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ENVIRONMENTAL ORIENTED INVENTORY MODEL AND BENEFITS OF INCINERATION AS WASTE DISPOSAL METHOD

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ABSTRACT:
It is well known that industrial sectors are the backbone of any nation's economy. The motive of the establishment of any industry is to satisfy the demands of the needy instantaneously, which explicitly states that it has social responsibilities. To make the fulfillment of the demands in right proportion and at the right time, inventory models [Economic order/production quantity) were formulated. In a production / inventory situation items which are, received or produced are not of perfect quality. Thus the presence of defects which is inevitable in a produced/ordered lot is sorted out by the process of screening. The imperfect items cannot be discarded as waste, as the industries possess environment responsibilities, remanufacturing tactics and waste management techniques have been implemented. Several literatures have discussed about inventory models with production, remanufacturing and waste disposal, but disposal methods and techniques were not discussed in particular. In this paper an inventory model is formulated in which the defective items in a lot are made to undergo seperate screening which in turn are categorised based on the Life Cycle Assessment (LCA) methodology as reusable, recyclable and final residues are subjected to incineration one of the waste disposal methods which is both economically and environmentally beneficial.

1. INTRODUCTION

Inventory models have been a great support for the successful run of the industries which undergo a number of modifications to act as the remedial measure to the problems that arise in the production /inventory situations. Demands of the customers must be satisfied instantaneously for which the production/ordering rate is fostered to avoid shortages. It is vivid that quantity of items is focused on, but in addition to it the quality of the items must also be given significance as customer's consistency depends on it. The quality of the produced / received lot is determined by the proportion of defective items present. The process of screening is carried out to isolate the perfect items from the imperfect ones. To transform the imperfect items as perfect, remanufacture is undertaken.

Remanufacture accounts to recycle, repair and rework. The items that are imperfect have defects, but the percentage of defects present in each item is distinct. A few numbers of defect can be mended manually within a short span of time so that they can be reused immediately, some defects need technical assistance along with a long span of time to get it recycled and certain defects cannot be reworked and those items that are unfit for reuse and recycle are subjected to waste disposal category. The defective items are identified after screening the entire production/received lot. But again the defective items are made to undergo screening to classify them as reusable, recyclable and residue. Thus generation of waste takes place in production/inventory situation at the end of second screening. Many inventory models were formulated to bring co ordination between the inventory/ production situations along with remanufacture and waste disposal but so far the disposal methods were not taken into account.

There are many waste disposal methods such as incineration, landfill, decomposing and few others which are employed in MSW (Municipal solid waste). After various analyses incineration seemed to be the suitable method as it is both economically and environmentally good. Industry is one of the major causes of generation of municipal waste which is the outcome of developmental activities. To minimize the risk of waste management and to abide by the legislations, many industries have constructed smaller incinerators within their own site for their personal use (www.eea.europa.eu/publications). One of the attitudes of these waste management techniques is the conversion of waste to energy. Waste is sometimes considered as a renewable fuel. Thus it is clear that benefits in terms of revenue could be earned out of the installation of such constructions to which incineration is not an exception. Bernadette [3] in his paper has mentioned the incineration cost parameters and revenue gained out of it. He has also finally concluded that use of incineration facility to manage a portion of waste was environmentally better than landfilling which ranks next immediate to incineration in the waste hierarchy suggested and used in waste policy making which are again examined by LCA methodology [7].

The remainder of the paper is organized as follows, Section 2 presents the literature review of the previous works cited. Section 3 describes about incineration briefly. Section 4 elucidates the model formation. Section 5 concludes the proposed work.

2. LITERATURE REVIEW

The Economic Order Quantity (EOQ) model has been extensively used in inventory management for a long time. The economic production quantity (EPQ) model is the oldest and most useful in production and inventory management which is regarded as the generalized form of the Economic Order Quantity [10]. A common unrealistic assumption in using the EOQ is that all units produced are of good quality [14] Zhang and Gerchak [18] considered the inclusion of inspection policy in a EOQ model where a random proportion of units are defective. Sawakhande etal [19] explored new technique to produce fuel from waste for decentralized processing of solid biodegradable wastes. Schrady [15] developed an EOQ model with instantaneous production and repair rates and no disposal. As environmental issues started surfacing and becoming a public concern, Richter [11] picked up the problem of Schrady [15] and turned it into a production, remanufacturing and waste disposal problem. The industrial sectors must bear the cost of disposal in addition to the cost of production and remanufacture.

