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Recovering value from "End-of-Life" Equipment

A case study on the role of product information

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Abstract

This report summarizes the findings from case studies conducted at eight remanufacturing/recycling facilities in the UK and one in France. The report draws out the common issues related to the product recovery decisions, information availability and the effect of this on product recovery operations. The study highlighted the important role that availability of product information plays in making effective product recovery decisions. It was also understood that the timeliness of information gathering is crucial for effective recovery of value from end-of-life products. The study revealed the potential benefits that networked product identity could bring towards enhancing the performance of product recovery operations and provided a strong basis for undertaking an extensive research on the value of readily available information in increasing the efficiency of product recovery operations.

1. Introduction

This case study was undertaken as part of a research project that aims to look at the various decisions involved while recovering end-of-life (or returned) products, their relationship and dependency on the availability of information associated with the product, and evaluate the impact of RFID-based product identification technologies on the performance of product recovery operations. It has been highlighted in the literature (refer to Parlikad et al. [19]) that product recovery decisions that are made when products are returned/discarded by their users depend on information associated with those products collected across their lifecycle. Nevertheless, it is argued that information regarding the product is typically lost/degraded after the point-of-sale [1]. The concept of networked product identity enabled by the technologies such as the one promoted by the Auto-ID Centre [2] makes it possible for a product to carry complete information associated with it throughout its lifecycle and ensure flow of this information between the various actors in the supply chain. The objective of this research is to test and prove the hypothesis that the ready availability of information associated with a product will lead to effective product recovery decisions, which in turn will result in improved performance of product recovery operations, measured by performance measures such as net profit generated and percentage of the product reused.

The research involves building a model to represent the core decisions made during product recovery and the inputs (product information) and constraints associated with those decisions. The primary objective of this case study exercise is to develop a better understanding of the product recovery process, in order to build arguments to support the case for this research, i.e., the need for complete and readily available product information for making product recovery decisions. This case study would help to understand the level of information (un)availability prevalent in the industry, and the various problems associated with making decisions under uncertainty. The secondary objective of this case study is to identify potential companies from where the data necessary for simulating the product recovery process using the decision model developed can be collected. This will also help in ensuring that the model is verified and validated in a real-life situation.

2. Selection of companies

The selection of companies for this case study was influenced by two factors:

- (a) Government regulations, and
- (b) Product characteristics.

On the first, there have been major concerns in the past decade or so regarding the increasing amounts of electric and electronic equipment that is being land filled and the effects they have on the environment. E-waste is the most rapidly-growing waste stream in Europe and is increasing at a rate about three times faster than the waste growth average [3]. The environmental degradation caused by this has made governments all around the world enact "producer responsibility" laws [4,5,6] to put pressure on such businesses to manufacture products that minimise eco-burden and to take responsibility for managing their products from "cradle to grave". On the second, research on product characteristics and their effect on the best EOL strategy [7] to be adopted show that electric and electronic equipment, are most suitable for reuse and remanufacturing due to their long wear-out life and short usage period. This led to focussing our attention on "brown goods" — electronic products such as computers, printers, etc., and "white goods" — commonly used electrical appliances such as fridges, washing machines, etc., and hence this case study will concentrate on companies dealing with these types of products.

3. Overview of companies

Nine different companies (hereafter called "remanufacturers") were visited during the course of this case study, out of which seven companies deal with brown goods, and two were white goods remanufacturers. The companies were spread across the UK and Europe. Table 1 shows the list of companies consulted during this exercise and their distinguishing characteristics.

Company	Location	Major activities (in order of volume)	Products handled	Supply chain role
COS Remarketing	Milton Keynes	Reuse, Refurbish, Cannibalize	IT Equipment	Independent + Third party
Calyx Group	Luton	Reuse, Refurbish	Photocopiers, Printers, Camcorders	Third party
M Baker	Liverpool	Shred, Cannibalize	Refrigeration equipment	Independent
RefurbIT	Hull	Dismantle,Reuse	IT Equipment	Independent
SecureIT	Birmingham	Shred, Reuse	IT Equipment	Independent
Mirec	Dumfries	Reuse, Refurbish, Cannibalize, Dismantle	Telephones,IT Equipment	Third party
Else Refining	Stevenage	Dismantle, Reuse, Cannibalize	IT Equipment	Independent
Technowaste	Basildon	Shred, Cannibalize	Refrigeration Equipment	Independent
IBM	Montpellier (France)	Reuse, Refurbish, Dismantle, Cannibalize	Server systems	Closed-loop

Table 1: List of companies

The information presented in this report has been collated from semi-structured interviews (see appendix A) with company personnel ranging from top-level executives to factory floor managers. Visit reports were prepared after each visit and this report is intended to be a summary of all the visits performed during the course of this study.

4. Key features of the product recovery industry

Several interesting features could be drawn from the interviews and observations made during these visits. These features will provide a better understanding of how the product recovery industry functions.

Types of product returns

We will first look at the sources from which the remanufacturers procure/obtain products in terms of the types of returned products injected into the reverse logistics stream. There are four primary types of returns:

- (a) supply chain returns,
- (b) warranty returns,
- (c) end-of-lease equipment, and
- (d) end-of-life/use products.

It was seen that the sources from which the products are obtained, as well as the reason for discarding has an indirect bearing on the ability to accurately deduce the state of the product when it is returned.

4.1 Supply chain returns

Supply chain returns are products that are put in the reverse logistics stream by the different actors in the supply chain except the end-user. This could be unsold products returned by the retailer, defective parts returned by the manufacturer, etc. In the case of unsold products, the returned products are mostly in pristine condition. They might be returned due obsolescence caused by overstocking or excessive inventory due to errors in sales forecasting. In the case of retailer returns, since the products are never sold and subsequently used, it is easy to obtain/estimate the state of the product (identity and condition).

