with moderate deterioration through environmental deliberations.

Authors	Green, stock and price sensitive demand	Deterioration	Preservation technology	inflation	Carbon reduction investment
Mishra et al.		✓	✓		
Toptal et al.					✓
Huang et al					✓
Priyamvada et al.		✓			
Das et al.		✓	✓		
Shikha et al.	✓	✓	✓		✓
This paper	✓	✓	✓	✓	✓

Table:1

II. NOTATIONS

In this paper following notations are used:

A: cost of ordering
a: demand function
b: demand sensitivity parameter related to selling price of the product
c: demand function
p: unit selling price
g: demand sensitivity parameter related to the environment performance of the product
G: green technology investment
I(t): inventory level
T: cycle time
T_1: production time
D: Demand rate
α: fraction of per unit profit
y_0 :deterioration rate without investment in preservation technology
s_0: fixed amount of emission during the shipping of Q units
s_1 : variable number of emissions during the shipping of Q units
h_0 : fixed amount of emission during the holding of Q units
h_1 : variable number of emissions during the holding of Q units
p_0 : fixed amount of emission during the preservation of Q units
p_1 : variable number of emissions during the preservation of Q units
γ : carbon emission per deteriorated item
B: backorder quantity
β : backlogged parameter
D_T : deteriorated units

III. ASSUMPTIONS

- Demand rate of inventory system is depended on price, green technology investment and stock i.e.

$$D(p,G) = \begin{cases} a - bp + gG + cI(t) & 0 \le t \le T_1 \\ D & T_1 \le t \le T \end{cases}$$

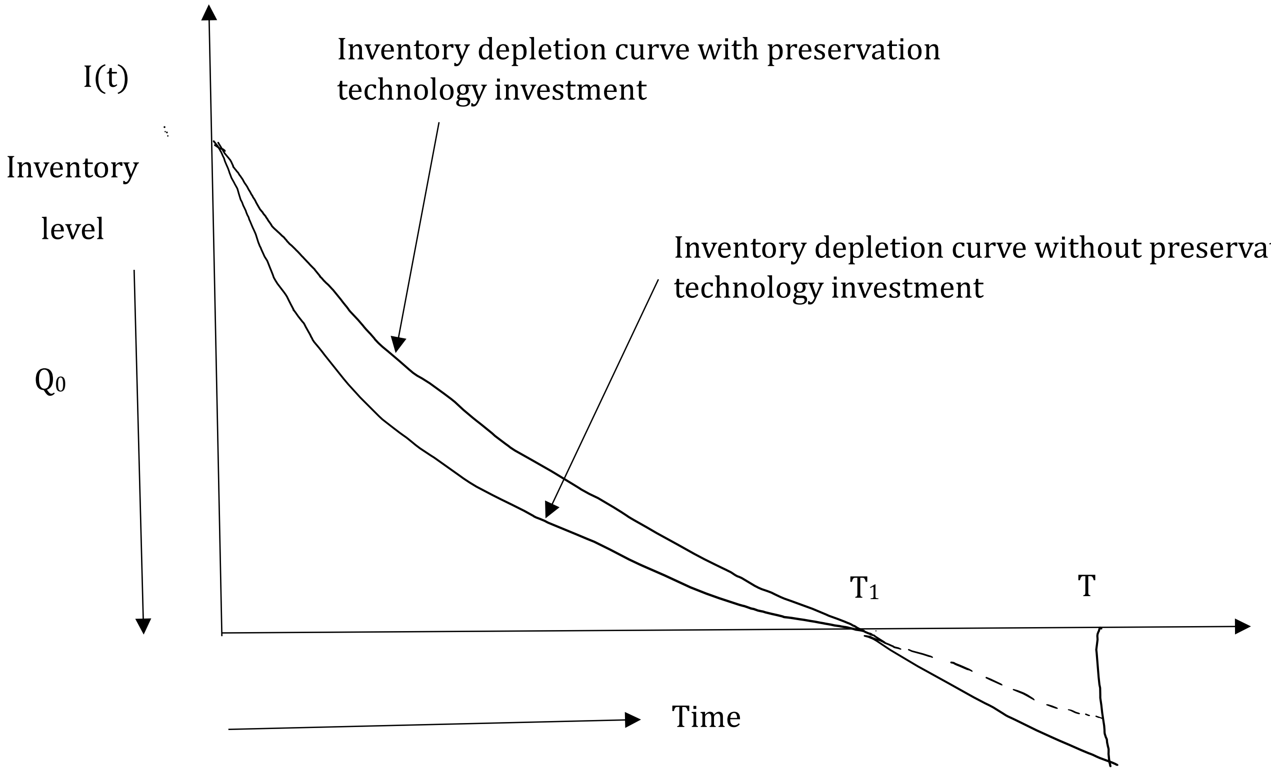
- The deterioration rate is constant throughout the cycle, but the replenishment rate is quick.
- Infinite planning horizon with negligible lead time.
- Shortage is allowed which is partial backlogged.
- PTI (preservation technology investment) reduces the rate of deterioration using a function $y(p,\alpha) = y_0 e^{-(p-d)^{2\alpha}}$ that is convex with $0 < \alpha < 1$, $p > 0$ and $y(p,0) = y_0$.
- There are four stages in the system where carbon emissions occur: transshipment, inventory holding, deteriorating items, and preservation.

