THE SUPPLY CHAIN MANAGEMENT IN REVERSE LOGISTICS: A CASE OF PRODUCT RECOVERY MANAGEMENT.

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ABSTRACT

The Supply Chain Management in reverse logistics has brought new development in the industry especially in the area of Product Recovery Management (PRM). Product Recovery Management is the technique of reducing costs and depreciation of products of a firm by collecting and reuse of the product for the same or totally different purposes. It is a portion of components used in the area of Reverse Logistics. Product Recovery Management is very important for maintaining the ecological value of the product and environment as well. Using this Product Recovery Management will decrease the number of waste of a manufacturing firm instead of increase the profit and public consciousness of the firm. We illustrate the PRM methodology with a case example.

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1.0 REVERSE LOGISTICS

Reverse logistics is generally defined as the process of returning faulty goods from customers to the suppliers or any other company acting as an agent to reverse logistics (CLM,1998). It is a returned good handling processes, which will reduce those cost of source, by improving manufacturing and shipping processes since many goods are damaged in transit. Reverse logistics means different things to different people. One authority has described it as the "process of moving a product from the point of consumption to another point for the purpose of recapturing the remaining value, or for the eventual proper disposal of the product" (Cooper et al., 1997). Since old times materials of used objects are recovered and reused for similar or completely different purposes.

2.0 CLASSICAL REASONS FOR REVERSE LOGISTICS

There are several reasons for doing the reverse logistics. The classical reasons which is widely known are, (Faria and Robertson, 1995)

- the scarcity of resources,
- the introduction of cheap materials and more efficient technologies to discover and obtain resources,
- gave rise to a society of mass consumption in the sixties, where reuse was often not economically justified.

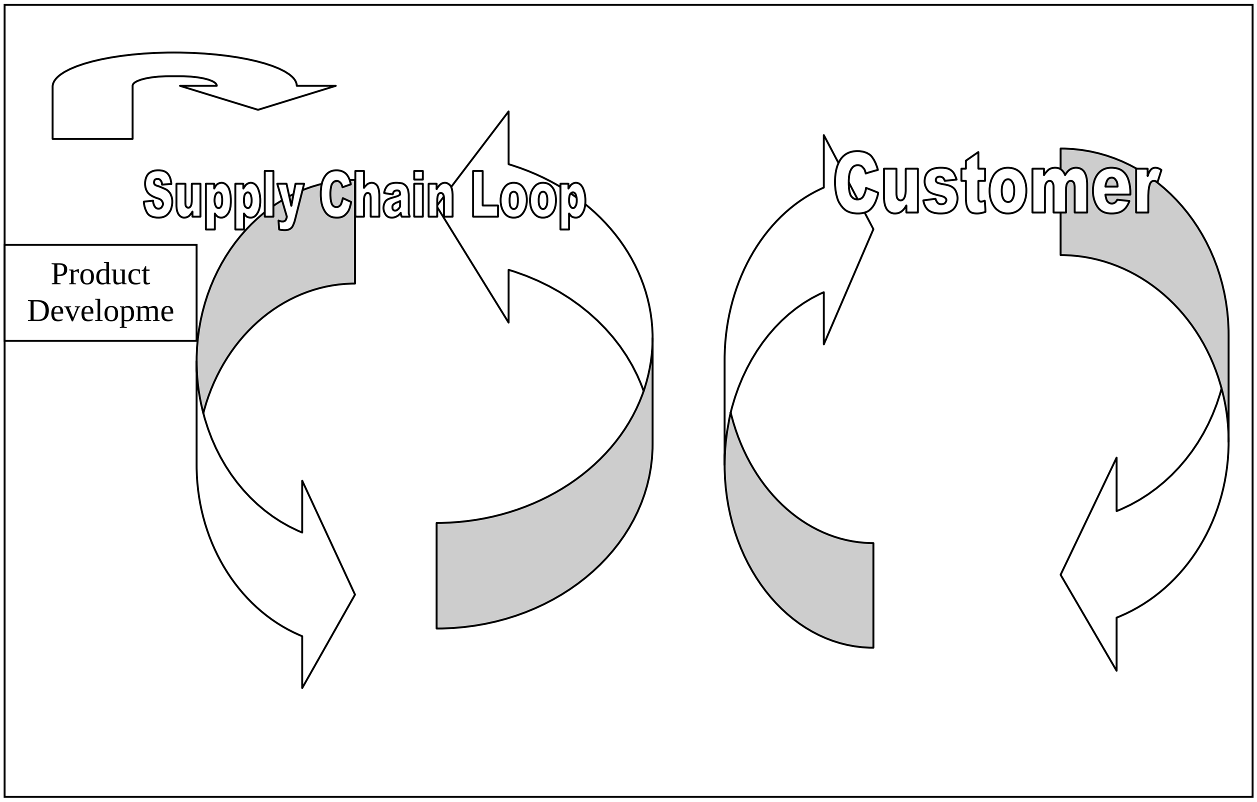
3.0 REVERSE LOGISTICS: SCOPE AND REASONS

