PANDIT DEENDAYAL PETROLEUM UNIVERSITY
A RESERVOIR OF KNOWLEDGE

LIBERAL STUDIES

A Bi-Annual Journal of School of Liberal Studies, PDPU, Gujarat

Vol. 2, Issue 1
January–June 2017
ISSN 2455-9857

SLS
SCHOOL OF LIBERAL STUDIES

Asheesh Shrivastava*
Yogita Khare

Recycling of Products Causing Pollution: A Suggestive Reverse Supply Chain Model for India

Introduction

The concept of reuse of metal scrap, waste paper, packing materials, soft drink bottles, etc has been in viable existence for some time. The primary reason for this is the simple fact that recycling of the used product is far more economical than disposal. Further, concerns for the environment have also promoted inclusion of several new products to the above list of 'reusable' items. Globally, waste reduction efforts have incubated the idea of developing reverse supply chains for recycling instead of only the forward supply chain. Total paper recycled in Europe, during 1994 was only 27.7 million tonnes. Thereafter, consumer awareness assured an annual increase in collections by about 70 per cent. By year 2000 Europe was recovering 43 per cent of the total paper consumption. During the same period, recycling of glass in Europe grew by almost 10 per cent (in tonnes collected) to more than 7 million tonnes, with a recycling rate of about 60 per cent (EUROSTAT, 1997).[2] Regulations in Germany mandate recovery rate for packaging materials between 60 per cent and 75 per cent. The Netherlands reuses 46 per cent of all industrial waste (CBS, 1997).[3] In these cases the concept of reuse gave rise to a new material flow system, i.e. from the user back to the producers. 'The management of this material flow opposite to the conventional supply chain is a fast growing field and now addressed as reverse logistics' (Stock, 1992)[4] (Kopicky, 1993).[5]

As per M Fleischmann, "Reverse Logistics encompasses the logistics activities from the point a product is no longer required by the user to the point it is reprocessed

---

* **Asheesh Shrivastava** is a serving officer in Indian Air Force in the Technical Branch. Currently he is a research fellow at Center for Air Power Studies (CAPS), New Delhi. **Yogita Khare** is an an environmentalist and expert on 'Air Quality Status and its Impact on Vegetation'.

again to a form that is usable in the market”.[6] He suggested that the process of recycling goods can be demarcated onto three distinct groups. The first area of activity involves the physical movement of used products from the end user back to a recycler, which is *Reverse Logistics Networks.* The next issue is the transformation of the returned products into usable products. From Techno-logistics point of view we can call it *Product Recovery System.* Finally, from a purely economics point of view, the cost analysis of the process, i.e. cost of collection, transportation and reprocess vis-à-vis review generated by the recycled product. We can call this group of activities as *Inventory Analysis*. These three domains can broadly evaluate the entire scope of the reclamation, recycle and reuse process.

Reclamation as an Objective of Reverse Supply Chain (RSC)

Waste reduction is receiving growing attention across the globe due to increasing cost on environment. Therefore, nations have enacted legislations/laws that make producers and users responsible for the products life cycle. Take-back obligation (after use) for recycling is one such measure to reduce generation of waste. For example the packaging ordinance 1991 of Germany, requires industry to take back all types of packaging materials. It mandates for use of certain percentage of recycled material in all new products. Similarly, in Netherland the automobile industry is responsible for recycling all used cars.[7] In India, the electronic scrap e-waste (Management & Handling) Rules, 2011 have set similar recycling goals for electronic goods. India generates about 17 lakh tonnes of e-waste annually.[8]

Even if legislations are not very stringent, thoughtful customers, in some countries also impose strong pressure on companies to take environmental aspects into account while developing a new product. ‘Green’ image has become an important marketing strategy for Multinational companies. This development has stimulated many industries to explore options for take-back and recycle/ re-engineer their products.[9]

The take-back policies have added a new dimension to the supply chain management. In a typical forward supply chain, the customer/ consumer is the end of the process. However, by changing the end-point of the products supply chain from the consumer to the product’s end-of-life, the supply chain presents an opportunity to extend the use of products, conserve resources, prevent waste and generate additional revenues. The chain also creates jobs in remanufacturing, reclamation and the recycling sectors. The supply chain that manages the flow of products from the consumer back to the reprocessing plant is termed as the reverse supply chain. Reverse Supply Chains (RSC) are the key strategy to sustain a production line that meets the environmental legislations and satisfies customers’ concerns. In practice, RSCs are more complicated since return flows may include products, sub-assemblies and materials that may be required to enter the chain at several return points. These products may also require sorting and dismantling before entering the supply chain. Further, the chain may also have various exit points. The entire scenario of the reverse supply chain has been enumerated as per the characteristics of the product by M Fleischmann[10]and is appended below.