  Carbon emissions for an order Q units
  - In Shipping is $s_0 + s_1(Q)$
  - In holding is $h_0 + h_1(AI)$
  - In deteriorating item is $\gamma(D_T)$
  - In preservation is $p_0 + p_1(AI)$
- Green investments do not achieve a full elimination of carbon emissions; their impact can be quantified and described through a quadratic function. The carbon investment function is:

$$CR = mG - nG^2$$

  m= carbon reduction efficiency factor
  n= carbon reduction offsetting factor

IV. MATHEMATICAL MODEL FORMULATION



The differential equation representing the inventory level is:

$$\frac{dI(t)}{dt} + y(p,\alpha)I(t) = -\left(a - bp + gG + cI(t)\right); 0 \le t \le T_1$$

$$\frac{dI(t)}{dt} = -D\beta; 0 \le \beta \le 1, T_1 \le t \le T$$

$$I(0) = Q_0, I(T_1) = 0, I(T) = -B$$

After solving with the help of boundary conditions:

We get

$$I(t) = \frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1 - T)} - 1\right] for\ 0 \le t \le T_1$$

$$I(t) = \beta D(T - t) + B \quad for\ T_1 \le t \le T$$

$$B = \beta D(T - T_1)$$

$$Q_0 = \frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]$$

Total number of deteriorated units during the total cycle time T, say D_T, is calculated as

$$D_T = Q_0 - D(p,G)T = \frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - D(p,G)T$$

Average inventory –

$$AI = \frac{a - bp + gG}{(y(p,\alpha) + c)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha) + c) - e^{(y(p,\alpha)+c)(T_1 - T)}\right]$$

The carbon emission occurs in four steps of the system, i.e. shipping, inventory holding, deterioration and preservation of deteriorating items are as follow:

(1) CEs in shipping Q units are:

$$= s_0 + s_1(Q_0) = s_0 + s_1\left(\frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right)$$

(2) CEs in holding Q units are:

$$= h_0 + h_1(AI)$$

$$= h_0 + h_1\left(\frac{a - bp + gG}{(y(p,\alpha) + c)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha) + c) - e^{(y(p,\alpha)+c)(T_1 - T)}\right]\right)$$

(3) CEs due to deteriorating items are:

$$= \gamma(D_T) = \gamma\left(Q_0 - D(p,G)T\right) = \gamma(\frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - D(p,G)T\right)$$

(4) Carbon emissions due to the preservation is:

$$= p_0 + p_1(AI)$$

$$= p_0 + p_1\left(\frac{a - bp + gG}{(y(p,\alpha) + c)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha) + c) - e^{(y(p,\alpha)+c)(T_1 - T)}\right]\right)$$

