Remanufacturing for Sustainable Development: Key Challenges, Elements, and Benefits

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***Abstract*—Importance of remanufactured products for protection of environment is well known, especially in the context of sustainable development. Study of key elements & challenges in the remanufacturing sector is essential for successful launching of remanufactured products. Study of the link between product cannibalization and remanufacturing opportunities is also important in the remanufacturing sector. Some important challenges like cost of End-of-Life Product, quality expectation of customers and supply limitation are discussed in this paper. Key elements like Product Acquisition Management, Reverse Logistic Collections, Supply and Demand of remanufactured products play an important role in grabbing the market share. Case studies of a cartridge industry and PC Monitors industry are explained for better understanding of remanufacturing issues and benefits.**

***Index Terms*—Remanufacturing, product life cycle, product cannibalization, end-of-life, reverse supply chain management, product acquisition management.**

I. Introduction

Estimates in the USA indicate that over 375 million empty toner cartridges and ink cartridges are thrown as scrap every year. Most of these printer cartridges end up on landfill sites or in incinerators. 375 million cartridges amount to roughly 11 cartridges being disposed of every second. This quantum of waste can be reduced through reuse and recycling. Yet approximately 70% of all ink cartridges and 50% of all toner cartridges are still not recycled. Continuous changes are happening today for the better with pressure from legislation & environmental awareness among consumers and these exist particularly in Small and Medium Enterprises (SMEs). The plastics used in printer cartridges are made of an engineering grade polymer that have a very slow decomposing rate ranging between 450 to 1000 years depending on the cartridge type. Remanufacturing is a way to deal with this and it is the process where used product is brought back to near new product standard [1].

To reduce the waste, the U.S. Environmental Protection Agency has also recommended adopting a reduce-reuse-recycle hierarchy and resorting to combustion only as a last option (U.S. EPA 2008).

Manuscript received December 30, 2011; revised February 10, 2012.

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In spite of this recommendation, 67.5 % of the municipal waste went directly to land-fills or incineration facilities in 2006 (U.S. EPA 2007). Therefore it is encouraging to have a market for remanufacturing. According to Hauser and Lund, there are 9000 firms in U.S. who claim themselves as remanufacturers [1]. Many industries in this sector include remanufacturing automotive parts, cranes & forklifts, furniture, medical equipment, pallets, personal computers, photocopiers, telephones, television, tires and toner cartridge etc. These products are put in the market by Original Equipment Manufacturers (OEMs) and/or independent manufacturers [2]. Due to the huge importance of remanufacturing in industries, many researchers are beginning to bring lots of innovative ideas into the market.

II. Product Life Cycle In View Of Remanufacturing

Study of Product Life Cycle (PLC) of an existing product is very much necessary for successful launching of a remanufactured product. Perfect Launching of a remanufactured product is necessary for deriving maximum share in the market [3]. Demand of remanufactured product depends upon the product life cycle of an existing product. Predicting the demand of remanufactured product and its perfect launching is not an easy task for the company [4]. Study of disposal rate of existing product is also another crucial issue for remanufacturing industries. It is also interesting to study the product cannibalization due to entry of remanufactured products [5].

A. Cannibalization and Remanufacturing Opportunity

A report of Electronics Waste Management in the United States published in 2011 shows the sale data of PC CRT monitors and PC Flat monitors in USA for the last 31 years. Product life cycle of PC CRT monitors and PC Flat monitors is shown in fig. 1.

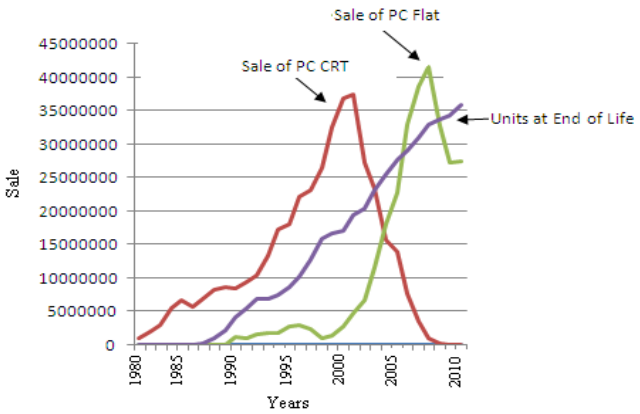

Fig. 1. Product cannibalization and remanufacturing opportunity.

