International Journal of Research in Engineering, Science and Management
Volume-2, Issue-6, June-2019
www.ijresm.com | ISSN (Online): 2581-5792

Reverse Logistic Network for used Refrigerators

S. Aneesh[1], N. Asok Kumar[2]
[1]M.Tech. Student, Department of Mechanical Engineering, College of Engineering, Trivandrum, India
[2]Assistant Professor, Department of Mechanical Engineering, College of Engineering, Trivandrum, India

***Abstract*: Reverse logistic is now becoming an important strategy to increase customer satisfaction and green image. Reverse logistics includes a series of processes involving product return, repairing, refurbishing, recycling remanufacturing and disposal of used or end of life products. Green Supply chain management incorporates the environmental idea in each and every stage of the product and service in a Supply Chain. Market size of refrigerators in India was drastically increasing from 2007 onwards. Statics shows that refrigerator market was worth around 1.2 billion US dollars in India during the year 2013. By the year 2020 it is predicted that it will increase to 3.6 million US dollars. The drastic increase in the sale of refrigerator will lead to makeable opportunity for growth in existing or emerging reverse logistic service providers for refrigerators. This paper mainly focuses on design of a reverse logistic network model for end of life refrigerator. Designed model is a help full tool for designers for solving the reverse logistic supply chain problems in the case of domestic appliances. Proposed model considered all kind of major costs incurred in different echelons so that the model can be accede as an effective tool for all kind of realistic network problems.**

***Keywords*: collection center, echelons, global warming, mathematical model, reverse supply chain, recycling, refrigerators, six R's.**

1. Introduction

Recent researches in the area of green manufacturing have extended into green supply chain management and Reverse Logistics (RL). Researcher's addresses issues related to evaluating current or potential suppliers' environmental practices, the environmental/economic benefits of establishing a green supply chain. Although this issue is relevant to any company for which the use of recycled materials is a viable option, these changes are especially important in refrigerators in domestic appliances which is a primarily considered for this paper.

Reverse logistics includes a series of processes involving product return, repairing, refurbishing, recycling remanufacturing and disposal of used or end of life products. Green Supply chain management incorporates the environmental idea in each and every stage of the product and service in a Supply Chain. Hence Supply chain managers have a great role in developing innovative environmental technologies to tackle the problems faced by the economy on environmental problems and communicate this to every stake holder in the supply chain and society. It includes the use of a RL system for the recovery of used materials and products. Recovery networks link a "disposer market" of used products available for repair, remanufacturing, or recycling with a "reuse market" which reflects the demand for these products. Increasing evidence and confidence on the impacts of global warming has compelled policy makers around the world to act for mitigating climate change.

Reverse supply chain abide of a recycler and a processor, then execute a game-theory based analysis for determining and optimizing the choice of recovery channels for WEEE or domestic home appliances. The performance of a recycling industry is improved by two approaches namely recyclable dealer collection recycler collection, recycling publicity is an effective method for improving recycling performance. Recycling publicity is adopted by both recyclable dealer approach and recycler approach.

In this paper a comparative study on two type of reverse logistic model with collection center and without collection center. Generally, all reverse logistic networks consist of a set centralized collection hub for sorting segregating, or these hub acts as a decision center of the network. First part of this paper consists of a literature review based on available reverse logistic networks. The main contribution of the paper is formulation a mathematical model which incorporates different variables and their influences on the performance on supply chain. The mathematical model is analyzed for the viability of eliminating the collection center from reverse network.

2. Literature Review

Reverse supply chain deals with the collection and treatment of used products. Recent researches in the area of green manufacturing have extended into green supply chain management and reverse logistics. Researcher's addresses issues related to evaluating current or potential suppliers' environmental practices, the environmental/economic benefits of establishing a green supply chain. Toktay et al., developed and analyzed a model of the supply chain for Kodak's single-use camera that minimizes the total expected procurement, inventory holding cost, and lost sale cost [8]. Reverse logistics is the collective noun for logistic environments with reuse of products and materials. Possible cost reductions, more rigid environmental legislations, and environmental concerns have led to increasing attention for reverse logistics in the recent past. A particular type of reuse is remanufacturing. After remanufacturing, an item is considered to beas good as new. A number of authors have proposed quantitative models for inventory systems with remanufacturing. An excellent review is provided by Fleischmann et al.

