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Research paper

A Deterministic Model for Remanufacturing Inventory for Reverse Supply Chain

Sasmita Mohapatra[1]*, R.N.Mahapatra[2], , B.B.Biswal[3],Bunil Balabantray[4] A.K.behera[5]

[1,5]*Siksha 'O' Anusandhan University INDIA*
[2, 3,4]*National Institute of Technology Meghalaya INDIA*
**Corresponding author E-mail: rnmahapatra@nitm.ac.in*

Abstract

Reverse logistics is a pervasive business activity. Companies spend a lot of time and money in fine tuning their forward supply chain while ignoring the reverse supply chain. Conventional supply chain processes, driven by customer demand which carry goods from suppliers through manufacturers and distributors to the final customers. Physical goods don't simply vanish once they have reached the customer. In today's trend reuse of products and materials (repair, remanufacturing, refurbishing and recycling) and recovering value incorporated in them is a common phenomenon. The paper deals with controlling inventory for a remanufacturing system in which the stationary demand is fulfilled by remanufactured products as well as newly purchased products. The model is based on the assumption that customer return items are remanufactured at a fixed rate. Remanufactured items can be treated as the new products. The economic order quantity for the manufactured and remanufactured items is calculated simultaneously.

***Keywords**: Reverse supply chain, Remanufactured, Inventory control, Economic order quantity, Optimization.*

1. Introduction

Since the early 1980s logistic as well as supply chain management has received a lot of attention. Traditionally, companies have focused on improving the forward supply chain for their products (e.g., manufacturer-wholesaler-retailer). In today's world reverse logistic cannot be treated as an afterthought. Now companies realize that properly understanding and managing their reverse logistic can not only reduce cost but also increase revenues. It can also make a huge difference in retaining consumer loyalty and protecting the brand. Capturing the potential benefits begins by clearly understanding the nature of reverse logistic. Reverse logistics practices have been around for a long time, like automotive industry, where manufacturers are trying to recover value from recycling automotive part. Serge et al. (2011) developed a conceptual frame work, considering seven important elements of reverse logistic system i.e. coordinating system, gate keeping, collection, sorting, processing or treatment, Information system and disposal system and tested the proposed frame work on different companies. Francisco et al. (2013) explained about the benefit of acquiring raw materials through the application of reverse logistic. The case study method is used to test the impact of independent variables on raw material procurement variables and involves multiple regression techniques. Rehman et al (2017) introduced the significance of reverse logistics in the area of supply chain, mostly focusing over the automobile industry, with an objective to maximize the economic value for the automobile companies that reflects the importance of reverse logistics. Baz et al (2018) studied the reverse supply chain and the bottle neck related to it with the help of a qualitative approach, considering remanufacturing, refurbishing and disposal processes. Jonrinaldi et al. (2013) proposed a mathematical model to represent the behaviors of the system. Semi-centralized decision-making process were proposed to solve the model while the centralized decision-making process was solved by a nonlinear programming method.

Sonia et al. (2013) developed a mixed integer linear programming (MILP) formulation for the design and planning of reverse flow supply chains while simultaneously considering production, distribution and reverse logistics activities.

2. Objective

The objective of this paper is only to follow the remanufacturing process of product recovery for the closed loop supply chain. To optimize the level of products both from direct manufacturing as well as the remanufacturing is the main aim. An orthodox reverse supply chain model with remanufacturing is shown in fig-1. The solid lines and dotted lines show the forward supply chain and the reverse supply chain respectively. It is worth of noting that, the output of both direct manufacturing and remanufacturing contributes to the finished product inventory. The other recovery processes like reuse, repair, refurbish and cannibalization are not being included for this model.

The methodology includes the calculation of the total cost considering both cycles as shown in fig.2. Considering the assumed parameters and applying partial differential method to optimize the total cost, this model tries to find out the optimum level of newly produced or procured products and optimum level of remanufactured products.

