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A Sustainability-Driven Production Model Considering Lightweight Packaging and Warehouse Design Under Cap-and-Trade Regulation

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Abstract

Objectives: To construct and evaluate a production inventory model that incorporates sustainability factors including package, warehouse design, and renewable energy adoption in order to reduce carbon emissions under cap-and-trade regulation. **Method:** An economic production quantity model along with carbon emissions is developed under two circumstances: (i) sustainable production model integrating lightweight packaging and energy efficient warehouse operations under cap-and-trade regulation (ii) production inventory model with on-site and off-site emissions under cap-and-trade regulation. Closed-form mathematical formulations are derived for the overall annual costs. To demonstrate the effectiveness of the suggested model, feasible parameter values were sourced from industry references and Daryanto's research. **Findings:** The suggested sustainable production inventory model shows that combining weight-optimized packaging and energy-saving warehouse practices greatly enhances both financial and ecological outcomes. Compared to model II, the overall cost reduces by 2.5% and overall emission quantity drops by 11.6%. These findings indicate that adopting sustainable approaches reduces emissions and operational expenditures without requiring extra production investment. As a result, the proposed model offers stakeholders a practical framework for striking a balance between cost efficiency and environmental stewardship in industrial operations. **Novelty:** This study is the first deterministic economic production quantity model to systematically incorporate three sustainability criteria within a carbon cap-and-trade system.

2020 Mathematics Subject Classification: 90B05.

Keywords: Cap and Trade Regulation; Economic Production Quantity Model; Lightweight Packaging; Sustainability; Warehouse Design

1 Introduction

In the contemporary industrial environment, production systems are under increasing pressure to attain financial efficiency while complying to ecologically sustainable standards. Global warming and environmental destruction have been worsened by the tremendous carbon emissions due to rapid population growth, power consumption and transportation development. In order to overcome these obstacles, firms are gradually shifting from expense-focused to environmentally conscious activities, where ethical behaviour and financial growth must coexist. In this context, Economic Production Quantity (EPQ) model remains as an essential analytical structure for figuring out the optimum quantity of batches that reduces overall cost while ensuring continuous production flow. The cap-and-trade mechanism which sets a legal restriction on overall emissions and permits enterprises to exchange excess, or carbon allowance shortfall is one of the primary strategies supporting sectors to minimize carbon emissions. This approach forces organizations to implement solutions that cut emissions from each stage of production and distribution by connecting both efficiency and sustainability.

Daryanto and Setyanto created a production inventory model that considers direct as well as indirect carbon emissions under cap-and-trade mechanism. Their approach laid the mathematical framework for emission-based inventory processes, demonstrating the impact of carbon emission costs on both production and holding decisions[(1)]. Huang presented a theoretical foundation for logistics and sustainable expenditures with various emission regulations[(2)]. Khan concentrated on a circularity index to control carbon emissions through product recycling within production systems[(3)]. Wangsa developed a vendor-buyer model that incorporates transportation and handling emissions[(4)]. Suvetha devised a sustainable inventory model encompassing power-pattern demand, emissions, and item lifespan impacts in order to demonstrate how degradation processes connect to emission-related pricing decisions[(5)]. Hasan analyzed the stock levels and investment in technologies under a variety of carbon regulatory environments like carbon cap-and-trade, carbon tax, and rigid carbon restrictions[(6)].

Sebatjane created an in-depth classification on sustainable inventory models under carbon emission regulations[(7)]. Singh constructed a sustainable production model that includes green technology under two carbon policies, emphasizing how ecological restrictions affect the investment rates and optimum production quantity[(8)]. Cannava evaluated photovoltaic internal energy consumption advancement methodologies, showing that integrating solar power in storage facilities can not only lowers emission intensity but also grid power demand[(9)]. Li investigated the combined benefits of carbon cap and trade and incentive policies, demonstrating their efficacy in enhancing commercial viability[(10)]. Tseng proposed an ideal carbon price and footprint concept in a two-tier manufacturing framework influenced by cap-and-trade limitations, examining how firms might strike a balance between the rate of production and carbon costs[(11)]. Cai formulated a decision-making scenario for pricing and reducing carbon emissions in a sustainable framework that fall under cap-and-trade rules, focussing on the financial consequences of emission trading schemes[(12)]. Sustainable packaging has been acknowledged as a successful tactic for lowering environmental effects in logistics. Asim highlights the importance of environmentally friendly packaging, proving that it reduces the use of materials and emissions caused by transportation[(13)]. Similarly, Postacchini established a design approach for enhancing sustainable responsibility of packing products in production operations[(14)]. Rani incorporated eco-packaging, carbon tax regulation, promotion, and pricing tactics into an inventory model, indicating that package layout decisions may have a major impact on economic as well as ecological consequences[(15)]. All of these studies emphasize how important is it to include technical aspects into production-inventory model.

