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Optimal Green Inventory model to regulate Eco-friendly Environment

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Abstract: Environmental sustainability is the study of interaction with the environment to prevent depletion of natural resources and allow for long-term environmental quality. The main aspect of going eco-friendly is about environmental sustainability. Global warming is the major threat to our planet. The reason for global warming is emission of greenhouse gases (GHGs). In this paper describes green inventory model of different social cost to reduce carbon emission strategies to achieve environmental sustainability under carbon-sensitive product. Finally determine optimal order quantity and the total cost of the system. As a result, the paper concludes with a numerical example.

Keywords: Eco-friendly environment, green inventory model, carbon sensitive products, pollution cost, sustainability.

1. Introduction:

Environmental sustainability which demands placed on the environment can be met without reducing its capacity to allow all people to live well, now and in the future. It has three main pillars: economic, environmental and social. These three pillars are informally referred to as people, planet and profits. Environmental sustainability is the rates of renewable resource harvest, pollution creation, and non-renewable resource depletion that can be continued indefinitely. Example: solar energy, wind energy, green space, sustainable construction, sustainable fishing practices, sustainable forestry etc. Eco-friendly literally means earth-friendly or not harmful to the environment. This term most commonly refers to products that contribute to green living or practices that help conserve resources like water and energy. Eco-friendly products also prevent contributions to air, water and land pollution. The main aspect of going eco-friendly is about sustainability. Since the world is corrupted with pollution and toxic amount of materials, making it sustainable can be a good call.

Global warming is a major threat to our planet. It poses severe risk to the nature, human health, and well-being. It has many catastrophic effects, such as rise of sea level, disruption in ecosystems, flood, drought, storm and increased clear-air turbulence. The reason for global warming is emission of greenhouse gases (GHGs), such as carbon dioxide (CO2), methane, and nitrous oxide. Main causes of GHG emissions are human activities, such as burning of fossil fuel for industrialization, transportation, generating electricity, and deforestation for urbanization. In addition, since the world economy depends upon the fossil fuel for industrial activities, the GHG emissions cannot be stopped completely. The primary task to mitigate global warming is to reduce the emission rate significantly. Industry is one of the major contributors of GHG emissions. In 2014, United States Environmental Protection Agency (EPA) reported that industry was the third major contribution to GHG emissions contributing 21% of the total GHG emissions in Unites States.

The first EOQ model was developed by Harris in 1913. Following him many researchers developed an inventory model along with an EOQ with various assumption like manufacture, logistics etc. Bonney and Jaber (2011) presented an inventory model with the need to construct a responsible inventory system. They discussed the importance of inventory planning to the environment. For further development they construct an analytical inventory model with a variation of EOQ. They suggested in the model, the importance of reducing transportation cost as well as carbon emission . Nowadays reducing carbon emission be a major task to protect our environment. Due to more transportation and industrial emission, it increases the environmental pollution. Arindum Mukhopadhyay and A. Goswami (2013) describes a pollution control cost in economic production quantity model.

Green production strategies for carbon sensitive products under carbon cap policy to regulate emission reduction. Low carbon economy direction to solving global warming described by Ma, C., Liu, X., Zhang, H., Wu, Y (2016). Carbon tax, Carbon cap and Cap and trade are the mechanism implemented by many countries to reduce carbon emission. Emissions can be reduced to some extent by capital investment on green technology, Tapan Kumar Datta (2017).

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, Paulraj et al. (2011). Green logistics or transportation, green packaging is about delivering goods directly to user site, using alternative fuel vehicles and grouping orders together, rather than in smaller batches, Thoo et al.(2014). This paper extends the model of Ma, C., (2016) by considering green inventory model of different social cost to achieve eco-friendly environment. 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.

2. Notations:

A Deterministic costs of each order at a particular time
k Carbon-sensitive coefficient
e Product's per-unit carbon emissions
a Unit of time of potential market demand
D Deterministic demand per unit of time
Q Production
h Annual inventory holding cost per unit product
c Cost of production per unit product
π_0 The pollution factor
c_π The pollution cost
x Fixed cost per trip
d Distance travelled
α Proportion of demand returned $(0 < \alpha < 1)$
v Average velocity
$c_{\pi c}$ The fixed capital cost of pollution control for production run
$c_{\pi 0}$ The operating and maintenance cost of pollution control per unit of production quantity
P Labor cost for packaging per parcel
L The cost of material used for packing per parcel
θ Proportion of waste produced per lot Q
γ Cost to dispose waste to the environment
γ_0 Fixed cost per waste disposal activity
N Number of parcels
g Amount of capital investment on green technology