Products, components, materials, equipment and even complete technical systems may go backwards in the supply chain (for brevity we will use the term products to refer to all of them), (Flapper and Clement, 1998). For some time we have been familiar with products being reworked during manufacturing due to unsatisfactory quality, or with good materials or components being returned from the production floor because they were leftover after production (**manufacturing returns**). Defective products may be defected after they have entered the supply chain resulting in a pull back of products through the chain (**product recalls**). From this stage there are more actors in the chain involve with the reverse flows on the basis of commercial agreements such as returning vs. taking back obsolete stocks of short-life products (**B2B commercial returns**). In addition, in the business-to-business scenery, products may be send back due to mismatches in the demand and supply in terms of timing and product quality (**B2C commercial returns**). A particular situation is e-commerce where high percentages of returned products are not a surprise. The average return rate has been estimated at some 36% (Morphy, 2002). During use and in presence of warranty or service possibilities, products may also be returned to be substituted by others, or to be repaired (**warranty and service returns**). Ultimately, even after use of product life, products are collected to be e.g. remanufactured, recycled or incinerated (**end-of-use and end-of-life returns**). At this point both material's hazard and environmental impact have to be taken into account (the latter especially in European Union countries). Concluding, products may reverse direction in the supply chain for a variety of reasons as listed below (Dekker and van der Laan, 2002; Dekker and de Brito, 2002):

- manufacturing returns
- commercial returns (B2B and B2C)
- product recalls
- warranty returns
- service returns
- end-of-use returns

Summarizing, a product is developed and goes into production following the supply chain with purpose of reaching the customer. However, at any moment, the product may go back in the chain. From this moment on, the chain does not deal any longer with supply alone, but also with recovery-related activities. Ergo, we refer to it as a supply chain loop. This denomination underlines the possible integration of forward and reverse flows. Furthermore, it embraces both the closed loop supply chains, where supposedly the reverse flows goes back to the original user or original function, as well as open loop supply chains.

Figure 1: Product life-path and return reasons



4.0 PRODUCT RECOVERY MANAGEMENT

Product recovery management is all about a process that tries to control the recovery of products. A formal description is given in Thierry (1997): "Product recovery management (PRM) encompasses the management of all used and discarded products for which a manufacturing company is responsible. The objective of (PRM) is to recover as much of their economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste".

A slightly more appropriate definition could be: "The management of all used and discarded products for which a manufacturing company takes responsibility" (Veera and Gupta, 1996). The objective of Product recovery management (PRM) is to recover that amount of products that is economically and ecologically justifiable, while satisfying the legal constraints.”

As a consequence of undesired environmental effects of waste disposal and limited availability of natural resource to manufacture new product, product recovery is gaining momentum. The product recovery is carried out mainly due to:(Lund, 2001).

