

Greening the Supply Chain with Reworked Items

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Abstract

In the Last few decades, realization about environment has given considerable attention to produce green Products in all fields worldwide. Along with producing green, reuse and recycle of used products also has been promoted to save the environment as much as possible. Though every industry is following its own way to implement green up to certain level but electronics industry is equally forcing reuse and recycle of used products to reduce the e-waste which is increasing at a high-speed due to small life cycle and tough to dump because of its toxic and hazardous nature, which further effects the environment safety. In this paper it has been explored how the forward-reverse supply chain model is decisive to the success of greening the products, specifically focusing on the life cycle cost, and effective cost and profit analysis by calculating total integrated profit function which reduces life cycle cost and satisfies customer requirements for a given period of time. The consequential of this study can be helpful to implement the GSCM concept in electronics Industry and final ratios of integrated profit can be improved by using reworked or reused products, simultaneously reducing the cost of products, in between supplier and buyer.

Keywords: Supply chain, Green supply chain, forward and Reverse Chain, Profit Analysis, JIT (Just in time), VMI (Vendor managed Inventory), WEEE (Waste Electrical and Electronic equipment), ROHS (Restriction of Hazardous Substances), ESCM (Environment safety chain management).

1. Introduction

Rise in the temperature of earth, deterioration in Ozone layer, melting of glaciers, numerous natural calamities, Phase-shift in environmental clock are the various rays converging at the point of alarm to nature or save environment. This alertness about saving the nature and its resources has emerged as both requirement and use of more and more greens products. So production of green products and managing the concept of green across the whole supply chain has become a central Challenge of most of the modern enterprises. Apart from these necessities and Market Challenges, the pressure from various national and international regulatory bodies working towards environment protection like WEEE (Waste Electrical and Electronic Equipment) of European Union (EU), Restriction of

hazards substances (ROHS) and Eco- Design requirements using product (EUP), NAPCC (National Action plan for climate control), has also shown the path of , green purchasing, green manufacturing, green distribution ,recycle, and reuse of products to pursue this concept of green has dotted in different forms as mentioned below.

- i. Applying green principles to their company by using environmental friendly raw material
- ii. Reducing the use of petroleum power and other natural resources
- iii. Using the recycle paper for packaging
- iv. Reducing the use of electronic gadgets (Beamon, B. 1999, Mittal et al., 2010)

(Lamming and Hampson, 1996) described that balance should be there between environmental management practices like life cycle analysis, waste management, product stewardship, etc. and supply chain management practices like vendor assessment, total cost and quality management, CPFR (collaborative planning, forecasting and resourcing). As a result of this supply chain managers started keeping the impact of their decisions on the environment, known as environment safety chain management (ESCM) or green supply chain management (GSCM) along with traditional performance related of supply chain like dimensions cost, quality, delivery, and technology. (Kumar and Malegeant, 2006); (Tsolfas and Pappies, 2006); (Boons, 2002); (Sharatt and Choong, 2002); (Geoffrey et al., 2002); (Zisdin and Siferd, 2001); (Jacqueline et al., 1995). In contrast to the Reverse Logistic Models (Linton, 1999); (Mulder et al., 1999); (Nagel et al., 1999); (Van Hoek, 1999); (Halt, 1997). GSCM (Green Supply Chain Management) is described as a wider term describing a range of opportunities through which different companies work with their suppliers to improve the environmental performance of their products, services and their manufacturing processes. This is the reason that GSCM is not defined, as a single track of business with one to one, business to business relationships, rather it's a network of multiple businesses and synchronized relationship, which works for environmental betterment with the help of parameters like coordination, integration, management amongst the various players of supply chain like raw materials suppliers, suppliers manufacturing (Geoffrey et al., 2002).

Though European is in the direction of following Green Supply Chain with a very close proximity, it has also applied WEEE directives which requires that manufacturer or producers should take the responsibility of collecting, treating, reviewing and disposing various types of waste (EU, 2003) which is also described as the

concept of EPR (Extended procedure responsibility) as per (Spicer and Johnson, 2004). In their directives WEEE covers large and small house hold appliances, telecommunication and IT equipments, lighting and electronic equipments, tools with exception of large stationary industrial tools, leisure tools, sports equipments, medical devices with exception of all implanted and infested product, monitoring and control instruments, automatic, dispensers etc.

In the traditional supply chain buyers and suppliers generally used to make the decisions independently, only to maximize their own-profit or minimize their own costs but the increased thought for supply chain coordination has thrown light in the form of various concepts like JIT, VMI, etc.

