

Abstract submitted to the 26th IMP Conference, September 2-4 2010, Budapest, Hungary

PRODUCT RECOVERY IN NETWORKS

Competitive paper

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ABSTRACT

This paper deals with product recovery. Especially the paper sets out to scrutinize the organization of product recovery starting with firms who want to ‘get rid of’ obsolete products, followed by the transformations of these products, so that they can be sold to new users. The paper provides two illustrations of how product recovery can be organized. We have chosen to use examples from the electronics industry, focusing on the product recovery processes of PCs. An industrial network perspective is applied to analyze how product recovery impact on the activity patterns, the resource constellation, and web of actors respectively.

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INTRODUCTION

The increasing attention to sustainable development has put pressure on firms to reduce the environmental impact of their business (Seuring and Müller, 2007). This can be accomplished in different ways. Making processes more efficient with regard to resource use is one common strategy. This can mean fine-tuning processes in terms of less material consumption or energy use or creating higher fill-rates or use of capacity in facilities. Another option is to create new processes in order to reduce the environmental impact. For example, by recovering consumed material back into the business systems firms may improve the sustainability of their business (Lebreton, 2006). Reuse, resell, repair, refurbishing, remanufacturing and recycling are examples of product recovery activities that have all gained increasing attention during the last decades.

However, product recovery is not a new idea. Typical examples of the products that have been recovered for centuries are high-value and low-volume items (Guide and van Wassenhove, 2009). During and after the Second World War product recovery experienced a boom (Sundin, 2006). This was caused by the lack of raw materials needed for manufacturing. And as today approximately 40 % of the global steel production and 50 % of the paper production originates from the recycling of these materials (Stena Metall, 2007). Prolonging the life of a product is the main aim with product recovery. However, when products can no longer be recovered they need to be disposed in accordance with safety and environmental regulations. These could be classified as natural and energy recovery. There are two main disposals of this kind; landfill and incineration (Thierry et al., 1995). Landfill refers to covering the waste with earth, and incineration has the purpose of burning waste at high temperatures.

A number of stakeholders can be identified with regard to product recovery. First, society as a whole can be seen as a stakeholder since there is an aim to reduce negative environmental impact from products. Society also tries to affect this with different kinds of regulations. For example, in the EU directive ‘Waste electrical and electronic equipment’ (WEEE), member states should encourage firms to design and manufacture electronic equipment so that they are easily dismantled and recovered. Second, firms who need to get rid of obsolete equipment are one kind of stakeholder. Third, firms and consumers that want to use recovered product is still

another stakeholder. Fourth, due to the increasing interest in product recovery there are firms that want to take part in these recovery activities as a business opportunity. They hence try to meet the needs of the other stakeholders by creating offerings related to product recovery processes.

In this paper we are interested in exploring how obsolete products at ‘Actors supplying products for recovery’, acting as the sources for product recovery, end up to be used as recovered products by ‘Actors demanding recovered products’. Involved in executing these processes are ‘Actors involved in product recovery.’ (see Figure 1).

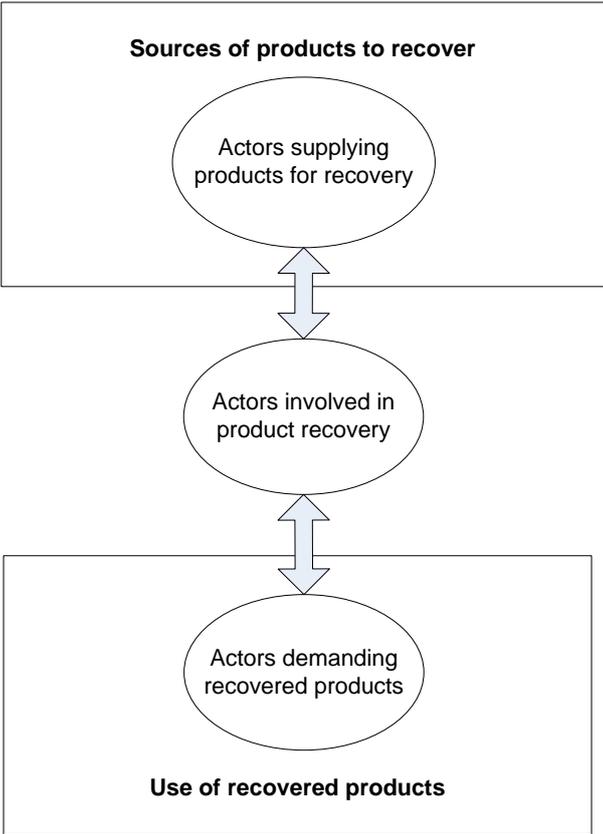


Figure 1. The context of the paper

So, the aim of this paper is to scrutinize the organization of this kind of transformation from obsolete to recovered products.

A FRAMEWORK FOR PRODUCT RECOVERY

As a starting point we take the supply side of product recovery, which represents the sources of products to be recovered. According to Flapper et al. (2005), material to be recovered can origin from a number of sources. First, the material can be *production related* (e.g. from manufacturing facilities). Obsolete materials (surplus production, components or semi-finished products, production scrap), production defectives (products not conform to some preset quality levels that are scrapped or reprocessed to a level where they can be sold as initially intended or as a lower quality product). Second, it can be *distribution related* (e.g. from distributors, retailers, third party logistics providers and users). Commercial returns,

order cancellation while the product is on the way to a certain customer, surplus stock - unsold stock returns, damaged goods/packaging, wrong deliveries that don't conform to specifications, recalls (returns in the context of actual or expected problems with products). Third, it can be *use related* (from users). The same or replaced products that should eventually return to the present users (repairs, warranties and recalls) or when companies are offering repair, refurbishment or remanufacturing of the products, products returned to the supplier (end-of-lease products), and products returned at the end of their technical or economical life from the point of view of their present user or their original manufacturer that still may start another life in a different market. Furthermore, products might be returned to the distributor or producer because they reached the end of their useful life. Their components and materials may be reused in other products. Consequently, the reused resources may be the whole products, parts, materials, energy, labor and other costs that have been accumulated in the production, distribution and use of the new products (Östlin et al., 2009).