Prior models have mostly concentrated either on policy-based tactics such as carbon tax or cap-and-trade or specific sustainability initiatives like eco-efficient warehousing, solar energy integration or sustainable packaging. Although several studies have examined environmentally conscious production models or emission related models, majority of the existing research have one or more following drawbacks: (i) they consider product weight, energy utilization, site performance as fixed parameters; (ii) they mostly rely on one-dimensional sustainability perspectives; (iii) they hardly assess the impact of managerial-level sustainability measures on overall cost and emission efficiency within a deterministic mathematical framework.

To the best of our understanding, no existing deterministic economic production quantity model has observed these efficiency gains across multiple aspects within a unified computational paradigm. To address these shortcomings, this study proposes a sustainable EPQ model that integrates three ecological-oriented factors: material efficient packaging, optimized warehouse design, and energy adoption under cap-and-trade regulation. It provides an operational tool for making decisions that enable firms to estimate the costs and environmental advantages of implementing design-focused sustainable practices. The suggested model is flexible and computationally reliable for practical application since it maintains its deterministic theoretical framework. Equipment setup cost, operational production cost, material handling cost, inventory holding cost, transportation cost, waste treatment cost and emission cost are all included in the total cost function. Numerical analysis confirms that the addition of three environmental characteristics results in a major reduction in carbon emissions and overall costs.

The rest of this research is arranged as follows: The analytical framework of the suggested model and solution approach are described in Section 2. The result and discussion are given in Section 3. Finally, the study is concluded in Section 4.

2 Methodology

A sustainable deterministic EPQ model is designed by integrating sustainability-oriented factors: material efficient packaging, optimized warehouse design, and energy adoption under cap-and-trade regulation. This research considers two cases: (i) sustainable production model integrating lightweight packaging and energy efficient warehouse operations under cap-and-trade regulation (ii) production inventory model with on-site and off-site emissions under cap-and-trade regulation. Closed-form mathematical formulations are derived for the overall annual costs. To demonstrate the effectiveness of the suggested model, parameter values were sourced from industry references and Daryanto's research. The suggested models were applied and analyzed to show their operational effectiveness in controlling emissions and cost savings.

Sections 2.1 and 2.2 describes the symbols and assumptions which were employed to build the proposed model.

2.1 Notations

d: Demand rate (units/year)

p: Production rate (units/year)

C_s: Setup cost ($/cycle)

C_p: Production cost ($/unit)

C_h: Holding cost ($/unit/year)

F_c: Lifting capacity (lbs/travel)

F_v: Forklift velocity (miles/h)

F_e: Forklift energy consumption (L/h)

F_d: Forklift travel ranges from the inbound area to the production site and from the production location to the outbound area (miles/travel)

C_f: Fixed cost ($/delivery)

R_f: Fuel rate ($/L)

P_e: Production energy consumption (L/unit)

L_e: Fuel emission limit (tonCO_2eq/L)

D_c: Manufacturer-Customer Distance (miles)

f_1: Fuel usage of an unfilled truck (L/mile)

f_2: Flexible fuel usage from truckload (L/mile/ton)

C_w: Waste treatment cost ($)

E_p: Electricity usage per cycle during production (kWh)

E_w: Electricity usage per cycle in warehouse (kWh)

E_l: Electricity emission limit (tonCO_2eq/kWh)

D_t: Manufacturer-Third party location Distance (miles)

E_q: Total emission quantity (tonCO_2eq)

E_c: Emission cap (tonCO_2eq)

C_c: Carbon cost ($/ton$CO_2$eq)

χ: Eco-friendly packaging

η: Warehouse configuration and energy optimization

μ: Renewable energy adoption

z_1: Raw material mass which is considered to be 110% of the item weight (lbs/unit)

z_2: Item weight (lbs/unit)

z_1^*: Raw material mass after eco-friendly packaging (lbs/unit)

z_2^*: Item weight after eco-friendly packaging (lbs/unit)