1. Hidden economic value in the product
2. Market requirements (Eco-friendly products)
3. Government regulations

Product recovery aims to minimize the amount of waste sent to land fills by recovering materials and parts from used products by means of recycling and remanufacturing (including reuse of parts and products). This reuse opportunity gives rise to a new material flow from user, back to the producer.

6.0 PRODUCT RECOVERY MANAGEMENT AREAS AND ITS ADVANTAGES

Product recovery is not an easy solution to the problem of waste reduction. PRM posses many difficult, but interesting questions in various areas, (Kopicki et al.,1993). Some of these areas are:

- *Product design*

  In order to be able to recover products or product components in an efficient way products need to be specially designed for quick disassembly and testing. While materials and product parts need to be of sufficient quality to make them reusable, reducing the number of materials used, avoiding composite components, marking parts and components to show their composition of materials.
- *Logistics*

  Materials and product parts need to be collected, possibly sorted and transported. In doing so several options should be considered:

  i. Are used products handled by the manufacturer itself or by an external actor.

ii. Does the manufacturer process the used products and if so are they incorporated in the existing production line, or does an external actor do it.

iii. Are distributions and collection completely separated or is there a level of integration.

iv. Should testing occur immediately after collection, decentralized, which saves transportation cost of non-reusable products or after transportation, centralized, which saves testing equipment. If sorting occurs early in the reverse logistics chain, this may save handling costs.

- *Production planning and inventory control*

  The flow of used products and used materials is usually more variable and uncertain than flows of ordinary raw materials and half-fabricates. Also, the combination of manufacturing and product recovery tends to make planning and control more complexes.

- *Information systems*

  Quality and timing of returned products and materials often have to be monitored. This may require information systems like electronic data interchange (EDI), and other new technologies to trace individual products while they are still in the market.

- *Finance*

  Intriguing is the problem of valuing reusable products and materials. Since materials and product components can be reused, sometimes more than once, it is far from trivial to assess their share in the total production costs.

- *Marketing*

  Considering the above, product recovery seems to pose many threats towards manufacturers, for instance large investments for business process redesign, uncertainty regarding legislation, and uncertainty regarding product quality and recovery rates. On the other hand, reusable products may be positioned as ‘environmental friendly’ to attract new or to commit already existing customers.

7.0 PRODUCT RECOVERY OPTIONS

The nature of the collected products after use (the ‘return’ flow), influences the nature and configuration of the product recovery process. In this light Thierry et al (1995) consider the following types of product recovery:

- *Repair*

  Products are bought to working order. This implies that typically the quality standards of repaired products are less than those for new products. Usually repair requires minor disassembly, since only the non-working parts need to be repaired or replaced.
- *Refurbishing*

  Products are upgraded to some prespecified quality standards. Typically these standards are less than those for new products are but higher than those for repaired products.
- *Remanufacturing*

  Products are upgraded in such a way that exactly the same quality standards are satisfied as for new products. This means that the remanufactured products can be resold at the market of new products.
- *Cannibalization*

