An Inventory Model encompassing the features of Industrial Ecology in Startup Industrial Sectors

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Abstract **: Industrial sectors are highly integrated with the productive dimension of the nation's economy. The outcome of products demands systematic implementation of industrial activities; if it fails at any juncture then it results in mishaps. Presently many environmental calamities are happening due to disorganized executions in the production sectors which have made the society to meet the most challenging disaster, the pollution which occurs in many forms and disturbs the entire environmental structure. As the effects of pollution are highly dreadful certain preventive measures have to be put into practice. To minimize the impacts of pollution the production activities have to be integrated with the elements of industrial ecology for which additional costs are incurred which have to be incorporated to the total inventory costs for building healthier environment. It is indeed a prime task of the startup industries to increase their revenue so as to formulate a strong foundation for their business. To facilitate their achievement an inventory model stating the facets of profit making with environmental promotion has to be framed for which this paper is a step towards it.**

1. INTRODUCTION

The ultimate aim of inventory control is to reduce investment in inventories and to ensure the production process does not suffer at the same time. To set a balance between these aspects the organizations have to get answers for the questions such as how much to order and when should the order be placed. To determine the solutions to these challenging queries, Economic Order Quantity (EOQ) inventory model was first devised by Harris in the year 1913 which assisted corporations in minimizing total inventory costs by employing mathematical techniques to derive an optimal order size that minimizes the long – run average inventory costs. Five years later, Taft proposed the Economic Production Quantity (EPQ) model in the year 1918 which is utilized by the manufacturing sectors, when the products are produced internally instead of being acquired from outside suppliers. This model is also known as Economic Manufacturing Quantity (EMQ) model. Inspite of the similarity that lie in the motive of both EOQ and EPQ models proposed by Harris and Taft respectively there arise differences in the aspects linked to assumptions, objective function, optimal order quantity and total inventory cost.

The models proposed by Harris and Taft were further modified to resolve the crises that crop up in the production – inventory system due to shortages, backorders, defective products in a lot, rework, deteriorating items, offering of discount and even in integrated approach in supply chain management. A brief note of earlier works are presented as follows: Montgomery (1973) presented an EOQ model with which focus on shortages and partial backordering. Park (1982), Pentico and Drake (2009) proposed similar models with different methods. Li developed EPQ based models with partial backordering. Rosenblatt and Lee developed inventory models considering defective items and its rework. Salameh and jabber formulated inventory models with the inclusion of screening and remanufacturing of imperfect quality producs. Kaplan, Berman ,Yadavalli developed inventory models for deteriorating items. These models were further extended by Goyal, Giri and Zipkin. Wen framed EOQ models with the inclusion of Discount, also Goyal, Banerjee, Aggarwal concentrated on supply chain management and framed inventory models to manage the problems that arise in that scenario. In addition to these inventory models Ren framed Model based on cross selling, Berman (2000) on inflation and trade credit. Numerous extensions were also made by several researchers which contributed a lot for further development of the inventory models addressing the above mentioned crises by modifying the assumptions, nature of demand pattern; They formulated models to investigate the effect of clubbing two or more crises together like Shortage and permissible delay by Kun, imperfect Quality, shortage and backordering by Hung, imperfect items and discount by Hong, deteriorating, inflation and time discount by Arindam, partial backordering and cross selling by Ren-qian, deteriorating and backorder by Gede, replenishment and supply chain by Mohammed and so on. Also in these models the authors adopted various mathematical techniques to discover a robustic method of determining the optimal order quantity.

But after profound and cautious study of the inventory models developed by the researchers and academicians, one will surely arrive at a conclusion that these inventory models do not provide a meaningful basis for analyzing many real and increasingly important practical inventory problems and situations. This was also strongly emphasized by Maurice Bonney and Mohammad Jaber (2011) in their research on inventory models and they have made a remark that these inventory models are conventional and therefore new paradigm of responsible inventory models reflecting the actual needs of the manufacturing enterprises must be developed because it is becoming increasingly difficult for them to compete on a global scale with the applications of the conventional inventory models. These two persons are the pioneer of formulation of Environmental Economic order quantity models who, after their deep analysis of the classical models clearly stated the demerits of these traditional models which are : difficulty in calculating the realistic costs, model assumptions are unrealistic, usage of cost minimization as a performance measure does not give sufficient importance to meet user’s and society’s requirements, different problems of measurement, appraisal of inventory performance is not exact. These limitations laid the foundation of the formulation inventory models encompassing environmental aspects for promoting the ecological sustainability.

Industrial ecology (IE) is the study of the industrial activities and the implementation of strategies to reduce the impacts of its actions. A sequence of activities is carried out by the industries in product production. They procure the available raw materials, process and dispose the waste which is a linear process. This dumps the waste into the environment which makes the industries to face the legal hurdles of mismanagement of waste. To minimize the rate of expulsion of waste the linear process has to be changed into cyclic process which is the core component of industrial ecology. The significant feature of IE is industrial symbiosis which involves alliance of many industrial sectors to exchange their by products or waste to another which become the raw material of other. It also emphasize on secondary production which is the outcome of industrial symbiosis. The ultimate aim of IE is to minimize resource utilization and waste generation; the repetitive accomplishment of these tasks protects the environment from ruins.

Generally production sectors maintain inventory of all inputs at all levels for continuous production process and disposes waste to the environment, but a production sectors embedded with the principles of IE collects the by products and waste and process it and use as secondary input or sells to other industries. The practice of using secondary input will decrease the rate raw material usage and waste disposal. Usually the production sectors get the assist of inventory models to determine the quantity to be ordered and the time to be order. This indeed helps them to determine the total costs. The production sectors strive hard for profit maximization and cost minimization which can be achieved by encompassing the principles of IE. If the activities of IE are to be included to the production processes then the costs associated with it should also be incorporated to the total inventory cost to maximize profit and to build healthier environment.