(a) **Product Life Cycle Returns**: Items returned under this classification are linked to the sales process. The reasons for the returns from the POS include problems with items under warranty, damage during transport or product recalled due to manufacturing defects.

(b) **Re-Usable Components**: This classification includes return of items related to consumption, use or distribution of the main product like customised packing cases, pallets, etc. These items are returned to the original equipment manufacturer for re-use.

(c) **End-of-Use Returns**: These are used items, components or sub-assemblies that have been returned after customer's usage. These used items are normally traded in open market as article of trade for being remanufactured.

(d) **End-of-Life Returns**: This classification includes items that are returned or taken back from the customer/ market to avoid environmental or commercial damage. Usually governed by take-back laws, and its ability to be recycled cost effectively.

Type of Reverse Logistics Networks

As discussed above, Reverse Logistics is the reverse flow of material as against the traditional or forward logistics.[11] Dowlatshahi defines reverse logistics as a process where a manufacturer is ready to accept a previously shipped product from the point for consumption for possible recycling/ re-manufacturing.[12] Thierry, Wassenhove, Van Nunen and Salomon[13] claim that reverse logistics have been widely used in the automobile industries such as BMW and General Motors. Other companies such as Hewlett Packard, HCL and TRW have also been using reverse logistics as a part of their supply chain process. Used products originating from different sources are brought to the recovery/ reclamation facility for recycling.

Caruso et al. proposed a model for a solid waste management system, which included collection, transportation, incineration, composting, recycling and disposal.[14] He coined the network as a "multi-objective location-allocation model" and also suggested some heuristics to plan the waste management system. The procedure resulted in calculating the number and location of waste disposal plants, short-listing best technology and optimising quantities of waste processed. Kroon and Vrijensalso presented a return logistics system for reusable containers which was developed as a case study for a logistics service organization. [15] The study analysed the transportation, maintenance and storage of empty containers. Thereafter, it suggested a plant location model to analyse the number of containers, the number of depots and their locations.

Drawing inferences from the various models suggested above, advancement in re-manufacturing technologies and consumers' awareness of using environment friendly products, there is a need to include more products in the list of recyclable products in India. This paper, discusses the reverse supply chain for End-of-Life Return situation which includes Sorting and Inventory Management as important elements.

Product Based Reverse Supply Chains

Most reverse supply chains are modelled on the requirements of Repair Systems. Such RSC consider the process of replacing the failed items noticed at customers end or Point of Sale (POS) by a serviceable item in the shortest possible time. The failed item is required to be sent to manufacturing unit or workshop for re-work as soon as possible. Thereafter, it is returned to the supply line as a fresh inventory. From the point of view of Inventory management, each failed or rejected delivery is characterized by two features: first, rejected item needs to be immediately replaced by issuing a new one, i.e. every rejection is accompanied by a demand. This situation does not lead to an increase of the total inventory until consumer decides to switch to another product or supplier. Secondly, the supply chain is essentially a closed loop, as the total number of items in the inventory remains essentially the same. This system where the returned product is recoverable and can be reused directly as a new product, leading to dual identity inventory was modelled by Cohen.[16] They assumed that fixed shares of products issued at a given time are likely to be returned after a fixed lead time. This model is an extension of the stochastic inventory model (with proportional costs) in a reusable items situation. The objective is to optimize the trade-off between holding costs and shortage costs. Cohen demonstrated that under certain assumptions a one-parameter ‘order upto’ policy is optimal.

