A note on life cycle analysis of electronic Products for exponential Demand with Negative Slope

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ABSTRACT: In previous years management of supply chain has emerged as a feed forward approach to improve environment related performance of products and processes in lieu of the requirement of environmental regulations. As per the type of products and services, as well as the their life, different approaches has been followed to obey the pressure from WEEE (Waste electrical and electronic equipment), ROHS (restriction of hazardous substances), EUP (Eco design requirements for energy using products) kind regulatory bodies and increasing number of countries as well as customers begin requirement of qualitative green products, so the need of the hour is to supply environmental friendly products. The production of environmental friendly products has further extended its wings by introducing the re-use and recycles of used products to save the environment as much as possible and reduces the cost of manufacturing processes by maximum utilization of e-waste which is becoming a trouble on the mother earth. This paper is an extension of the work, previously done by same the authors in a manner that what will be the impact on total integrated profit, if the demand of the products is satisfied by the reusable and recycle products when the demand is exponential with negative slope because in most of the electronic products cases, the demand exponentially decrease for a time period T and then the product become obsolete from the market. The ensuing of this research paper can be used to employ the concept of green across supply chain of electronic industry products, and ratios of profit can be improved by reducing the cost of products between supplier and buyer.

KEY WORDS: Supply chain Management, Green supply chain, cost benefit analysis, Production, Inventory, JIT (Just in time), VMI (Vendor managed Inventory), WEEE (waste electrical and electronic equipment), ROHS (restriction of hazardous substances).

1. INTRODUCTION

As per the necessity of different countries both from developed and developing world, the need of quality green products is the need of hour and incorporating the concept of green across the supply chain has become an escalating challenge for most of the organizations. Though people are aware that the environmental problem has spread across the globe with various fancy names like tco_2 emissions, carbon credit, 350 ppm, etc. steps taken to respond for green products by different greening principle to their companies were adopted by various organizations in various forms like use of environmental friendly raw materials, reducing the use of power, using the recycled papers for packaging, (Beamon, B.M., 1999, Mittal, et al., 2010). (Lamming and Hampson, 1996) proposed that balance should be there between environment utilizing practices and product design, waste management, product stewardship etc. Initially supply chain managers kept the effect of their decisions only on the Environment safety chain management (ESCM) or Green supply chain management(GSCM) along with conventional dimensions of low cost , quality, delivery technology (Kumar,Malegeant,2006); (Tsolfas and Pappies, 2006); (Boons, 2002); (Sharat and Choong,2002); (Geuffrey, et al,. 2002,Zisdin and Sifered, 2001); (Jacqueline et al,. 1995). Green supply chain management has also been explained on a broader note as a

Pappies, 2006); (Boons, 2002); (Sharat and Choong,2002); (Geuffrey, et al,. 2002,Zisdin and Sifered, 2001); (Jacqueline et al,. 1995). Green supply chain management has also been explained on a broader note as a term which helps different companies to improve the environment related performance of their products and processes, along with using green raw material, semi-finished goods with the help of their supplier. As a result this GSCM cannot be defined as a single track of business rather it's a combination of multiple businesses which should synchronize their relationship as much as possible to work for environmental betterment with various parameters like coordination among players, sharing of information, minimization of waste etc.

Initially European Union directed, how to follow green supply chain from a very close corner, sooner it also described WEEE directives for manufacturers to take initiative for collecting, treating, reviewing, reusing as well as appropriately disposing the waste (EU, 2003), which is further known as EPR (extended procedure responsibility) as per the literature of (Spicer and Johnson, 2004). In the traditional supply chain where buyers and suppliers used to take independent decisions for following "I win-you lose" or Silo mentality but the increase awareness about environment and research in the various sub corners of the supply chain models are showing different conduit like JIT, VMI etc. This study focuses how reusable and reworked products can be used for attaining more profits and minimizing production costs to satisfy the demand of the customer when the demand is a negative exponential function of time for a complete cycle. The organization of the paper is as follow

Section: 1 Is the Introduction.

Section: 2 Describes the modeling and investigation of the study with different used assumptions, notations and steps to develop the same.

Section: 3 Describes the total integrated profit and solution procedure to get the values of k and T with maple.

Section: 4 Throws light upon the results drawn from this model with numerical example and describes the various values of profit function.