4.2 Warranty returns

Warranty returns are products that are returned by the end-users within a limited period as specified by the product manufacturer or the retailer. The total value of products returned by customers in the U.S[1] is estimated at $100 billion per year [8]. Products returned within the warranty period are failed units or products that were simply purchased and returned (due to the customer being unsatisfied with the product). Irrespective of the reason for return, the products are treated as faulty by default. In fact, it is seen that, on an average, around 70% of the returned products are non-defective[2]. Most manufacturers/retailers request the customer to attach a returns material authorisation (RMA) document (authorised by the manufacturer/retailer beforehand) for recording details regarding the reason for returning the product. Nevertheless, in practice, it is seen that this procedure is often not carried

[1] Official estimates for reverse logistics volumes and value for the U.K is not yet available. A UK remanufacturing survey report will soon be published by Oakdene Hollins Ltd, which hopefully would provide an idea of the size of the reverse logistics market in the UK.

[2] Approximate figure obtained from BT and Mirec.

out due to the fact that the customer is expected to identify the issue (often with the help of online customer support personnel) and fill up the RMA document before sending the product back to the manufacturer/retailer, and in most cases the customer would not have the expertise/inclination to do so. There is also a growing trend to accept returned products "no questions asked" in favour of maintaining good relationships with the customers. This results in crucial information regarding the condition of the product when returned being lost. Although, since in such cases the products have been in use only for a limited period of time, it is often possible to make a reasonable estimation about the condition of the product.

4.3 End-of-Lease returns

In recent years, there has been an increasing trend towards moving from selling products to selling services. This means that instead of selling equipment to customers, equipment is often leased for a particular period for which they are charged for the service provided by the equipment (for instance, charging customers for photocopies instead of selling the photocopier). At the end of the leasing period, the equipment is often taken back and replaced by new equipment (subject to a renewed contract). Such a contract usually comes along with maintenance agreements that require the manufacturer or the leasing company to replace faulty equipment. The end-of-lease/faulty equipment is often returned to the manufacturer or the leasing company as the case may be, and is sent to either third-party or independent remanufacturers for value recovery. Customers are often bound by the contract not to modify the leased equipment in any manner. Nevertheless in some ases, the service providers (manufacturers/leasing companies) often find that the equipment to be modified during its use. Hence, in this case, even though there are mechanisms to keep the information associated with the product up-to-date (through service logbooks etc.), the complete identity of the product is not known with a 100% certainty.

4.4 End-of-Life returns

The fourth type of products is end-of-life products which are discarded by the user after the end of their useful life as perceived by that user (in fact the product may still be functioning as always, but has been superseded by a better model, or the need has changed, etc.). Legislative requirements along with aggressive marketing techniques has resulted in a number of manufacturers and retailers offering take-back programs to customers by which a customer is able to return a used product in lieu of a new product (sometimes sold at a discount) on a like-for-like basis. The returned products collected in this manner are then sent to third-party remanufacturers or sold to independent recyclers for value recovery or proper disposal. In spite of the existence of such take-back programs, a majority of users discard the products and are collected at civic amenity sites. The civic amenity sites then send these products to remanufacturing and recycling companies for value recovery or proper disposal. In the case of these products, limited information is retained after the point of sale; and it also becomes difficult to retrieve information even about its design specifications due to the age of the product.

Now that we have understood the type of products that are injected into the reverse logistics stream and their sources, we will look at how the remanufacturing companies can be classified in terms of their business models.

Supply chain business models

The business model adopted by a remanufacturing firm depends on the relationship of the remanufacturer with the product manufacturer/supplier, if any. Three different types of business models are found:

- (a) Independent operators,
- (b) Third-party service providers, and
- (c) Closed loop supply chains.

a) Independent operators

It can be seen from Figure 1 that majority of the companies visited (six out of nine) were remanufacturers that operate independently with no direct relationship with the product manufacturers/suppliers or the end users. From discussions with company managers, it was clear that the distribution represented by the case study is fairly representative of the actual industry scenario.

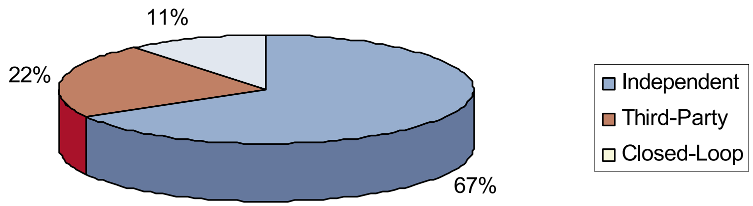

Fig. 1: Distribution of companies w.r.t. supply chain role

These remanufacturers receive products directly from end-users or from civic amenity sites, where the products are returned to by the end-users (refer to Figure 2). The logistics is arranged either by the originator (end-user/civic amenity sites) or by the remanufacturer. In the latter case, a charge is normally levied to cover the cost of transportation. In most cases, the remanufacturer accepts products free of charge, except in the case of products that require special processing, such as monitors, refrigerators, etc., where the originator is charged for recycling/disposal. It has to be noted that there are several charity-based /educational organisations that accept used products of all types and quality without any charge. These organisations do not operate their product recovery facilities on a for-profit basis. One of such an organisation visited during the course of this case study was Refurbit UK [9], whose major focus is to provide education and vocational training in PC repair/remanufacture to the local community. Occasionally, the remanufacturers also buy end-of-life/lease equipment in order to meet their demand (for instance, to fill a big order). This points to one of the most significant differences between forward and reverse logistics - the inventory has significantly less value attached to it as in most cases the "raw material" is not "bought".

As can be seen from Figure 2, the remanufacturer, depending on the estimated residual life and market value of the product, chooses the most suitable product recovery option [10]. The mechanics of making this decision will be examined in detail later in this report. In the case where the returned product does not have a profitable market value, depending on the facilities available, it will either be shredded and the different materials separated, or it will be sent to a specialist shredding company where those operations will be performed. The costs involved in doing so makes it advantageous for the remanufacturer to obtain complete information about the incoming products before-hand, so that he can control the type and quality of products coming into his facility. In other words, products below a certain quality level can directly be sent to a shredding facility or landfill in order to reduce pre-sorting, transportation, and storage costs.

The separated materials are then sent to metal recycling companies where it will be purified and put back into the manufacturing cycle. Usually a small proportion of the products is landfilled after proper treatment according to the environmental laws.