In the present study, inventory cost and profit analysis of green electronic products has been done. Here the supply chain moving in forward direction is carrying a series of activities to transform the raw materials into finished goods, while the reverse or backward supply chain refers to retrieve the product from a customer, rework upon it for reuse or dispose it off in an environmental friendly manner if it can't be recovered after rework. In this paper cost and relevant issues of electronic products with forward and backward supply chain are considered and the model explores how the demand of electronic goods which customers appreciate only for a certain period of time, can be satisfied when it increases for a specific cycle with the reverse chain. The objective of this study is to develop a replenishment strategy for the buyer and supplier using VMI, to see the effect of various replenishment frequencies for a specific time cycle on the total profit which will be distributed between the two players. This paper has been organized in the following manner

Section one describes the review of life cycle cost, reverse supply chain, Vendor managed inventory etc

and how does it affect the green concept to incorporate products.

In second section the total costs for supplier, buyer and the revenue earned has been illustrated with various assumptions used in the model.

Section three describes the total integrated profit and solution procedure to get the values of k and T with maple.

Section four, throws light upon the results drawn from this model with numerical example and describes the various values of profit function as per table 1 and figure 2.

Section five summarizes the results and gives a concluding remark for the same.

2. Modeling and Analysis:

In general the framework of the electronic products which are returned by the buyer after using them for a short span of time is shown in fig-1; this framework of the inventory supply chain model has been adapted from (Koh et al., 2002)

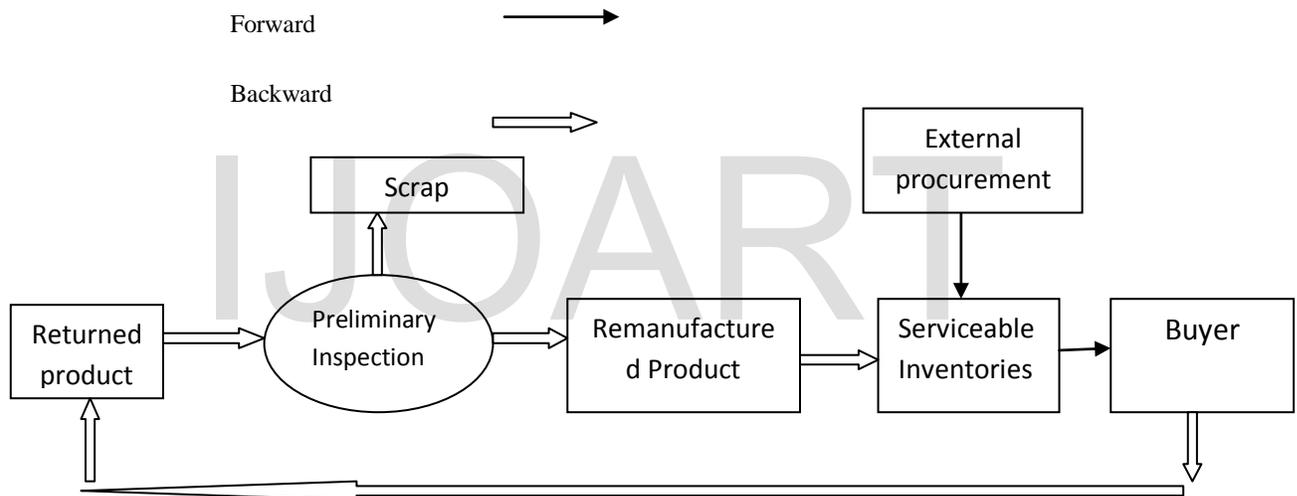


Fig: 1The frame work of the used inventory Model (Koh, et al.2002)

2.1 Assumption and Notations

Different assumptions and notations used in this paper are mentioned below.

Assumptions

- This model has single supplier and single buyer
- The demand rate is increasing function of time.
- Buyer order interval is constant
- The deteriorating rate is a constant $\theta, 0 \leq \theta \leq 1$
- The received returned products satisfy the poisson distribution.
- Shortage is not allowed.

Notations

q = order quantity for buyers

k = A value which is positive which represents replenishment frequency between supplier and buyer.