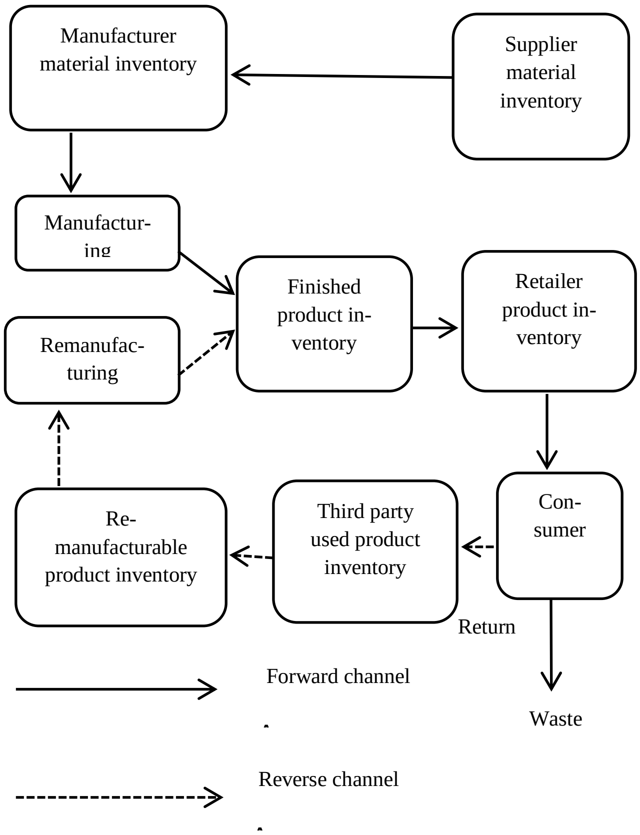

Fig. 1: Model for direct manufacturing and remanufacturing

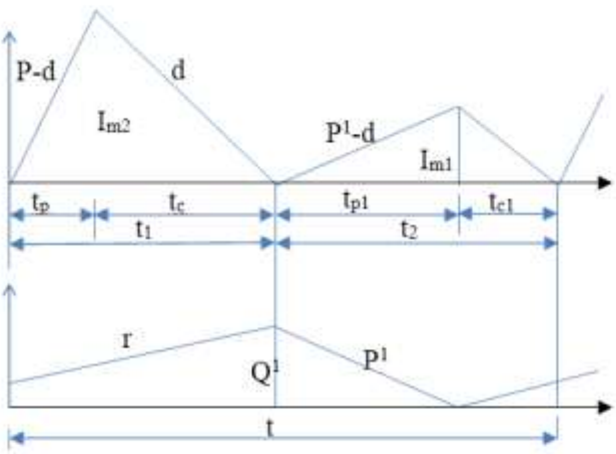

Fig. 2: Inventory model for direct manufacturing and remanufacturing

3. Notations

Known Parameters:
d Number of items required/unit time (demand rate)
p: Number of items required/unit time (production rate)
p^1: number of items remanufactured/unit time (Remanufacturing rate)
C1: Cost of holding inventory/ item unit time
C2: Set up cost for production run for remanufacturing
C3: Cost of setting up a production from raw materials
Q: Number of items manufactured / run
Q^1: Number of items remanufactured/ run
t_1: Time interval for the production run from raw materials
t_2: Time interval for the remanufactured items

r: Rate of collecting return item
The inventory buildup during the time period t_p is I_m

$$Im = (p-d)\times t_p$$

$$\Rightarrow t_p = \frac{Im}{(p-d)}$$

Q is the amount of items manufactured for the time period t_p and Q is the quantity consumed during the same period is d xt_1.

$$Q = d\times t_1$$

$$\Rightarrow t_1 = \frac{Q}{d}$$

$$Q = p\times t_p$$

$$\Rightarrow t_p = \frac{Q}{p}$$

Holding cost per production run i.e. for the time period t_1 is = $\frac{1}{2}\times Im\times t_1\times C_1$

Set up cost per production run = C_3

The total cost for the production of finished goods from the raw materials

$$= \frac{\left(\frac{1}{2}\times Im\times t_1\times C_1 + C_3\right)}{t_1}$$

$$= \frac{1}{2}\times Im\times C_1 + \frac{C_3}{t_1}$$

$$= \frac{1}{2}(p-d)\times t_p + \frac{C_3}{(Q/d)} = \frac{(p-d)\times Q\times C_1}{2p} + \frac{d\times C_3}{Q}$$

The remanufactured items processed at a rate of p^1. So the inventory buildup during the time period $t_p{}^1$

$$Im^1 = (p^1 - d)\times t_p{}^1$$

The quantity produced during the time period $t_p{}^1$ is Q^1,

$$t_p{}^1 = \frac{Q^1}{p^1}$$

$$Im = (p^1 - d)\times\frac{Q^1}{p^1}$$

The holding cost for this is for the time period t_2 is

$$\frac{\frac{1}{2}\times Im^1\times t_2\times C_1}{t2} = \frac{1}{2}\times Im^1\times C_1$$

$$= \frac{(p^1-d)\times Q^1\times C_1}{2p^1}$$

Remanufacturing cost for the proposed model can be calculated as:
The rate of collection of material is r, and the inventory buildup time is t_i. The quantity produced during the time t_i is Q^1.
So

$$Q^1 = r \times t_i$$

$$\Rightarrow t_i = \frac{Q^1}{r}$$

The rate of production is p^1 and to produce the desired material from Q^1 quantity of raw material takes t_p time.