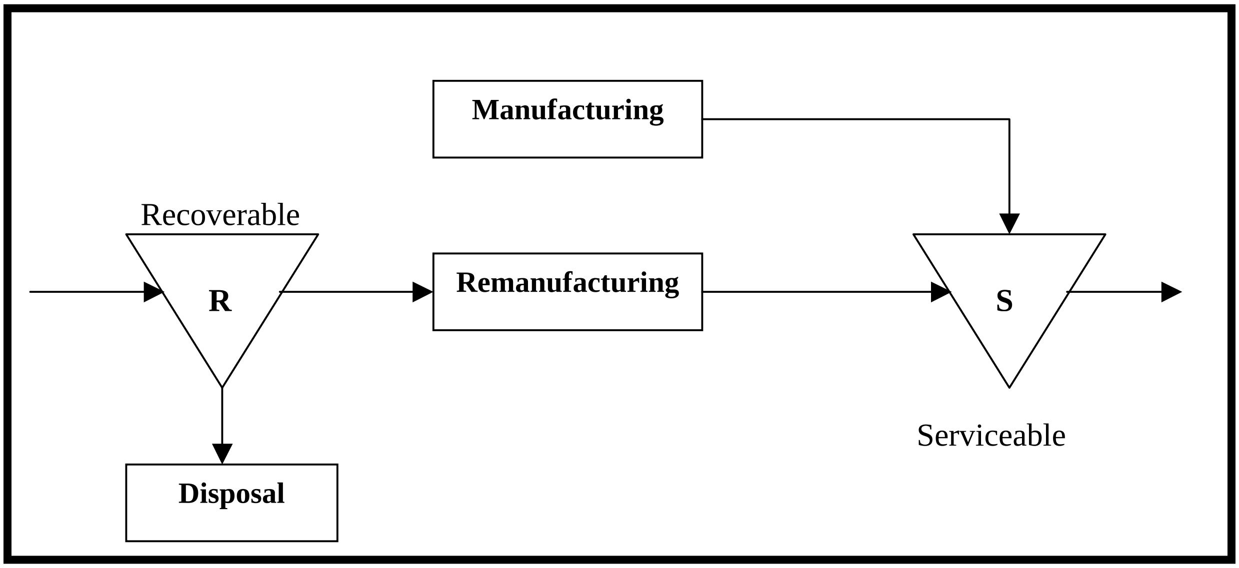
  This involves selective disassembly of used products and inspection of potentially reusable parts. Parts obtain from cannibalization can be reuse in the repair, refurbishing or remanufacturing process.
- *Recycling*

  Materials rather than products are recovered. These materials are reused in the manufacturing of new products.

8.0 INVENTORY CONTROL FOR PRODUCT RECOVERY SYSTEM

A product recovery system consists of two stocking points, which are the serviceable and recoverable. An external demand in the system is satisfied by serviceable inventory. Serviceable inventory can either be replenished by new products (manufactured) or by returned products (remanufactured). The return product can either be kept in recoverables for future remanufacturing or disposed. The product recovery system is shown below.