Having discussed the sources of supply of materials that can be recovered, the next step is to discuss different options for how this recovery can be accomplished. Thierry et al. (1995) depict five general options for material recovery, aimed at recapturing value from returned products and components with the most environmentally friendly alternatives at the top of the list. First, *repair or reuse*, aims to return used products in working order. The quality of the repaired products could be less than that of the new products. Second, *refurbishing* refers to bringing the quality of used products up to a specified level by disassembly to the module level, inspection and replacement of broken modules. Refurbishing could also involve technology upgrading by replacing outdated modules or components with technologically superior ones. Third, *remanufacturing* brings used products up to quality standards that are as rigorous as those for new products by complete disassembly down to the component level and extensive inspection and replacement of broken/outdated parts. Fourth, *cannibalization* has the purpose to recover a relatively small number of reusable parts and modules from the used products, to be used in any of the three operations mentioned above. Fifth, *recycling* means reusing materials from used products and parts by various separation processes and reusing them in the production of the original or other products.

Krikke et al. (2004) has made an adapted outline of recovery options based on the work of Thierry et al. (1995). They separate *direct reuse*, meaning checking and cleaning, from *repair*. Furthermore, they identify *scrap*, i.e. shred, sort, recycle, and dispose of, as one option. The options of refurbishing, remanufacturing and cannibalization are identical to those of Thierry (1995).

Inspired by the models in Thierry et al. (1995) and Krikke et al. (2004) we identify six such product recovery options. First, *reuse* means checking on damage and cleaning the product. Second, *repair* aims to restore used products to working order by reparation and/or replacement of components. Third, *refurbishing* means bringing the quality of used products up to a specified level by different degrees of disassembly, inspection and replacement of broken modules. Refurbishing could also involve technology upgrading by replacing outdated modules or components with technologically superior ones. Fourth, *remanufacturing* aims to bringing used products up to quality standards that are as rigorous as those for new products by extensive inspection and replacement of broken/outdated parts. It can also mean manufacturing of new products from old parts. Fifth, *component retrieval* has the purpose to recover a relatively small number of reusable parts and modules from the used products, to be used in any of the three operations mentioned above. Sixth, *recycling* aims at reusing

materials from used products and parts by various separation processes and reusing them in the production of the original or other products.

Each of these recovery options involve some general activities that need to be undertaken in a recovery process (Krikke et al., 2004). The order and importance of them can however differ from situation to situation. Inspired by Krikke et al. (2004) we define five such activities. First, product *acquisition* concerns how the acquiring firm is getting hold of the products to be recovered. Second, product *collection* concerns how the product to be recovered is collected from the source. Third, product *recovery logistics* relates to the transportation from the source to the location of recovery. Fourth, *classification* is tightly connected and a result of testing and inspection. Classification means deciding on how to handle different products and components with regard to the recovery options discussed above. Fifth, the chosen *recovery option* (reuse, repair, refurbishing, remanufacturing, component retrieval, recycling) is undertaken. Sixth, the products are *distributed* either to new buyers or to recycling or disposal. The discussion so far can be summarized in Figure 2.

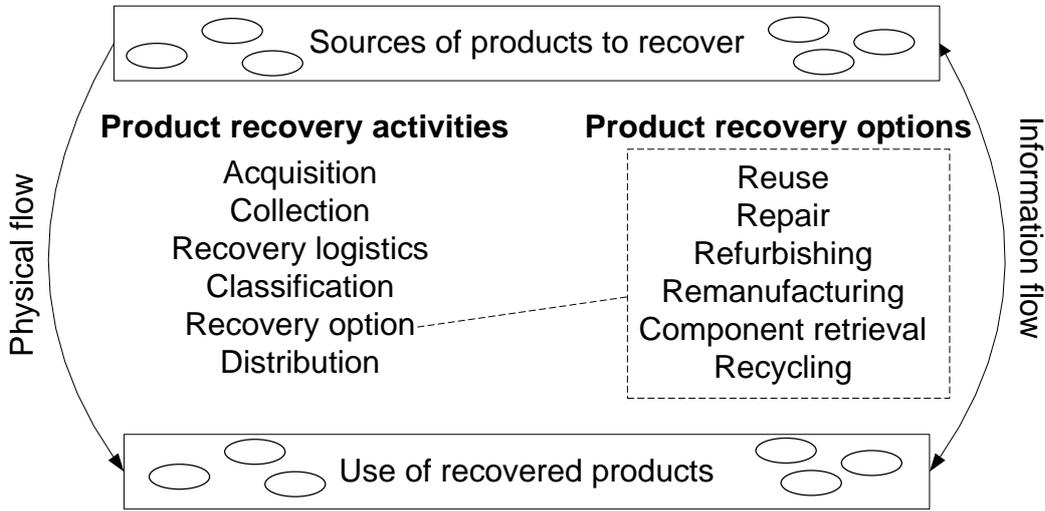


Figure 2. A framework for product recovery

Firms involved in product recovery meet different types of challenges. For example, uncertainty is often an important aspect to consider for these firms. Fleischmann et al. (2000:664) argue that ‘Supply uncertainty both in quantity and quality appears to be a major distinction between product recovery networks and traditional production-distribution networks.’ According to Guide et al. (2000) there are a number of characteristics of the recovery network that leads to a number of uncertainties. First, uncertainty concerning the when in time and in which quantity products get available for acquisition is important. This reflects the nature of life of a product. Hence depending on the nature of the product it can be more or less easy to now when it will be ‘ready’ for product recovery. This is in turn associated with the life-cycle of products and the rate of technological change. Related to this is the uncertainty of the place, or at which source, the product to be recovered appears and how the recovery firm can connect to these different sources. The sources can be customers, brokers and OEMs as well as other third-party vendors. According to Guide et al. (2000) the acquisition part of product recovery is a very important activity that has not been researched to a sufficient degree. Another uncertainty is the condition of the product. Two seemingly