According to Amirsaman Kheirkhah & Saeid Rezaei 2015 the problem of designing a reverse logistics network is the process of specifying the number, location and capacity of collection, recovery and disposal centers. Reverse logistics networks include particular specification in comparison to forward ones one of which is the significant role of collection/inspection centers in such networks. Cross-docking operation is a distribution strategy in reverse logistics which is currently used by many companies in different industries. In this strategy, incoming packages to the cross-docking center are quickly inspected, sorted and classified respectively in the operational sector, and immediately loaded onto outbound trucks in the sending platforms. Reverse Logistics can recover economic, environmental, and social value. The economic value includes cost reduction for industrial companies and municipalities. Industrial companies receive returns at low prices and use as raw materials or fuel. It also helps to create and maintain a positive corporate image and to comply with legislation. The environmental value includes reducing the use of virgin materials; the social value includes generating jobs and income for vulnerable populations of poor communities [10].

There is a lot of research related to reverse logistics network design and closed-loop supply chains (CLSC) combined with forward and reverse logistics. Several studies have been focused on remanufacturing the returned products. Kim et al. developed a mathematical model for the remanufacturing process of reusable components in reverse supply chains [3]. Developed a stochastic mixed integer programming model for connecting manufacturing and remanufacturing activities and found that inventory control is of considerable interest in joining the manufacturing and remanufacturing systems in the CLSC network. Das and Chowdhury considered a modular product design architecture for supporting recovery processes and using integrated recovery service providers for handling product recovery [5].

3. Six R's in Reverse Logistics

Simply reverse logistics is the process that deals with flow of products and materials including returned or damaged goods from the consumer back to the producer, besides customer dissatisfaction, other reasons consumers send back products include: warranty returns, damaged or defective product, to upgrade the product, delivery error and end of life equipment.

Product Return is the first stage in reverse logistics is return of product; customers may return a product due to several reasons like defective, not working, buyer's remorse etc. In the case of a retail sector product return means taking back a previously sold item back from the customer and in turn customer will get refund of payment or exchange for another same or different item. In the case of online market product return is a very common and simple process, and it is not considered as a bad thing. Remanufacturing is the patching of a product to the specifications of the original manufactured product using a combination of reused and repaired. It encourages waste reduction and material conservation through the use of materials regained from solid wastes. In remanufacture a current product is inspected for its physical structure or solvency for its respective function. In the case of automobiles, copier machines, furniture's etc. Refurbishing is the process of renovating an older or damaged product to a workable or better condition, majority of refurbished products are older model or wore in condition. A typical model product may be returned for refurbishment due to introduction of a newer or advanced model of same category. Such products are labelled as refurbished after their reconditioning and sell on reduced prices at primary or secondary market and donatede for charity. Repairing is based on the type of product returned, it is classified as end of use return and end of life return mostly the second type of products are considered as repairable, reusable or repairable component were disassembled and sent to repairing center.

All the major suppliers provides zonal or area wise repairing centers for providing service or repairing facility to their products. Recycling is the prime important process in reverse logistics; it involves the process of collecting, sorting and processing of materials to reuse and turning them into new products. Recycling is beneficial to both community and environment. Waste from industrial, municipal, agricultural, construction and demolition (C&D) and other processes normally contain base materials in the form of scrap, like ferrous metal, non-ferrous metals, plastics and glass. Recovery and disposal in reverse supply chain recovery and disposal are the final stage or the bottom most echelon, in which the all the unusable components and materials recovered from above echelons are sorted and moved to recovery center. Disposal items are properly disposed according to the directions of various environmental agencies. Recovery is using wastes as an input material to create valuable products as new outputs.