Sale of PC CRT monitors were in growing phase between years 1990 to 2000. During these years the opportunity of remanufacturing is more for the companies. Maturity phase of PC CRT monitors is very small. After launching of PC Flat Monitors in 1988; it started cannibalization of CRT PC monitors and the rate of cannibalization has increased between the years 2000 to 2011. Here the decline phase of PC CRT monitors is observed as being quite healthy. Around 2009, sale of PC CRT monitors was totally replaced by Flat PC monitors and the demand of remanufactured PC CRT monitors was also replaced by remanufactured Flat PC monitors. It is seen that the demand of remanufactured product depends upon the product cannibalization of existing product. Product life cycle of remanufactured product depends upon the product life cycle of existing product. Quantity of End-of-Life (EOL) product also shows the opportunity for remanufactured product in the market.

B. *Extension of Product Life Cycle*

The actual process of remanufacturing is almost always less expensive than producing a brand new unit of the product because many parts and components can be reused, thus avoiding the need to procure them from supplier [5], [6]. Launching of remanufacturing of used product is important to extend the product life cycle in the decline phase (see fig.2.). There are many potential financial benefits to extending product life cycle besides the pure profit margin obtained by selling the remanufactured product [6]. Many OEMs were initially ignoring the remanufacturing of used products resulting in SMEs entering into remanufacturing which caused huge cannibalization. Now, many OEMs are entering into remanufacturing area to grab the secondary market [7], [8].

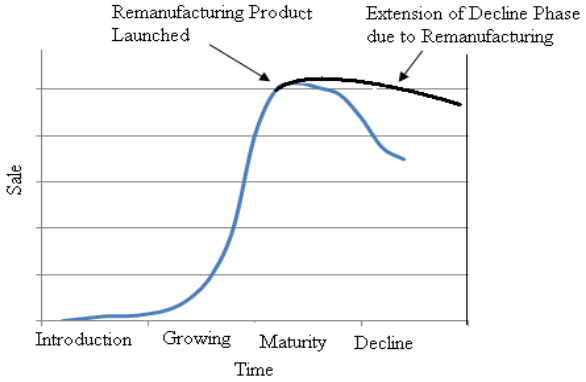

Fig. 2. Extension of decline phase due to remanufacturing.

III. Product Cannibalization Issues in Remanufacturing

Remanufacturing is the process where in a company conducts many operations on used products to bring it back in near total new conditions with same warranty as new one has [9]. Sale of remanufacturing will displace the sale of new product causing the cannibalization [10], [11]. Not much detailed study has been conducted so far in the field of product cannibalization and its importance. Many companies have tremendous fear about cannibalization of old products. Concept of product cannibalization is still fully not understood by many OEMs. Detailed study of product cannibalization in view of product development and marketing phase is very necessary. Most of the literature has been written on new product launching and cannibalization of old products [12]-[14]. It is very interesting to study the launching of remanufactured product and its effect on sale of new product [3]. Many marketing managers of OEMs feel that remanufacturing the product will cannibalize the new product which will result in reduction of market share [15]. Remanufacturing manager has to give answer to such questions frequently. Many managers do not think about launching remanufactured products. They feel that only new products will make more profits in the market, which is not completely true [16].

It is difficult to ignore the importance of remanufactured product for sustainable product development. Many OEMs are making good profit in remanufacturing sectors. Awareness about the remanufactured product is necessary in the SMEs' consumers for sustainable development. People really don't know the exact concept of remanufacturing. In the coming years, remanufacturing will become a growing sector in the world.

