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GREEN INVENTORY MODEL WITH VENDOR- BUYER ENVIRONMENTAL COLLABORATION TO ACHIEVE SUSTAINABILITY

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ABSTRACT

In today's competitive environment, it is extremely difficult to be successful without considering sustainability. Global warming impacts are becoming more observable in our daily life. Supply chain activities and many logistics activities are the important sources of carbon dioxide (CO2) emission and environmental pollutions. These issues have increased concerns to reduce CO2 emissions amount through the development of an inventory model. This paper incorporates environmental thinking into the inventory model to achieve sustainability .In this paper, we present a green inventory mathematical model which especially focuses on carbon cap-and-trade mechanism which is used to lower carbon emission in practice. One of the primary goals is to assess the environmental influence of various production and/or distribution approaches to reduce the greenhouse gases (GHG) emission through logistics activities. Finally, the paper concludes with a numerical example.

KEYWORDS: carbon cap-and-trade, CO2 emission, environmental collaboration, green inventory, sustainability.

INTRODUCTION

Operations research has been recognised by many studies as an effectual tool to deal with CO2 emission in the design and planning of green supply chains. To date, a number of literature reviews have highlighted the contribution of operations research to green supply chain management with broader areas of focus. Business activities can pose a major threat to the environment in terms of carbon monoxide emissions, discarded packaging materials, scrapped toxic materials, traffic congestion and other forms of industrial pollution [22]. Green supply chain management received the highest attention in 2010 [12]. With these practices in mind, firms develop environmental management strategies in response to the changes of environmental requirements and their impacts on supply chain operations [6]. A supply chain is a network consists of all parties involved (e.g. supplier, manufacturer, distributor, wholesaler, retailer, customer, etc.), directly or indirectly, in producing and deliver products or services to ultimate customers – both in upstream and downstream sides through physical distribution, flow of information and finances [13]. Environmental collaboration is one of the initiative responses to environmental problems, focuses on environmental protection, and promotes synchronized development of economic and environment perspectives [11]. According to Ninlawan et al. [14] and Thoo et al. [20], green procurement, green manufacturing, green distribution and green logistics are vital dimensions of green supply chain management practices needed by manufacturing sectors to achieve enhanced sustainable performance. Green et al. [7] suggested that green supply chain management GSCM practices should include internal environmental management, green information systems, green purchasing, cooperation with customers, eco-design and investment recovery. The benefits that can be derived from environmental collaboration have been recognized in the green supply chain management literature [9] [15].

Research on carbon emission management is becoming a significant part of the green supply chain background as more businesses maintain to make it part of their business strategy, amid pressures from customers, competitors and regulatory agencies. The carbon tax mechanism and carbon cap-and-trade mechanism are the most efficient market-based options used to lower carbon emission in practice. Carbon emission trading is another efficient way to diminish carbon emission in which mandatory limit or cap is set on carbon emission over a specific time period and a total number of permits or carbon credits are allocated to firms by regulating institutions. Similar to other commodities, carbon trading takes place either through exchange or over the counter. If the amount of carbon emission by a firm exceeds its cap, the firm will have to buy credit from the carbon trading market. Otherwise, it can sell its surplus carbon credit. The cap may also be interpreted as the amount of pollutants or emission the firm may be able to release into the environment. Cap-and-trade system of carbon emission control has been widely implemented by intergovernmental institutions, governments and multinational firms such as British Petroleum (BP). BP [16] implemented cap-and-trade across its business units and, according to its 2003 annual report, achieved its first GHG target in 2001, lowering its carbon emissions by 10% from its 1990 levels. Under the carbon cap-and-trade mechanism carbon cost is based on carbon price and carbon emission quantity in excess of the carbon cap. This is the carbon trading model [18].