ESC: Equipment setup cost

OPC: Operational production cost

MHC: Material handling cost

IHC: Inventory holding cost

ITC: Transportation cost

WTC: Waste treatment cost

EC: Emission cost
C_T: Total cost ($)
Q_1: Optimal lot size per cycle for model I
Q_2: Optimal lot size per cycle for model II
T_1: Time cycle for model I
T_2: Time cycle for model II

2.2 Assumptions

- Only one kind of product is taken into account.
- Demand rate is known and constant.
- The system functions in a predictable environment where $p > d$.
- Shortages are not permitted, as the manufacturing system reflects an industrial environment where continuous supply is essential, and commercial services prohibit backorders.
- If the overall emissions go beyond the limit, the industry purchases additional carbon quotas. If it drops below the cap, then the industry can sell the excess quotas.
- The manufacturer delivers product via truck. In order to account for the impact of the number of loads, the fuel usage of the vehicle is separated into two categories: one which is empty and the another one which is influenced by the mass of the truckload.
- The manufacturer transports the necessary materials from the inbound area to the production site. When the production once done, the final goods are loaded into a truck at the outbound area. Both the production location's distance from the inbound area and the outbound area are the same.
- A portion of the electricity used in warehouses comes from natural sources.

Sections 2.3 to 2.9 describes the costs needed to assess the financial impact within the production process.

2.3 Equipment setup cost

This represents the equipment setup cost required when every production run is initiated.

$$ESC = C_s \frac{d}{Q_1} \tag{2.1}$$

2.4 Operational production cost

The production process cost is for resources, machines and the use of energy.

$$OPC = C_p d \tag{2.2}$$

2.5 Material handling cost

This focusses on how a forklift handles materials during loading and unloading activities. It is based on the total weight of the supplies handled for each product. Eco-friendly packaging is employed to minimize raw material and item weight, which leads to reduce material handling needs.

Therefore, $z_1^* = 110\%(z_2^*); z_2^* = (1-\chi)z_2$

The material handling cost per year is determined as

$$MHC = \frac{d(z_1^* + z_2^*)}{F_c} \frac{F_e F_d R_f}{F_V} \tag{2.3}$$

2.6 Inventory holding cost

Holding cost represents the stock carrying cost involved with storing final products. Sustainable warehousing indicates enhanced lighting, greater space utilization and successful management lower energy consumption, upkeep costs and operational expenses. The inventory holding cost per year is determined as

$$IHC = C_h \frac{Q_1 d}{2p}(1-\eta) \tag{2.4}$$

2.7 Transportation cost

Transportation cost comprises both fixed cost for each trip and variable expenses based on the delivery weight. Here, sustainable packaging reduces item weight, thereby reducing the amount of fuel used per trip.

$$ITC = \frac{d}{Q_1}\left(C_f + 2D_c f_1 R_f + D_c Q_1 z_2^* f_2 R_f\right) \tag{2.5}$$

2.8 Waste treatment cost

A specific quantity of solid waste is generated and that amount is calculated as the difference between the weight of the raw materials and the final products. At the end of the period, they are taken to the third-party firm's treatment facility and disposed of. Since less weight packaging minimizes the quantity of waste material produced, the disposal cost falls accordingly.

$$WTC = \frac{d}{Q_1} C_w (1-\chi) \tag{2.6}$$

2.9 Emission cost

Emission cost represents the monetary effect of carbon emissions within cap-and-trade regulation. If the overall emissions go beyond the limit, the industry purchases additional carbon quotas. If it drops below the cap, then the industry can sell the excess quotas. This cost demonstrates the systematic reduction of emissions from on-site, off-site, and third-party operations through design and energy-dependent approaches.

$$\text{The emission cost is } EC = (E_q - E_c) C_c \tag{2.7}$$

$$\text{whereas } E_q = s_1 + s_2 + s_3 \tag{2.8}$$

s_1 is sum of the on-site emissions caused by the fuel usage of the steam engine in manufacturing, forklift and truck.

$$s_1 = (dP_e L_e) + \left(\frac{d(z_1^* + z_2^*)}{F_c}\frac{F_e F_d L_e}{F_V}\right) + \left(\frac{d}{Q_1}(2D_c f_1 L_e + D_c Q_1 z_2^* f_2 L_e)\right) \tag{2.9}$$

$s_2$indicates the off-site emissions caused by power usage during manufacturing and storage.

$$s_2 = \frac{d}{Q_1}(E_p + E_w(1-\eta)(1-\mu))E_l \tag{2.10}$$

$s_3$refers to the unavoidable indirect emissions that comes from the outside entity which takes the garbage to their processing facility.