The relationship between the remanufacturer and the product manufacturer/supplier affects the availability of information associated with the products to the service provider. The absence of a business relationship with the product manufacturers leads to a severe lack of product information availability. These companies depend on the knowledge base of their personnel as well as detailed inspection through disassembly to identify and sort the returned products. The issues related to information shortage and the problems arising from them will be discussed in detail later in the report.

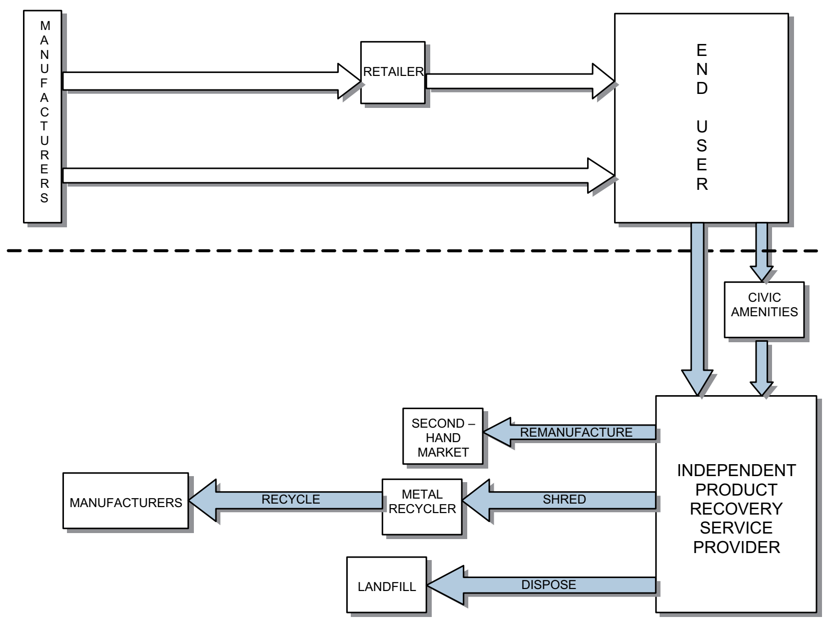

Fig. 2: Product flow diagram for independent service providers

b) Third-party service providers

Under the Waste from Electric and Electronic Equipment (WEEE) directive [4], electrical and electronic equipment manufacturers, and retailers selling these products have the responsibility for the proper recovery and disposal of end-of-life/returned products. Since these companies do not see these functions as part of their core competency, they prefer to outsource this to companies that specialise in them. This gives rise to the second type of remanufacturing firms, which are third-party remanufacturers (3PR) who deal with the returned products on the behalf of product manufacturers and retailers (refer to Figure 3). It was also seen that the remanufacturers also get equipment returned by end-users at the end of its leasing period (leased either by leasing companies or by the manufacturers themselves).

In this case study, we visited three such companies, viz. Mirec Asset Management Ltd [11], which deals with telephones manufactured by British Telecom (BT) [12], computers manufactured by Sun Microsystems, and electronic equipment sold by the UK high street retailer Dixons [13]; Calyx Group [14], which deals with Photocopiers and scanners manufactured by Canon [15]; and COS Remarketing [16], which procures equipment from a number of leasing companies (in addition to operating independently). These companies specialise in a particular product or product group, and handle the reverse logistics functions including in some cases (for e.g., Calyx), maintenance and repair of the products (in which case they are also called *4 party service providers* [17]). The manufacturers/retailers usually have short to medium term contracts with these remanufacturers, and they normally deal with all the equipment (within the contracted product group) belonging to the particular manufacturer/retailer returned by the endusers.

Depending on the contractual obligations, the remanufacturer will have to return the remanufactured products and cannibalised parts back to the manufacturer. In some cases, due to intellectual property rights protection issues, the remanufacturer might be forced by the contractual obligations to shred the returned products and recover materials in spite of them having a good market value (for e.g., such an agreement was found to be in place between Sun Microsystems and Mirec).

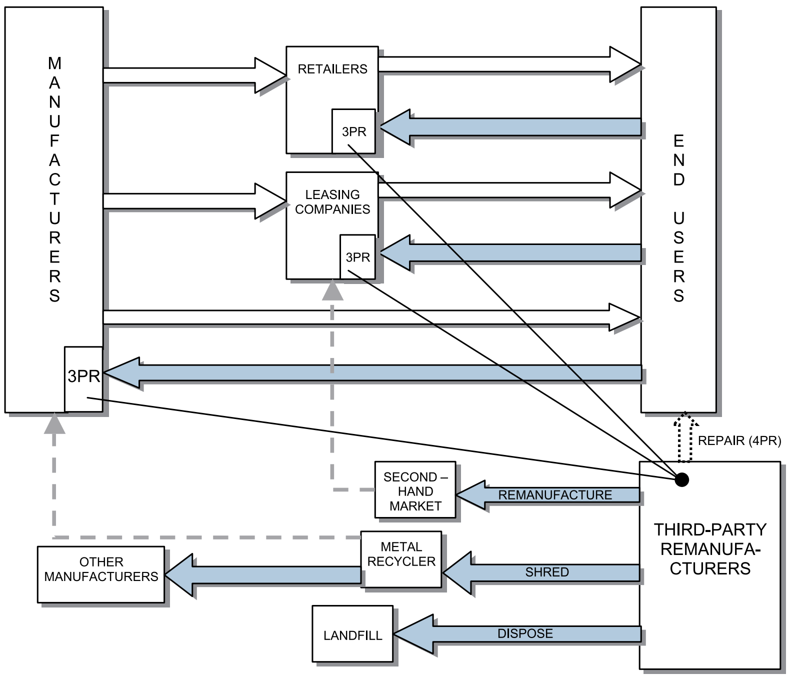

Fig. 3: Product flow diagram for 3rd party remanufacturers

Due to the contractual relationship with product manufacturers, product information availability for third-party remanufacturers is better than that of the independent operators. The manufacturers either share their product information databases (provide remote access to their databases), or provide hotline telephone facilities to the remanufacturer to access information about the products. This enables the remanufacturer to obtain design information about a particular product/product type based on its product code/serial number. Other methods used for information collection will be entailed in the later part of this report.