identical products entering the recovery system can turn up in very different shapes and need very different recovery options. The condition of the product is also decisive for what recovery option that can be chosen and often this decision cannot be taken until the product has been more or less disassembled. The condition of the product is age-, environment- and usage specific (ibid). Linked to this is the fact that products can be more or less easy to disassemble depending on their design (Bostel et al., 2005). So to what degree the product is designed for recycling or remanufacturing has a great impact on how product recovery can be accomplished (ibid). How the products are collected and brought to the recovery center is another uncertainty that needs to be considered. This can involve decisions regarding transportation modes and facilities as well as the involvement of third-party providers. (Guide et al., 2000). Furthermore, handling of packaging material and shipping material can be included in this. In order to handle these challenges, firms try to organize recovery activities in a way that reduces these uncertainties. Further ahead in this paper we will illustrate how different ways of organizing product recovery activities. However, first we provide an argument for why a network perspective is suitable for analysis of product recovery.

A NETWORK PERSPECTIVE ON PRODUCT RECOVERY

There are many sources of products that can be recovered as well as many users and potential uses of recovered products. Furthermore, these sources and users can be connected in a multiple number of ways. So, products, parts, components and materials that may well be recovered can be collected from different sources and at different point in time and end up at different actors. This is caused by the multitude of actors who are involved in product recovery. As pointed to above it is not evident where a certain product in need of recovery will end up, both with regard to how it is 'sorted' in the process from 'source to use' or where it will end up. Furthermore, most often this 'reverse' flow is integrated more or less with the 'forward flow', where many resources are shared among these different flows (e.g. White et al., 2003; Flapper et al., 2005).

All in all, the multitude of options available for product recovery and the complex organizational context in which it is performed calls for a holistic approach for its analysis.

In this paper we therefore take a network perspective on product recovery. We take the point of departure in the Industrial Network Approach (Håkansson and Snehota, 1995). The industrial network approach contributes to the understanding of the interrelated activities, resources and actors involved in product recovery. A network in this view is constituted of three interrelated layers; a web of actors, a resource constellation, and an activity pattern. The three layers interact in a way that actors control and make use of resources when they perform activities.

Actors involved in product recovery are of many types but can be divided into three main categories; actors supplying products to be recovered, actors demanding recovered products, and actors involved in product recovery (see figure 3).

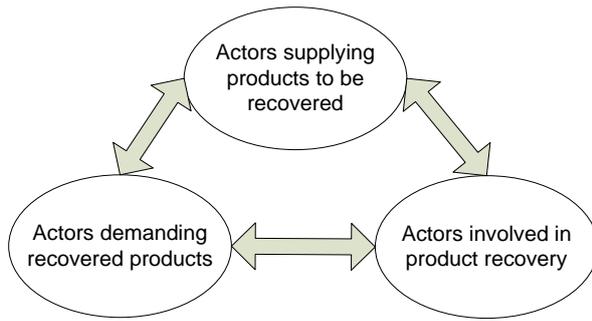


Figure 3. Actors involved in product recovery

As described above in our framework, a number of different activities are involved in product recovery. The main activities in product recovery are acquisition, collection, recovery logistics, classification, execution of recovery option, and distribution. Further, each of these activities can be divided into more detailed sub-activities. The activities will be more or less interdependent on each other. First, they can be sequentially interdependent if they need to be performed in a certain order. Furthermore, some activities make use of the same resources as other activities, which creates a parallel interdependence. This can be activities related to product recovery or to activities related to the ‘forward flow’. Furthermore, these interdependencies might occur within firms as well as across firm boundaries. How activities are organized within and across firm boundaries is decisive for how efficiency can be obtained in the network. We use Alderson’s (1965) activity concepts transformations and sortings to describe a certain ‘product’s’ path in the recovery process. Transformations change the product in time, place or form. Each transformation needs to be followed by sorting, which means redirecting the product to a new transformation. Hence sorting is a decision activity. In order to understand how product recovery can be organized we use two in principle different principles for this; the principle of speculation and the principle of postponement. According to the principle of speculation, differentiation ‘in form, and the movement of goods to forward inventories, should be made at the earliest possible time in the marketing flow’ (Bucklin, 1965:68). The principle of speculation relies on forecasts of demand. Speculation generally supports the capturing of economies of scale, but may result in substantial inventories. The principle of postponement was originally mostly discussed in terms of time and place postponement - taking ‘finished products’ as the point of departure (van Hoek, 2001). Form postponement was later added and discussed, for example, by Zinn & Bowersox (1988), who identified a number of different types of form postponement; labeling, packaging, assembly, and manufacturing.

We identify two relevant dimensions of resources in product recovery. First, various facilities are used in product recovery when different activities are performed. Examples of such facilities used for transformations can be packaging and material handling equipment, trucks forklifts, assembly equipment, etc. We can also identify sorting resources that are used to take sorting decisions. Furthermore, the product to be recovered is in itself a resource that undergoes transformations in time, form, and place (Alderson, 1965) during the recovery process and therefore acts as input into the facilities.

EMPIRICAL EXAMPLES

The paper provides two illustrations of how product recovery can be organized. We have chosen to use examples from the electronics industry, focusing on the product recovery processes of PCs and PC related products. This product category is interesting from a product recovery perspective since the resource consumption during the use of the product is lower compared to the stages of extraction and production (Grote, 1994). This is to be compared with other product categories where the situation is quite the opposite. In addition, electric and electronic waste is the fastest increasing waste stream in Europe, growing at a rate of 3-5% yearly, which is three times quicker than the waste growth average (Thomas et al., 1999). One of the reasons is the shortening of sales life cycles. As a consequence, an environmental law has been passed, forcing producers to pay fees for the recycling and disposal of electronic waste. Consequently, computer manufacturers have recognized an increasing interest of product recovery. Another issue is that more and more customers do not consider it necessary to keep pace with every innovation cycle and thereby they are more open for buying PCs on secondary markets (Lebreton, 2006). That is why many computer manufacturers now also offer refurbished computers. Increasing environmental awareness of the population is also creating opportunities for marketing of the recovered goods (Stock, 1998). Another interesting aspect of the PC in relation to product recovery is its modular design, which facilitates disassembly, refurbishing and remanufacturing activities.