While evaluating ‘Product based Reverse Supply Chain’ models, no ‘Fit-All’ model, establishing numerical relationship between rejected inventories and rate of re-engineering activities could be found. Literature review brings forth a number of studies suggesting relationship between the inventory control and the production capabilities, a few of which have been discussed earlier in the paper. However, as far as handling of the waste/ the polluting product as an input for the recycling industry is concerned, the chain modelled according to the Closed Loop Supply Chain Management (CLSCM) concept is best suited.

The Closed Loop Supply Chain Management (CLSCM) has its own merits in improving the rate of reclamation of polluting products. The requirements of the environmental legislations are also met as CLSCM encompasses Green Operations (Reverse Logistics), Green Design, Waste Management and Product Life Cycle Assessment. CLSCM also takes into consideration ecological as well as economic causes as objectives and closing the supply chain gives operational and financial advantages to an organization. Effective implementation of CLSCM leads to following:

- Overall reduction in waste
- Substantial reduction in environmental pollution
- Increased optimization rate of the utilization of resources
- Overall reduction in the costs of operation.

Therefore, we can deduce; for product based Reverse Supply Chains, especially reclaimable ones, CLSCM is the best model.

Process Based Reverse Supply Chain

Another criterion that governs the selection of the right model for a reverse supply chain, is the type and size of inventory that the chain is likely to handle. Type and size of inventory will also affect the production planning which pulls the supply chain. According to M Fleischmann,in case of direct reusable items like, transportation packages, pallets, boxes or bottles where returned products can be reused in 'as is' (possibly after cleaning or minor repair) no additional production process needs to be planned.[17] In such cases focus is on inventory collection rather than on production planning. Recycling, in such cases, does not involve new/ additional production processes. Returned products only have to be transformed into fresh material by means of refurbishing. However, the difficulty lies in establishing the network for collection of reusable raw materials rather than in planning and controlling the re-engineering activities. From a purely production control point of view these activities are beyond the scope of traditional production planning processes.

However, inventory management becomes complex if some technical activities like disassembling, sorting, etc are required before start of the re-engineering process. The repair operations needed to convert a returned product back to a 'recycled' state depends on the condition of the received product. This may vary from product to product and item to item. In general the number of testing and disassembly operations required for remanufacturing process, can only be decided after pre-receipt inspection of the article. A high degree of coordination is required in this process; as disassembly of a returned product releases a number of sub-assemblies simultaneously. Concurrently, repetitive sorting may also be required for channelizing the sub-assemblies to the correct reclamation bays. This indicates that production planning in a re-engineering environment is much more complex.

Material Requirement Planning (MRP)-based approach is another evaluative tool for such operations, which involve re-manufacturing. The concept of scheduling the production requirements in order to meet the varying demands is MRP. Several authors have analysed the industry practices under the MRP model for reclamation. In particular, the criteria for choosing between using a reclaimed component from disassembly line or a fresh component from store for the production line are weighed.

Another, methodology of designing the RSC, is the concept of 'reverse' Bill of Materials (BOM). This methodology involves documenting every returned product, listing its sub-assemblies and then estimating the time required for dismantling. The objective is to correctly sequence and schedule the disassembly operations taking into account the dependency between components and services in the same product line. The component with the largest time and space requirements determines the size/ layout of disassembly and /or the re-engineering line. The objective is to identify and design the most cost efficient production line for a product with respect to time and costs. For each type of item received for reclamation/ re-engineering a separate BOM is prepared. The BOM specifies the expected amount of reusable components it is likely to generate and accordingly helps in scheduling the production activities.

Case Study: Supply Chain for Reclamation of Plastic

So far, we have discussed the different methods of identifying and planning a sustainable model for reverse supply chain of recyclable products like plastic, motor oil, glassware, ceramic fittings, etc. Literature review suggests that while designing a Reverse Supply chain for polluting products, following criteria may be evaluated:

Criteria 'A': End-of-Life Returns: Short listing those products which may be recovered from the market after completion of its designed life, to avoid environmental and/ or commercial losses.

Criteria 'B': Product Based Reverse Supply Chains: Designing a Closed Loop Supply Chain for improving the rate of reclamation of polluting products, by correctly estimating waste generation and matching it with production (recycling) capabilities.

Criteria 'C': Process Based Reverse Supply Chain: Production planning for reclamation based on as per size and type of item to be recycled. Tailoring the MRP model on BOM algorithm to minimise recycling time and cost.