Product cannibalization will not become an issue when remanufactured product is a perfect substitute for new product. When the cost of remanufacturing product is less than cost of new product then the company can enjoy more profit through remanufactured product [8]. The Kodak line single use camera is the best example of a perfect substitute for new product. 'Xerox' company offers remanufactured, updated new product for customers for less price. Here company makes more profit in remanufacturing the product. 'Xerox' company handled the issue of cannibalization of new product by remanufactured product by making more profit in the market.

IV. Remanufacturing Challenges

A. *Cost of EOL Product*

Cost involved in the return of EOL product to a remanufacturer is the largest cost involved in the remanufacturing process. To reduce this cost, remanufacturer offers incentives to consumers to return EOL product by offering discount on new product in return for old. An EOL product goes through many tests before remanufacturing and the cost associated for these tests are high. Sometimes, if the product is not suitable for remanufacturing, then recycling or landfill will remain the next option [17]. Proper design of product in view of remanufacturing is necessary.

B. *Quality Opinion*

From a customer perspective, remanufactured product and low-end product are different. Even if function wise both products are of same quality, the customer is not fully positive about remanufactured product. Customer's willingness to pay toward remanufacturing is necessary to be understood. Many customers do not want the tag of remanufactured product especially for high–end products.

C. *Supply Limitation*

Remanufacturing supply mostly depends upon the product life cycle of old product. Return flow of used product is a

most necessary element for successfully remanufacturing products. Used product availability and time required to return the product is necessary to increase the profitability of the company. OEMs can predict the market of low-end products. Prediction about the return of used product is very difficult. Hence return-flow supply of used product always becomes challenging for remanufacturing industries. It totally depends upon the customer's intensity of use.

D. Competition

Producing of low-end product is directly under the control of OEM. Remanufacturing of product is not directly controlled by OEM. If OEMs are not remanufacturing the product, then other competitors will remanufacture product to grab the market share. On behalf of OEMs, many third party industries make remanufactured products. Poor quality of remanufactured product may cause damaging the brand. OEMs can produce the remanufactured product at low cost so that it can directly compete with low-end product manufacturers.

E. Change of Technology

Demand of a remanufactured product also depends upon pace of change in technology. Acceptance of remanufactured product by consumer depends upon the need and price of the product. Nowadays, PLC is becoming shorter and shorter with reduction of price. Early launching of remanufactured product will result in more profit in the market. New technology will replace old technology product and remanufactured product. Hence, the pace of change of technology will decide the market of remanufactured products.

V. KEY ELEMENTS OF REMANUFACTURING

For remanufacturing industries, a closed loop supply chain management (CLSC) of EOL product is the main challenge. Closed loop supply chain management is important and an integral part of remanufacturing process. Success of perfect launching of a remanufactured product mainly depends upon CLSC. Following are some important key elements in the remanufacturing sector.

A. Product Acquisition Management (PrAM)

Reverse flow of used product with right quantity and good quality at right price and right time is the most important aspect in remanufacturing industries.

B. Framework for Reverse Logistic

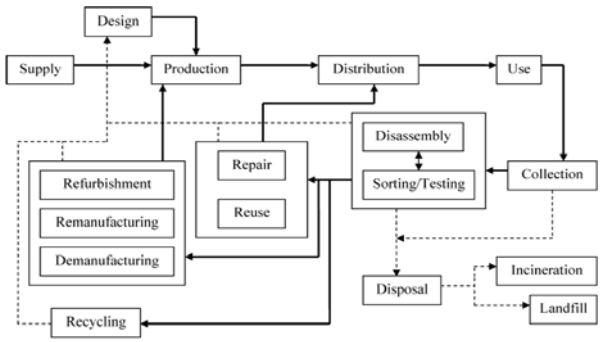

Fig. 3. A framework for reverse supply chain activities.
(Source: Sasikumar and Kannan, 2008)

Frame work of Reverse Logistic fit into remanufacturing processes (see fig. 03). An EOL is dissembled into parts where in some are fitted into remanufacturing; some are fitted for recycling [18].

C. Reverse Logistics Collection Models

There are basically three methods for collection of EOL products for the purpose of remanufacturing. Here mainly remanufacturer, retailer, third party and consumers are involved in reverse logistic collections.

