PRODUCT RECOVERY MANAGEMENT: INDUSTRY PRACTICES AND RESEARCH ISSUES

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Abstract

We present a review of some articles about Product Recovery Management, with emphasis on the recycling projects in the automobile industry and on the remanufacturing of photocopiers, disposable cameras and machine tools. From these observations we conjecture the existence of some characteristics related to the process driver and to the product identity that will provide guidance on modeling different remanufacturing processes. We conclude suggesting two broad research issues in this topic. The appendices provide an overview of the pertinent German legislation and a glossary of terms. [1]

Keywords: reverse logistics, remanufacturing, recycling, refurbishing, waste reduction

1. Introduction

1.1 Why Product Recovery Management?

The academic literature in product remanufacture and recycling is still in its infancy. The subject gained more attention with the continuous increase of the environmental movements, which have extended the meaning of *pollution prevention* to include *waste reduction*, and the acknowledgment of the economic value of used machines, equipment and appliances when they are disposed at the end of their useful lives. Since the environmental concern is relatively recent, we observe that most of the product recovery effort is economically motivated. Once a valuable good expires its useful life, because of obsolescence or a significant breakdown, the user may find economically viable to give it a "second life" through what we call remanufacturing. This kind of product recovery, while extremely relevant, is simple problem of investment decision.

What we are looking after, is the product recovery process that manufacturers of durable products will have to engage, either because of legislative pressure to ensure the environmental protection, or because of the business opportunity inherent to reusing parts that would have been discarded otherwise. If the early projects were limited to the remanufacturing of capital goods or to the recycling of metals, environmental concerns threaten to make producers of all goods liable for the impact that a product may cause to the environment not only during its useful life but also in its afterlife, if they are not disposed properly.

The Centre for Exploitation of Science and Technology (UK) produced a comprehensive report about the disposal of electronic equipment in UK and in the European Community (Roy 1992). It is motivated by the foreseeable legislative threat, and the lack of preventive action by the bulk of the British electronic industry.

[1] Originally written in August 1994.

It estimated that the European legislation would be approved and start implementation by the member states by 1995. The report forecasts that new European legislation would require that the percentage of plastics to be landfilled in Europe should reduce from 70% to 10% by year 2000. Although the time scale may not confirm, there is enough evidence that the legislation is on the way, and that similar regulation could be approved earlier in some European countries - namely Germany, the Benelux and Scandinavia - and in Japan.

1.2 Industry Practice

Most equipment and appliances could enter some sort of materials recovery process at the end of their useful lives, in particular when the metal content is high. Some high value-added modules with good resistance to wear can be recovered for reuse. The rest of the equipment can be dismantled for recycling. Usually, the limitations lie on the recycling of some "difficult" materials like plastics, rubber and composites. The increased use of polymers has prompted research on efficient recycling of plastics, which has followed two different approaches: *cascade* and *like-for-like.* The cascade recycling takes plastic from higher quality to lower quality application each time the item is returned for recycling, until it can't be used as a raw material anymore, and it is incinerated to collect the energy it can produce. The like-for-like recycling tries to reuse the plastic in the same or equivalent application as before recycling. Like-for-like recycling is obviously more desirable.

To ensure the correct understanding of the issue, our review observes the product recovery processes of a variety of industries and their different outcomes. We give emphasis to the recovery of the automobile, the photocopier, the disposable camera and machine tools.

1.3 Product Recovery Drivers, Product Identity and Conditions for Success

The case studies help understanding the logic behind each product recovery case. Product recovery has different purposes depending on which industry adopts it. Following the case studies, three sections address these questions:

1. What drives the firm's decision to engage into a product recovery process? What are the product recovery drivers?
2. Why can some firms remanufacture their products while others have to content with recycling them? What are the conditions for successful remanufacturing?
3. What are the changes that occur into the products identity, once remanufactured? How can we link the changes in product identity with other process parameters?

The answer to these questions is crucial for the correct analysis of each process.

1.4 Research Issues

The last section suggests some research issues in product recovery. Two sets of problems are proposed: the first regards the effects of several sources of uncertainty in scheduling a remanufacturing line and the second regards the changes in the market structure to accommodate the return flows of reclaimed raw material.

2. Remanufacturing and Recycling Cases

2.1 Reclaiming Automobiles

The automobile industry is probably the largest and the most influential industry in the world economy. It is not a surprise that the growing pressure about industrial waste would affect the automobile industry quite directly. At the end of their expected life of 10-15 years, automobiles meet the unavoidable fate of all industrial products and are disposed. It is easy to guess the size of the trash pile. The number of cars disposed each year is approximately the same as the yearly production of roughly 12 years ago. More precisely, 6 industrial countries are responsible for the disposal of 20 million cars each year[2]. The world production of cars (40M) and commercial vehicles (4M) of today corresponds to the amount of vehicles to be trashed in 2010.