The economic order quantity (EOQ) can be traced back to Harris (1913) [8]. Later, Taft [17] extended that basic model to the production line as the economic production quantity (EPQ), which was followed by the joint economic lot size (JELS) model by Banerjee [1]. Tao et al. [19] present cost-based models which integrate unspecified green costs into carbon emission cost and other environmental costs into EOQ/EPQ models, and derive the optimal order and production quantities. Bonney & Jaber [4] and Wahab et al. [21] present EOQ model with environmental concern as constraints. Benjaafar et al. (2010) and Chen et al. [5] developed EOQ-like models, subject to the quantity of carbon emission. Their findings provided insight on business decisions while considers the minimization of carbon emission. Hua et al. [10] presented a mathematical model that includes the carbon emission cost through a cap-and-trade system under the assumption that carbon emission from logistics and warehouse is linear with order quantity. The authors also investigated the impact of carbon cap-and-trade system on operational order decisions, carbon emissions and total cost. Wahab et al. [12] presented a JELS-like model that incorporated fixed and variable costs of carbon emission from transportation and investigated the optimal production-shipment policy for the buyer, vendor from an international two-level supply chain perspective. Jaber et al. (2013), Wahab et al. (2011) and Benjaafar et al. (2010) investigated the collaboration of a two-level supply chain based on JELS model when economic and environmental objectives are of anxiety.

Green procurement is defined as a set of supply-side practices employed by an organization to efficiently select suppliers based on their environmental competence, technical and eco-design capability, environmental performance, capacity to develop environmentally friendly goods and ability to support focal company’s environmental objectives [15]. Green manufacturing is a production process which converts inputs into output by reducing hazardous substances, increasing energy efficiency in lighting and heating, practicing 3Rs, minimizing waste [14], actively designing and redesigning green processes [20]. Green distribution consists of green packaging with the aims to downsize packaging, use “green” packaging materials, promote recycling and reuse programs, cooperate with the vendor to standardize packaging, encourage and adopt returnable packaging methods, minimize material uses and time to unpack, use recyclable pallet system and lastly, save energy in warehouses. Green logistics or transportation is about delivering goods directly to user site, using alternative fuel vehicles and grouping orders together, rather than in smaller batches [20]. Different from the literature, this paper provides a mathematical formulation of green inventory model with cap and trade mechanism. The rest of the paper is organized as follows section 2 comprises of mathematical formulation of the green inventory model with its notations and assumptions. Section 3 presents a numerical example and Section 4 concludes the proposed work.

Notations

The green inventory model is proposed using the following notations and assumptions

D	-	Annual demand
Q	-	Order quantity per cycle
A	-	Order cost per cycle
C	-	Carbon emission price
A_C	-	Carbon emission quantity from order per cycle
S	-	Setup cost
S_C	-	Carbon emission from setup
n	-	Number of times the order is produced
M	-	Manufacturing cost
M_C	-	Carbon emission from Manufacturing
C_S	-	Screening cost
LCA(T)	-	Life cycle assessment technology cost
h_r	-	Inventory holding cost per unit time
h_{rc}	-	Carbon emission quantity from inventory holding
P	-	Production rate
h_m	-	Inventory holding cost per unit time and per unit quantity for manufacturer

h_{mc}	-	Carbon emission quantity from inventory holding for manufacturer
p	-	Labour cost for packing per parcel
L	-	The cost of material used for packing per parcel
N	-	Number of parcels
a	-	Fixed cost per trip
b	-	Variable cost per unit transported per distance travelled
d	-	Distance travelled
x	-	Proportion of demand returned
g	-	Social cost from vehicle emission
v	-	Average velocity
Ψ_0	-	Fixed cost per waste disposal activity
Ψ	-	Cost to dispose waste to the environment
θ	-	Proportion of waste produced per lot
α	-	Cap of carbon emission for the retailer
β	-	Cap of carbon emission for the manufacturing industry
R_N	-	Revenue earned due to LCA