The third party service providers usually operate on a profit-sharing basis with the manufacturer/retailer. The products are shipped to the refurbishing/recycling facilities and they are repaired, refurbished, or shredded depending on their quality and residual life, and the profit obtained from the sale of the refurbished/repaired products or recycled material is then shared with the manufacturer/retailer.

c) Closed-loop supply chains

In spite of the concerns about operating outside the realm of their core competencies, a small number of manufacturers take back and perform product recovery operations themselves. A number of reasons are cited for this:

- (a) Increasingly, manufacturers are aware of the economic benefits that come along with the effective management of returned products. IBM [18], for instance, is said to be making a profit of $500 million per annum from its remanufacturing operations. The Mean Time Between Failures (MTBF) for an IBM z-series server is said to be around 50 years, where as on average it is returned by the customer in 5-10 years. Evidently, the same machine can be used as a multiple revenue stream instead of scrapping it after the first use.
- (b) Some of the manufacturers are keen to keep a tight control over the flow of their products for competitive reasons such as to protect the design of certain sensitive and highly valuable components.

- Offering customers the facility to return used equipment in lieu of new equipment gives manufacturers to maintain its customer base and also helps in increasing customer satisfaction by selling a complete lifecycle package that includes service and takeback instead of just selling the equipment.

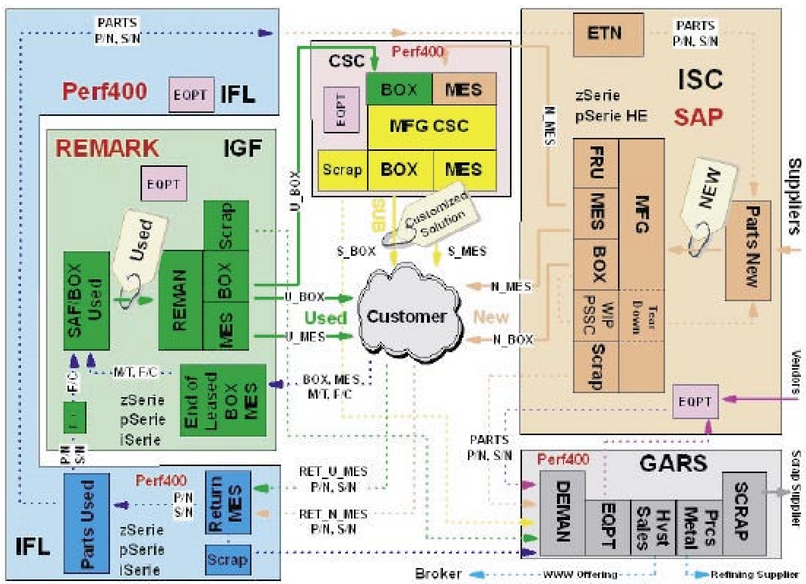

Fig. 4: Product flow diagram for closed-loop supply chains (IBM)

IBM takes back used computers, servers and peripherals and tries to recover value from those equipment. This is done by offering free take-back programs to customers, and also through equipment leasing programs. Figure 4 shows the product flow diagram for IBM’s z, p, and i-series servers. Servers returned by customers from all over Europe are sent to IBM’s central collection and remanufacturing centre at Montpellier, France. There, they are inspected, tested, and if required disassembled and put back into the supply chain as remanufactured servers, or as parts and components for equivalent-to-new (ETN) servers. Some of the “harvested” (IBM term for cannibalisation) parts are also used as replacement spare parts for on-site maintenance.

As expected, in the case of closed-loop supply chains, information availability tends to be higher than that of the other two models. Nevertheless, it is seen that even in this case, complete and up-to-date information about the state of the product is not often available.

Now we will categorise the companies in terms of their primary choice of recovery option (refer to Thierry et al. [10] for the various recovery options available when a product is returned after its use) for the returned products.

Operational focus

In terms of the operational focus, the companies can be classified into

- (a) product recovery (or refurbishing), and
- (b) material recovery (or recycling) companies.

The term *recycling* has to be used carefully in this context. The so-called “recycling” companies only perform shredding operations that pulverise the product into small pieces (this process will be described in detail in section 5) so that the different materials can be easily separated. The separated materials are later sent to specialist metal recycling companies which smelt and purify the materials (or in other words, recycle the materials) so that it can be reused for manufacturing new products. In contrast, product recovery companies are those firms whose primary choice of recovery option is to reuse the products and their components (after repair/refurbish, if required) to the maximum extent.

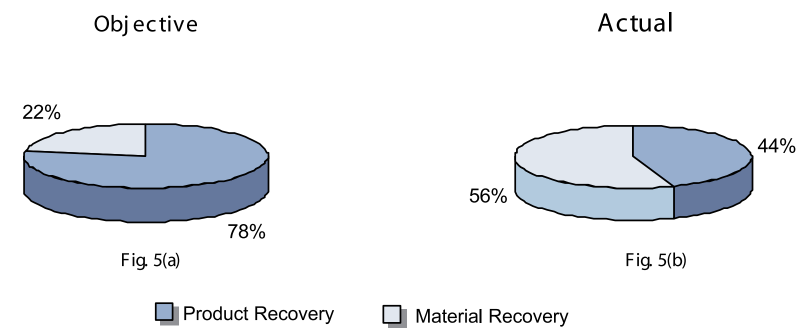

Fig. 5: Operational focus (percentage of companies)

Figure 5(a) shows the distribution of the companies visited during this study according to their primary objective and Figure 5(b) shows the distribution of companies according to their actual volume of operations. It shows that even though most of the companies wish to perform product recovery, i.e., try to refurbish and resell returned products, most of them end up recovering materials from them. Most of these are independent operators whose supply of products is mostly end-of-life equipment, for which the refurbishment and repair operations are not viable. In addition to the lower quality of these products, extracting enough information about the identity of the products that is essential for reselling them is time consuming and thus makes it inefficient. The factors that result in the inefficiency of product recovery operations are examined in section 5.

Now, we will look at the various channels through which the returned products can be given a second life.

Marketing channels

The products returned by end-users are injected back into the market by the following options:

- (a) repair and resell,
- (b) sell after refurbishment,
- (c) disassemble and sell the valuable components, or
- (d) shared into different materials and sell to metal recyclers.

