An Extension of Product Life Cycle in Closed-Loop Supply Chain Management System through Product Remanufacturing

Sandipa Bhattacharya [a*] and Seema Sarkar (Mondal) [b]

[a] *Research Scholar*
Department of Mathematics
National Institute of Technology, Durgapur
Mahatma Gandhi Avenue, West Bengal-713209, India

[b] *Professor*
Department of Mathematics
National Institute of Technology, Durgapur
Mahatma Gandhi Avenue, West Bengal-713209, India
** Corresponding Author*

ABSTRACT

A manufacturing system has the capability of product manufacturing and remanufacturing activities to capture the value of the product life cycle after the use of it. The remanufacturing activity can extend the product life cycle after the use of it. The integration of product manufacturing and remanufacturing activities in an entire supply chain management system is known as a closed-loop supply chain network. In this paper, a closed-loop supply chain network model is designed with a single product that consists of a single plant, single demand market, single collection center and a single disposal center. The objective of this model is to minimize the total cost of the entire supply chain network. Some optimization techniques are applied in our model as a method of solution. Finally, the computational results are compared with the two optimization techniques.

Keywords: Manufacturing activity, Remanufacturing activity, Closed-loop supply chain, Product life cycle.

I. Introduction

A manufacturer tries to attempt to recover the value of the residuals of their used products through remanufacturing. Most of the researchers focused on the forward supply chain strategy to optimize their supply chain management system. However, the recovery of the product means to minimize the returned product from the demand market. The objective of the remanufacturing of the product is to extend the life cycle of the product and to recover the value of the product to be reused. The returned product will get back to its new state through the remanufacturing procedure. Therefore, there is a necessity to redistribute the product in a reverse flow direction for an environmental aspect like a forward flow direction in the closed-loop supply chain network.

A general policy is developed in Hill (1997) for a single-vendor, single-buyer production inventory management system. The model is developed depending on the successive shipments of a production batch size.
The life extension of the product offers the economic and environmental benefits in an application of the industries in Linton and Jayaraman (2005). They proved that the product life extension increases the economic value simultaneously it reduces the environmental impact of a product.

Total cost is not only an objective function in Salema et al. (2007). They considered multi-objective functions in their supply chain model. They extended their model to a reverse logistics scenario. In this paper, they introduced uncertainty in customer demand and the returned product. They applied a mixed-integer linear programming technique in their model.

A two-stage stochastic programming model for a closed-loop supply chain network is developed in Lee and Dong (2009). Simulated annealing is introduced as a method of solution in its supply chain model.

Optimum usage of secondary lead batteries is recovered from the used batteries in Kannan et al. (2010). The objective of this model is to develop a multi-echelon, multi-period, multi-product closed-loop supply chain model and they determine the number of product distribution, the number of product recycle and the number of product disposal. In this paper, they applied genetic algorithm as a method of solution to solve the mixed-integer linear programming model.

Vahdani et al. (2012) developed a multi-objective closed-loop supply chain model in an uncertain environment. In this paper, they introduced a robust optimization technique to configure the closed-loop supply chain network.

Manufacturing, remanufacturing, transport warehousing closed-loop supply chain model is developed in Turki et al. (2017). The objective of this model is to minimize the total cost function of the entire supply chain model. An optimization technique based on a genetic algorithm is introduced to solve the model.

A two-stage stochastic model in a closed-loop supply chain network is developed in Fard et al. (2017). The objective of this model is to reduce the expected total cost and the downside risk simultaneously. They applied some optimization techniques like genetic algorithm, particle swarm optimization technique as a solution methodology. The model is verified with a real-life example.

In Gu et al. (2018), a three-period electric vehicle battery recycle and reuse in a closed-loop supply chain model is developed with the purpose of energy storage in a future aspect. In this paper, they compared the consumption of raw material of the new battery manufacturing with battery recycling and reusing battery. The objective of this model is to maximize the total profit in the entire supply chain model in different period of battery use.

Single manufacturer and single retailer closed-loop supply chain model is developed in Song Q-n(2018). The co-ordination function with the revenue sharing contract is discussed here.