So

$$Q^1 = p^1 \times t_p$$

$$\Rightarrow t_p = \frac{Q^1}{p^1}$$

Total cycle time is t and

$$t = t_i + t_p$$

$$\Rightarrow t = \frac{Q^1}{r} + \frac{Q^1}{p^1} = Q^1(\frac{1}{r} + \frac{1}{p^1}) = Q^1 \times (\frac{p^1 + r}{P^1 \times r})$$

To calculate the remanufacturing cost per unit time

$$= \frac{(\frac{1}{2} \times Q^1 \times t \times C_1 + C_2)}{t} = \frac{1}{2} \times Q^1 \times C_1 + \frac{C_2}{t}$$

$$= \frac{1}{2} \times Q^1 \times C_1 + \frac{C_2 \times (p^1 r)}{Q^1 \times (p^1 + r)} \text{.......................}(3)$$

Total Cost per unit time Tc = Eq (1) +Eq (2) + Eq (3)

$$= \frac{(p-d) \times Q \times C_1}{2p} + \frac{dC_3}{Q} + \frac{(p^1 - d) \times Q^1 \times C_1}{2p^1}$$

$$+ \frac{1}{2} \times Q^1 \times C_1 + \frac{C_2(p^1 \times r)}{Q^1(p^1 + r)}$$

For minimum value total cost (T)

$$\frac{dT_c}{dQ} = 0$$

$$\Rightarrow \frac{(p-d) \times C_1}{2p} - \frac{d \times C_3}{Q^2} = 0$$

$$\Rightarrow \frac{d \times C_3}{Q^2} = \frac{(p-d) \times C_1}{2p}$$

$$\Rightarrow Q^2 = \frac{2p\,dC_3}{(p-d)C_1}$$

$$\Rightarrow Q = \sqrt{\frac{2p\,dC_3}{(p-d)C_1}}$$

and,

$$\frac{dT_c}{dQ^1} = 0$$

$$\Rightarrow \frac{(p^1 - d)C_1}{2p^1} + \frac{1}{2} \times C_1 - \frac{C_2(p^1 \times r)}{Q^{1^2}(p^1 + r)} = 0$$

$$\Rightarrow \frac{(p^1 \times r)C_2}{Q^{1^2}(p^1 + r)} = \frac{(p^1 - d) \times C_1}{2p^1} + \frac{1}{2} \times C_1$$

$$\Rightarrow \frac{1}{Q^{1^2}} = \frac{(2p^1 - d) \times C_1}{2p^1} \times \frac{(p^1 + r)}{(p^1 \times r \times C_2)}$$

$$\Rightarrow Q^1 = \sqrt{\frac{2p^{1^2} \times r \times C_2}{(2p^1 - d)(p^1 + r)C_1}}$$

The above model can be a substitute to the existing model where the demand rate is uniform.

4. Results and Discussion

The above discussed model can be substitute to the existing model where the demand rate is uniform, production rate is finite and the shortages allowed. Considering the following example this will be clear.

Example:

A company has a demand of 12000units/year for an item and it can produce 2000 such items per month. The cost of one set up is Rs 400 and the holding cost/unit/month is 0.15.It is to find out the total cost per year, assuming the cost of 1 unit as Rs.4. The shortage cost of one unit is Rs.20 per year.