$$s_3 = \frac{d}{Q_1}(2D_t f_1 L_e + D_t Q_1 (z_1^* - z_2^*) f_2 L_e) \tag{2.11}$$

Therefore,

$$E_q = \begin{pmatrix} (dP_e L_e) + \left(\frac{d(z_1^* + z_2^*)}{F_c}\frac{F_e F_d L_e}{F_V}\right) + \left(\frac{d}{Q_1}(2D_c f_1 L_e + D_c Q_1 z_2^* f_2 L_e)\right) + \\ \frac{d}{Q_1}(E_p + E_w(1-\eta)(1-\mu))E_l + \frac{d}{Q_1}(2D_t f_1 L_e + D_t Q_1 (z_1^* - z_2^*) f_2 L_e) \end{pmatrix} \tag{2.12}$$

Then, the emission cost is

$$EC = \left[\begin{pmatrix} (dP_e L_e) + \left(\frac{d(z_1^* + z_2^*)}{F_c}\frac{F_e F_d L_e}{F_V}\right) + \left(\frac{d}{Q_1}(2D_c f_1 L_e + D_c Q_1 z_2^* f_2 L_e)\right) + \\ \frac{d}{Q_1}(E_p + E_w(1-\eta)(1-\mu))E_l + \frac{d}{Q_1}(2D_t f_1 L_e + D_t Q_1 (z_1^* - z_2^*) f_2 L_e) \end{pmatrix} - E_c\right] C_c \tag{2.13}$$

2.10 Model I: Sustainable production model integrating lightweight packaging and energy efficient warehouse operations under cap-and-trade regulation

A sustainable deterministic economic production quantity model is formulated by incorporating three sustainable activities such as material efficient packaging, optimized warehouse design, and energy adoption under cap-and-trade regulation. Each component alters emission formulas and certain costs within the EPQ model. Unlike prior research that examined these factors independently, the suggested model evaluates their overall financial and environmental effects, proving how effective operational adjustments can lower carbon emissions and total cost simultaneously. By employing eco-friendly packaging, firms can lower transport-related fuel expenses and waste disposal necessities. By improving warehouse energy usage, industries can reduce managerial electricity consumption along with holding costs. Also, enterprises can lessen reliance on power supply and attain emission goals by incorporating sustainable energy sources. As a result, the proposed method gives industries a quantitative route to lasting competitiveness by balancing operational performance and ecological consciousness.

From equations (2.1) - (2.13), the industry's overall cost for the EPQ model with sustainability-driven factors such as weightless packaging and energy saving warehouse activities under cap-and-trade regulation is defined as

$$C_T = ESC + OPC + MHC + IHC + ITC + WTC + EC$$

Thus, the industry's overall expenses are calculated by

$$C_T = C_s \frac{d}{Q_1} + C_p d + \frac{d(z_1^* + z_2^*)}{F_c} \frac{F_e F_d R_f}{F_V} + C_h \frac{Q_1 d}{2p}(1-\eta) + \frac{d}{Q_1} \begin{pmatrix} C_f + 2D_c f_1 R_f \\ + D_c Q_1 z_2^* f_2 R_f \end{pmatrix}$$

$$+ \frac{d}{Q_1} C_w (1-\chi) + \left[\begin{pmatrix} (dP_e L_e) + \left(\frac{d(z_1^* + z_2^*)}{F_c} \frac{F_e F_d L_e}{F_V} \right) \\ + \left(\frac{d}{Q_1}(2D_c f_1 L_e + D_c Q_1 z_2^* f_2 L_e) \right) + \\ \frac{d}{Q_1}(E_p + E_w(1-\eta)(1-\mu)) E_l \\ + \frac{d}{Q_1}(2D_t f_1 L_e + D_t Q_1 (z_1^* - z_2^*) f_2 L_e) \end{pmatrix} - E_c \right] C_c \tag{2.14}$$