Figure 2: Product Recovery System

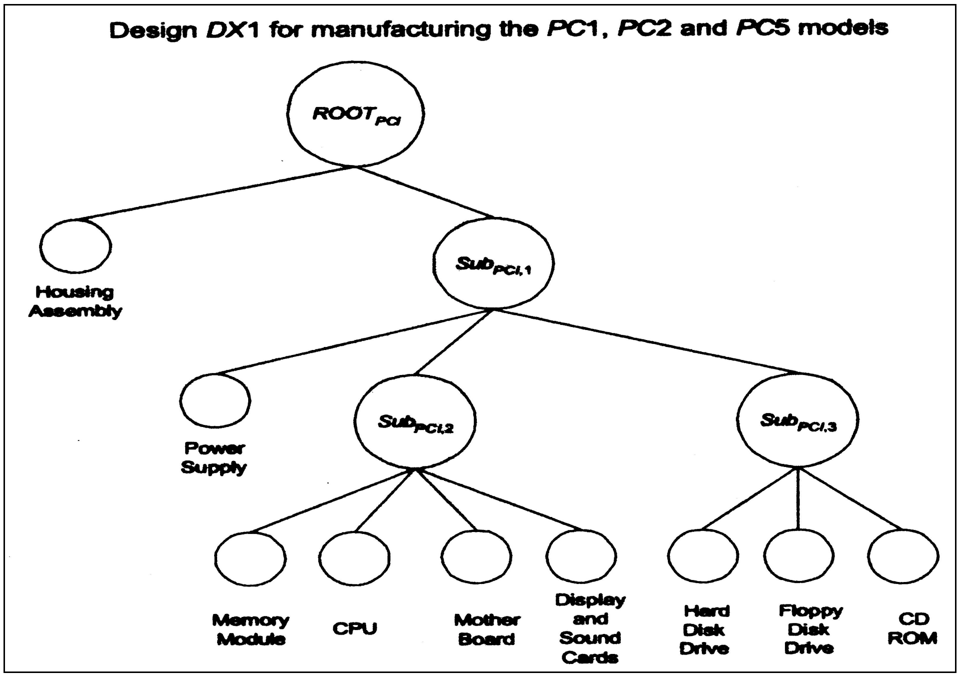


9.0 CASE EXAMPLE

We consider a case example to illustrate the application of the supply chain optimization through PRM. A computer company remanufactures and distributes two new computer models (PC5 and PC6), which partially utilize the components from four different computer models (PC1, PC2, PC3 and PC4) at the end of their lease terms (Fig. 3 and 4). Let the planning horizon be ten periods, and the Assembly and Ordering Lead Times (LT and RT) be one period each (assume that items can be disassemble in the same period they are received).

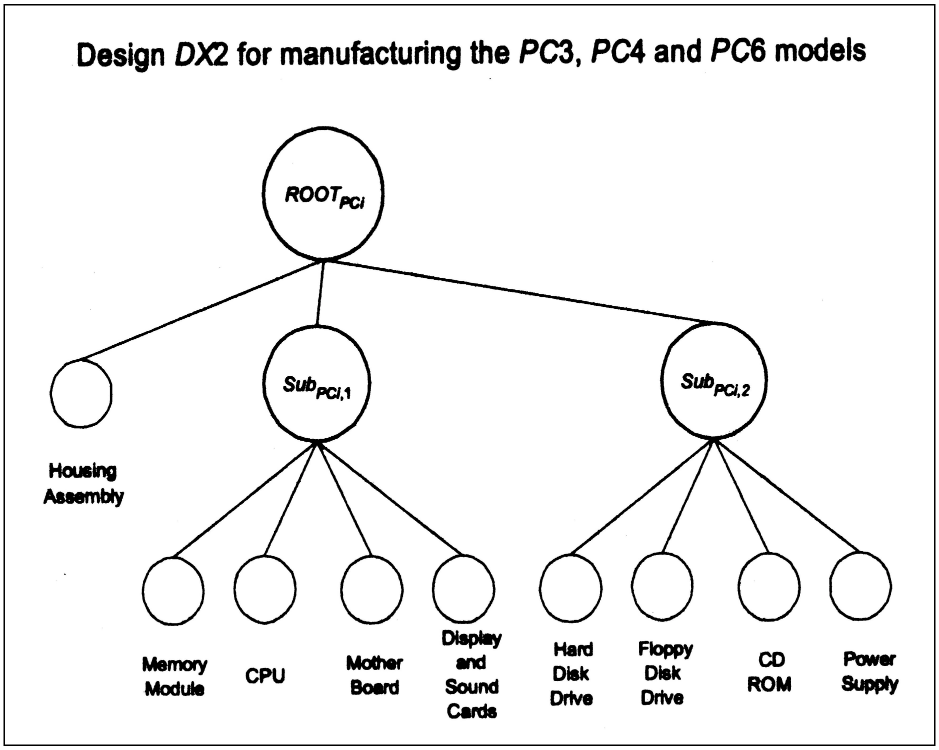
Table 1 and 2 show a sample of the input data that is required on each product and its components. The procedure detailed in the previous section is applied to the case example using all the input data,. The components yield, the result of the optimization in each period, and the partial listing of CRP are shown in Tables 3, 4 and 5 (Veera and Gupta, 1996)

Figure 3: Product structure for model PC1, PC2 and PC5



Adopted: Veera and Gupta, (1996)

Figure 4: Product structure for model PC3, PC4 and PC6



Adopted: Veera and Gupta, (1996)

The results for this case example show that the lead times (for assembly and disassembly) have adverse effects on the behavior of the supply chain, causing a certain degree of oversupply and potential shortages (Tables 3 and 4). For example, in the case example, the demand figures have been assumed to include the seasonal effects of consumer demand. Customers tend to order a higher number of computers in periods nine and ten. The results from CRP scheduling show that, with the total lead time of two periods, there are shortages in period 7 of components 9, 13 and 14, and in period 8 of components 9, 13, 14, and 15, even though there is ample supply of products in periods 9 and 10 (Table 5). This suggests that, in the reverse logistics supply chain where customers usually trade-in (or swap) the computers in that same period, manufacturers may not be able to take full advantage of the reusable components retrieved from the traded-in products to fulfill the demand of remanufactured products, if the assembly and disassembly lead times are long.