Designing an effective Reverse Supply Chain model for reclaiming a product which has reached 'end of use' life is a challenge. This is primarily due to large number of variables in the chain. Furthermore, it is also difficult to correctly estimate cost of determining factors like reclamation technology, taxation/ regulatory policies, sorting cost, plant location, etc as these are affected by external factors.

The Reverse Supply Chain for reclaiming plastic in United Kingdom is analysed, to demonstrate the capabilities of the suggested model. Users across all section of Indian society are also aware of the ill effect of using plastics as most plastics used here are non bio-degradable. It is not easy to replace plastic with paper (or similar products) in India due to cost of the replacement material and our socio-economic conditions. In some cases, it has also been observed that use of plastics save energy and even reduces CO_2 emissions as it can be recycled for over five times, unlike paper or starch. Valuable input on plastic recycling has been taken from the study by Che Wong of Hull Business School and Logistics Institute, UK for designing a similar chain for India.[18]

The study maps the flow of material from consumer (post-use) to reclamation plant. It employs a cradle-to-grave approach called the Life Cycle Assessment (LCA) to evaluate the impact of End-of-Life return policy. Thereafter, it recommends a policy of cradle-to-reincarnation approach as most plastic waste can be re-processed to form a similar or new plastic product of varying quality.

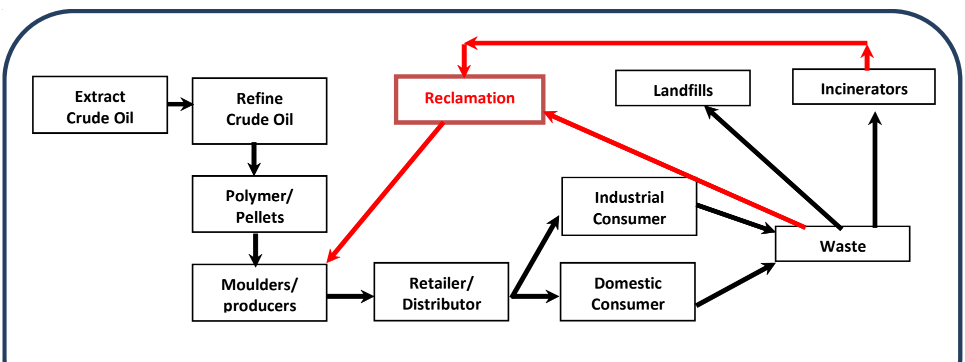
There are typically two major waste streams; municipal solid waste (MSW) and commercial and Industrial (C&I) waste streams. Municipal waste mainly comprises of domestic plastics packing material such as bottle, trays, bags, etc. Whereas, commercial waste consists of mouldings, fixtures, automobile parts and rejected articles, commercial waste has identifiable specification and homogeneous non-contaminated constituent.

Post collection, plastic articles need to be sorted as per polymer type and colour. Mixing of polymer/ colour lowers the grade/ quality of recycled plastic. Thereafter, the articles can be recycled by two major processes:

- Mechanical Recycling
- Feedstock Recycling

Mechanical recycling includes; shredding and melting to produce granules. New products can be produces from these granules. Feedstock recycling breaks down polymers into their constituent monomers. The process produces virgin plastics which can be used to make a new range of product. Finally, non-recyclable plastic waste can be used to generate power to fuel the recycling furnace/ plant. The following Block diagram depicts the forward and reverse supply chain of plastic:

China is the world's largest importer of recovered plastics. The country has a large capacity to recover plastics from both domestic as well as commercial waste. UK exports 80 per cent (5,17,000 Tones) of recovered plastics to China, which is about 9 per cent of China's import.[19] About 55 per cent of recoverable plastics including bottle and



FORWARD AND REVERSE SUPPLY CHAIN: PLASTIC

packing materials, of UK is being exported to China. Ironically, UK imports 1/3rd of its plastic (Fluff/ Pellets) from China.