As empirical examples we use one illustration on how a reseller of IT-products, the distributor, is involved in product recovery and one illustration of how a regional government in Sweden has organized the handling of their obsolete IT-equipment.

EXAMPLE 1: THE DISTRIBUTOR AND THEIR ROLE IN PRODUCT RECOVERY

Many large organizations face the challenge of getting rid of obsolete IT-equipment in a safe way, both with regard to environment and data security. This case describes how a large reseller of IT equipment, the distributor, takes an active role in handling this challenge for firms. The distributor is a major actor in the distribution and sales of IT-products in Sweden. They work closely with many of the largest PC assemblers and sell IT equipment directly to large IT users. These can be large corporations, universities, governmental agencies etc. Besides providing new equipment for these customers, they also offer different kinds of product recovery services since 1998. The capacity of the recovery facility is about 200 000 units per year.

The distributor has established four different recovery processes, or loops, that can be more or less adapted towards different needs of customers. What kind of loop that is appropriate for each customer depends on a number of factors such as for example the status of the product that is to be recovered and security issues.

The *acquisition* of the products can be accomplished in two principal ways. First, and most often the customer contacts the distributor when they have some obsolete equipment they want to get rid of. Depending on how the customer perceives the status of the products, one of three loops are chosen. LOOP1 is directed for handling equipment that the customer considers to be scrap, i.e. obsolete and broken IT equipment as well as other electronic equipment such as for example coffee machines that is hard to discard for the single firm. Often firms regard the handling costs, such as classification and getting rid of these things, as higher than the actual storage costs. LOOP2 is used when the customer has IT equipment that is no longer

used but is still functional. It can also be that the customer is uncertain about what is to be regarded as scrap and what can be reused. LOOP3 is used when a higher level of security is needed, for example when PCs containing personal or organizational related data is involved. Second, in some cases the acquisition of obsolete equipment is coordinated with deliveries of new products. In this case LOOP4 is used. The price for the services is a fixed cost plus a cost per kilo. LOOP1 is least expensive and LOOP 4 most expensive. When a LOOP is ordered a booking order is sent to the distributor's recycling center, and an order is sent to the carrier who contacts the customer within two working days.

The *collection* is organized differently in the various LOOPS. In LOOP1 and LOOP2 the carrier contacts the customer for coordination of the delivery of the steel cage fixed on a EUR pallet. The cage can be filled with a maximum of 500 kilos and it can fit for example 60 laptops or 40 PC desktop units. When the cage is delivered to the customer it is kept for five working days. The customer fills it up and the cage is then collected by the carrier. LOOP3 is similar to the previous two LOOPS with the exception that the steel cage is substituted to a steel box with a lock. This box can fit 50 laptops or 25 PC desktop units. The customer keeps the steel box for ten days instead of five. In LOOP4, a specially designed steel cabinet is used. The steel cabinet fits 30 laptops or 16 PC desktop units. When delivered it is filled with unwrapped new equipment. The customer unpacks the steel box and fills it up with obsolete equipment. The customer keeps the box for five days. This way of organizing the collection means that the box is filled both when delivered and returned from the customer, something that leads to less transportation as a whole.

When it comes to *recovery logistics*, this is managed by the distributor's partner Euroenvironment, an actor specializing in electronics logistics. For the transport, different carriers are used but most of the transports are handled by Schenker. The carrier picks up the box or cage by truck at the customer facility and transports it to Euroenvironment's hub in Enköping (Sweden). Only certified personnel at the hub have access to the premises where the equipment is stored and the premises are kept locked when unmanned. All LOOPS in Sweden are transported to this hub and the equipment is stored there until a truck can be filled to a maximum and then transported to the distributor's recovery facility in Växjö (Sweden). The turnaround is 14 days, which means that the equipment is stored in average 14 days before delivered to Växjö. The trend is that the number of days for turnaround is decreasing since the volume of equipment is increasing, meaning that trucks bound for Växjö can be filled up faster. Of security reasons, LOOP3 and LOOP4 are kept locked all the way to Växjö. When the LOOPS arrive to Växjö, *classification* starts with that the equipment is unloaded and registered as incoming goods. Hardware is tested to control and ensure functionality and the status of the equipment. The result is stored digitally.

The result of the classification is decisive for which *recovery option* that is chosen. Equipment in LOOP3 and LOOP4 are handled by authorized personnel in a certain 'security area', separated from the rest of the warehouse. The equipment that can be resold is registered in a protocol. This equipment is then made anonymous in terms of for example removing stickers with organizational identities as well as company logos and security marks. This is done mainly with blasting with carbon dioxide ice holding a temperature of minus 80 Celsius. All data is erased with security certified software. Some components might need to be exchanged and the distributor keeps a small inventory of used but functioning components taken from malfunctioning IT-equipment that has been discarded. When the units are refurbished they are ready to be sold. For equipment that is not reusable the customers often require that the equipment is destroyed in a way that makes it impossible to use the unit and extract any data

from it. Data is erased with certified software and the hardware is degaussed with a powerful electromagnet. All these activities take place at the Växjö facility. Equipment passed on to be recycled is handled by one of the distributor's partners for recycling. In 2007 the LOOPs reused about 50% of the incoming equipment. Of the remaining, 99,7% was recycled and only 0,3% was disposed. Different partners are used for recycling of metals. All equipment containing hazardous substances are taken away for special treatment. A part of the material goes to the partner's shredder plants where the equipment is decomposed in order to be able to distinguish pure metal or plastic parts for further refinement.