The different notations used by buyer are:

C_B = Ordering cost of buyer

H_B = holding cost of buyer

D_B = deteriorating cost of buyer

TC_B = Total inventory cost of buyer

$I_B(t)$ = buyer inventory level at time t

T = cycle for which the demand increases linearly up to a certain level for a specific product

The different notations used by supplier are

C_s = Ordering cost of the supplier

H_s = holding cost of the supplier per unit per time

Q = order quantity during period

D_s = deteriorating cost of the supplier

I_{Di} = Inventory level after i shipment for $i = 1, 2, 3 \dots K$

TC_s = total life cycle cost

P = selling price per unit

TR = supplier's total revenue

The different notations used in reverse supply chain are

C_R = supplier's remanufacturing cost per unit.

C_C = supplier's cost of processing the scrap per unit.

H_R = cost of holding the remanufactured products per unit per unit time for supplier.

λ = Rate of returned products from buyer to supplier

Φ = perfect proportion of remanufactured product received by suppliers

I_{Ri} = suppliers inventory level after i shipment with

perfect remanufactured items for $i = 1, 2 \dots k$

The buyer and supplier notation are

TIP = total integrated profit function the supplier and buyer

$(a + bt)$ = demand rate during period t which is increasing linearly till end of cycle T .

T = cycle for which the demand increases

2.2. Buyer Inventory Model

As per the inventory model developed by (Ghare and Schrader, 1963) for deteriorating items, if we take demand as an increasing function of time, the inventory level at any time t of a cycle T can be elaborated as

$$\frac{dI_B(t)}{dt} + \theta I(t) = -(a + bt) \quad 0 < t < T \quad (1)$$

Where, $(a + bt)$ is the demand linearly increasing with time

The solution of the differential equation with boundary condition $I_B(t) = 0$ is referred to as (Bronson and Costa, 2006), the level of inventory for the buyer is given by

$$I_B(t) = \frac{a}{\theta} (e^{\theta(T-t)} - 1) + \frac{b}{\theta} (T e^{\theta(T-t)} - t) - \frac{b}{\theta^2} (e^{\theta(T-t)} - 1) \quad (2)$$

At $t = 0$, $I(0) = q$ so putting $t = 0$ in equation (2), q received is mentioned below

$$q = (e^{\theta T} - 1) \left(\frac{a}{\theta} - \frac{b}{\theta^2} \right) + \frac{bT}{\theta} e^{\theta T} \quad (3)$$

The buyer's holding inventory level for the complete cycle of 0 to T will be given by

$$\int_0^T I(t) dt \quad \text{So the buyer's total inventory}$$

holding cost for complete cycle T will be

$$H_B k \left(\frac{b}{\theta^2} (1 - e^{\theta T}) + \frac{1}{\theta^2} * (a e^{\theta T} + bT e^{\theta T} - a) - \frac{T}{\theta} (aT + \frac{bT}{2}) \right) \quad (4)$$

The deteriorating inventory during period T is $q -$

$$\int_0^T (a + bt) dt \quad q - (a.T + \frac{bT^2}{2}) \quad (5)$$

Substituting q from equation (3) to equation (5), we get deteriorating inventory for the buyer, so the deteriorating Inventory cost of buyer will be,

$$D_B k \left((e^{\theta T} - 1) \left(\frac{a}{\theta} - \frac{b}{\theta^2} \right) + \frac{bT}{\theta} e^{\theta T} \right) - (a.T + \frac{bT^2}{2}) \quad (6)$$

The total inventory cost for the buyer during period T is the sum of ordinary cost, holding cost and deteriorating cost so

$$TC_B = C_B k + H_B k \left(\frac{b}{\theta^2} (1 - e^{\theta T}) + \frac{1}{\theta^2} * (a e^{\theta T} + bT e^{\theta T} - a) - \frac{T}{\theta} (aT + \frac{bT}{2}) \right) + D_B k \left((e^{\theta T} - 1) \left(\frac{a}{\theta} - \frac{b}{\theta^2} \right) + \frac{bT}{\theta} e^{\theta T} \right) - (a.T + \frac{bT^2}{2}) \quad (7)$$

2.3 Supplier's Inventory Model.

In case of vendor (supplier) the inventory at the end of period T will be described as shown in equation (8),

where I_0 is initial inventory, θ is the constant

deterioration rate, and $I_s(T)$ is the inventory level so

$$I_s(T) = I_0 (1 - \theta)^T \quad (8)$$

For supplier the inventory level decreases to $(Q-q)$ after first replenishment to the buyer. Hence substituting this value of I_0 in equation (8), capitulate the ending