Fig.4. shows that the consumer directly returns the used product to manufacturer. Here, the retailer is not involved in the reverse logistic collections. Many remanufacturing companies like Xerox, Canon and Hewlett Packard are collecting EOL products directly from customers.

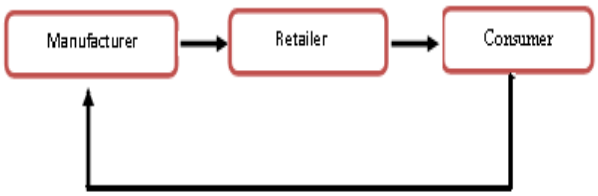

Fig. 4. Manufacturer collects from consumer.

Fig.5. explains the involvement of retailers in the collection of EOL product from consumer. Here, retailers supply the EOL product to the manufacturer. Consumer always feels comfortable to return EOL product to retailers. Single use of Kodak Camera, television, refrigerators are returned from consumer to retailer. This method is usually is adopted by most of the remanufacturers.

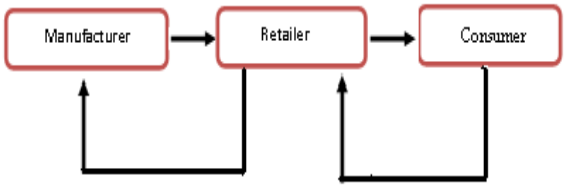

Fig. 5. Retailers collect from consumer.

Fig.6. shows that the third party is collecting the EOL products from consumer on behalf of manufacturer. In this case retailer is not involved in reverse logistic operation. Cars, Automobile parts etc. are collected by third party and a third party agency supplies the same to manufacturing units.

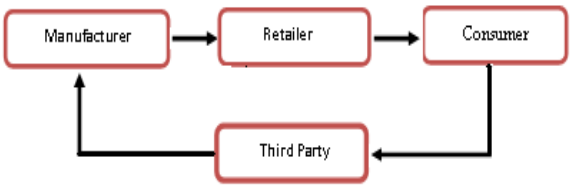

Fig. 6. Third party collects from consumer.

D. Basic Remanufacturing Product Development

When an EOL product is collected for remanufacturing, it goes into several stages of operations for bringing it back to new conditions. Fig.7. shows the steps of remanufacturing in the industries. After receiving the EOL products, companies sort the products in different groups for dissembling and cleaning, heating, machining and fabrication operations conducting it step by step. All operated components are

reassembled for testing and finally products are ready for packaging.

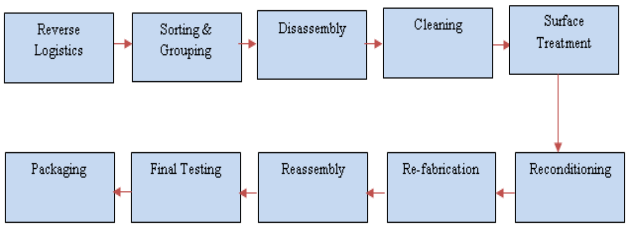

Fig. 7. Basic remanufacturing product development model.

E. Demand and Supply for Remanufactured Product

Market demand of remanufactured product and availability of used products are two important factors which decide the remanufacturing strategies. Fig.8. shows four quadrants in which 'No Action' quadrant show insufficient market demand and sufficient supply of remanufacturable products. The "Watch" quadrant shows sufficient market demand, but an insufficient supply of remanufacturable products available. The situation should be carefully watched since this is a potentially profitable market and third-party remanufacturers will be attracted. The "Remanufacture" quadrant is where there are both market demand and sufficient quantities of remanufacturable products available. Remanufacturing them should be initiated as soon as possible. The final quadrant, "Recycle" is when there are sufficient supplies of remanufacturable products, but no market demand. The best choice in this situation is to obtain some revenue via materials recycling.