From the earlier discussion two main types of products can now be *distributed* as a result from the recovery options chosen. First, the product is a result from any of these recovery options: reuse, repair, refurbishing, remanufacturing, or component retrieval. Second, the product is 'raw material', such as pure plastic or metal, used as input in another production process. For the first case and if the original customer supplying the products agrees on it, the distributor works with a number of brokers specializing on selling these products. All brokers need to sign an agreement that regulates for example environmental issues as well as ethical. The distributor tries to gather up large batches of a certain product, brand, and performance, before offering different brokers to bid on each of these batches. The broker with the best bid wins. The original customer is then paid for the sold units. This customer also gets a detailed protocol of the refurbished units and a certificate that ensures that data has been erased. For the second case, the products (raw material) resulting from the recovery are not supplied by the distributor but by one of their recycling partners. The market for recycled material, e.g. metal, is global and the distributor's partners deliver raw material to actors in Sweden, Europe and Asia, where it enters new production processes. For an illustration of this case see Figure 4.

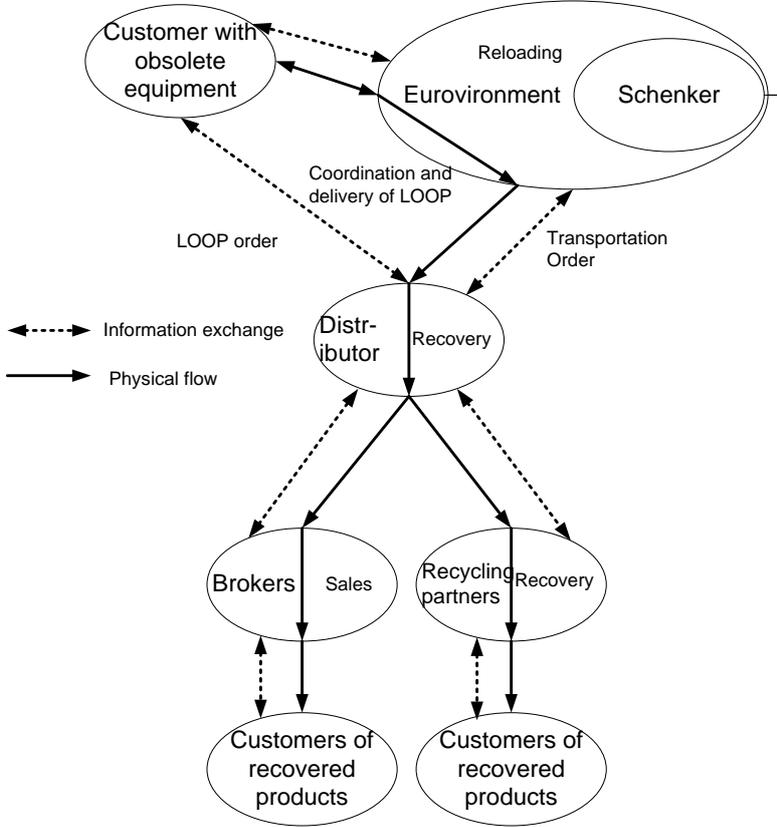


Figure 4. Actors involved in the product recovery organized around the distributor

EXAMPLE 2: THE REGIONAL GOVERNMENT AND THEIR HANDLING OF OBSOLETE IT EQUIPMENT

This empirical illustration concerns region government and its constant need to ‘get rid of’ obsolete IT equipment. The regional government is a public region located in Sweden, with many kinds of operations including healthcare and other public services.

In this handling regional government works closely with one PC supplier, who in turn works closely with a firm, a maintenance and repair service provider, specializing in the management of 3PL projects. With regard to *acquisition*, a leasing agreement between regional government and the PC supplier makes both actors aware several months ahead when and where obsolete PCs are to be replaced by new. This creates opportunities for making both the production and delivery of new PCs, as well as the ‘taking back’ of old, more efficient than if this was done more on an ad-hoc basis, which was the case before. Each month, regional government sends a consolidated order to the maintenance and repair service provider. The accumulation of orders leads to lower administration costs for regional government. In this process, the maintenance and repair service provider actually buys the used PCs from PC supplier Financial Services. When the order from regional government arrives the maintenance and repair service provider transmits it to PC supplier, who can start plan for the assembly of the new PCs. For PC supplier this means that they know in advance that a certain number of components will be demanded, and this information can also be transferred back to suppliers for their planning. The order information is also transferred to two other important actors in the project, the remanufacturer and the second hand broker or retailer. The remanufacturer is involved in PC recovery and works closely with The second hand retailer, a retailer of recovered PCs. The information they receive contains the date of the delivery of the products to be recovered and the type and quantity of these products, which enables them to make production plans and to start promoting the PCs and searching for the customers of the equipment already at this time. Sometimes there is already a known demand for the equipment available through the second hand retailer’s information system. The remanufacturer pays a small amount for every piece of equipment that comes from the PC supplier- regional government project.

In order to arrange the collection and logistics, maintenance and repair service provider has established a close collaboration with a third party logistics provider, 3PL. This firm has low fixed costs due to its organization with a flexible number of employees that can easily be adapted to different projects. The low fixed costs and the limited space at maintenance and repair service provider were two of the reasons why the maintenance and repair service provider decided to outsource the centralized unwrapping and delivery of the new products and the simultaneous collection of the used products.

With regard to *collection*, route planning for the collection of the used units are tightly coordinated with the delivery of the new PCs. When the order arrives in the beginning of every month, a route plan is created, taking into consideration for example aspects as type of old and new PC, geographical dispersion of users, and use of small or large trucks. Certain rules of priority concerning these ‘dimensions’ decide the route. Route planning for the collection is done on a working day basis and it is grounded in the planning for the delivery of the new products.

The time aspect is crucial in this kind of project involving installation of many units on site. Time studies have been performed since these services started and every step is measured in

seconds. Basically planners at 3PL, and the maintenance and repair service provider estimate how geographical dispersion will affect the time for the delivery and installation of the new goods and collection of the used goods. The number of places or users that can be visited during a day determines the quantity that can be collected (and delivered) during a single working day and thus the size of the truck in order to achieve full truck loads.