Assumptions

1. Life cycle assessment (LCA) approach is used for assessing products environmental impacts
2. The units transported are finally packed in parcels
3. Waste Management focuses on source reduction, pollution prevention, and disposal
4. The materials converted using LCA technology are reused as raw materials in manufacturing
5. For retailer and manufacturer, the carbon emission quantities obey EOQ and EPQ assumptions, respectively
6. Eco-friendly materials are used for packaging

MATHEMATICAL FORMULATION

For the retailer-manufacturer system under a carbon cap-and-trade mechanism with green inventory model comprises of green procurement cost , green setup cost, green manufacturing cost, holding cost, screening cost, green distribution cost, green logistics cost, cap and trade , waste produced by the inventory system , life cycle assessment technology cost.

$$TC = \frac{D}{Q}\left[(A+CA_C)+\left(\frac{S+CS_C}{n}\right)+(M+CM_C)+C_S+LCA(T)+2\,\mathrm{a}+\frac{2gd}{v}+\Psi_0+(p+L)N\right]$$
$$+\frac{Q}{2}\left[(h_r+Ch_{rc})+\left(n(1+\frac{D}{P})-1\right)(h_m+Ch_{mc})\right]+\frac{bd(1+x)+\Psi(\theta+x)}{D}-C(\alpha+\beta)-R_N \quad \text{----- (1)}$$

In order to find the optimal order quantity the above equation is differentiated with respect Q and equated to zero. The optimal order quantity is derived as Q*

$$Q^* = \sqrt{\frac{2D\left[(A+CA_C)+\left(\frac{S+CS_C}{n}\right)+(M+CM_C)+C_S+LCA(T)+2\,\mathrm{a}+\frac{2gd}{v}+\Psi_0+(p+L)N\right]}{(h_r+Ch_{rc})+\left(n(1+\frac{D}{P})-1\right)(h_m+Ch_{mc})}} \quad \text{----- (2)}$$

The combined carbon credit equation for retailer-manufacturer system is

$$(x_r+x_m)=\left[(\alpha+\beta)+Green\,inventory\,carbon\ \mathrm{credit}\ earnings\right]-\frac{D}{Q}(A_c+S_c)-\frac{Q}{2}(h_{rc}+\frac{D}{P}h_{mc}) \quad \text{---- (3)}$$

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NUMERICAL EXAMPLE

Consider the following data to illustrate the proposed green inventory model

D	-	60000	N	-	600
P	-	80000	a	-	50
A	-	200	b	-	5
C	-	0.2	d	-	250
A_C	-	400	x	-	0.2
S	-	800	g	-	0.5
S_C	-	400	v	-	180
n	-	1	Ψ_0	-	1
M	-	300	Ψ	-	0.8
M_C	-	400	θ	-	0.5
C_S	-	0.2	α	-	8000
LCA(T)	-	0.25	β	-	6000
h_r	-	0.8	R_N	-	200
h_{rc}	-	2	h_m	-	0.4
h_{mc}	-	1	p	-	0.3
L	-	2			

Using the above data in the equation (2) we obtain the optimal order quantity as
Q* = 12,069 units
Using the equation (1) we obtain the total inventory cost as
TC = Rs.16, 913.885
Number of Carbon credits obtained to sell (using equation 3) = **3083.005**

CONCLUSION

Considering environmental impacts of industrial decisions plays an imperative role in preserving our environment. At the present time, environmental problems are one of the most vital issues concerning human beings' life. In order to conserve our environment and resources for future generations, we need to change the way we are managing and operating our supply chains. In this paper a green inventory model with cap and trade mechanism is presented. The firm and society are benefited by using this green inventory model. Some of them to mention are the reduction of raw material and energy costs used, insurance costs are decreased as this model reduces risk; control waste bills and pollution fines. This model helps the firm to improve productivity since it uses natural light and ventilation. The firm can increase the property value by lowering operating costs. Enhancing, the public image through green inventory model leads to increased sales, better public perception and community support. This model helps in creating healthier environments which leads to less toxins and cleaner air with less hazardous production processes.

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