Products (a)-(b) are sold through different marketing channels such as: (i) through the company's web site (for e.g., http://www.crs-uk.biz/trade), (ii) internet auctions (for e.g., eBay), and (iii) through high street second-hand shops. These products find their market in consumers unable to afford the cost of buying new products and are happy with the functionality provided by slightly outdated or remanufactured products. These include schools, leasing companies, third-world countries, etc. Manufacturers prefer to keep the refurbished products out of reach of their primary market due to the fear of damaging their new-product sales. Parts and components retrieved from returned products are often sold to leasing and service-based companies that use the components as replacement spare parts during field maintenance.

Now that we have had an overall idea about how the product recovery industry operates, we will examine how product recovery is actually performed.

4 Product recovery operations

In this section, we will extract the common features found in the different companies and present a general model of how product recovery is performed in the industry. We will also discuss how information associated with the product is collected and used throughout the different steps. Figure 6 shows the typical steps that are performed during product recovery. Obviously, there are subtle variations to how things are done in different companies. We will point out the differences when they deviate widely from the norm.

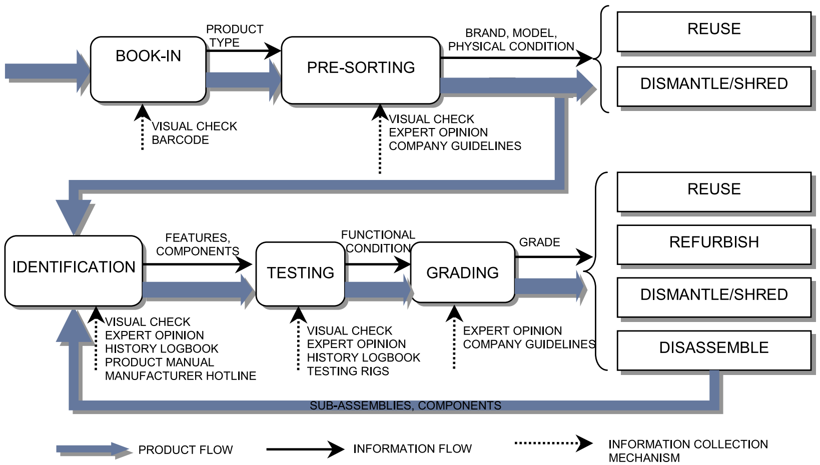

Fig. 6: Remanufacturing operations

Book-in

The first thing that is done when products come in through the remanufacturing shop floor is to *book-in* all the products into the company’s product database. The product database systems are designed to hold detailed information about the products and their components. Most of the companies visited (around 65%) use some type of database management system to keep track of their inventory (refer to Figure 7). At this stage, only the product type is noted (laptop/desktop/tower etc.). This is done for

- inventory purposes,
- for the sales department to have an idea of the stock (in order to speed up the marketing efforts),
- to acknowledge the receipt of the products to the sending party so that appropriate invoicing can be done, and
- to cross-check against the pre-inventory list received from the sending party before the goods arrive.

While the preferred way of booking products in is to do it individually, it was seen that around 40% of the companies visited booked-in products in terms of their weight. In these cases, little information is gathered about the identity of individual products (refer to Figure 7).

When the remanufacturer receives a product that he has not seen before, for e.g., a new product such as a digital photocopier, they are quarantined and expert opinion (sometimes from outside the company) is sought to identify them. This causes a delay in processing the products and the issue of invoices. In some cases, the product identity is misinterpreted and wrong information is entered into the database. The delay in identification of the product, or even worse, the mis-identification of the product affects the marketability of the product. It is also seen that there are often mismatches between the pre-inventory list and the actual products received. This is due to mis-identification either at the shipping point or at the booking-in point. Apparently, automatic product identification enabled by networked RFID would eliminate these errors by providing complete and accurate information about the identity of the product, and by automating the booking-in process.

While booking in, each product (ideally) is given a unique ID that will help store related information in the information system and to track its progress. Around 40% of the companies provide unique identification numbers to each and every product received, where as another 20% of the companies prefer to identify the products in terms of batches. As mentioned before, the remaining 40% do not use any mechanisms for product tracking.

Two types of tagging methods were seen to be used to identify individual products and batches:

- (a) printed serial numbers, and
- (b) barcodes.

In some cases, a combination of the two was also used (see Figure 8). Where printed serial numbers are used, there is a chance of typing errors when data is entered into the information system. Barcodes offer an efficient way to automate the data entry process. Nevertheless, it is often seen that more than one barcode is attached to every product as the product moves along its lifecycle (manufacturer barcode, retailer barcode, asset identification barcode used by the customer, etc.) and this gives rise to a lot of confusion. Here again, the concept of a single unique number (EPC code) embedded in an RFID tag attached to the product throughout the lifecycle eliminates the need for multiple barcodes and thus would make the process less error-prone and more efficient.

Fig. 8: Product tracking using barcodes (Courtesy: Calyx)

Pre-sorting

There are several options available for giving a returned product a second life as we enumerated when we discussed about the marketing channels. The remanuafacturer has to decide upon the most profitable option for a given product. Making this decision requires information about the product identity as well as its condition, in addition to other external information (refer to Parlikad et al. [19] for a thorough discussion on information requirements for product recovery decision making).

After booking-in, products are *pre-sorted* into different quality groups in order to make a preliminary assessment of its value and to make a decision whether to perform further inspection and testing in order to obtain the information required for making a proper product recovery decision. In many companies, the booking-in and pre-sorting steps are often combined. The pre-sorting decision is mainly made on a minimum system requirement basis, (for e.g., Pentium 550MHz) that is obtained from the guidelines provided by the sales department (which makes this decision on the basis of the market situation). It is assumed that anything below this specification is not worth testing as it would not be cost-effective to do so.

Hence, here the product is identified in some more detail by noting the manufacturer, brand, and the model number, if any. One should keep in mind that in most cases, the components of the system varies widely within the same model (especially Dell computer systems), but that level of detail is not captured at this stage. Products are identified using various methods such as the manufacturer's barcode, manuals and specifications attached to the product, or in many cases, expert knowledge of the people handling the products (refer to Figure 9 for the different product identification methods used). It is seen that the information required is not normally readily available, and in many cases, the available information is seen to be inaccurate or incomplete.