(5) Therefore, the total amount of CEs are:

$$\text{CE} = \left[s_0 + s_1\left(\frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right) + h_0 + p_0 + (h_1 + p_1)\left(\frac{a - bp + gG}{(y(p,\alpha) + c)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha) + b) - e^{(y(p,\alpha)+c)(T_1 - T)}\right]\right) + \gamma\left(\frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - D(p,G)T\right)\right]$$

To control the exceeding amount of CEs, carbon reduction investment has been considered to reduce the emissions and the carbon reduction investment function is:

$$CR = mG - nG^2$$

Where m represents the carbon reduction efficiency factor and n represents the carbon reduction offsetting factor. This indicates that CEs can be reduced if the supply chain invests the green cost G in green technology. However, since the use of green technology may also result in energy consumption, these additional CEs are denoted by nG^2.

A. Amount of CEs with carbon reduction green investment is:

$$CEs = \left[s_0 + s_1\left(\frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right) + h_0 + p_0 + (h_1 + p_1)\left(\frac{a - bp + gG}{(y(p,\alpha) + c)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha) + b) - e^{(y(p,\alpha)+c)(T_1 - T)}\right]\right) + \gamma\left(\frac{a - bp + gG}{y(p,\alpha) + c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - D(p,G)T\right) - mG + nG^2\right]$$

B. Ordering cost = A

C. Purchase cost = $eQ_0 = e\left(\frac{a-bp+gG}{y(p,\alpha)+b}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right)$

D. Holding cost = $(h + gt)\int_0^{T_1} I(t)dt = (h + gt)\int_0^{T_1} \frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1 - T)} - 1\right]dt$

$$= \frac{a - bp + gG}{(y(p,\alpha) + b)^2}\left[h\left(e^{(y(p,\alpha)+c)T_1} - T_1(y(p,\alpha) + c) - 1\right) + \frac{g}{2(y(p,\alpha) + b)}\left(2\left(e^{(y(p,\alpha)+c)T_1} - 1\right)\left(T_1(y(p,\alpha) + c) + 1\right) - T_1^2\right)\right]$$

E. Shortage cost = $-s_c\int_{T_1}^{T} I(t)dt = -s_c\left[\beta D\left(\frac{T^2}{2} - TT_1 - \frac{T_1^2}{2}\right) - B(T - T_1)\right]$

F. Lost sale cost = $c_i\int_{T_1}^{T}(1-\beta)Ddt = c_i(1-\beta)D(T-T_1)$

G. Preservation technology cost =$(p-d)\alpha Q_0 = \frac{((p-d)\alpha)a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]$

H. Transshipment cost = = $V_1 + V_2Q_0 = V_1 + V_2\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right)$

I. Green Investment cost = G

J. The carbon emission cost under the emission tax policy is provided by

$$\text{Tax}^c = \omega(\text{CE}) = \omega\left(s_0 + s_1\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right) + h_0 + p_0 + (h_1+p_1)\left(\frac{a-bp+gG}{(y(p,\alpha)+b)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha)+b) - e^{(y(p,\alpha)+c)(T_1-T)}\right]\right) + \gamma\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - D(p,G)T\right) - MG + NG^2\right)$$

Total revenue per unit time

$$= P\big(a - bp + gG + cI(t)\big)T + D_1\left(\frac{a-bp+gG+cI(t)}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - \big(a-bp+gG+cI(t)\big)T\right) + pB$$

The Total Profit of the system will be:

$$TP(p,G,\alpha) = \left(\frac{1}{T}\left(\left(P\big(a-bp+gG+cI(t)\big)T + D_1\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - \big(a-bp+gG+cI(t)\big)T\right) + pB\right) - A - e\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right) - \left(\frac{a-bp+gG}{(y(p,\alpha)+c)^2}\left[h\left(e^{(y(p,\alpha)+c)T_1} - T_1(y(p,\alpha)+b) - 1\right) + \frac{g}{2(y(p,\alpha)+c)}\left(2\left(e^{(y(p,\alpha)+c)T_1} - 1\right)(T_1(y(p,\alpha)+c)+1) - T_1^2\right)\right]\right) - \left(-s_c\left[\beta D\left(\frac{T^2}{2} - TT_1 - \frac{T_1^2}{2}\right) - B(T-T_1)\right]\right) - \big(c_i(1-\beta)D(T-T_1)\big) - \left(\frac{((p-d)\alpha)a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right) - \left(V_1 + V_2\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right)\right) - G - \left(\omega\left(s_0 + s_1\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right]\right) + h_0 + p_0 + (h_1+p_1)\left(\frac{a-bp+gG}{(y(p,\alpha)+c)^2}\left[e^{(y(p,\alpha)+c)T_1} - T(y(p,\alpha)+c) - e^{(y(p,\alpha)+c)(T_1-T)}\right]\right) + \gamma\left(\frac{a-bp+gG}{y(p,\alpha)+c}\left[e^{(y(p,\alpha)+c)(T_1)} - 1\right] - D(p,G)T\right) - MG + NG^2\right)\right)\right)\right)$$