Inventory level with deteriorating items for supplier as shown in equation (9),

$$I_{Di} = (Q-q) (1 - \theta)^T \quad (9)$$

Further rearranging the terms to receive the value of Q we get

$$Q = \frac{I_{Di} + q(1-\theta)^T}{(1-\theta)^T} \quad (10)$$

For the products which are remanufactured, in the first replenishment the lot of received products, received by the supplier is average, which is λT during the period T from the buyer. Following the process of remanufacturing the perfect quantity for k replenishments (I_{Ri} , $i = 1, 2, \dots, k$) becomes $\lambda T \Phi$ and the scrap quantity turn out to be $\lambda T(1 - \Phi)$. Hence the final inventory after i shipments with deteriorating items is given as shown in expression

$$I_{Di} = \begin{cases} (Q-q)(1-\theta)^T, & i=1, I_1 = I_{D1} + I_{R2} \\ (I_{i-1}-q)(1-\theta), & i=2,3,\dots,k-1, I_i = I_{Di} + I_{Ri} \\ 0, & i=k \end{cases} \quad (11)$$

The suppliers holding inventory with deteriorating item during period T is given by

$$\int_0^T I_s(t) dt = \int_0^T I_0 (1-\theta)^t dt = \frac{[I_0((1-\theta)^T - 1)]}{\log(1-\theta)} \quad (12)$$

Substituting $(Q-q)$ and $(I_{i-1} - q)$ respectively for I_0 Eq.(12), we get the inventory for $i=1$ and $i=2,3,\dots,k$

subsequently as; $\frac{(Q-q)((1-\theta)^T - 1)}{\log(1-\theta)}$ and $\frac{(I_{i-1}-q)((1-\theta)^T - 1)}{\log(1-\theta)}$.

So the cost of holding the inventory with deteriorating items for supplier during decision period which passes through k replenishment will be given by

$$H_s \left[\frac{(Q-q)((1-\theta)^T - 1)}{\log(1-\theta)} + \sum_{i=2}^k \frac{(I_{i-1}-q)((1-\theta)^T - 1)}{\log(1-\theta)} \right] \quad (13)$$

The cost of holding the remanufactured product during the decision period is given by

$$H_R(\lambda T) \Phi K \quad (14)$$

The suppliers total holding cost for deteriorating item and remanufactured product is

$$H_s \left[\frac{(Q-q)((1-\theta)^T - 1)}{\log(1-\theta)} + \sum_{i=2}^k \frac{(I_{i-1}-q)((1-\theta)^T - 1)}{\log(1-\theta)} \right] + H_R(\lambda T) \Phi K \quad (15)$$

For the returned products the process of remanufacturing will start up with the preliminary inspection for perfect products, hence the cost of remanufacturing with perfect ratio Φ is

$$C_R(\lambda T) \Phi K \quad (16)$$

And the cost of scrap processing with imperfect ratio $(1 - \Phi)$ is given by

$$C_c((\lambda T)(1 - \Phi) K \quad (17)$$

During the replenishment period, the cost of deterioration is stated as

$$D_s[(Q - q)(1 - (1 - \theta)^T) + \sum_{i=2}^k (I_{i-1} - q)(1 - (1 - \theta)^T)] \quad (18)$$

So the total cost of inventory for the supplier in replenishment period T will be the sum of ordering Cost, holding cost, deteriorating cost, remanufactured cost, and scrap processing cost. So the total inventory cost of the supplier can be written as per the equation (19).

Total Suppliers, Cost TC_s

$$TC_s = C_s k + H_s \left[\frac{(Q - q)((1 - \theta)^T - 1)}{\log(1 - \theta)} + \sum_{i=2}^k \frac{(I_{i-1} - q)((1 - \theta)^T - 1)}{\log(1 - \theta)} \right] + H_R \lambda T \Phi k + C_R \lambda T \Phi k + C_c \lambda T (1 - \Phi) k + D_s [(Q - q)(1 - (1 - \theta)^T) + \sum_{i=2}^k (I_{i-1} - q)(1 - (1 - \theta)^T)] \quad (19)$$

The supplier total revenue is $TR = pqk$ (20)