When the new equipment from PC supplier is delivered by Schenker to 3PL' facility in Växjö (Sweden) it is classed by delivery date to users. When it is time for delivery the equipment is unwrapped and loaded on special steel boxes called an 'IT box'. The IT box is a load carrier on wheels that maximizes the usage of the space in trucks, since it is adapted to the dimensions of the 'standard truck'. It is loaded with unwrapped units, which in turn increase the fill rates of the trucks and reduces the need of transportation. It also allows for fast delivery and collection to and from the user site since it is adapted to Swedish standard for indoor environment (e.g. doors, elevators). So these IT boxes are delivered, loaded with new equipment, to the users at the regional government. During this delivery it is sometimes reloaded, at one of 3PL' local hubs, for convenient and efficient transportation to local sites. Hence, a key aspect for 3PL is to maximize the fill rates by combining smaller and larger trucks. Besides the minimization of loading and reloading work this system provides a safe and secure transport of the used IT equipment due to the fact that goods are not handled in shared or public facilities. This is an important factor for the former user because the information that can be retrieved from the hardware might be regarded as sensitive, e.g. information about patients at hospitals.

During the collection of goods at the user's site there are notes on every IT box reminding the personnel of the rules of packaging and placement in the boxes. The collection is performed by personnel from 3PL, and they have detailed instructions on how to wrap the products, e.g. monitors are placed together, wrapped with reusable thin protective plastics. Furthermore there are also instructions on what equipment goes on top and what goes at the bottom of the boxes due to stability reasons. With regard to *recovery logistics*, the equipment, placed in the IT boxes, is then transported to the remanufacturer's facilities in Gothenburg. In order to consolidate physical flows and increase fill rates the equipment is often reloaded at a local hub. Combined delivery of new products and collection of old products may take 1-3 days depending on how the configurations of the new products are organized.

Remanufacturer, the partner for recovery activities, reconditions laptops, printers, desktops and everything that is regarded as IT today. For the remanufacturer the main aim is to find a second user of the recovered products and to avoid recycling as long as possible, which is regarded as failure. 3PL delivers the goods to the remanufacturer. The equipment is registered and scanned in the database and the goods is separated into three flows depending on how it is *classified*. The first classification concerns goods containing no sensitive information. This can for example be monitors. Some equipment only needs to be cleaned up while others are defective and will need to be repaired, refurbished, or end up in recycling. It is the knowledge and experience of the personnel that decide on what option to choose. This decision is taken after the goods are tested with special software and cleaned by highly experienced workers who can notice scratches and damage due to pressure, which are not visible for most users. If damaged, these units are discarded and stored in order for them to be recycled. Another classification concerns goods that contain information that needs to be deleted. After an initial test it is decided whether these goods can be refurbished after data erasure or if it will be passed on to recycling. Some goods are passed on to recycling directly. This often concerns specific components such as mouse, keyboard and cables that are relatively inexpensive and

with most visually ‘damaged’ parts. Large traders or retailers of used equipment, which are customers of the remanufacturer, usually complement the recovered PCs with new mice and keyboards.

So based on these classifications different *recovery options* are executed. Some equipment only needs to be cleaned up while others are defective and will need to be repaired or refurbished. There is sometimes a small inventory of retrieved components but this is usually kept for the situation when a rather large series of computers is processed in order to complete a more or less uniform batch. All equipment that contains some data must go through a deletion process. This most often concerns PCs. First, the PCs are tested with regard to function with certified software, which guarantees that the hardware (memory, hard drive, network, mother card etc.) is functional. After this all information is deleted by using the same software and all identification on the ‘surface’ is removed. If the information cannot be erased with software, or if some customers do not think this is enough, then the component is processed through a large electromagnet which destroys the memory and then the same component is cut into two pieces with an axe. The outcome of the activities is stored in a report for customers, i.e. PC supplier in our case. Another advantage of the software is traceability. The database enables the traceability of the machines. There is an EU directive forcing the remanufacturer to provide traceability of every product that leaves their facility. The purpose is to avoid that products end up in countries that has no secure way of handling these products. For PC supplier and their customer, the regional government, the information about deletion of information is most central. For the remanufacturer, the report gives a clear picture about the product’s characteristics which is crucial in selling the equipment further.

For recycling, the remanufacturer uses Stena Metall that takes care of all kinds of waste to be recycled except for cables. Stena Metall collects a cage with the goods once a week. Cables are instead transported to a company that pays for the copper within these.

With regard to the *distribution* of refurbished equipment, the remanufacturer is closely related to the second hand retailer, a dealer of used IT equipment. The two companies are located at the same facility and have a common past history but are now two individual corporations working together. About 85 % of the PCs are sold abroad to 10 partners in Eastern and Southern Europe. The second hand retailer is connected to an international broker network where they are able to buy and sell used equipment. This enables them to closely follow the development of prices on the refurbished equipment. The broker network makes it possible for the second hand retailer to search for customers of a certain product category and sell the equipment before it actually enters the facilities for refurbishing. An example of this is when a broker wants to buy a certain product and put a request to the second hand retailer. They can ‘search for’ this kind of products and this also opens up for cooperation with ‘competitors’. Another example is when a large corporation wants to extend the life of its PC system instead of exchanging the whole system, something which is very expensive. In such a case the second hand retailer can help to find such PCs in order to complement the existing PC environment. The value of the goods is usually declining by 2-5 % per month and there is a great urgency to move the goods as soon as possible through the distribution networks. For customers this means a challenge when it tries to fill a container with computers to achieve cost savings in distribution while at the same time the price that a user will pay for the product is decreasing every day. The international customers handle large quantities such as full containers or truckloads due to the fact that low value of the used equipment cannot bear costs of several loadings and re-loadings. 15 % of the products are sold to Swedish customers such as for example municipalities, schools, and enterprises. The second hand retailer most often

uses Schenker or Posten to service Swedish customers. Customers have 6 months guarantee on the equipment and get original equipment specifications. Interesting to note is that the second hand retailer doesn't provide mouse, keyboards, software configuration etc. Most of the value in the product provided by the second hand retailer lies in the licenses of software that follows the PC. So these other accessories are added later on, closer to the end user, by the customers of the second hand retailer.