Products that are deemed not to be valuable enough to undertake detailed inspection and testing are either sold as-is at a low selling price (due to the fact that the buyer takes all the risk about the functionality of the products), or are dismantled and shredded into constituent materials. It has to be kept in mind that this decision is made with incomplete information about the product and hence often be sub-optimal. For instance, the internal components of the product are not identified at this stage and even though the product might not have significant value in the market, certain components might be valuable enough to be cannibalized, and could be sold/used for a significantly higher value than that would be obtained if recycled.

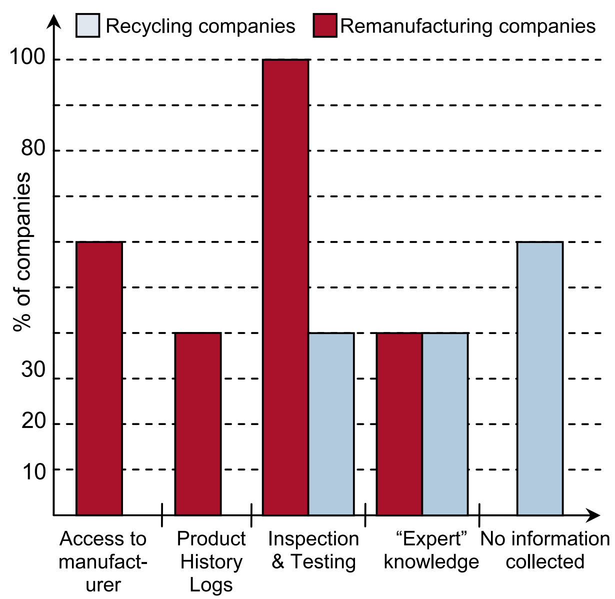

Fig. 9: Product identification method used

Identification

If a product is deemed to be valuable enough to warrant further inspection and testing, additional efforts are put in to gather the required information. The first step is to obtain the complete *identity* of the product. By "identity", we mean all the information that is required to completely describe the product (for e.g., technical specifications, components etc.). This information can be collected by way of contacting the manufacturer, by consulting the product manual and the maintenance logbook (if available), or by detailed inspection of the product Direct access to the manufacturer is available for third-party remanufacturing companies. Some companies also gather information related to the product by accessing the manufacturer's web sites where details of their product range are provided for marketing purposes. . The maintenance logbook is an important source of information for products that undergo a lot of maintenance and parts replacement throughout its life. For certain products such as computers, identification of the product and its components can be performed by executing a program that scans the system for its components and features (for e.g., PC Check).

In companies where the primary objective is to recycle the product, it is required to know what the constituent materials are so that appropriate separation and purification techniques can be applied. Environmental regulations also stipulate that certain hazardous substances have to be separated first (for e.g., batteries) before the product can be shredded.

Testing

Making a decision whether the product is to be re-used, refurbished, or cannibalized for parts and recycled requires more than just knowing the identity of the product. The decision also depends on the functional condition of the product and its components and its market value. Hence, the product and its components have to be tested rigorously to ascertain its functional condition (Figure 10 shows a testing rig for photocopiers). In the case of computers, identification and preliminary testing can be performed at a single step, as the product scanning programs will identify non-functioning components. Nevertheless, this program will not be able to identify the exact fault in a component, and hence further testing will be required to be performed to ascertain that.

In cases where cetain parts/components of the system are not functioning, a decision is made whether to refurbish or to recycle. This depends on the potential market value of the product after refurbishing and the cost of refurbishing. If the potential value is less than the cost incurred, the product is sent for recycling after important parts such as drives, network cards, etc. or compressors in the case of fridges, are cannibalized. The residual value of the product depends on various quality parameters such as the age, functional condition (working, or not working), physical condition, functional age (as a measure of obsoleteness), remaining useful life, etc. The values of these parameters, which define the current state of the product, are determined through testing or estimated from knowledge gathered from experience.

Products with moderate to long usage life tend to change or evolve over the usage phase. Parts or components might be added or removed during maintenance and upgrade and the manufacturer’s specification would not match the actual configuration of the product when it reaches the EOL stage. For example, the product manual might show that the product is ten years old, leading to a low residual value for the product. Nevertheless, certain components might have been replaced or upgraded recently that would increase the product’s residual value. Without this information, the product might end up being recycled for material recovery or even disposed, where as it could have been potentially reused. Hence, the availability of maintenance and replacement history will lead to greater chance of part or module reuse and reduce the cost of lost opportunity due to the disposal of potentially reusable parts and modules. Such information can be obtained from the maintenance history logbooks that accompany the product. Although, in most cases it is found that they are unavailable or not updated. Hence, in the absence of the availability of necessary information, products are often undervalued and are either sent for recycling, in spite of having a good market value, or are sold for a price that is below the actual marketvalue of the product.

Fig. 10: Testing rig for photocopiers (Courtesy: Calyx)

From the above discussion it is clear that the availability of product information plays a very crucial role in the effectiveness of decisions made during product recovery. As information collection is currently an onerous task, only those products that are evidently valuable on the outset get recovered efficiently. It is here that the benefits of networked product identity become evident. By enabling ready availability of product information through networked databases linked to the product, it is possible to combine the presorting and identification steps, i.e., it is possible to obtain complete identity information about the product when the decision whether to test the product is made. As the EPC network would enable ready availability of complete lifecycle information about the product, the decisions made at this point are far better informed than how it is done currently. In addition, it is also possible to monitor critical performance parameters of the product (temperature, number of revolutions, etc.) throughout its life and make this information available at the identification step itself. This helps the decision maker to filter the products going to the testing process, or make early assumptions on the cost of repair/refurbishment, so as to optimise the performance of the whole operation. In the case of recycling, this would alert the recycler about potential hazardous substances in the product, and help identify the products that require special processing.

5. Important issues in the product recovery industry

A number of interesting issues were noticed that prevents the product recovery industry from operating in an efficient manner. We will now look into some of those important issues.