For this problem,
P=2000*12=24000units/year
d=12000/year
C1=0.15*12=Rs 1.8/unit/year
C3=Rs.400/setup
S= shortage cost=Rs 20/year

The total cost

$$= 12000 \times 4 + \sqrt{2 \times C1 \times C3 \times d} \times \sqrt{\frac{S}{C1 + S}} \times \sqrt{\frac{(p-d)}{p}}$$

$$= 48000 + \sqrt{2 \times 1.8 \times 400 \times 12000} \times \sqrt{\frac{20}{20 + 1.8}} \times \sqrt{\frac{24000 - 12000}{24000}}$$

$$= \text{Rs.}50{,}185 / \text{year}$$

Now solving the problem with our model with remanufacturing
For this we have to consider another three parameters like
Remanufacturing rate p1=1100/month
Rate of collection of recycle material r = 33% of demand rate=
$0.33 \times 12000 = 3960 \, units / year$

C2 is the remanufacturing cost which is much less than the manufacturing cost which is = Rs.200/ setup

Putting these to find out Q and Q^1

$$Q = \sqrt{\frac{2pdC_3}{(p-d)C_1}}$$

$$= \sqrt{\frac{2 \times 24000 \times 12000 \times 400}{(24000 - 12000) \times 1.8}}$$

$$= 3266 \, units$$

Similarly

$$Q^1 = \sqrt{\frac{2{p^1}^2 \times r \times C_2}{(2p^1 - d)(p^1 + r)C_1}} =$$

$$= \sqrt{\frac{2 \times (13200)^2 \times 3960 \times 200}{(2 \times 13200 - 12000)(1100 + 3960) \times 1.8}}$$

$$= 1451 units$$

So the total cost using remanufacturing

$$= (8309 \times 4) + (3691 \times 2) + \frac{(p - d) \times Q \times C_1}{2p}$$

$$+ \frac{dC_3}{Q} + \frac{(p^1 - d) \times Q^1 \times C_1}{2p^1} + \frac{1}{2} \times Q^1 \times C_1$$

$$+ \frac{C_2(p^1 \times r)}{Q^1(p^1 + r)}$$

$$= 33236 + 7382 + 1469.7 + 1469.69 + 118.71$$

$$+ 1305.9 + 419.87$$

$$= \text{Rs}.45401.87$$

So the total savings is

$$\text{Rs}.50,185 - \text{Rs}.45401.87 = \text{Rs}.4783.13$$

This is clear from the above model that the model with remanufacturing provides less total cost. Therefore this model can be recommended.

5. Conclusion and future scope

The scope and application of the reverse supply chain is actually too big to discuss. This paper is just one step in remanufacturing part of the reverse supply chain. The model discussed took into account the remanufacturing aspect of the reverse supply chain with the implementation of a mathematical model. The calculation of the optimum quantity for remanufactured products and directly manufactured products is justified by a simple numerical example.

The future analysis of the model is necessary to explore more about this topic. This can be taken as a base model for the probabilistic model in the field of reverse supply chain with remanufacturing. Different dimensions can be added like recycling, refurbishing etc. to this model to study the feasibility.

References

[1] Lambert S,Riopel D,Kader WA, "A reverse logistics decisions conceptual framework", *Computers & Industrial Engineering*,Vol. 61, No.3, (2011),pp. 561–581. https://doi.org/10.1016/j.cie.2011.04.012

[2] *Rodrı´guez FJG,Gutie CC,Flores CB, "Implementation of reverse logistics as a sustainable tool for raw material purchasing in developing countries: The case of Venezuela", Int. J. Production Economics,Vol.141,(2013),PP.582–592,* http://dx.doi.org/10.1016/j.ijpe.2012.09.015

[3] Rehman SA,Zhang YU,Khan SS, "Reverse Logistics and Challenges: Supply Chain Management of Automobile Industry", *Advances in Applied Sciences*,Vol.2,No.5,(2017),pp.80-86.https://doi: 10.11648/j.aas.20170205.15.

[4] Baz JEI, Frei R,Laguir I, "Reverse supply chain practices in developing countries: the case of Morocco", *Journal of Manufacturing Technology Management*, Vol.29, (2018),No. 1, pp.198-216, https://doi.org/10.1108/JMTM-04-2017-0068.

[5] Jonrinaldi J, Zhang D, An integrated production and inventory model for a whole manufacturing supply chain involving reverse logistics with finite horizon period",*Omega*,Vol.41, No. 3 (2013),pp. 598-620,https// DOI: 10.1016/j.omega.2012.07.001.

[6] Cardoso SR,Barbosa Pova APFD,Relvas S, "Design and planning of supply chains with integration of reverse logistics activities under demand uncertainty" *European Journal of Operational Research*,Vol.226,No.3(2013),pp.436-451, https://doi.org/10.1016/j.ejor.2012.11.035