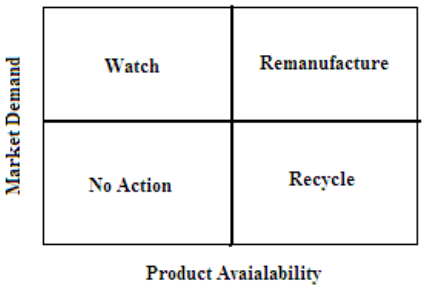

Fig. 8. Product remanufacturing matrix.

F. Remanufacturing Decision

Table I shows very important decisive conditions by which a company can decide whether they can go for remanufacturing or not. The decision to stop remanufacturing a product is a function of many factors, including the presence of third-party remanufacturing, age of the technology, the availability of replacement parts & components and a need to retire legacy systems. From Table I, it can be seen that remanufacturing cost, supply of used product & size of functionality-oriented customer segment are decisive parameters for remanufacturing. If remanufacturing costs are high, the functionality-oriented segment is large with sufficient quantities of used products available than company can think about remanufacturing. In this case products will lie in 'Remanufacture' quadrant. If the remanufacturing costs are low, remanufacturing is profitable in three scenarios. But if the supply of used products is limited and there is a large functionality-oriented segment, remanufactured products should not be offered, for example as in the 'No Action' quadrant in fig. 8.

TABLE I: REMANUFACTURING DECISION

Remanufacturing Costs	Supply of EOL Products	Consumer Segment	Remanufacturing Decision
Low	Low	Low	√
Low	Low	High	X
Low	High	Low	√
Low	High	High	√
High	Low	Low	X
High	Low	High	X
High	High	Low	X
High	High	High	√

VI. RIFFILING VS REMANUFACTURING

There are two methods of refurbishing the printer cartridge. Cartridge can simply be refilled or remanufactured. Understanding the difference between these two is essential. From the customer point of view, price and quality of cartridge will play an important role before a buying decision is made. Here a clear-cut comparison between refill and remanufacturing did by a Cartridge company, World Pasadena is examined.

TABLE II: REFILL PROCESS AND OPERATION TIME

Sr. No	Refill Process	Approximate Time in Minutes	Operation Time in %
1	Cartridge is electrically tested in a generic tester	0.5	5%
2	Old ink is removed by spinning the cartridge	3.0	28%
3	Print head is cleaned using an ultrasonic cleaner	0.10	1%
4	Generic ink is injected into the cartridge	4.0	38%
5	Cartridge is print tested on a generic tester	1.0	9%
6	Packaging	2.0	19%
Total time required for refill of the ink printer cartridge		10.60	100%

Table II Shows the refill process and operation time required for ink printer cartridge. Within 10 to 12 minutes of time, refilling process can be done. Due to less operation time, labor & material cost reduces. As shown in Table III, remanufacturing process and operation time are explained in detail. Remanufacturing of cartridge took around 30 hrs for operations. Cost associated with remanufacturing product is high as compared to refilling process. Remanufacturing process required more operations as compared to refilling process. In remanufacturing operation process, cartridge

drying process took maximum operation time. Near about 81.5 % operation time is consumed in cartridge drying process. Cartridge goes through multiple cycles of vacuum boiling, spinning and atomizing. To fully clean out and rejuvenate requires 240 minutes and cartridge acclimate after refill process takes around 60 minutes. Labor and material cost associated with remanufacturing process is high as compared to refilling process.

TABLE III: REMANUFACTURING PROCESS AND OPERATION TIME

Sr. No	Remanufacturing Process	Approximate Time in Minutes	Operation Time in %
1	Cartridge is electrically tested in a generic tester	0.5	0.03
2	The print head of the cartridge is soaked in a special ink dissolving solution	0.5	0.03
3	Old ink is removed by spinning the cartridge	15	1.0%
4	Print head is further cleaned using a specially designed water atomizing gun	02	0.10 %
5	Cartridge goes through multiple cycles of vacuum boiling, spinning and atomizing to fully clean out and rejuvenate the cartridge	240	14 %
6	Cartridge is completely dried	1440	81.5 %
7	Ink specially designed for the cartridge which matches original ink as close as possible is injected into the cartridge	03	0.2 %
8	Cartridge is allowed to rest and acclimate after the refill process	60	3%
9	Cartridge is print tested in the printer for which it was designed for	01	0.06
10	Packaging	02	0.10
Total time required for remanufacture of the ink printer cartridge		1766	100%