The paper is organized as follows: section 2 describes the benefits of encompassing production sectors with IE; section 3 consists of model development; section 4 discusses the results of the model and section 5 concludes the paper.

2. BENEFITS OF ENCOMPASSING STARTUP PRODUCTION SECTORS WITH IE

In these days the industries are encouraged to carry out eco friendly activities to promote the sustainability of the environment which can be made possible with IE. Let us consider the case of a startup production sector which procures the raw material Q at a cost s per unit. The production sector uses p% of Q and produce product Y at a costs of q per unit and also it results in by product Z. r% of Q becomes as waste as it does not enter the production process. It is quite common to dispose the waste and discard the by product without subjecting it for the secondary production. This activity of the production sectors increases the input costs of each production run. This is the case of production sectors without IE, but a production sector with IE will make use of waste and by product in a more productive manner. The incorporation of the features of IE will facilitate the way of turning the by product to input materials and utilization of waste for energy generation by spending additional monetary values on it. This will decrease the procurement input costs and production costs of the next production run which indeed maximizes the profit.

The noteworthy benefits of IE are profit maximization and waste minimization. The greener environment is the outcome of integrating IE with the industrial activity. The implementation of IE relaxes the production sectors from the environmental regulations. The analysis of the inputs and costs benefits facilitates the industries to tackle the financial crisis. The mitigation of pollution and environmental degradation are the effects of assimilating IE.

3. MODEL DEVELOPMENT

3.1Problem Description

The production sector buys the required input materials, processes it and sells the product. In addition, it disposes the waste.To maximize the profit it puts the features of IE into practice which is industrial symbiosis and waste management. These two features pave way for promoting the environmental sustainability. To determine the profit of these production activities the associated costs and revenue must be determined per unit of time.

3.2 Assumptions

1. Shortages are not allowed
2. The demand is constant
3. Lead time is zero
4. Planning horizon is infinite.
5. Instantaneous selling of products and by products takes place

3.3 Notation

O	Ordering Cost
Q	quantity of raw material
s	purchasing costs of Q
L	processing costs of Q
q	production costs
p	percentage of Q becomes non - productive
1-p	percentage of Q becomes productive
f	selling price of the productive products
g	selling price of non-productive products after treatment
m	unit material evaluation costs
n	evaluation rate
t	treatment costs of non-productive products

h holding costs per unit per unit of time
d disposal costs of waste
T cycle length

Define N(Q,p) as the number of productive products and it is represented as
N(Q,p) = Q – pQ = (1-p)Q.
To avoid shortages the material evaluation rate
the percentage of non-productive in Q is restricted to
$1- D/n$ i.e $p \leq 1- D/n$.
Let TR(Y) and TC(Y) be the total revenue and the total cost per cycle,respectively
The total costs $TC(Q) = O + sQ + L + mQ + q + h[\frac{Q(1-p)T}{2} + \frac{pQ^2}{n}] + d + tpQ$
The total Revenue TR (Q) = gpQ +f(1-p)Q
The total profit $TP(Q) = gpQ + f(1-p)Q - [O + sQ + L + mQ + q + h[\frac{Q(1-p)T}{2} + \frac{pQ^2}{n}] + d + tpQ]$
The total profit per unit of time $TPU(Q) = \frac{1}{T}[gpQ + f(1-p)Q - [O + sQ + L + mQ + q + h[\frac{Q(1-p)T}{2} + \frac{pQ^2}{n}] + d + tpQ]$
The total profit per unit of time $TPU(Q) = \frac{D}{(1-p)Q}[gpQ + f(1-p)Q - [O + sQ + L + mQ + q + h[\frac{Q(1-p)T}{2} + \frac{pQ^2}{n}] + d + tpQ]$

$$TPU(Q) = D * (f - g + \frac{hQ}{n}) + D * [g - \frac{O}{Q} - \frac{L}{Q} - \frac{q}{Q} - \frac{d}{Q} - \frac{hQ}{n} - s - m] \frac{1}{(1-p)} - \frac{hQ(1-p)}{2}$$

$$\frac{\partial TPU(Q)}{\partial Q} = \frac{\partial}{\partial Q} (D * (f - g + \frac{hQ}{n}) + D * [g - \frac{O}{Q} - \frac{L}{Q} - \frac{q}{Q} - \frac{d}{Q} - \frac{hQ}{n} - s - m] \frac{1}{(1-p)} - \frac{hQ(1-p)}{2})$$

$$TPU'(Q) = \frac{hD}{n} + \frac{D}{Q^2} [O + L + q + d] \frac{1}{(1-p)} - \frac{hD}{n(1-p)} - \frac{h}{2} + \frac{hp}{2}$$

The objective is to determine the optimal quantity. The necessary condition is $\frac{\partial TPU(Q)}{\partial Q} = 0$

$$Q = \sqrt{\frac{2nD [O+L+q+d]}{hp [2Dp-2ph+n+np^2}}$$

4. DISCUSSION

This model encompasses the aspects of material evaluation and selling of by product after treatment using industrial symbiosis which is the constituents of industrial ecology. This integration of inventory with ecology indeed stimulates the need of promoting the environmental concerns. The main origin of such environmental crisis starts from the percentage of non – productive part of the input which still hurdles the production processes and the output of the product. If material evaluation is dome effectively then the value of p decreases and it also decrease the related costs. This inventory model facilitates the ways and means of enclosing the aspects of industrial ecology to industrial production.

CONCLUSION

This article describes a bio friendly inventory model which includes the environmental costs parameters. This reflects the need of incorporating the features of industrial ecology. This model is indeed lending high assistance to industrialists in handling the problems of production and prevention of environment.

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