Section: 5 Sums up the results and gives a closing remark along with the further extension of the work.

2. MODELLING AND ANALYSIS

In general the outline of the electronic products which are returned by the buyer after using for a short time period is as shown in the figure (1) adapted from (Koh et al 2002)

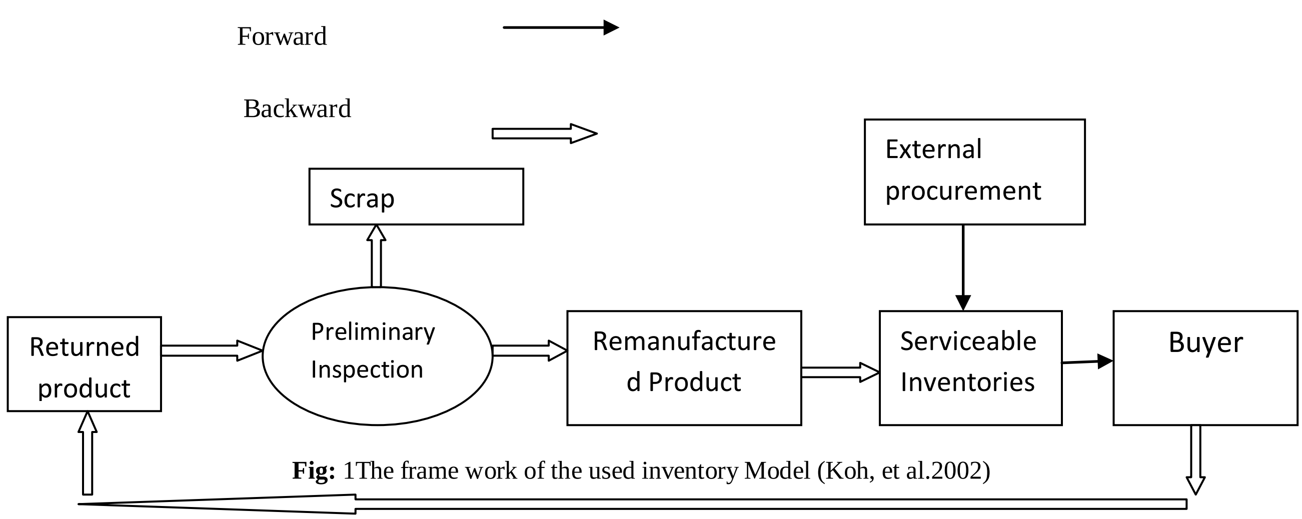

Fig: 1The frame work of the used inventory Model (Koh, et al.2002)

2.1 Assumption and Notations.

Different assumptions and notations used in this paper are mentioned below

Assumptions

a) This model has single supplier and single buyer.
b) The demand rate is exponential function of time.
c) Buyer order interval is constant.
d) The rate of deterioration is constant θ, $0 \leq \theta \leq 1$.
e) The returned products which supplier/buyer receives assure the poison distribution.
f) Shortage and back ordering is not allowed.

Notations

q = order quantity for buyers

k = is replenishment frequency between supplier and buyer which is a positive integer

Value

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 an exponential manner with decaying slope for a specific product

The different notations used by supplier are

C_S = Ordering cost of the supplier per order

H_S = Holding cost of the supplier per unit per unit time

D_S = Deteriorating cost of the supplier per unit

I_{Di} = Inventory level after i shipment for i = 1, 2 …k

TC_s = Total life cycle cost

p = Selling price per unit.

TR = Supplier total revenue

The different notations used in reverse supply chain are

C_R = Supplier's remanufacturing cost per unit

C_C = Supplier's scrap processing cost per unit

H_R = Holding cost of remanufactured items per unit per unit time

λ = Product return rate 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…, k

The buyer and supplier notation are

TIP = the supplier and buyer total integrated profit function

T =kt is the cycle for which the demand is visualized.