4. Reverse network model formation

This section formulates a general network and mixed integer linear programming for reverse logistics for end of life refrigerator, initially in the general network model considered with a set of collection center used for collecting, storing and inspecting EOL refrigerators from different set of product return zones. The network structure consists of facilities such as product return zones, collection centers, remanufacturing centers, dismantling centers, repairing centers and disposal centers and the following markets secondary markets and scrap markets. The overall problem is to take a decision on the quantity of flow of components/product between facilities of top echelon to next downstream echelon. The objective of this model is to maximize the profit. Other costs considered in this model is transportation cost calculated on the basis of distance between each facility and unit transportation cost for each item.

If the compressor and evaporator are not in working condition, they are considered as dismantlable. Either compressor or evaporator is working and 30% of body parts (Cabin, metal parts, and interiors) are damaged, they are considered as dismantlable. If compressor and evaporator is in working condition and less than 30% of body parts are damaged, they are considered as dismantlable. If the compressor and evaporator are in working condition but more than 50% of its body parts are damaged, they are considered as dismantlable. Incoming refrigerators of all other conditions are considered as remanufacturable

The remanufacturable items are moved to remanufacturing centers where simple patch works, painting simple repairing works were completed and made it working condition. They are sold in secondary market and generate revenue. Dismantlable items coming from collection centers are disassembled and components are sorted in the following manner. Compressor and evaporator are moved to repairing center and repaired evaporator and compressor are sold out at secondary market and generate revenue.

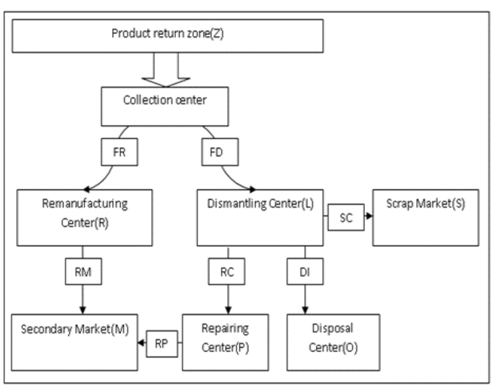

Fig.1. Reverse logistic network

Similarly scrap items dismantled from refrigerator are classified into plastic and metal and sold out at scrap market to generate revenue; cost for scrap item is on unit wise plastic item and metal item. Pre-defined dismantling cost will be collected at dismantling center for dismantling of each unit, and a pre-determined repairing cost will be incurred for repairing of evaporator and compressor at repairing center.

The demand sources of repaired items are repairing shops where uses these repaired parts as spare parts. Disposable items are identified and moved to disposal center, were a unit wise disposal cost is charged for disposal. The overall problem is to take a decision on the quantity of flow of components/product between facilities of an echelon to next downstream echelon. So as to maximize the profit and to minimize the total supply chain cost. Other costs considered in this model is transportation cost calculated on the basis of distance between each facility and unit transportation cost for each item.

5. Mathematical model

Notations used

Z- set of product return zones indexed by z

C- set of collection center indexed by c

R- set of remanufacturing centers indexed by r

D- set of dismantling centers indexed by l

S- set of scrap markets indexed by s

M- set of secondary markets indexed by p

O- set of disposal centers indexed by o

A-Set of all facilities in the network

RR- Returned refrigerator in case of without collection center

FR- set of refrigerators collected from collection center to remanufacturing center

FD- set of refrigerators collected from collection center to dismantling center

RM- set of remanufactured refrigerator (all remanufactured refrigerators has same price in any market mi)

RC- set of repairable items moved from dismantling center to repairing center

SC- set of scrap items moved from dismantling center to scrap market.