5.1 Unorganised sector.

It was noted that the product recovery industry is largely unorganised as compared to the traditional manufacturing sector. Most of the remanufacturing/recycling firms operated independently with no formal contractual relationships with their suppliers or their customers. This is very much in contrast with traditional manufacturing companies where relationships with suppliers as well as customers are very well managed. One of the reasons behind this phenomenon is the fact that the market for remanufactured products as well as recycled materials is relatively immature. The resulting volatility and the high risks associated with the second-hand market acts as a hindrance to the formation of remanufacturing supply chains with partnerships and commercial contractual relationships as is prevalent in the manufacturing supply chains.

5.2 Information shortage.

As described in the previous section, information associated with products is often irretrievably lost after the point of sale. Even in the case of products where the design information could be obtained from the manufacturer, information that provides an indication of the residual life and value of the product is often not available. It is not the “availability” of information that is the critical issue here. In the case of products that are apparently valuable, this information is collected by performing extensive inspection and testing. Information required to make product recovery decisions *can* (in most cases) be retrieved if enough time and effort is put into it. This being labour intensive and thus very expensive, in most cases is not economically justifiable due to the low-value nature of returned products. Hence, it is the absence of “readily available” information that is the biggest hindrance to making effective decisions and thus efficient operations.

Timely availability of information is also important due to the volatility in the value of returned products. Figure 11 shows how the market value of a P3 650MHz laptop deteriorates with time (courtesy: analysis performed by RefurbIT UK). This corresponds to Blackburn et al. [20] which finds that the value of volatile products like computers and laptops deteriorates at the rate of more than 1% per week and that the rate increases as the product nears the end of its life cycle. Given the fact that the remanufacturing companies often hold around 6-7 weeks worth of inventory, the products lose around 10% of their value between the time the remanufacturer receives the product and the time they sell it.

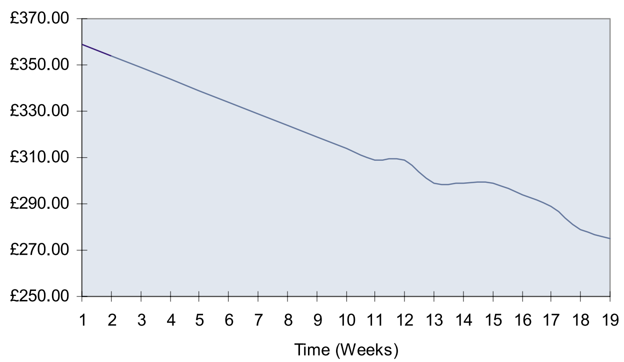

Fig. 11: Value depreciation of a 650MHz laptop (Courtesy: RefurbIT UK)

Moreover, some of the contracts between manufacturing companies and their 3rd party remanufacturers) stipulate a maximum threshold period before which the remanufacturer has to sell the products (for e.g., 30 days for Mirec and BT). If the remanufacturer is not able to sell it within that stipulated time, the product will have to be bought from the manufacturer at a previously arranged price, which in most cases would be more than what the remanufacturer would be able to sell for in the secondary market due to rapidly declining prices. Hence, it is clear that the ability to collect complete information about the product is not just sufficient – it is necessary to be able to collect this information in a timely manner.

5.3 Supply driven.

The traditional manufacturing industry is demand-driven, i.e., the industry operates to meet the customer demand. The supply of raw materials required to manufacture products to meet the customer demand is more or less in the manufacturer's control. In contrast, it is found that the remanufacturing industry is supply-driven, i.e., the industry operates on the basis of the products injected into the reverse supply chain by the end users, and tries to generate the demand for those products. The remanufacturer has no control over the rate of returns of products, although several models have been developed to forecast the rate of returns on the basis of primary market demand, and the expected life of the products [21].

5.4 Lack of control.

As described above, the remanufacturing industry is typified by exogenous raw material (returned products) supply. This, together with the shortage of information required to accurately assess the identity of the returned products translates into a high level of uncertainty in the quantity, quality and timing of returned products and resulting lack of control. In addition, due to the lack of proper tracking and recording mechanisms, it was seen that the flow of goods from the collection point to the remanufacturing facility (i.e., reverse logistics), is also not managed properly. One of the executives from a fridge recycling company pointed out that around 30% of the products are often lost within the reverse supply chain due to theft and pilferage.

5.5 Manual processes.

In spite of the advances in automation and control systems, it is seen that product recovery operations are entirely conducted manually. The research community has been active in developing automated disassembly tools [22], but in fact these are not seen to be applied in the industry. This makes the product recovery process slow, expensive, error-prone, and inefficient. One of the biggest obstacles against automation of product recovery and disassembly processes is the lack of tools with the high level of flexibility that is required by these processes, as well as the absence of a mechanism that enables ready availability of complete information associated with the products.

5.6 Low margins.

The upshot of the issues described above is that the product recovery industry operates on very low margins. Most of the companies visited put down their revenues as "negligible" or "break-even". The exception to this rule was IBM, which had a profit of $500 million per annum. Clearly, in the case of IBM, the above-said issues were found to be relatively better merely due to the nature of their operations and the level of control that allows them over their supply chain.

This shows that there is a lot of scope for improvement in product recovery operations. Better control, which could be afforded by providing readily available product information, could be the answer to the woes of this industry.

6. Conclusions

One of the most important and heartening observation was that companies have increasingly begun to recognise the need for efficient product tracking. One of the reasons for this is to meet the compliance standards set by remanufacturing consortium bodies such as the Industry Council for Electronic Equipment Recycling (ICER) [23], which requires its certified members to be able to keep track of the products that enters their facilities at the individual item level. Another reason is the realisation that in order to maintain proper control over their operations and thus to make them efficient, they have to be able to keep an accurate record of each and every product. It was seen in the previous section how different companies used different product identification techniques to tie the product flows with their information systems.

There is a marked lack of timely information availability for making product recovery decisions which hampers the efficiency of product recovery operations. The low margins and increasing volatility of returned products make timely information gathering a high priority. From the observations made during this study, as well as from case studies conducted by other researchers, it is clear that this is an area with a lot of potential for bringing improvements to. There is a general agreement among the floor managers and sales personnel that the existing systems for product identification and information management do not sufficiently address the requirements for effectively determining the residual value and extracting the real value of the product in the secondary market.