Now customers have three choices in buying the cartridge. Customer can buy refilled or remanufactured or can buy new cartridge itself. Price of refilled cartridge is less as compared to remanufactured or new cartridge. However, quality of refilled cartridge is very low as compared to remanufactured or new one. Quality of remanufactured cartridge is same as new one and hence customers give more preference to buying remanufactured cartridge. Price of remanufactured cartridge is 70 % as compared to newly manufactured cartridge by OEM.

VII. DEMAND OF REMANUFACTURING PRODUCT

According to Ink Guides Company, many industries are making huge profit by selling remanufactured cartridges. Fig.9. shows cartridge brands and cost saving due to remanufacturing over OEM. HP and EPSON are saving around 65 % manufacturing cost due to remanufacturing. Due to huge cost saving, companies can offer competitive price for remanufactured products. Here company can earn more profit as compared to new one.

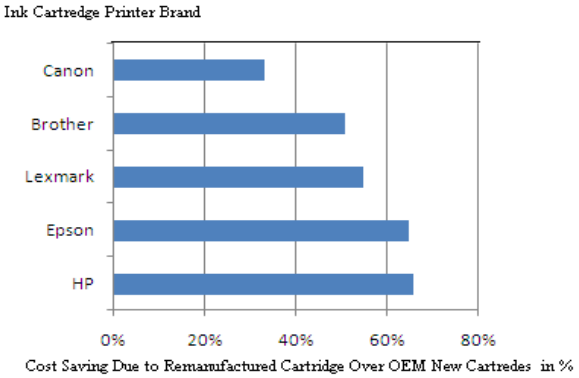

Fig. 9. Cost saving cartridges over OEM.

Ink Guide indexes well over 10,000 ink and toner cartridges from 10 well known on line ink stores. Fig.10. shows sale volume of remanufactured cartridges as compared to new sale of cartridges by OEM. Simply, the printer brands with the maximum volume of sold cartridges are listed in the fig.10.

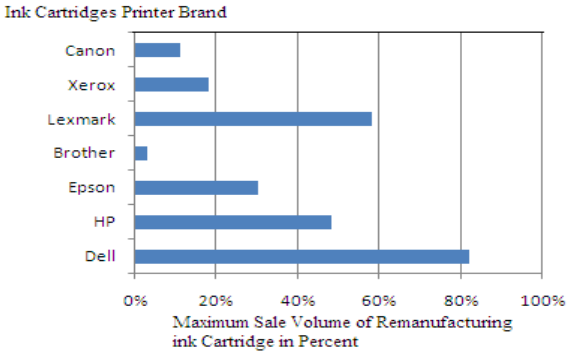

Fig. 10. Maximum sale volume of remanufactured cartridge.

VIII. CORRELATION BETWEEN COST SAVING AND MAXIMUM SALE VOLUME

From the analysis, it is very interesting to find the correlation between cost saving due to remanufactured cartridges and maximum sale volume of remanufactured cartridges (see fig.9 and fig.10.) Coefficient of correlation between cost saving cartridges remanufactured and maximum sale volume of remanufactured cartridge is 0.5771. This value shows not so strong or too weak correlation i.e. $R=0.5771$ and $R^2=0.3331$.

Coefficient of determination shows the value of 0.3331 and hence dependency of cost saving due to remanufactured cartridges is 33.31 % for maximum sale volume of remanufactured cartridge.

IX. CONCLUSION

Remanufactured products are in good demand in the market due to low price and remarkable functional quality as new products have. Demand of remanufactured products depends upon the pace of product cannibalization of existing product. There are some challenges like expectation of quality, supply limitation, competition and change of pace of technology for remanufacturing industries. Here some

important elements like Product Acquisition Management, Reverse Logistic, Reverse Logistic Collection Models and Basic of Remanufacturing Product Development are discussed for perfect launching of remanufactured products. Product remanufacturing matrix explains the decision about EOL products. Case study of PC Monitors explains the importance of product cannibalization for remanufacturing of products. Cost saving due to remanufacturing has shown some impact on sale of remanufactured cartridges. Coefficient of determination value of 33.31% shows the impact of cost saving due to remanufactured cartridges on the sale volume of these cartridges.