V. NUMERICAL ILLUSTRATION

Values of parameters are-

parameter	Values	parameter	values
A	8 $	h	1$ /unit
a	1000	b	1
c	0.5	S_c	10$/unit
d	0.001 $/unit	e	0.1
g	0.7	α	0.1

β	0.1	γ	0.01
D	20 unit/month	Y_0	0.09
S_0	10 unit/month	S_1	2 Unit/month
h_0	10 unit/month	h_1	10 unit/month
P_0	4unit/month	P_1	0.5unit/month
c_i	2$/unit	D_1	100 Rs/item
V_1	500 Rs	V_2	200 Rs
T_1	1year	w	8 Rs
M	300	N	50

Comparative results for different cases: with and without preservation technology investment-

	With preservation technology investment
Selling price	7.5
Green technology investment cost	19.76
Cycle length	233
Total profit	**79802.3**

VI. CONCAVITY

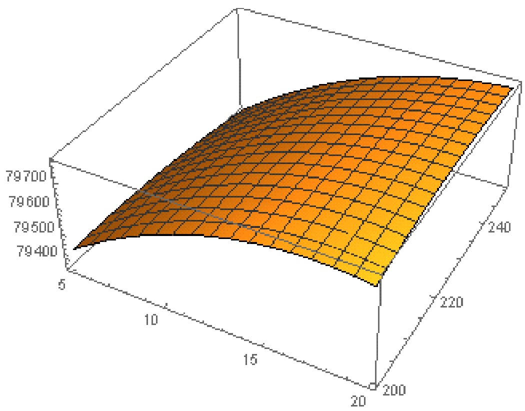


Fig: 2. concavity Between T(cycle length) and G(Green technology investment cost)

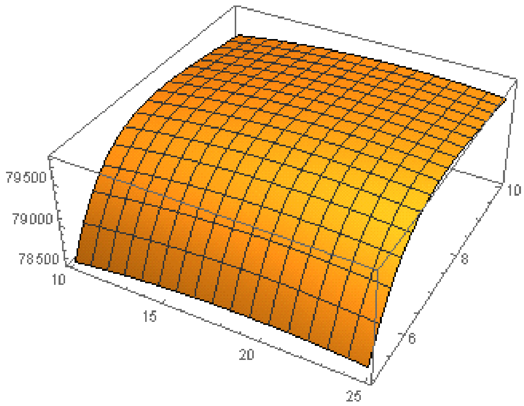


Fig: 3. concavity Between p (selling price) and G (Green technology investment cost)

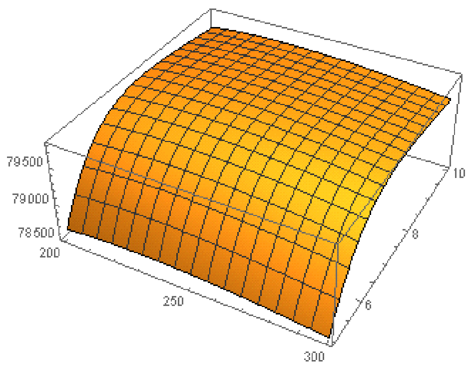


Fig:4. concavity Between T(cycle length) and p (selling price)

VII. SENSITIVITY ANALYSIS

This section presents a sensitivity analysis of different parameters, demonstrating how changes in theses parameters impact the optimal solution.