It would be interesting to investigate how ready availability of product information would impact the effectiveness of product recovery decisions and the efficiency of the operations. Providing the ability to extract product information in a timely manner could bring two-fold benefits: (a) decision improvements – being able to make informed decisions in a timely manner that could lead to higher profits, and (b) process improvements – being able to facilitate automation of disassembly processes, thus improving the efficiency and cost-effectiveness of product recovery operations. Increasing the overall cost-effectiveness of operations could result in increased amounts of reuse of products and components in future.

It cannot be disputed that final testing of the product cannot be dispensed of even if the products are embedded with identification tags that enable ready identification. Nevertheless, the floor managers agree that lifecycle usage data would greatly improve the quality of decisions made as in many cases it would decrease the rigorousness of testing required to be performed. The concept of networked product identity would enable lifecycle usage data to be collected using appropriate sensors and to be linked directly to the product. Such systems are already under development [24], and it will be interesting to ascertain the value of providing this information to the decision-makers.

From Figure 9, we can see that the independent operators that perform recycling or dismantling obtain very little information about the products. There is an interesting possibility that warrants further investigation - by providing a mechanism for easy retrieval of product information, will these companies be able to reuse more products/components than that is done currently? However, for these independent operators, there is a concern about how networked RFID-based information sharing might work. It depends on how the business and information models evolve in future, and also depends on up to what level information sharing requirements are imposed on the manufacturers by government environmental regulations.

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Appendix
Case study questionnaire

PART A: COMPANY DETAILS

1) Products handled
   - No. of companies
   - No. of brands per company
   - Products types (computers, copiers, etc.)
2) Operations handled
   a) Test, Repair & Return
   b) Refurbish
   c) Inventory Management
   d) ------------------------
3) Employees ----------------
4) Turnover ----------------
5) Profits ----------------
6) Who are your major customers (top 3) and what is the type of relationship them?[Ψ]
   ☐ Long term contracts
   ☐ Short term contracts
   ☐ No contract. Supply upon demand.
   ☐ Other………..
7) Who are your major suppliers (top 3) and what is the type of relationship with them?
   ☐ Long term contracts
   ☐ Short term contracts
   ☐ No contract. Supply upon demand.
   ☐ Other………..

PART B: UNDERSTANDING THE REFURBISHMENT/REPAIR PROCESS

1) Flow chart of operations.
   a) Distinguish between value-added and NVA operations.
   b) Identify the bottlenecks.
   c) Track and trace system (ID system, and where the Ids are used along the operation)
   d) Data associated with each product as it moves along the floor
   e) At each where products change hands/location, note the data transferred/ recorded. (Mode/Frequency/Format). Typically, ask the following questions:
      i) What data is generated and where is it used?
      ii) What data is stored?
      iii) How long is the data stored for (life of the data)?
      iv) What data is used and where was it generated?
      v) How is the data accessed?

[Ψ] Relationship with customers and suppliers are important in terms of RFID tagging of products

2) Product Identification methods
   a) History book
   b) Expert knowledge
   c) Call manufacturer
   d) Access to manufacturer database
   e) Manufacturer Part ID - Link to Information system
   f) Other
3) How do you rate the track-ability of your system?
   ☐ Fully track-able: Ready availability of all necessary product information throughout the system.
   ☐ Partially track-able: I can track all my products uniquely through my system, but product information is not readily available.
   ☐ No track-ability: I cannot track my products.
   ☐ Other.
4) Identification-ability
   a) Time taken to identify a product/components
   b) Cost associated with product identification
   c) If information is held elsewhere (e.g., manufacturer), cost and time associated with retrieving the information
   d) % error due to manual identification (e.g., 2 times out of 10)
5) Automation Level.
   a. Identification & % errors associated with them
      ☐ Fully automated (Information attached to the product/id)
      ☐ Partly automated (Information can be retrieved from product/id)
      ☐ Expert Knowledge
      ☐ Identified by manual inspection & testing
   b. Inspection & Testing
      ☐ Fully automated
      ☐ Semi automated
      ☐ Manual
   c. Decision making
      ☐ Manual
      ☐ Passive DSS
      ☐ Active DSS
      ☐ Other …………
6) Decision variables (Variables that affect recovery decisions)
   a) Quality variables
      i) Age
      ii) Colour
      iii) Technical condition (working/not working)
      iv) Physical condition (wear & tear)
      v) Other…
   b) Measurement of the above variables
      i) How are they measured?
      ii) Where is the data obtained from?
      iii) How often is the data accurate?

iv) Are these variables co-related to the value of the variables of the parent sub-assembly? (e.g.: age of components ≤ age of product)
v) What are the issues associated with evaluating these variables?

c) Quality requirements
i) Who specifies the requirements?
ii) % error in conforming to requirements
iii) Investigation of Type I and Type II errors

d) What are the other considerations/decision variables associated with deciding the disassembly level?

e) How do you decide the disassembly sequence?
i) Break open
ii) Disassembly diagrams supplied by manufacture
iii) Expert knowledge
iv) Step-by-step evaluation

f) What is the cost of each operational step/how long does it take (if cost/hour)?

7) Other operational variables

8) How do you measure the performance of your process?

a) Profit
b) % parts recovered
c) Environment
d) Other

PART C: UNDERSTANDING THE INFORMATION SYSTEMS

1) What is the system used? (SAP, etc.)

2) What is the system used for?
- ☐ Electronic Data Interchange (EDI). ……………………..
- ☐ Enterprise Resource Planning ……………………..
- ☐ Customer Relationship Management. ………………
- ☐ Warehouse/Inventory Management. …………………
- ☐ Automated Data Capture (ADC). ……………………..
- ☐ Product Information Managament. ……………………..
- ☐ Others.……………

3) What is the information model underlying the Information system in place? (How is product data captured and subsequently retrieved?)

4) If more than one system is in place, are they integrated?
i. If so how are they integrated?
ii. If not, what are the issues arising due to this?

5) Information evaluation
i. For each piece of information, what are the "components of value"? (Where is that information used during the process?)
ii. How much does that information affect the performance (profit) of your operations?