A closed-loop supply chain with a single manufacturer and two competing retailers are developed in Huang (2018). The model is implemented with three different scenarios of trade-in strategy-manufacturer trade-in strategy, single retailer trade-in strategy and two completive retailers' trade-in strategy.

A multi-objective closed-loop supply chain model is developed in Papen and Amin (2019). In this paper, they minimize the impact of bottled water production and simultaneously they maximize the total profit of the entire supply chain model. The recycling centers are placed inside the manufacturers with the same location. Finally, they verified their model with a real-life example.

In this paper, we develop a model in a closed-loop supply chain environment to reduce the total cost in the entire environment. The model consists of a single plant, single demand market, single collection center and single disposal center. In a plant the new product is manufactured then the finished product is distributed to the demand market. In the demand market if any shortcoming is found in the product or it is not fulfilled to the customer needs then it moves to the collection center. The collection center has the full authority to decide the product to be remanufactured or to be disposed off. The product which is recoverable will move to the plant for remanufacturing and the remaining product will move to the disposal center. Finally, the model is verified and compared with a numerical example.

II. MODEL FORMULATION

In this paper, a closed-loop supply chain inventory model is designed for a single plant and single demand market for a single product with a single collection center and single disposal center. The product is manufactured in a plant after that the finished product is ready to distribute to the demand market according to the customer demand. If the demand is not satisfied according to the customer needs then it distributes to the collection center. In the collection center, the product is segregated for remanufacturing and disposal. The product which has some value is decided for recoveries at the plant through remanufacture procedure and treated as a remanufacturing product and the remaining is moved to the disposal center and they are treated as the dispose product. In this paper, the objective of this model is to minimize the total cost of the entire supply chain management system. We apply some optimization techniques as a method of solution in our model. Finally, the model is verified and compared with a numerical example.

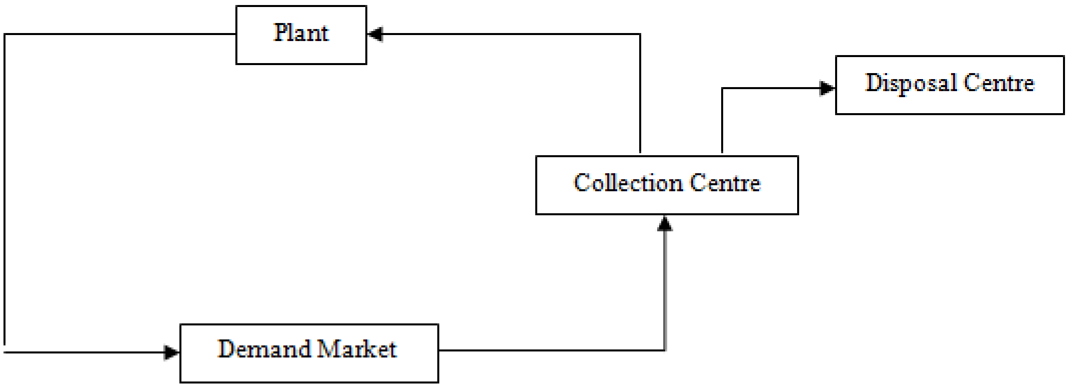

Fig: An Integrated Model of Closed Loop Supply Chain

Notations

A= Transportation Cost per km. distance per unit item between Plant to Demand Market

C= Transportation Cost per km. distance per unit item between Demand Market to Collection Centre

D= Transportation Cost per km. distance per unit item between Collection Centre to Plant

E = Transportation Cost per km. distance per unit item between Collection Centre to Disposal Centre

t= Distance between Plant to Demand Market

t_1 = Distance between Demand Market k to Collection Centre

t_2 = Distance between Collection Centre to Plant

t_3 = Distance between Collection Centre to Disposal Centre

P = Production Cost per unit item

F = Disposal Cost per unit item

R = Product Recovery Cost per unit item or Inspection cost per unit item

S = Product Remanufacturing Cost per unit item

β = Minimum Disposal Fraction of each item

Assumptions

(1) Shortage is not allowed.