DI- set of disposable item moved from dismantling center to disposal center

RP- set of repaired items moved from repairing center to secondary market

K-set of all the items in the network

CR- cost of returned refrigerator

V_{mi} – Unit processing cost for item i at facility m

TC – unit transportation cost of item i per unit distance

D_{mn} – distance between facility m and n where m,n € A

Y_{mni} – quantity of component /item i shipped from m to n where m,n € A, I € K

α_j - Quantity of repairable item I produced from one unit of refrigeratror

β_j - Quantity of scrap item produced from one unit of refrigerator

γ_j - Quantity of disposable item produced from one unit of refrigerator

REV_{mi} – set of revenue from secondary market m for item i

REV_{si} - set of revenue from scrap markets for item i

PR_z – number of refrigerators returned at product return z

Objective Function:

Maximize profit

$[(\sum_{r\epsilon R}\sum_{m\epsilon M}\sum_{i\epsilon RM} Y_{rmi}REV_{mi})+(\sum_{p\epsilon P}\sum_{m\epsilon M}\sum_{i\epsilon RP} Y_{pmi}REV_{mi})+(\sum_{l\epsilon M}\sum_{s\epsilon S}\sum_{i\epsilon SC} Y_{lsi}\ REV_{si})] - [\sum_{z\epsilon Z}\sum_{c\epsilon C}\sum_{i\epsilon RR} Y_{zci}$
$[CR_i+(D_{zc}TC_i)+V_{ri}] + [(\sum_{z\epsilon Z}\sum_{r\epsilon R}\sum_{i\epsilon FR} Y_{zri}\ [(D_{cr}TC_i)+ V_{ri}]\ ]+$
$[(\sum_{z\epsilon Z}\sum_{l\epsilon L}\sum_{i\epsilon FD} Y_{zdi}\ [(D_{cl}TC_i)+ V_{li}\ ]\ ] +$
$[(\sum_{r\epsilon R}\sum_{m\epsilon M}\sum_{i\epsilon RM} Y_{rmi}\ (D_{rm}TC_i)] + [(\sum_{l\epsilon L}\sum_{p\epsilon P}\sum_{i\epsilon RC} Y_{lpi}$
$[(D_{lp}TC_i)+ V_{pi}] + [(\sum_{l\epsilon L}\sum_{s\epsilon S}\sum_{i\epsilon si} Y_{lsi}\ (D_{ls}TC_i)] +$

$[(\sum_{l\epsilon L}\sum_{o\epsilon O}\sum_{i\epsilon DI} Y_{loi}\ (D_{lo}TC_i) + V_{oi}] + [(\sum_{p\epsilon P}\sum_{m\epsilon M}\sum_{i\epsilon RP} Y_{pmi}\ (D_{pm}TC_i)]]$

Subject to

$\sum_{c\epsilon C}\sum_{i\epsilon FR} Y_{cri} + \sum_{l\epsilon L}\sum_{i\epsilon FD} Y_{cli} = NR_C \quad \forall\, rr$……….(1)

$\sum_{c\epsilon C}\sum_{i\epsilon FR} Y_{cri} = \sum_{m\epsilon M}\sum_{i\epsilon FR} Y_{rmi} = NR_C \quad \forall\, r$……....(2)

$(\sum_{c\epsilon C}\sum_{i\epsilon FD} Y_{cli})\alpha_j = \sum_{p\epsilon P} Y_{lpj} \forall\, l, \forall\, j\epsilon RP$ …………..(3)

$(\sum_{c\epsilon C}\sum_{i\epsilon FD} Y_{cli})\beta_j = \sum_{s\epsilon S} Y_{lsj}\ \forall\, l,\ \forall\, j\epsilon SC$…………..(4)

$(\sum_{c\epsilon C}\sum_{i\epsilon FD} Y_{cli})\gamma_j = \sum_{o\epsilon O} Y_{loj} \quad \forall\, l,\ \forall\, j\epsilon DI$………..(5)

$(\sum_{l\epsilon L}\sum_{i\epsilon RP} Y_{lpi}) = (\sum_{m\epsilon M}\sum_{i\epsilon RP} Y_{pmi})\ \forall\, P$………..(6)

$Y_{pqi} \geq 0\ \forall\, p, q, i,$ where, p,q ϵ A,i ϵ k…………….....(7)

Objective maximizes the total profit of the supply chain. Revenue generated by resale of remanufactured refrigerator, repaired evaporators and compressors, scrap sale of plastic and metal items. Different costs in the network are collection cost of item, processing cost of each facility, transportation cost for each item transported from one level to next level.