3. Cost of life cycle after integration and analysis of Profit

The supplier and buyer profit is equal to the revenue earned by the supplier minus the total costs of buyer and supplier. This total profit is described as total integrated profit (TIP) function which can be represented as:

$$TIP = TR - TC_B - TC_S$$

$$TIP = pqk - \left[C_s k + H_s \left\{ \frac{(Q - q)((1 - \theta)^T - 1)}{\log(1 - \theta)} + \sum_{i=2}^k \frac{(I_{i-1} - q)((1 - \theta)^T - 1)}{\log(1 - \theta)} \right\} + H_R \lambda T \Phi k + C_R \lambda T \Phi k + C_c \lambda T (1 - \Phi) k + D_s [(Q - q)(1 - (1 - \theta)^T) + \sum_{i=2}^k (I_{i-1} - q)(1 - (1 - \theta)^T)] \right]$$

$$\left[C_B k + k H_B \left\{ \frac{b}{\theta^2} (1 - e^{\theta T}) + \frac{1}{\theta^2} (a e^{\theta T} + b T e^{\theta T} - a) - \frac{T}{\theta} (a + b T / 2) \right\} + k D_B \left\{ (e^{\theta T} - 1) \left(\frac{a}{\theta} - \frac{b}{\theta^2} \right) + \frac{b T}{\theta} e^{\theta T} \right\} - (a T + \frac{b T^2}{2}) \right] \quad (21)$$

Where,

$$q = \left((e^{\theta \cdot T} - 1) \cdot \left(\frac{a}{\theta} - \frac{b}{\theta^2} \right) + b \cdot T \cdot \frac{e^{\theta \cdot T}}{\theta} \right) \quad (22)$$

$$Q = \frac{(q - \lambda \cdot T \cdot \phi) \cdot (1 - \theta)^T \cdot (1 - (1 - \theta)^{k-1})}{(1 - \theta)^{k \cdot T} \cdot \theta} - \frac{\lambda \cdot T \cdot \phi}{(1 - \theta)^{k \cdot T}} + q \quad (23)$$

Substituting Q, q in the equation (21) of (total integrated profit function) and writing it as a function of k and T the total integrated profit function can be optimized by taking the first derivative of the same with respect to k and T and setting the partial derivative equal to zero. With help of software Maple, the values received by the authors for k and T are T=.1811(or 66 days approximately) and k=.00063 mentioned in Numerical example. Since keeping T as fixed and taking three integer values for k to implement the solution procedure, we receive the value of profit function as mentioned in next section in table.

4. Numerical example and Results.

$p = 100, C_B = 20, H_B = 50, D_B = 20, C_S = 20, H_S = 150, D_S = 50, C_R = 80, C_C = 20, H_R = 30, \lambda = 15, \phi = .2, \theta = .08, a = 10000, b = 400, T = 0.1811, k = 0.0063$

T	K	TIP
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66	1	$1.408254 * 10^5$
66	2	$4.104199 * 10^5$
66	3	$8.452021 * 10^5$

Table - 1: Integrated Profit

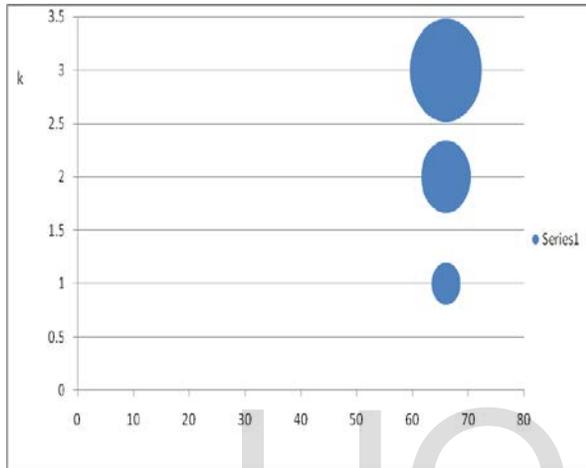


Fig 2: Profit representation in Bubble diagram

5. Summary, Conclusion and future scope

As shown in the table, after getting the results for total integrated profit, it is concluded that for a fix time cycle if the demand is increasing linearly with time, rather than adopting for more new production setups the customer demand should be satisfied by reworking upon the returned products.

This can be put into practice by frequently replenishing the inventory of buyer by the supplier with right information sharing for market demand. Some of the best possible ways are to collect the products to be reworked in shorter time span and reduce the waste of any short term used products.

Frequent replenishing for a fix cycle will increase the total profit which may be distributed accordingly among the buyer and supplier and will reduce the waste to integrate Green across supply chain.

Though the result of this paper can provide better insights to the managers for adopting Green across the supply chain still the future research can be extended by allowing shortages or by changing the nature of demand which is not always linear for a fix time cycle.

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