Table:3.4

Parameter	% value	Total profit	T	G	p
A	+20%	79801.6	233.49	19.77	7.5
	+10%	79802	233.47	19.77	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79802.6	233.429	19.76	7.5
	-20%	79803	233.403	19.76	7.5
h	+20%	79802.1	233.46	19.76	7.5
	+10%	79802.1	233.46	19.76	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79802.1	233.46	19.76	7.5
	-20%	79802.1	233.46	19.76	7.5
a	+20%	96239.8	255.96	21.42	7.7
	+10%	88016.7	244.96	20.61	7.6
	0	79802.3	233.45	19.76	7.5

	-10%	71597.8	221.34	18.87	7.5
	-20%	63405	208.53	17.93	7.4
b	+20%	79678.9	233.27	19.75	7.4
	+10%	79740.3	233.362	19.76	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79864.9	233.54	19.77	7.6
	-20%	79928.2	233.632	19.78	7.7
c	+20%	79870	229.80	19.31	7.4
	+10%	79842.2	231.26	19.6	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79747.3	236.55	19.98	7.6
	-20%	79673	240.84	20.28	7.7
s_c	+20%	79365.9	208.38	17.92	7.5
	+10%	79577.8	219.85	18.77	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	80041.7	249.92	20.97	7.5
	-20%	80299.9	270.457	22.48	7.5
D	+20%	79802.3	233.45	19.76	7.5
	+10%	79802.3	233.45	19.76	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79802.3	233.45	19.76	7.5
	-20%	79802.3	233.45	19.76	7.5
e	+20%	79731.9	233.32	19.75	8.3
	+10%	79802.3	233.45	19.76	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79732.1	233.31	19.75	8.3
	-20%	79732.1	233.31	19.75	8.3
g	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79695.9	227.48	17.69	7.5
	-20%	79601.1	222.50	15.77	7.5
α	+20%	79854.7	233.55	19.77	6.9
	+10%	79830.2	233.50	19.77	7.2
	0	79802.3	233.45	19.76	7.5
	-10%	79770	233.38	19.76	7.9
	-20%	79732	233.31	19.75	8.3
β	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	71597.8	221.34	18.87	7.5
	-20%	63405	208.53	17.93	7.4
γ	+20%	96291.1	255.94	21.42	8.2
	+10%	88007.2	244.57	20.59	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	79802.1	233.46	19.76	7.5
	-20%	79802.1	233.46	19.76	7.5
d	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79806.8	236.88	22.24	8.3

	-20%	79901.5	241.58	25.45	8.38
y_0	+20%	79695.9	227.48	17.69	7.5
	+10%	79601.1	222.50	15.77	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	71597.8	221.34	18.87	7.5
	-20%	63405	208.53	17.93	7.4
s_0	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79802.1	233.46	19.76	7.5
	-20%	79802.1	233.46	19.76	7.5
M	+20%	96291.1	255.94	21.42	8.2
	+10%	88007.2	244.57	20.59	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	79806.8	236.88	22.24	8.3
	-20%	79901.5	241.58	25.45	8.38
N	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79806.8	236.88	22.24	8.3
	-20%	79901.5	241.58	25.45	8.38
h_1	+20%	96291.1	255.94	21.42	8.2
	+10%	88007.2	244.57	20.59	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	71597.8	221.34	18.87	7.5
	-20%	63405	208.53	17.93	7.4
p_0	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79802.1	233.46	19.76	7.5
	-20%	79802.1	233.46	19.76	7.5
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	+10%	88007.2	244.57	20.59	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	79802.1	233.46	19.76	7.5
	-20%	79802.1	233.46	19.76	7.5
c_i	+20%	80053.8	249.21	24.51	7.5
	+10%	79921.2	240.6	22.02	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	71597.8	221.34	18.87	7.5
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	-20%	79901.5	241.58	25.45	8.38
V_1	+20%	96291.1	255.94	21.42	8.2
	+10%	88007.2	244.57	20.59	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	79806.8	236.88	22.24	8.3
	-20%	79901.5	241.58	25.45	8.38