Constrain 1- Ensures all the returned products at collection center are sent to L or R

Constrain 2- Ensures all incoming item at remanufacturing center 'r' are dispatched to secondary market 'm'

Constrain 3 - Ensures repairable components of all incoming item at dismantling center 'l' are sent to repairing centers (P)

Constrain 4- restricts maximum flow from dismantling center to repairing center , Ensures scrap items of all incoming item are sent to repairing centers

Constrain 5- restricts maximum flow to scrap market from dismantling center Ensures disposable items of all incoming item are sent to disposal centers

Constrain 6 - Ensures repaired components of all incoming item are sent to secondary market (M)

Constrain 7 – ensures all the flowing quantities must be positive.

6. Model Application and conclusions

The proposed model can be applied to the flow type network design problem for refrigerator recovery/remanufacture or repair in reverse supply chain, the values of different variable and parameters can be given as in put for the mathematical model and their quantity of flow between different set of facility centers to down ward echelons will be available as output.

Proposed model will be a help full tool for designing reverse logistic supply chain problems of all kind of domestic appliances. This model considers all kind of costs incurred in different echelons so the model can be acceding as an effective tool for all kind of realistic network modeling problems. The model can accommodate different number of sub-assemblies at different stages, so this can be conceding for any domestic appliance with more than one sub-assemblies.

7. Limitations and scope for future work

The proposed model doesn't consider holding cost at different stages or facilities in the supply chain, inspection cost at collection center is included in the processing cost itself but the inspection cost may vary according to condition of incoming used item. The possible extensions of this work are developing a linear model considering holding cost at all the echelons of the supply chain gives a realistic approach to the model. The model can be analyzed and validated using a real life problem from the same area. Another important suggestion is to analyze the viability of removing the centralized collection hub and there by moving the end of life item directly from product return zone to third set of echelons in the proposed network.

References

[1] Tsai-YunLiao (2018) Reverse logistics network design for product recovery and remanufacturing, Applied Mathematical Modelling Volume 60, August 2018, Pages 145-163

[2] Fleischmann, Moritz and Bloemhof-Ruwaard, Jacqueline and Dekker, Rommert and Van der Laan, Erwin and van Nunen, Jo and Van Wassenhove, Luk (1997) Quantitative models for reverse logistics European journal of operational research 103(1997)1-17

[3] El-Sayed, M and Afia, N and El-Kharbotly, A (2010) A stochastic model for forward--reverse logistics network design under risk Elsevier Computers & Industrial Engineering 2010 58(3) (423-431

[4] Agrawal, Saurabh and Singh, Rajesh K and Murtaza, Qasim (2015) A literature review and perspectives in reverse logistics}, Resources, Conservation and Recycling Elsevier (2015)97 (76-92)

[5] Das, Kanchan and Chowdhury, Abdul H (2012) Designing a reverse logistics network for optimal collection, recovery and quality-based product-mix planning}, Elsevier International Journal of Production Economics 2012 135 (1) (209-221)

[6] John, Sajan T and Sridharan, R and Kumar, PN Ram and Krishnamoorthy, M (2018) Multi-period reverse logistics network design for used refrigerators, Elsevier Applied Mathematical Modelling 2018 (54) 311—331

[7] Xu, Zhitao and Elomri, Adel and Pokharel, Shaligram and Zhang, Qin and Ming, XG and Liu, Wenjie (2017) Global reverse supply chain design for solid waste recycling under uncertainties and carbon emission constraint Elsevier Waste Management 2017(64)358-370

[8] Toktay, L Beril and Wein, Lawrence M and Zenios, Stefanos A (2000) Inventory management of remanufacturable products INFORMS Management science 2000 46(11)1412-1426

[9] Mutha, Akshay and Pokharel, Shaligram (2009) Strategic network design for reverse logistics and remanufacturing using new and old product modules, Elsevier Computers & Industrial Engineering 2009 56 1(334-346)

[10] www.statista.com/statistics