The design of a product structure may also influence the preference for its disassembly. Notice that *PC*3 and *PC*4 are preferred over *PC*1 and *PC*2. This is partly due to the fact that *PC*3 and *PC*4 require less time to disassemble (and hence less processing costs) than *PC*1 and *PC*2. Another reason is that *PC*3 and *PC*4 are both built with more expensive, more advanced components, which in turn, prove to be more attractive for reclamation. Hence, in the reverse logistics supply chain, products built with components of higher value will make remanufacturing more attractive provided, of course, proper procedures are available for the collection, disassembly and retrieval.

Table 1: Supply and Demand Information

Time Period	1	2	3	4	5	6	7	8	9	10
Supply										
PC1	***75***	***75***	***75***	***50***	***50***	***45***	***45***	***30***	***0***	***0***
PC2	***65***	***70***	***105***	***90***	***90***	***80***	***80***	***75***	***0***	***0***
PC3	***85***	***70***	***100***	***100***	***90***	***85***	***100***	***115***	***0***	***0***
PC4	***85***	***105***	***110***	***145***	***130***	***130***	***150***	***140***	***0***	***0***
Demand										
PC5	***0***	***0***	***95***	***100***	***110***	***120***	***85***	***70***	***135***	***150***
PC6	***0***	***0***	***100***	***125***	***125***	***100***	***95***	***125***	***150***	***150***

Table 2. Component Structure of Computers.

Component Number (i)	Component Name	Multiplicity (Q_{ij})					
		Supply				Demand	
		PC1	PC2	PC3	PC4	PC5	PC6
1	Housing Assembly (*PC*1, *PC*2)	1	1	-	-	-	-
2	Housing Assembly (*PC*3, *PC*4)	-	-	1	1	-	-
3	Memory Module, 16 MB, SDRAM	2	-	-	-	-	-
4	Memory Module, 32 MB, SDRAM	2	4	2	-	2	2
5	Memory Module, 64 MB, SDRAM	-	-	2	4	2	2
6	Pentium II 350 MHz CPU and Heat Sink	1	-	-	-	-	-
7	Pentium II 400 MHz CPU and Heat Sink	-	1	1	-	1	-
8	Pentium II 450 MHz CPU and Heat Sink	-	-	-	2	-	2
9	Mother Board (*PC*1, *PC*2, *PC*5)	1	1	-	-	1	-
10	Mother Board (*PC*3, *PC*4, *PC*6)	-	-	1	1	-	1
11	Display and Sound Cards (*PC*1 - *PC*4)	1	1	1	1	-	-
12	4 GB Hard Drive	1	-	-	-	-	-
13	9.1 GB Hard Drive	-	1	2	-	2	-
14	12.8 GB Hard Drive	-	-	-	2	-	2
15	1.44-MB Diskette Drive	1	1	1	1	1	1
16	32X CD-ROM Drive (*PC*1 - *PC*4)	1	1	1	1	-	-
17	Power Supply (*PC*1 - *PC*4)	1	1	1	2	-	-
18	Housing Assembly (*PC*5)	-	-	-	-	1	-
19	Housing Assembly (*PC*6)	-	-	-	-	-	1
20	Display and Sound Cards (*PC*5, *PC*6)	-	-	-	-	1	1
21	DVD-ROM Drive (*PC*5, *PC*6)	-	-	-	-	1	1
22	Power Supply (*PC*5, *PC*6)	-	-	-	-	1	1

Table 3. Components Yield for the Case Example.