• The study carried out a detailed comprehensive Life Cycle Inventory Analysis (LCIA) of plastics in UK and noted that the country is throwing away four bottles out of every five bottle sold. It brought out that recycle of waste/ used plastic in UK would reduce energy consumption, crude import, transportation and also reduce CO_2 emissions.[20] Deliberating on the study report, the following recommendations can be made for policy makers:

- Collect weight-wise and area-wise statistics on each type of recyclable material/ item/ product, thereafter make realistic collection targets for local bodies/ municipal councils. Design product based RSC.

- Commission comprehensive reviews for each material to select compatible processes/ technologies for recycling. Process based RSC.
- Improve economy of scale to gain efficiency by policy revision and ensuring adherence.
- Restrict export of waste (anti-dumping policy) and encourage local recycling to reduce un-necessary transportation.

Conclusion

Automobile oil, paper, aluminium cans, glass, edible oil, cloth, electronic gadgets and appliances, tyres/ tubes/ rubberised items, batteries, etc. are a list of some items that can be recycled. Cost effective technologies are available globally for recycling these items. Recycling not only saves energy, but also reduces pressure on production/ extraction of new material and reduces the carbon footprint and landfills. However, available statistics in India reveals a poor rate of reclamation for these products. There can be many reasons for this; a few are listed below:

- Lack of awareness/ motivation amongst consumers and local authorities
- Low return to consumer on selling of used product or additional cost for organised disposal
- Inefficient logistic with respect to sorting and transportation
- Economy of effort due to low volumes (collection)
- Geographical/ regional mapping of logistical and ecological flow of waste

There is a need to acknowledge this and institute measures to improve the rate of reclamation in India. A systematic overview of all issues encompassing the sector-wise issues for each product is required. Thereafter, the determinants for a reverse logistic chain according to the type of product, quantities generated and geographical location of reclamation facilities can be shortlisted. Each type of polluting product would have a unique RSC model, based on 'End of Use' utility and the reclamation process. The process would not only increase LCA of raw material and reduce the carbon footprint but also generate ancillary revenue for the consumer.

Notes

1. "Panorama of EU Industry", *EUROSTAT,* 1997.
2. CBS, *Statistical Yearbook for The Netherlands,* 1997.
3. J. R. Stock, "Reverse Logistics", *Council of Logistics Management, Oak Brook, IL*, 1992.
4. RJ Kopicky, et al. "Reuse and Recycling: Reverse Logistics Opportunities", *Council of Logistics Management, Oak Brook, IL,* 1993.
5. Moritz Fleischmann, et al., "Quantitative Models for Reverse Logistic: A Review", *European Journal of Operational Research* , 1997, p. 7.
6. F. Cairncross, "How Europe's companies repositioned to recycle", *Harvard Buiness Review*, March-April 1992.
7. Environment Minister Anil Madhav Dave in Rajya Sabha, August 2016.
8. M.C. Thierry, *An Analysis of Impact of Product Recovery Management on Manufacturing*

Companies, Netherlands: Erasmus University Rotterdam, 1997.

9. *Ibid.*
10. B. Beamon, "Designing the Green Supply Chain", *Logistics Information Management*, vol. 12, no. 4, 1999 , pp. 332-342.
11. S Dowlatshahi, "Developing a reverse logistics theory", *Interfaces,* No. 30, 2000, pp. 143-155.
12. M Thierry, et al., "Strategic issues in product recovery management", *California Management Review*, no. 37, 1995, pp. 114–135.
13. C. Caruso, A. Colorni, M. Paruccini, "The regional urban solid waste management system: A modelling approach", *European Journal of Operational Research*, 1993, pp. 16-30.
14. L. Kroon, G. Vrijens, "Returnable containers: An example of reverse logistics", *International Journal of Physical Distribution & Logistics Management*, 1995, p. 25.
15. M A Cohen, "A Dynamic Inventory System with Recycling", *Naval Research Logistics Quarterly* , vol. 27, no. 2, 1980, pp. 289-296.
16. Fleischmann, n. 5, pp. 1-17.
17. Chee Wong, "A Study of Plastic Recycling Supply Chain", *The Chartered Institute of Loistics and Transport*, UK, October 2010, pp. 19-22, 60-64.
18. "Waste and Resources Action Program (WRAP)", *Local Authorities Plastic Collection Survey 2008*, ARAP2009, pp. 1-51.
19. *Ibid,* pp. 60-63.