θ=deterioration rate

$D = ae^{bt}$ Where b is the slope which is negative

I_S (T) = $I_0 (1-\theta)^T$ (1)

For supplier the inventory level decreases to (Q-q) after the first replenishment to the buyer so substituting I_0 in equation (1), resultant provides ending inventory level with deteriorating items as shown in equation (2)

I_{Di} = (Q-q) $(1-\theta)^T$ (2)

Splitting up and rearranging the terms of equation (1) and (2) to receive the value of Q we get

$$Q = \frac{I_{Di}+q(1-\theta)^T}{(1-\theta)^T} \quad (3)$$

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 I_{Ri}, i= 1, 2…k) becomes λTΦ and the scrap quantity becomes λT (1- Φ). Hence the final inventory after i shipments with deteriorating items is given as shown in equation (4). I_{Di} =

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

(4)

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

2.2 Vendor supplier Inventory Model

For the case of vendor / (supplier) the inventory at the end of period T will be described as shown in equation (1), where I_0 is the initial inventory level at time T, θ is the deterioration rate constant and the inventory level at T is I_S (T) described as (Ghare and Schrader, 1963).

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

(5)

Substituting (Q-q) and ($I_{i-1} - q$) for I_0 in the equation (5) respectively we get, the values of inventory levels for i=1 and i=2, 3, k consequently as

$$\frac{(Q-q)(1-\theta)^T - 1}{\log(1-\theta)} \text{ and } \frac{(I_{i-1}-q)(1-\theta)^T}{\log(1-\theta)}$$

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

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

(6)

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

$H_R(\lambda T)\Phi k$ (7) Hence

The suppliers total holding cost for deteriorating item and remanufactured product can be illustrated as

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

$$H_R(\lambda \mathrm{T})\Phi \mathrm{k} \quad (8)$$

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

$$C_R(\lambda \mathrm{T})\Phi \mathrm{k} \quad (9)$$

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

$$C_c\left((\lambda \mathrm{T})(1-\ \Phi)\ \mathrm{k} \quad (10)\right.$$

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

$$D_S\left[(Q-q)\left(1-(1-\theta)^T\right)\right)+\sum_{i=2}^{k}(I_{i-1}-q)\left(1-(1-\theta)^T\right)\Big)\Big]$$
(11)

The total cost of inventory for the supplier in replenishment period T will be the sum of ordinary 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 (12).

Total Supplier`s Cost TC_s

$$TC_s = C_s k + H_s\left[\frac{(Q-q)((1-\theta)^T-1)}{\log(1-\theta)}+\sum_{i=2}^{k}\frac{(I_{i-1}-q)((1-\theta)^T-1)}{\log(1-\theta)}\right]+H_R\lambda \mathrm{T}\Phi \mathrm{k}+\mathrm{C_R}\lambda \mathrm{T}\Phi \mathrm{k}+$$
$$\mathrm{C_c}\lambda \mathrm{T}(1-\Phi)\mathrm{k}+\mathrm{D_s}\left[(\mathrm{Q}-\mathrm{q})\left(1-(1-\theta)^{\mathrm{T}}\right)+\sum_{i=2}^{k}(\mathrm{I}_{i-2}-\mathrm{q})\left(1-(1-\theta)^{\mathrm{T}}\right)\right]$$
(12)

The supplier’s total revenue is $TR = \ pqK$. (13)

2.3 The buyer inventory model will be

The buyer’s inventory model for deteriorating items with exponential demand having negative slope can be written as per the developed model for deteriorating items by (Ghare and Schrader, 1963).The inventory level for the buyer at time t can be explained as

$\frac{dI_b(t)}{dt} = -ae^{bt} - \theta I_b(t)$, 0<t<T where ae^{bt} is

demand exponential in nature The solution of the differential equation with boundary condition

$I_B(t) = 0$ is referred to as (Bronson and Costa, 2006), So the level of inventory for the buyer is given by ,

$$I_b(t) = \frac{-ae^{bt}}{(b+\theta)} + (a)\frac{e^{(b+\theta)T-t\theta}}{b+\theta} \quad (14)$$

$$at \quad t=0 \ , I_b(0) = q \quad so$$

$$I_b(0) = q = \{\left(\frac{a}{b+\theta}\right)\left\{e^{(b+\theta)T} - 1\right\}$$

(15)

The buyers holding inventory during period 0 to T is given by

$$\int_0^T I_b(t)dt = \int_o^T\left\{\left(\frac{-ae^{bt}}{(b+\theta)}\right)+\left(\frac{ae^{(b+\theta)T-\theta t}}{(b+\theta)}\right)\right\}dt$$