Most of the equipment that is refurbished at the remanufacturer's site and sold through the second hand retailer are rented or leased in 3 year cycles as is also illustrated in the regional government cases. The remanufacturer cooperates with several financial units of the largest assemblers, of which PC supplier is only one. By close cooperation with these actors the remanufacturer is provided with information about what products that can be expected when the leasing periods expire. Furthermore, the second hand retailer works very proactively with the broker network in which the potential customers' demands of recovered products become visible. This means that products can often be reconditioned-to-order as the second hand retailer has already contracted customers on a specific volume and product. This is made possible due to the long time horizon for planning, resulting from the leasing agreements. So, in order to manage this, the remanufacturer and the second hand retailer are working closely together to try to acquire large quantities of products to be recovered in order to keep the economies of scale of the reconditioning facilities. They also try to work with large customers and large volumes of a specific product to match these volumes in supply and demand. Furthermore, remanufacturer aims to match the batch sizes in the refurbishing process with full truckloads. For an illustration of this case see Figure 5.

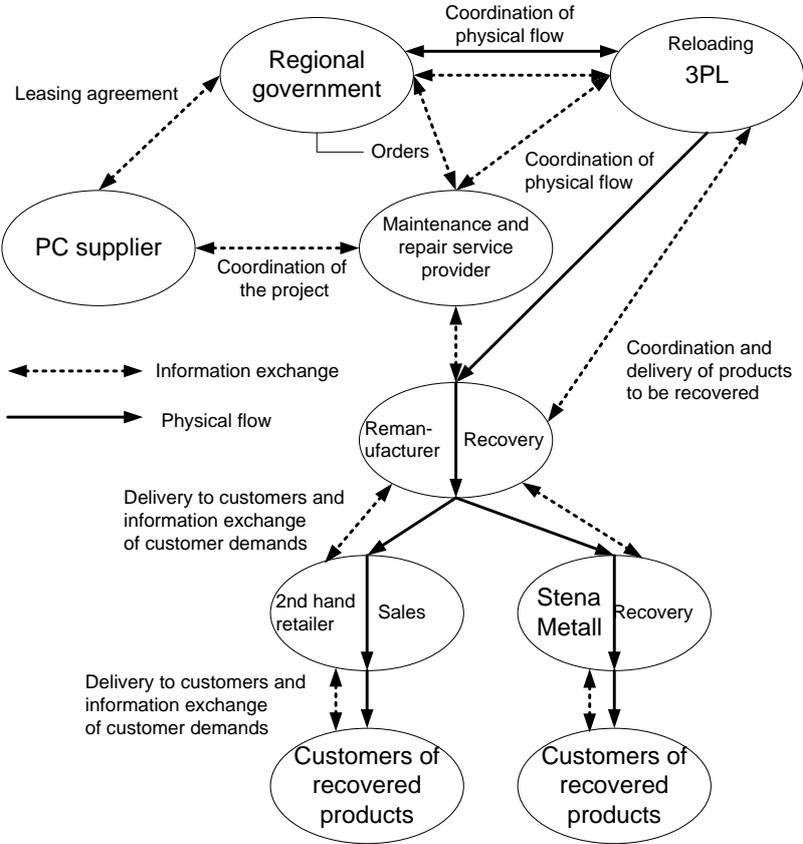


Figure 5. Involved actors in the product recovery of the regional government's obsolete IT products

ANALYSIS

The forthcoming analysis takes point of departure in the three network layers and how product recovery can be analyzed and understood with regard to the resource constellation, activity pattern, and web of actors respectively.

PRODUCT RECOVERY AND THE RESOURCE CONSTELLATION

The cases illustrate that the use of resources in terms of facilities is crucial for the creation of efficiency in product recovery. First, by *resource adaptations*, the involved firms try to make the resource constellation more efficient. In both illustrations the actors involved in product recovery have tried to adapt different facilities in a way that improves the opportunities for resource utilization. For example, at the distributor the different facilities used in the LOOPS are specially designed for their specific purpose. Furthermore, by specifying what kind of products (with regard to their status) that enters each LOOP, the distributor tries to control and facilitates the classification of the products already at this stage at the customer premises. This further facilitates the classification activity performed at the recovery facility. In a similar way, the IT box used in the regional government case is specially designed to fit into the 'Swedish standard truck' as well as to the standard 'business indoor environment'. Furthermore, detailed packaging instructions on the IT boxes helps to increase fill rates as well as to facilitate the handling of the products when delivered to the recovery facility.

Another issue concerns how resources are made use of with regard to *resource utilization*. Both cases illustrate how the involved firms try to coordinate different physical flows in order to increase capacity utilization. This can be exemplified by LOOP4, where old equipment is collected simultaneously as the new equipment is delivered. The steel cabinet used in LOOP4 has been designed to fit both new and old equipment. By using the same resource for these two physical flows, capacity utilization can be increased as well as transportation work decreases. The same setup is used in the regional government case as a result of the leasing agreement between the regional government and the PC supplier. This means that the two flows are coordinated, which impact on the use of resources. Furthermore, the involved firms also try to increase resource utilization with regard to the facilities in recovery logistics. By using logistics hubs and various sizes of trucks, the firms actively try to improve fill rates. An increasing volume of products as a whole has made it easier to match different deliveries and facilities with each other, which has enabled improved resource utilization.

With regard to the product itself as a resource, its modular *product design* plays an important role for how product recovery can be accomplished. The fact that it is rather easy to replace malfunctioning components makes it often worthwhile to repair the product even though the PC is confronted with fast pace of technological development, leading to continuous price reductions. The design of the product is hence decisive for which recovery options that can be realized and to what cost.