(2) An infinite planning horizon.

(3) Quantity discount is not allowed

(4) Deterioration is not allowed.

(5) Remanufacturing product is not compared with the newly manufacturing product.

(6) Lead time is zero.

Decision Variables

X= Quantity of Product Produced by Plant to Demand Market

Z_1 = Quantity of Product Returned from Demand Market to Collection Centre

U = Quantity of Product Returned from Collection Centre to Plant for Remanufacturing

V = Quantity of Product Disposed from Collection Centre to Disposal Centre

TC = Total Cost in Supply Chain Management System

Objective Function

Minimize

$$TC = \left[(P + A \times t) \times X + (R + C \times t_1) \times Z_1 + (S + D \times t_2) \times U + (F + E \times t_3) \times V \right]$$

Constraints

(1) Non-Shortage Constraint:

i.e., $X \geq (U + V)$

(2) Minimum Disposal Fraction of Each Product in Disposal Centre:

i.e., $\beta \times Z_1 \leq V$

III. COMPUTATIONAL RESULTS

Input Parameters:
P=250; A=50; t=14;
R=100; C=50; t_1=10;
S=75; D=35; t_2=12;
F=35; E=25; t_3=8;
β=0.14;

(a) Result 1: (Using LINGO)

X	Z_1	U	V	TC
200	23	18	5	21105

(b) Result 2: (Using Genetic Algorithm)

X	Z_1	U	V	TC
200	19	16	3	18070

IV. CONCLUSION

The objective of this closed-loop supply chain model in supply chain management system is to minimize the total cost in the entire supply chain environment. We obtain the total cost in Rs. 21,105 and Rs. 18,070 using an optimization technique and genetic algorithm respectively. We observed that the total cost is reduced by Rs. 3,035 or near about 14.38% by using genetic algorithm. We observed that the number of product retuned from demand market to collection center in the first case is 23and in the second 19. Therefore, the number of product sold at demand market is 177 or near about 88% and in the second case is 181 or near about 90%. After inspection at collection center it is found that the number of product is required to be remanufactured in the first and second case is 18 and 16 respectively and the remaining will move for disposal center in both the cases. We can obtain better result by using genetic algorithm rather than one comparatively. We have applied LINGO software and genetic algorithm as a method of solution. But, we may use some other advanced optimization technique as a method of solution. In this paper, we develop our model in a deterministic nature but in real life example it may not possible in always. We can extend our model in an uncertain environment. We can extend our model in an uncertain environment. In our model, we consider a single objective function but we can extend our model with a multi-objective function in the future.

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AUTHOR

Sandipa Bhattacharya is PhD research scholar from Department of Mathematics of National Institute of Technology Durgapur, West Bengal, India. She received her B.Sc. degree in Mathematics from Burdwan University, West Bengal and Masters in Computer Applications from West Bengal University of Technology, (Presently MAKAUT). She obtained her M.Tech degree in Operations Research from Department of Mathematics of National Institute of

Technology Durgapur. She has participated in many National and International Workshops and Conferences in India. Her research interests include in Operations Research, Supply Chain Management, Soft Computing and some other related fields in Applied Mathematics.

Dr. Seema Sarkar (Mondal) is Professor of Department of Mathematics of National Institute of Technology Durgapur, West Bengal, India. She received her B.Sc. degree in Mathematics from Presidency College (Presently Presidency University) Kolkata and M.Sc , M.Phil & PhD degree in Applied Mathematics from University of Calcutta, Kolkata.

Her research interests include Geophysics, Operations Research and some other related fields. She has authored/coauthored more than 25 publications and received 'Best Paper Award' in International Conference on 'Information and Management Science' in China during August, 2010. She had also received "National Scholarship" during Secondary Examination.

Six students have completed their PhD and awarded doctorate degree under her supervision and 6 more are pursuing their doctoral study. She is a Life Member of 'Calcutta Mathematical Society' and 'Operational Research Society of India', Kolkata Chapter.