2.1 Assumptions:

1. The manufacturer produces a single product under deterministic demand
2. To achieve carbon emission reduction, low-carbon and environmental protection features, those features are associated with the products, carbon-sensitive co-efficient k
3. Under deterministic demand, demand is equal to Economic order quantity (EOQ) and the relationship between demand and the carbon-sensitive co-efficient k is $= a - ke$ $(D, a, k, e > 0)$.
4. Waste Management focuses on source reduction, pollution prevention, and disposal.
5. Eco-friendly materials are used for packaging
6. Operating and maintenance cost of pollution per unit of production quantity.
7. All the quantity of pollutants are under the control and usable for further treatment process.

2.2 Mathematical formulation:

In this paper extends the model of Ma, C., (2016) by considering green inventory model of different social cost to achieve eco-friendly environment under carbon-sensitive products. In green inventory model with retailer -manufacture system comprises of Green setup cost, Green procurement cost, holding cost, Green logistic cost, Pollution control cost, Waste produced by the inventory system, Green packaging cost, Green technology investment.

EOQ cost per cycle = $A + cQ + \frac{Q^2 h}{2D}$

Waste produced by the inventory system per cycle = $\gamma_0 + \gamma Q(\theta + \alpha)$

Amount of capital invested on green technology investment = g

The pollution prevention procedure can be implemented by A.Mukhopadhyaya & Goswamia (2014) dependent on production quantity and independent of time.

Pollution control cost $(c_\pi) = c_{\pi c} + c_{\pi 0}\pi_0 Q$

Green packaging cost = $(P + L)N$

Green Logistic cost = $2x + 2\beta\frac{d}{v}$

$$\textbf{Total cost} = A + cQ + \frac{Q^2 h}{2D} + 2x + 2\beta\frac{d}{v} + c_{\pi c} + c_{\pi 0}\pi_0 Q + \gamma_0 + \gamma Q(\theta + \alpha) + (P + L)N + g$$

The total cost per unit is, where $T = {}^{Q}/_{D}$ then

$$\textbf{Total cost} = \boldsymbol{A\frac{D}{Q} + cD + \frac{Qh}{2} + 2x\frac{D}{Q} + 2\beta\frac{dD}{vQ} + c_{\pi c}\frac{D}{Q} + c_{\pi 0}\pi_0 + \gamma_0\frac{D}{Q} + \gamma(\theta + \alpha)D + (P + L)N\frac{D}{Q} + g\frac{D}{Q}} \quad (1)$$

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^*

$$\boldsymbol{Q^*} = \sqrt{\frac{2(a - ke)\left[A + 2x + \frac{2\beta d}{v} + c_{\pi c} + \gamma_0 + (P + L)N + g\right]}{h}} \quad (2)$$

3. Numerical Example:

For the convenience of numerical analysis, $A = 10$, $h = 20$, $c = 50$, $e = 10$, $a = 100$, $k = 1$, $P = 3$, $L = 2$, $N = 1$, $\gamma_0 = 1$, $v = 180$, $x = 5$, $\beta = 0.5$, $d = 250$, $\gamma = 0.8$, $\alpha = 0.2$, $\theta = 0.5$, $\pi_0 = 0.3$, $c_{\pi c} = 40$, $g = 300$, $c_{\pi 0} = 4$

Using this above data, substitute in equation (1), we get the optimal order quantity Q^*,

Optimal order quantity Q^* = 57.5 units

Using this above data, substitute in equation (2), we get the total inventory cost,

Total cost = Rs. 5520

4. Conclusion:

Environmentally responsible or green procurement is the selection of products and services that minimize environmental impacts. It requires a company to carry out an environmental consequence of a product at all stages as raw materials, manufacturing, transporting, storing, handling and disposing of the product. Green inventory is rooted in the principle of pollution prevention which helps to reduce risk to human health and the environment. Green products are generally produced in a manner that consumes less natural resources or uses as with sustainable forestry. They may involve less energy in their manufacture and contain fewer hazardous or toxic materials. In this model implemented green inventory cost with pollution control strategy under carbon-sensitive products. So this model achieve eco-friendly environment and helps to reduce risk for both human beings and environment. Also this model introduce green technology investment for companies to improve their operations, performance, productivity and efficiency, while lowering their costs, energy consumption, inputs, waste or pollution which result more economic value for the company and its shareholders.

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