By differentiating the overall cost with respect to Q_1, and setting the partial derivatives equal to zero, the optimum production quantity is formulated as

$$Q_1 = \sqrt{\frac{2p \begin{pmatrix} C_s + C_f + C_w(1-\chi) + 2D_c f_1 R_f + 2D_c f_1 L_e C_c + 2D_t f_1 L_e C_c \\ + E_p E_l C_c + E_w (1-\eta)(1-\mu) E_l C_c \end{pmatrix}}{C_h (1-\eta)}} \tag{2.15}$$

$$\text{Then, the time cycle is calculated by } T_1 = \frac{Q_1}{p} \tag{2.16}$$

2.11 Model II: Production inventory model with on-site and off-site emissions under cap-and-trade regulation

Without considering sustainability-oriented factors like weightless packaging and energy saving warehouse activities, the industry's total cost for the EPQ model with on-site and off-site emissions under cap-and-trade regulation is defined as

$$C_T = ESC + OPC + MHC + IHC + ITC + WTC + EC$$

Thus, the industry's total cost is calculated by

$$C_T = C_s \frac{d}{Q_2} + C_p d + \frac{d(z_1 + z_2)}{F_c} \frac{F_e F_d R_f}{F_V} + C_h \frac{Q_2 d}{2p} + \frac{d}{Q_2} \left(C_f + 2D_c f_1 R_f + D_c Q_2 z_2 f_2 R_f \right)$$

$$+\frac{d}{Q_2}C_w+\left[\left(\begin{array}{l}(dP_eL_e)+\left(\frac{d(z_1+z_2)}{F_c}\frac{F_eF_dL_e}{F_V}\right)+\left(\frac{d}{Q_2}(2D_cf_1L_e+D_cQ_2z_2f_2L_e)\right)+\\ \frac{d}{Q_2}(E_p+E_w)E_l+\frac{d}{Q_2}(2D_tf_1L_e+D_tQ_2(z_1-z_2)f_2L_e)\end{array}\right)-E_c\right]C_c \quad (2.17)$$

By differentiating the total cost with respect to Q_2, and setting the partial derivatives equal to zero, the optimum lot size is formulated as

$$Q_2=\sqrt{\frac{2p\left(C_s+C_f+C_w+2D_cf_1R_f+2D_cf_1L_eC_c+2D_tf_1L_eC_c+E_pE_lC_c+E_wE_lC_c\right)}{C_h}} \quad (2.18)$$

Then, the time period can be calculated by $T_2=\frac{Q_2}{p}$ (2.19)

3 Result and Discussion

The existing study has comprehensively explored the sustainable EPQ models under various operational contexts such as carbon taxation, trading and environmentally conscious investment strategies. For instance, Hasan achieved 4% cost savings by technological enhancement under carbon tax, carbon cap-and-trade policies[6]. Singh examined inventory production model under sustainable technology investment, indicating 3-4% cost reductions but did not consider warehouse or product-level efficiencies[8]. Tseng proved that improving carbon prices in a dual-phase production process could reduce emissions by almost 10%[11]. Nevertheless, no research has simultaneously integrated optimized warehouse design, solar energy adoption, and eco-friendly packaging within an analytical economic production quantity model to numerically assess their collective impact on emissions and total costs under a cap-and-trade scheme. It emphasizes that sustainability is more than just an extra cost; it can also be used tactically to improve operational efficiency. So, this research intends to show the effectiveness of three sustainability-driven parameters within the production inventory model in order to optimize the overall expense of the industry.

3.1 Example

To show the efficiency of the suggested model, parameter values were taken from industry references and Daryanto's research[1].

$$\begin{aligned}
d &= 10{,}000units/year; p=20{,}000units/year; C_s=\$1400/cycle; C_p=\$50/unit;\\
C_h &= \$5/unit/year; P_e=0.00965L/unit; F_c=3300lbs/trip; F_v=6miles/h;\\
F_e &= 3L/h; F_d=0.015miles/trip; R_f=\$1.02/L; z_1=22lbs/unit; z_2=20lbs/unit;\\
D_c &= 50milesdistance; C_f=\$1000/delivery; f_1=0.4345L/mile; f_2=0.0092L/mile/ton;\\
C_w &= \$600/cycle; D_t=30miles; L_e=0.01268tonCO_2eq/L; \chi=0.10; \eta=0.25; \mu=0.15;\\
E_p &= 1159kWh; E_w=1545kWh; E_l=0.02264tonCO_2eq/kWh; E_c=10{,}000tonCO_2eq;\\
C_c &= \$10/tonCO_2eq.
\end{aligned}$$

By using the method outlined in Section 2.10 and 2.11, optimum lot size, time cycle, total emission quantity and the total cost of the industry with and without sustainability-oriented parameters are given in Table 1.