The items that cannot be remanufactured are disposed. A number of disposal methods are available, but the proper method has to be selected to minimize the cost of disposal and the environmental effects for which LCA is preferred due to its systematic approach and the frame work of waste hierarchy which is widely accepted by the decision makers in industries[2].The international standard ISO 14040-43 defines LCA as a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [2].Life-cycle assessments were initially developed for the purpose of analysing products, although recently, it has also been applied to the treatment of waste. LCA studies the environmental aspects and potential impacts throughout a product's life. The structure of LCA is discussed briefly in [7]

Salameh [14] in his paper has formulated a simple inventory model in which the defective items which are expressed as the percentage (p) of lot size y with a known probability density function are sold as a single batch at a discounted price after 100% percent of screening and also the total profit per unit time is determined. In this paper this model is modified by the inclusion of screening cost of the defective items, cost of remanufacture and the cost of incineration. Also in addition, it is assumed that defectives of a known proportion were present in produced / received lot. In this paper an integrated inventory model which includes production, remanufacture and waste disposal method – incineration is formulated.

3. INCINERATION

Waste is considered as fuel and Waste to energy has become the major goal to be achieved in the implementation of any waste disposal activity. Amidst a number of waste disposal options incineration is judged to be desirable after the analysis of social cost. Incineration is the most important way of utilizing the energy content of the waste which is the conclusion made by Bernadette [3] in his paper and also he has explained about the incineration method briefly as follows. Incineration is a controlled process which involves oxidative conversion of combustible solid material to harmless gases suitable for atmospheric release. It converts a waste to a less bulky, less toxic, or less noxious material. It also reduces sludge to an ash residue which can be more easily handled for ultimate disposal. Incineration has its own environmental effects which could be minimized by proper installation of mitigating techniques to treat the emissions. The cost of setting an incineration plant and its associated cost parameters such as operating, maintenance, residue disposal, transportation waste haulage and fuel surcharge are included, and the revenue earned out of it is briefed in the literature. After the analysis of the various disposal methods incineration rank first, because even though the incineration operational tasks are expensive; it yields revenue in terms of energy and materials. This advantage of incineration has encouraged many industrial sectors to construct small incinerators within their firms for waste management to promote environment sustainability.

4. MODEL FORMULATION

4.1 Problem Description

Consider the case where a lot of size Y is delivered instantaneously with a purchasing price of c per unit and an ordering cost of K. It is assumed that each lot received contains a known percentage of defectives p, after 100% percent of screening imperfect items is separated from the good items. To make profit out of the defective items, they are made to undergo second screening i.e the LCA methodology is used to rank the defective items as reusable, reworkable and the residues to be incinerated based on their proportion which is expressed as the percent of imperfect items. It is classified based on the degree and nature of defects present in each imperfect item.

4.2 Notations

The following notations will be used throughout the paper when developing the mathematical model.

- Y order size
- c unit variable cost
- K fixed cost of placing an order
- p percentage of defective items in Y
- q percentage of defective items those are suitable for reuse.
- r percentage of defective items those are suitable for recycle.
- i percentage of defective items that are subjected to incineration.(1-q-r)
- s unit selling price of items of good quality.
- v unit selling price of defective items that are categorized as reusable. ($v < s$)
- R unit cost of recycling
- R_1 unit selling price of recycled items.($R_1 > R$)
- I unit cost of disposal by the method of incineration
- I_1 revenue earned per unit.
- x screening rate
- d unit screening cost

d_1 unit screening cost of the defective items.

E Emission caused by incineration mitigating cost

T cycle length.

3.3 Assumptions

1. The demand is constant.
2. No shortages are allowed.
3. The items to be reused, reworked and incinerated are expressed as the percentage of imperfect items.
4. The cost of mending the items that are categorized as reusable is neglible.
5. Lead time is assumed to be Zero.
6. Planning horizon is infinite.

4.4 Mathematical Model.

As in Salameh [30] model to avoid shortages it is assumed that

Dt ≤ N(Y,p) , where N(Y,p) is the number of good items in each order, also in addition to that p, the percentage of defective items in y is restricted to

$1- {}^{D}/_{x}$ i.e $p \le 1- {}^{D}/_{x}$.