Periods	1	2	3	4	5	6	7	8	9	10
Supply of Products										
PC 1	75	75	75	50	50	45	45	30	0	0
PC 2	65	70	105	90	90	80	80	75	0	0
PC 3	85	70	100	100	90	85	100	115	0	0
PC 4	85	105	110	145	130	130	150	140	0	0
Yield of Component P_i										
P_1	140	145	180	140	140	125	125	105	0	0
P_2	170	175	210	245	220	215	250	255	0	0
P_3	150	150	150	100	100	90	90	60	0	0
P_4	580	570	770	660	640	580	610	590	0	0
P_5	510	560	640	780	700	690	800	790	0	0
P_6	75	75	75	50	50	45	45	30	0	0
P_7	150	140	205	190	180	165	180	190	0	0
P_8	170	210	220	290	260	260	300	280	0	0
P_9	98	101	126	98	98	87	87	73	0	0
P_{10}	127	131	157	183	165	161	167	191	0	0
P_{11}	310	320	390	385	360	340	375	360	0	0
P_{12}	75	75	75	50	50	45	45	30	0	0
P_{13}	176	157	228	217	202	187	210	228	0	0
P_{14}	127	157	165	217	195	195	225	210	0	0
P_{15}	248	256	312	308	288	272	300	288	0	0
P_{16}	310	320	390	385	360	340	375	360	0	0
P_{17}	395	425	500	530	490	470	525	500	0	0

Table 4. Result of the Optimization in Each Period.

Time Period (*t*)	1	2	3	4	5	6	7	8
Profit (or Loss)	($2,652)	($1,399)	$127	$753	$2,059	$3,416	$1,358	$1,535
Number of products to order for disassembly (units)								
PC 1	73	73	53	40	32	20	45	30
PC 2	65	70	105	90	90	80	80	75
PC 3	62	66	78	96	70	54	100	115
PC 4	75	103	110	134	127	130	150	140

Table 5. Partial Listing of CRP for the Case Example.

Time Period (*t*)	1	2	3	4	5	6	7	8	9	10
Item *PC* 5										
Gross Requirements (Demand):	0	0	95	100	110	120	85	70	135	150
Item *PC* 6										
Gross Requirements (Demand):	0	0	100	125	125	100	95	125	150	150
Item Sub*PC* 5,1										
Gross Requirements:	0	95	100	110	120	85	70	135	150	0
Item Sub*PC* 5,2										
Gross Requirements:	0	95	100	110	120	85	70	135	150	0
Item Sub*PC* 5,3										
Gross Requirements:	0	95	100	110	120	85	70	135	150	0
Item Sub*PC* 6,1										
Gross Requirements:	0	100	125	125	100	95	125	150	150	0
Item Sub*PC* 6,2										
Gross Requirements:	0	100	125	125	100	95	125	150	150	0
Number of Product PC1 to Disassemble:	73	73	53	40	32	20	45	30	0	0
Number of Product PC2 to Disassemble:	65	70	105	90	90	80	80	75	0	0
Number of Product PC3 to Disassemble:	62	66	78	96	70	54	100	115	0	0
Number of Product PC4 to Disassemble:	75	103	110	134	127	130	150	140	0	0
Item *P* 1										
Number of Components Discarded:	138	143	158	130	122	100	125	105	0	0
Item *P* 2										
Number of Components Discarded:	137	169	188	230	197	184	250	255	0	0
Item *P* 3										
Number of Components Discarded:	146	146	108	80	84	40	90	60	0	0
Item *P* 4 (Shelf Life = 1, Quality = 100%)										
Gross Requirements:	390	450	470	440	360	390	570	600	0	0
Receipts from External Sources:	0	0	0	0	0	0	0	0	0	0
Available Balance:	0	140	248	460	632	584	468	508	498	0
Net Requirement:	390	310	222	0	0	0	102	92	0	0
On Hand from Disassembly:	530	558	682	632	584	468	610	590	0	0
Number Used from Disassembly:	390	310	222	0	0	0	102	92	0	0
Number of New Components Required:	0	0	0	0	0	0	0	0	0	0
Number of Components Discarded:	0	0	0	20	272	174	0	0	498	0
Item *P* 5 (Shelf Life = 1, Quality = 100%)										
Gross Requirements:	390	450	470	440	360	390	570	600	0	0
Receipts from External Sources:	0	0	0	0	0	0	0	0	0	0
Available Balance:	0	34	128	254	542	648	628	800	790	0
Net Requirement:	390	416	342	186	0	0	0	0	0	0
On Hand from Disassembly:	424	544	598	728	848	628	800	790	0	0
Number Used from Disassembly:	390	416	342	186	0	0	0	0	0	0
Number of New Components Required:	0	0	0	0	0	0	0	0	0	0
Number of Components Discarded:	0	0	0	0	182	288	88	200	790	0
......										