Table 1. Displays the efficiency of the proposed model

Model	Optimum lot size	Time cycle	Overall Emission Quantity	Total cost of the production industry
Model I	$6091.3units$	$0.30457years$	$1195.3tonCO_2eq$	$\$507,020.53$
Model II	$5415.0units$	$0.27075years$	$1352.5tonCO_2eq$	$\$519,755.58$

In contrast to Daryanto's research[1], the proposed sustainable production model integrating lightweight packaging and energy efficient warehouse operations under cap-and-trade regulation reduced overall cost by 2.5% and emission quantity by 11.6%.

3.2 Sensitivity analysis

In this subsection, sensitivity analysis was performed by modifying three sustainability factors χ, η, andμindividually within a $\pm$20% range while holding all other parameters fixed. The corresponding variations in Q_1, T_1, E_q, C_T were analyzed to assess the robustness of the model. The results that were obtained are shown in Table 2.

Table 2. Sensitivity analysis of $\mathbf{Q_1}$, $\mathbf{T_1}$, $\mathbf{E_q}$, $\mathbf{C_T}$

Parameter	Results	-20%	-10%	Base Value	+10%	+20%
χ	Q_1	6,101.8	6,096.6	6,091.3	6,086.1	6,080.8
	T_1	0.30509	0.30483	0.30457	0.30431	0.30404
	E_q	1,219.9	1,207.6	1,195.3	1,183.0	1,170.7
	C_T	509,165.82	508,093.97	507,020.53	505,948.44	504,874.80
η	Q_1	5,910.5	5,998.7	6,091.3	6,188.8	6,291.6
	T_1	0.29553	0.29994	0.30457	0.30944	0.31458
	E_q	1,200.3	1,197.7	1,195.3	1,192.8	1,190.3
	C_T	507,419.35	507,218.61	507,020.53	506,814.41	506,607.23
μ	Q_1	6,098.2	6,094.8	6,091.3	6,087.9	6,084.4
	T_1	0.30491	0.30474	0.30457	0.30440	0.30422
	E_q	1,196.4	1,195.8	1,195.3	1,194.7	1,194.0
	C_T	507,030.21	507,022.98	507,020.53	507,013.20	507,003.37

Figure 1 shows the sensitivity of the overall cost with respect to the sustainability factors χ (eco-friendly packaging), η (warehouse efficiency), and μ (renewable utilization). The findings demonstrate that improvements in these criteria constantly reduce total cost, highlighting the economic benefits of sustainability-driven operational enhancements.

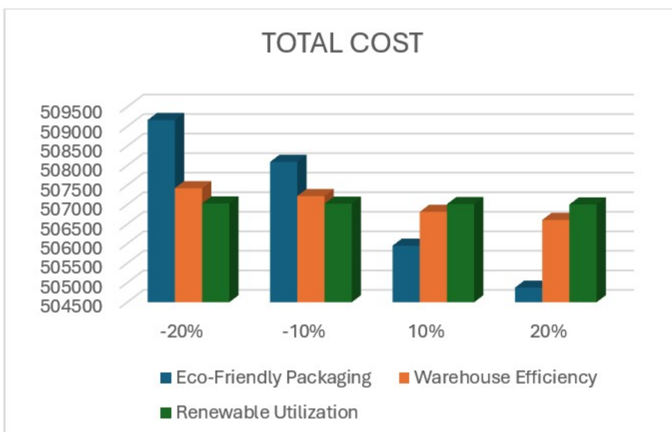

Fig 1. The effect of various cost parameters on total cost

4 Conclusion

In today's industrial landscape, attaining economic efficiency while maintaining ecological responsibility is no more an alternative mission but rather an essential imperative. This research developed a sustainable economic production quantity model that incorporates environmental tactics such as weightless packaging, renewable energy consumption, warehouse layout efficiency into a carbon cap and trade structure. The suggested model retains the conceptual clarity of the EPQ framework while including practical environmental initiatives into the emission and cost computations. It shows that even slight efficiency upgrades at the material, and electrical levels can result in major reduction on overall cost and emission intensity. Comparative analysis revealed that the overall cost dropped from $\$519,755.6$ to $\$507,020.5$ and the overall emissions reduced from $1352.5 tonCO_2eq$ to $1195.3 tonCO_2eq$, showcasing their concurrent financial and ecological performance. Despite the model's assumptions of consistent operational efficiency and deterministic demand, future studies may broaden this approach by incorporating uncertain demand, renewable energy unpredictability, multi-stage distribution network scenarios thereby bolstering its real-world applicability. Overall, this study proves that embedding environmental principles within deterministic production inventory models helps enterprises to operate in a low-carbon, inexpensive, and ecologically conscious manner.

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