V_2	+20%	79731.9	233.32	19.75	8.3
	+10%	79802.3	233.45	19.76	7.5
	0	79802.3	233.45	19.76	7.5
	-10%	79802.1	233.46	19.76	7.5
	-20%	79802.1	233.46	19.76	7.5
T_1	+20%	79806.8	236.88	22.24	8.3
	+10%	79901.5	241.58	25.45	8.38
	0	79802.3	233.45	19.76	7.5
	-10%	71597.8	221.34	18.87	7.5
	-20%	63405	208.53	17.93	7.4
S_c	+20%	96291.1	255.94	21.42	8.2
	+10%	88007.2	244.57	20.59	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	71465.9	211.144	18.924	8.4
	-20%	63209.6	211.007	18.924	8.5
S_1	+20%	79773.3	232.93	20.32	8.3
	+10%	79752.5	233.13	20.04	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	79711.8	233.48	19.46	8.3
	-20%	79692	233.62	19.18	8.3
h_0	+20%	79621.4	228.26	16.15	8.3
	+10%	79671.4	250.52	17.77	8.3
	0	79802.3	233.45	19.76	7.5
	-10%	79806.8	236.88	22.24	8.3
	-20%	79901.5	241.58	25.45	8.38

VIII. CONCLUSION

In emerging economies, researchers and practitioners are addressing the negative environmental impacts of CEs to inform operational decision-making. Inventory management within supply chains is a critical area of concern, as it has emerged as a critical component in emission reduction efforts. Businesses can effectively manage emissions and cut costs by implementing sustainable inventory strategies. In such cases, price and environmental practices have a significant impact on consumer demand. Additionally, when working with perishable items, proper preservation measures can be lifesavers. The government's carbon policy, which limits carbon emissions from specific processes or operations, may put pressure on industries. The study created an economic order quantity (EOQ) model for deteriorating items in which demand is determined by selling price, stock, and investment in green technology (or carbon reduction investment), and the rate of deterioration is controlled by investment in preservation technology. Furthermore, salvage trading makes it easier to manage deteriorated unit waste while also generating revenue. Furthermore, to reduce CEs, the model included investments in green technology and a carbon tax policy. The findings demonstrate the financial and environmental benefits of the proposed carbon reduction strategy. Finally, some important implications and theoretical contributions are discussed in light of the numerical and sensitivity MEQ analyses, which demonstrate the method's viability. This study suggests strategies for managing demand, deterioration, and emissions. These findings will be useful to policymakers, managers, and regulatory authorities, as well as in developing industry standards. On increasing in parameter, A total profit decreases, cycle length and green technology investment cost are increasing while selling price is constant. On increasing parameter, h total profit and cycle length fluctuate while green technology investment cost and selling price are constant. On increasing parameter, a total profit, cycle length, green technology investment cost and selling price are all increase.

REFERENCES

1. Taylor, T. A., & Plambeck, E. L. (2007). Supply chain relationships and contracts: The impact of repeated interaction on capacity investment and procurement. *Management science*, *53*(10), 1577-1593.
2. Ghosh, D., & Shah, J. (2015). Supply chain analysis under green sensitive consumer demand and cost sharing contract. *International Journal of Production Economics*, *164*, 319-329.

3. Wang, H., Bai, C., Wei, Q., & Lev, B. (2021). Inventory and pricing decisions when dealing with strategic consumers: A comprehensive analysis. *Computers & Operations Research*, *136*, 105473.
4. Sarkar, B., & Bhuniya, S. (2022). A sustainable flexible manufacturing–remanufacturing model with improved service and green investment under variable demand. *Expert Systems with Applications*, *202*, 117154.
5. Purnomo, M. R. A., Wangsa, I. D., Rizky, N., Jauhari, W. A., & Zahria, I. (2022). A multi-echelon fish closed-loop supply chain network problem with carbon emission and traceability. *Expert Systems with Applications*, *210*, 118416.
6. Maheshwari, S., Gautam, P., Kausar, A., & Jaggi, C. K. (2023). Optimal inventory replenishment policies for deteriorating items with preservation technology under the effect of advertisement and price reliant demand. *International Journal of Systems Science: Operations & Logistics*, *10*(1), 2186753.