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

Hence the holding cost of buyer will be

$$\left[H_B.k\left\{\frac{a}{b(b+\theta)}\left(1-e^{bT}\right)+\frac{ae^{(b+\theta)T}}{\theta(b+\theta)}\left(1-e^{\theta T}\right)\right\}\right]$$
(16)

The buyer's deteriorating inventory will be

$$q-\int_0^T ae^{bt}\,dt$$

$$q-\frac{a}{b}\{e^{bT}-1\}=\left[\frac{a}{b+\theta}\{e^{(b+\theta)T}-1\}-\frac{a}{b}\{e^{bT}-1\}\right]$$
(17)

So the buyer's deteriorating inventory during period 0 to T can be written as

$$\left[D_B.k\left\{\frac{a}{b+\theta}\left(e^{(b+\theta)T}-1\right)-\frac{a}{b}\{e^{bT}-1\}\right\}\right]$$
(18)

So, the total cost of the buyer's will be

TC_B= (ordering cost + holding cost + deteriorating cost)

$$TC_B=\left[C_B.k+H_B.k\left\{\frac{a}{b(b+\theta)}\left(1-e^{bT}\right)+\frac{ae^{(b+\theta)T}}{\theta(b+\theta)}\left(1-e^{\theta T}\right\}\right.\right.$$
$$\left.+D_B.k\left\{\frac{a}{b+\theta}\left(e^{(b+\theta)T}-1\right)-\frac{a}{b}\{e^{bT}-1\}\right\}\right]$$

(19)

3. Calculations for Integrated profit Analysis and Life Cycle Cost .

As per the trading terms, after calculating total cost of supplier and buyer the distribution of profit between buyer and supplier can be obtained by subtracting their total costs from the revenue earned by them which is termed as the total integrated profit (TIP) function by the authors and represented as

$$TIP = TR - TC_B - TC_S$$

$$pqk-$$
$$\left[C_B.k+D_B.k\left\{\frac{a}{b+\theta}\left(e^{(b+\theta)T}-1\right)-\frac{a}{b}\{e^{bT}-1\}\right\}+H_B.k\left\{\frac{a}{b(b+\theta)}\left(1-e^{bT}\right)+\frac{ae^{(b+\theta)T}}{\theta(b+\theta)}\left(1-e^{\theta T}\right\}\right]\right.$$
$$\left[C_S k+H_S\left\{\frac{(Q-q)((1-Q)^T-1)}{in(1-Q)}+\sum_{i=2}^{k}\frac{(I_{i-1}-q)((1-Q)^T-1)}{n(1-Q)}\right\}+H_R.\lambda T o K+C_R.\lambda T\emptyset k+\right.$$
$$\left.C_C\lambda T(1-\emptyset)k+D_S\{(Q-q)(1-(1-\theta)^T)+\sum_{i=2}^{k}(I_{i-1}-q)(1-(1-\theta)^T\}\right]$$
(20)

Where, $q=\left\{\left(\frac{a}{b+\theta}\right)\{e^{(b+\theta)T}-1\}\right\}$ (21)

$$Q=\frac{(q-\lambda\cdot T\cdot\phi)\cdot(1-\theta)^T\cdot\left(1-(1-\theta)^{k-1}\right)}{(1-\theta)^{k\cdot T}\cdot\theta}-\frac{\lambda\cdot T\cdot\phi}{(1-\theta)^{k\cdot T}}+q$$
(22)

Substituting Q, q in the equation (20) from equations (21) and (22) respectively and writing this equation as a function of k and T, to receive the optimal value of total integrated profit function by taking its first derivative with respect to k & T and putting the partial derivative equal to 0.This calculation is done with help of software Maple, and the values received by the authors for k and T are T=0.3614(132 days approximately) and k = 3.5875 as 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.

$$p = 100, C_B = 20, H_B = 50, D_B = 20, C_S = 20, H_S = 150, D_S = 50, C_R = 80, C_C = 20, H_R = 30, \lambda = 15, \phi = .2, \theta = .08, a = 1000, b = -4, T = 0.3614, k = 3.5875$$