PRODUCT RECOVERY AND THE ACTIVITY PATTERN

A general aim in product recovery is to avoid passing on products to recycling as long as possible. With regard to this classification activities are important since the results of these

activities decide on what recovery option to choose. From a theoretical point of view, this means that *sorting* is crucial since it directs the ‘product’ to the next transformation. The sorting decision can lead to *transformation* in form, e.g. recovery in terms of repair, cleaning, refurbishing etc. However it can also result in transformation in place and time. This can lead to that the product is stored somewhere in wait for the next sorting decision. In turn, this might result in that the product loses ‘value’ due to the technological development referred to above. This means that the sorting resources used, be it a human resource or a machine, are crucial since the output of these resources in terms of a diagnose of the product, is used to make a ‘sorting decision’ directing the product to the next transformation, and thereby to the recovery option. Depending on these decisions, more or less products will end up in recycling or even worse, disposal. As pointed out in the regional government case it takes experienced and knowledgeable people to make the ‘right’ recovery option for each piece of equipment. However, what is the ‘right’ decision is not evident since this means a balance between cost aspects and environmental concerns. However, sorting is not only important in the classification activity. The paper shows how sorting is also a key issue for obtaining cost efficient recovery logistics by sorting products towards different resources at different times in order to improve resource utilization. Furthermore, the cases also show how detailed ‘sorting rules’ in terms of instructions lead to efficient collection as well as prerequisites for production planning.

Another important aspects is that detailed information and information exchange among actors in the network provide opportunities for *activity coordination*. For example, the regional government case illustrates how the second hand retailer and the remanufacturer together try to use the detailed information about the products to organize and match the recovery activities and the sales and distribution activities. This means that since they know in advance what products that will be supplied, The second hand retailer can start to search for potential customers already at this point in time. It also gives time to actively search for complementing products or components in the wider network to fulfill a certain customer need. By actively using the broker network, they try to match customer demand with the incoming products. Then, when the products are delivered, recovery activities directed to a certain customer can start directly. Activity coordination is also a critical issue in collection and recovery logistics. For example, in the regional government case heavy activity coordination is required since new equipment is delivered at the same time as the old is collected. Furthermore, each PC is specific with regard to user, place, and delivery time, which sets high requirements on the planning of these deliveries. This, in turn, requires extensive information exchange among the actors involved in collection. Furthermore, in order to increase resource utilization in recovery logistics, the activities involved in these physical flows need to be closely coordinated. This is accomplished through information exchange among the involved actors in the network.

The cases illustrate how the firms try to work with different kinds of *postponement*. When the second hand retailer sell the equipment they mainly sell licenses, PC, and monitors. These are also the most expensive components related to the PC. Less expensive components like mouse and keyboard are added by the broker since the user often has certain demands with regard to this. The same is valid for the software configuration, which if often adapted to specific user needs. So these activities are postponed (in form) to the broker, who are closer to the user. Another type of postponement is present in the distributor case where delivery and sales activities are postponed until a certain size of batches of similar products have been reached.

PRODUCT RECOVERY AND THE WEB OF ACTORS

As identified in the framework three important kinds of actors take part in product recovery; the actors supplying the products to be recovered, the actors demanding recovered products, and the actors involved in product recovery. How these actors relate to each other and the nature of the business relationship among them will have impact on how product recovery can be organized.

One issue concerns the acquisition and the overall *business agreement* between the actor supplying the products to be recovered and the actors involved in product recovery. One of the cases illustrates how a leasing agreement created opportunities for organizing activities and resources in the network. The leasing agreement as illustrated in this paper sets the prerequisites for the product recovery based on a three year routine. Involved in this setup are a number of different specialized firms that interact and work together. One actor, the maintenance and repair service provider, acts as a coordinator of the different physical flows involved in collection and recovery logistics. By extensively exchanging information with the other actors this creates opportunities for each actor to make plans for how resource can be utilized and activities coordinated both within each firm but also across firm boundaries. This business setup also means a reduction of administration cost per product unit for every actor in the project since orders and physical flows are consolidated. In the distributor case, the business agreement is arranged differently and on a more short time basis. However, by predefining different offerings (the LOOPs) the distributor tries to reduce uncertainty concerning the status of the products on an aggregate level, and also it defines when and where the products are available.

Both cases show how firms involved in product recovery try to reduce uncertainty by interacting and *exchanging information* with each other. Detailed information about products, consequently impacts on how transformations and sortings are organized in the network, and therefore impacts on product recovery.

CONCLUDING DISCUSSION

The paper shows that product recovery is a complex issues and that it requires a holistic perspective for its understanding. In this paper we have applied an industrial network approach, something that proved fruitful. From our analysis, some aspects of product recovery can be distinguished.

With regard to activities, the paper shows that the concepts sortings and transformations are useful for analyzing product recovery arrangements. The concepts can fruitfully illustrate the path that a product takes from the source, i.e. the actor supplying products to be recovered, to the use of the recovered product, i.e. the actors demanding recovered products. Sorting was found to be especially crucial in the collection, classification, and recovery logistics activities. In collection and recovery logistics sorting is decisive for resource utilization as it decides what transformation resources to be used. In classification it is decisive for what recovery option that is chosen, in turn being a key decision in product recovery. This decision hence impacts directly on what transformations the products will undergo, in time, place, and form. In turn, this means that this decision also have effect on environmental impact as well as on the cost structures of the involved firms. In turn, what sorting resources that are used play an important role in order to accomplish efficient and effective sorting. These can be persons

with experience of such decisions, a database with information, or rules or instructions that directs sorting decisions.

This brings us to the role of information and information exchange among the actors involved in product recovery. Information about products, their design, availability in time and place, and their general status, facilitates sorting as well as activity coordination among the actors. The cases also showed how information exchange provides possibilities for matching supply and demand of the recovered products as well as it can improve use of facilities. The use of facilities is also affected by to what degree resources are adapted to each other. Both cases show how facilities have been adapted to improve efficiency in product recovery by, for example adapting material handling equipment. Furthermore, the design of the product itself plays a crucial role for how product recovery can be organized. A modular design, for example, creates great opportunities for efficient performance of recovery options.

Finally, the overall business agreement concerning acquisition of the products to be recovered showed to have impact on how product recovery might be organized. An example of this was the leasing agreement in one of the cases that enabled detailed information about the 'supply' in advanced which created opportunities for the planning of activities and resource use within and across firm boundaries.

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