Table 5. (Continued)

Time Period (t)	1	2	3	4	5	6	7	8	9	10
......										
.....										
Item #8 (Shelf Life = 6, Quality = 70%)										
Gross Requirements:	95	100	110	120	85	70	135	150	0	0
Receipts from External Sources:	0	0	0	0	0	0	0	0	0	0
Available Balance:	0	0	0	0	0	0	0	0	0	0
Net Requirement:	95	100	110	120	85	70	135	150	0	0
On Hand from Disassembly:	98	100	110	91	85	70	87	73	0	0
Number Used from Disassembly:	95	100	110	91	85	70	87	73	0	0
Number of New Components Required:	0	0	0	29	0	0	48	77	0	0
Number of Components Discarded:	43	43	48	39	37	30	38	32	0	0
......										
Item #13 (Shelf Life = 6, Quality = 75%)										
Gross Requirements:	190	200	220	240	170	140	270	300	0	0
Receipts from External Sources:	50	50	25	0	0	0	0	0	0	0
Available Balance:	0	0	0	0	0	0	0	0	0	0
Net Requirement:	140	150	195	240	170	140	270	300	0	0
On Hand from Disassembly:	141	151	195	211	172	141	210	228	0	0
Number Used from Disassembly:	140	150	195	211	170	140	210	228	0	0
Number of New Components Required:	0	0	0	30	0	0	60	72	0	0
Number of Components Discarded:	49	52	66	71	60	48	70	77	0	0
Item #14 (Shelf Life = 6, Quality = 75%)										
Gross Requirements:	200	250	250	200	190	250	300	300	0	0
Receipts from External Sources:	100	100	50	0	0	0	0	0	0	0
Available Balance:	0	0	0	0	0	0	0	0	0	0
Net Requirement:	100	150	200	200	190	250	300	300	0	0
On Hand from Disassembly:	112	154	165	201	190	195	225	210	0	0
Number Used from Disassembly:	100	150	165	200	190	195	225	210	0	0
Number of New Components Required:	0	0	35	0	0	55	75	90	0	0
Number of Components Discarded:	50	56	55	68	64	65	75	70	0	0
Item #15 (Shelf Life = 6, Quality = 85%)										
Gross Requirements:	195	225	235	220	180	195	285	300	0	0
Receipts from External Sources:	0	0	0	0	0	0	0	0	0	0
Available Balance:	0	0	0	0	0	0	0	0	0	0
Net Requirement:	195	225	235	220	180	195	285	300	0	0
On Hand from Disassembly:	220	249	276	288	255	227	300	288	0	0
Number Used from Disassembly:	195	225	235	220	180	195	285	288	0	0
Number of New Components Required:	0	0	0	0	0	0	0	12	0	0
Number of Components Discarded:	80	87	111	140	139	89	90	72	0	0
......										
Item #22										
Number of New Components Required:	0	195	225	235	220	180	195	285	300	0

10.0 CONCLUSIONS

In summary, Product Recovery Management is a beautiful part of reverse logistics. Firms need to understand the new market demand of the Reverse Logistics products and services. Cooperation between existing vendors is the priority in this business. Firms can build internal capabilities through the merging programs or alliances or partnering with the existing vendors. Product Recovery Management should be adopted by each and every manufacturing firm, as there are many advantages of the system to the world community and environment as well as the firm itself.

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