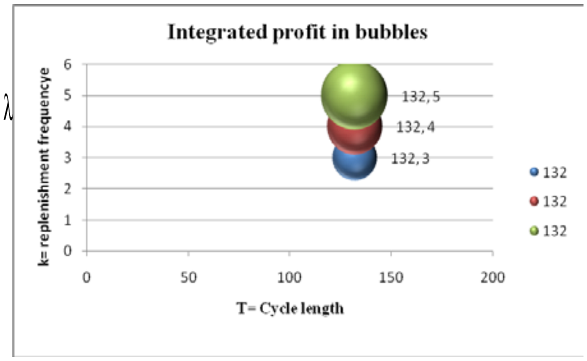

Fig 2: Integrated Profit

Table 1: Total Integrated Profit for different values of K

T	K	TIP
132	3	37773
132	4	58196
132	5	84221

5. Conclusion and Future scope.

- As per the statistics of table, received from numerical example, it is concluded by the authors that for a fix time period if the demand is increasing exponentially with negative slope, instead of doing more production it should be satisfied by the reverse chain products by minor reworking or reusing their dissembled parts specially for electronic products because their life span is very flickering.
- This implementation can be done by doing regular replenishments for the fix length of cycle time, which is possible by exact and appropriate sharing of information among buyer and supplier and by doing this; the increment in profit amount can be shared in between buyer and supplier.
- This will further boost the concept of Green across whole supply chain and will reduce waste in various industries especially for electronic and electrical products which is increasing very fast in Asian region.
- Though the resultant of this model can provide better insights to the managers of the electronics and electrical products still the future research can be extended by allowing shortages in the same.

References

1. Bronson, R., & Costa, G.B. (2006). Differential Equations Schaum`s Outline series. (3rd ed.) McGraw Hill.

2. Ghare, P.N. & Schrader G.F. (1963). A model for exponentially decaying inventories. *Journal of Industrial Engineering*, 15, 238-243.

3. Goyal, S.K. & Giri, B. C. (2001). Recent trends in Modeling of deteriorating inventory. *European Journal of operations research*, 123, 1-16.

4. Guide, Jr., V.D.R., Van,W.& L.N. (2002). The reverse supply chain. *Harvard business review*, 80 (2), 25-26.

5. Koh, S.G., Hwang, H., Sohn, K.I., & KO, C.S., (2002). An optimal ordering and recovery policy for reusable items. *Computers & Industrial Engineering*, 43, 59-73.

6. Konstantaras, I., & Papachristos, S. (2008). An optimal ordering and recovery policy for reusable items. *Computers & Industrial Engineering*, 55, 729-734.

7. Konstantaras, I., Skouri, K., & Jaber, M.Y. (2010). Lot sizing for a recoverable product with inspection and sorting. *Computers & Industrial Engineering*, 58, 452-462.

8. Mittal, R., Abbasi, H., & Pareek, S. (2012). Supply Chain Integration in Vendor managed inventory. *Journal of Supply Chain Management Systems*, 1 (2), 56-63.

9. Ning, L., Youngjoo, K., & Hark, H. (2009). An optimal operating policy for the production system with rework. *Computers & Industrial Engineering*, 56, 874–887.

10. Parlor, M., (2000). Interactive operations research with maple: Methods and Models Birkausher Boston.

11. Piet, V.D., Kuik, R., & Verheijen, B. (2007). Note on supply chain integration in vendor-managed inventory. *Decision Support Systems* 44, 360 – 365.

12. Roy, A., Maity, K., Kaur, S., & Maiti, M. (2009). A production–inventory model with remanufacturing for defective and usable items in fuzzy-environment. *Computers & Industrial Engineering* 56, 87–96.

13. Silver, E.A., Pyke, D.F., & Peterson, R. (1998). Inventory Management and production planning and scheduling. (3rd edition), John Willey & Sons New York.

14. Wang, W.T., Wee, H.M., & Tsao, H.S.J. (2010). Revisiting the note on supply chain. Decision Support System, 419-420

15. Wee, H.M., Lee, M.C., Yu, J.C.P. & Wang C.E. (2009) .Life Cycle analysis to improve operations and supply chain management of green electronic products. Proceedings of Sixth Australian conference on life cycle assessment.

16. Yao, Y., Evers P.T., & Dresner, M.E.(2009). Supply chain integration in Vendor-managed inventory. *Decision-Support Systems*, 43,663-674.

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