REFERENCES

[1] W.M. Hauser and R.T. Lund, "Remanufacturing: Operating practices and strategies," Boston University, May 2008.

[2] M. Ferguson, "Strategic issues in closed-loop supply chains with remanufacturing," College of Management, Georgia Tech, Atlanta, GA 30332, 2009.

[3] H.Vasudevan, V. Kalamkar, and R. Terkar, " Product cannibalization due to remanufacturing and its decisive strategies," *International Conference on Sustainable Manufacturing: Issues, Trends and Practices*, Bits, Pilani, November 10-12, 2011, pp. 13-18

[4] Johan Östlin, Erik Sundin, and Mats Björkman, "Product lifecycle implications for remanufacturing strategies," *Journal of Cleaner Production*, 2009, (17), 11, pp. 999-1009.

[5] H. Hermansson and E. Sundin, "Managing the remanufacturing organization for an optimal PLC,"*1-4244-0081-3/05/$20.00 ©) IEEE*, 2005.

[6] V.D.R. Guide, "Production planning and control for remanufacturing: Industry practice and research needs," *Journal of Operations Management*, 18_2000. pp.467–483, 2000.

[7] V.D.R. Guide and Li J, "The potential for cannibalization of new products sales by remanufactured products," *Decision Sciences Journal*, vol.41, Number 3, 2010.

[8] Atasu, V.D.R. Guide, and L.N.V.Wassenhove, "So what if remanufacturing cannibalizes my new product sales?" *California Management Review*, vol. 52, No. 2, CMR.Berkeley. Edu, 2010.

[9] L. Debo, L.Toktay, and L. Wassenhove, "Life cycle dynamics for portfolios with remanufactured products," Carnegie Bosch Institute 2005.

[10] M. Matsumoto and Y. Umeda, "An analysis of remanufacturing practices in Japan," *Journal of Remanufacturing*, Springeropen journal 2011.

[11] Y. Ogush and M. Kandlikar, "The impact of end-of-life vehicle recycling law on automobile recovery in Japan," *1-4244-0081-3/06/$20.00 @2005 IEEE*, 2005.

[12] R.Terkar, H. Vasudevan, "Need for product cannibalization in small scale manufacturing industries through product life cycle management," *International Conference on Modern Trends in Industrial Engineering*, November 17-19, 2011 S.V. National Institute of Technology, Surat – 395 007, Gujarat, India, 2011.

[13] R. Terkar, H. Vasudevan, V. Sunnapwar, and V. Kalamkar, "Perfect product launching strategies in the context of survival of small scale consumer product industries," *ICSTM 2011,* CCIS 145, pp.321-326 2011.

[14] R. Terkar, H. Vasudevan, and V. Sunnapwar, "Importance of innovative product launching and product life cycle management in small scale consumer industries," *International Journal of Computer Application*, Number-3, Article-2, 2011.

[15] Wi Jun-yu, Y. and Wei, ZHAOtty, "Points worth re-consideration concerning product life cycle management," *IEEE*, 2010.

[16] A. Sarvary and M.L. Wassenhove, "Remanufacturing as a marketing strategy," *Management Science,* vol. 54 (10), 2009, pp. 1731-1747.

[17] C. Peizhi, Y. Jukun, and Z. Sheng, "Information-based remanufacturing upgrade study," *ICRM2010-Green Manufacturing,* Ningbo, China, 2010.

[18] Sasikumar and G Kannan, "Issues in reverse supply chains, part I: End-of-life product recovery and inventory management – an overview," *International Journal of Sustainable Engineering*, vol. 1, Issue: 3, Publisher: Taylor and Francis, 2008, Pages: 154-172.

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