Let TR(Y) and TC(Y) be the total revenue and the total cost per cycle,respectively. TR(Y) is the sum total sales volume of good quality, reusable items, reworked items and the revenue from the incineration of non- repairable units.

$TR(Y) = sY(1-p) + vqpY + R_1rpY + I_1ipY$

TC(Y) is the sum of procurement cost per cycle, screening cost per cycle, holding cost per cycle,Screening cost of defective items per cycle, Remanufacturing cost per cycle,cost of incineration per cycle.

$$TC(Y) = K+cY+dY+d_1\,pY+ E +h^*\left[\frac{Y(1-p)T}{2}+\frac{pY^2}{x}\right] + RrpY + IipY$$

The total profit per cycle is the total revenue per cycle less the total cost per cycle, TP(Y) = TR(Y) – TC(Y), and it is given as

$$TP(Y) = sY(1-p) + vqpY + R_1rpY + I_1ipY -\{ K+cY+dY+d_1\,pY+E+h^*[Y(1-p)T/2 + (pY^{\uparrow}2)/x] + RrpY + IipY\}$$

The total profit per unit of time is given by dividing the total profit per cycle by the cycle length, $TPU(Y) = {}^{TP(Y)}/_{T}$; and can be written as

$$TPU(Y) = D^*(s - vq- R_1r - I_1\,i + Ii + d_1 + hy/x + Rr) + D^* \left[vq + R_1r + I_1\,i - Ii - d_1 - \frac{hy}{x} - Rr - c - d - \frac{K}{Y} - \frac{E}{Y}\right]\frac{1}{(1-p)} - \frac{hy(1-p)}{2} \quad (1)$$

$$(\partial TPU(Y))/\partial Y = \partial/(\partial Y)(D^*(s - vq- R_1r - I_1\,i + Ii + d_1 + hy/x + Rr) + D^* \left[vq + R_1r + I_1\,i - Ii - d_1 - \frac{hy}{x} - Rr - c - d - \frac{K}{Y} - \frac{E}{Y}\right]\frac{1}{(1-p)} - \frac{hy(1-p)}{2}$$

$$TPU'(Y) = \frac{hD}{x} - \frac{hD}{x}\left(\frac{1}{(1-p)}\right) + \left[\frac{K}{Y^2}+\frac{E}{Y^2}\right]\left(\frac{D}{(1-p)}\right) - \frac{h}{2} + \frac{hp}{2} \quad (2)$$

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

$$Y^* = \sqrt{\frac{2KEDx}{h[(1-p)^2x + 2Dp]}} \quad (3)$$

Note that when p = 0, Eq.(3) reduces to the traditional EOQ model. $Y = \sqrt{2KD/h}$. The reason why E vanishes is, if there is no defective items present in the produced lot then there is no need of the waste disposal method incineration so the costs associated with emission mitigation is excluded.

5. NUMERICAL RESULTS.

To illustrate the usefulness of the model developed in Section 4, let us consider the inventory situation where a stock is replenished instantly with Y units of which not all are of the desired quality.

The parameters needed for analyzing the above inventory situation are given below:

D = 50,000 unit / year; c = $ 25 / unit; K = $100 / cycle; s = $ 50/unit; v=$40/unit; h = $ 5 /unit / year; R=$5/unit;E = $ 500 / cycle R_1 = $ 15 / unit ; I = $ 2 / unit ; I_1 = $ 5 / unit ; x = 1 / unit / time ; d = $0.5 /unit; d_1 = $0.5 / unit; p =0.05; q = 0.5; r = 0.3, i = 0.2.

Assume that the inventory operation operates on an 8 hours/day, for 365 days a year, then the annual screening rate, *x*=1*60*8*365=175 200 units/year.

Then the optimum value of Y that maximizes Eq.(1) is given from Eq.(2)

$$Y^* = \sqrt{\frac{2 * 100 * 500 * 50000 * 175200}{5[(1-0.05)^2 * 175200 + 2 * 175200 * 0.05]}}$$

= 31583 units.

Substituting $Y^* = 31583$ units in Eq.(2) the maximum profit per unit year is given as

TPU(Y) = 1290321.9/year.

6. CONCLUSION

This paper presents an environmental oriented inventory model which discusses about the benefits that are gained out of using incineration, the waste disposal method. This paper presents a numerical example to validate the above model also it discuss about the waste disposal method in particular. This model also assists the decision makers in industries to expel the waste more economically and also enables the industries in fulfilling its environmental responsibilities.

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