Luckily, automobile is one of the most recycled industrial products. The large fraction of metals in a car has attracted small businesses throughout the world to recycle the steel, iron, lead and aluminum present in each of them. Nearly 75% of every disposed car are recycled. The dark side of the story lies on the remaining 25%. They are composed of glass, rubber, plastics, cloth, fluids, wood and dirt - usually called "fluff" - that cannot be recycled either for economic or technical reasons. Barth (1993) offers a comprehensive description on the automobile production and recycling process.

Some automobile firms in Europe and in Japan have made considerable progress extending the recyclable limit of the car; a few of them committed to approaching the 100% recyclability level.[3] The main research effort involves finding ways to recycle the plastic, rubber and glass in it. The large variety of plastics that compose 10% of a car's weight is a great hurdle since the different kinds of plastic cannot be recycled together. They are not chemically compatible and have to be separated before the process takes place. Consequently, most car makers have been coding the plastic parts so that the identification process is simplified when the car returns for recycling at the end of its useful life. A more efficient approach has been to reduce the variety of plastics used, preferring those kinds that are easier to recycle - like polypropylene (PP) - and reducing the use of thermosets which are hard to recycle.

The German car makers seem to have the leadership in these efforts, anticipating the requirements of the proposed Old Car Ordinance. The Ordinance, under discussion in the German Cabinet, is expected to require that car makers take back their old cars, completely recycle them and deliver disposal certificates to the last owner (Griffiths 1992c, Feast 1991). Although it is not law, yet, every German manufacturer is committed to take responsibility for recycling their cars. Research has been directed to

1. developing disassembly techniques to reduce disassembly time;
2. designing components and modules to facilitate disassembly;
3. reducing raw materials variety and designing parts with separable materials for recycling;

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[2] The number of disposed cars in some developed countries each year are: US: 8 million, Japan: 4 million, Germany + France: 4.5 million, Italy + England: 4 million.

[3] US manufacturers' policy for the environment prioritizes the reduction on emissions and fuel consumption, to fit the EPA regulations and state laws.

Automobile Part	Reclaim Process
battery	Batteries are usually destroyed to separate the plastic and the lead for recycling. Alternatively, the battery can be incinerated, and the plastic used as fuel, to obtain pure lead.
bumper	Bumpers are the largest plastic parts in a car. Bumpers are ground into pellets, cleaned and used to make new bumpers (like-for-like recycling) or other parts from lower grade plastics (cascade recycling).
other plastic parts	Smaller parts may be incinerated, larger ones recycled.
steel body	The body (55% of a car's weight, 24% of volume) is recycled as scrap steel.
engine	The engine, made of cast iron and aluminum (17% of weight, 15% of volume) is recycled or reconditioned for reuse as spare.
transmission	Same process as engine.
rear axle	Same process as engine, in front wheel cars.
alternator	Used alternators are inspected and reconditioned and sold as spare part.
catalytic converte	Catalytic converters are recycled to recover the platinum and the iridium within, worth 300-400DM.
tires	Tires can be incinerated as fuel in cement or paper and pulp plants. One fifth of them could be retreaded and reused.
brake fluid	Brake fluids are recycled into industrial detergents.
lubricants	Motor oil and transmission oils are recycled into itself, with the addition of the usual ingredients.
coolant	Used coolant is recycled to salvage the refrigerant ingredient to make new coolant.

4. developing overhauling and reconditioning techniques that allow reuse of components (engines, gearboxes, water pumps, starters and even electronic parts) in the replacement market or in the assembly line.

Some automobile parts are already recovered and sold as spares. The objective is to enlarge the list of items that can be remanufactured, and to include plastic parts in it. While reuse is not possible, large plastic parts, such as bumpers, are now recycled into plastics of the same grade, which may be used to make bumpers again, an example of the *like-for-like* recycling concept. However, recycling of the 20 different kinds of plastic usually found in a car is rather complicate. Typically, the recycling process degrades the plastic such that a part made of higher grade material will produce lower grade plastic, an example of *cascade* recycling. This process may repeat for 2 or 3 times until the material has no use but to incinerate for the energy that it will deliver (Siuru 1990, Vandermerwe and Oliff 1991, Griffiths 1991a, Daniels 1992, American Embassy Bonn 1992, Fisher 1993).

Efforts to reduce automobile waste are different in each country (when existent at all), and the solutions adopted by different firms vary with their commitment or with the threat imposed by local laws. In the UK, the British Govt. provided a £300,000 grant[4] to a 4-company consortium to recycle automobile plastics. Meanwhile, buy back schemes loom: Porsche, Ford, GM and Mercedes are some of the companies offering to buy back their cars after a period of years for a pre-specified price. Also, the Society of Motor Manufacturers and Traders, the UK-based automobile association, signed up Ford, Vauxhall (GM's subsidiary in the UK), Jaguar, Nissan, Peugeot and Toyota for the research program ACORD - Automotive Consortium on Recycling and Disposal, with the advice from United Engineering Steels, the UK firm that sells 2 million tons of engineering steel from scrap each year, (Griffiths 1992b, Cropley 1993, Taylor 1993).

[4] Find in Appendix 4 an approximate exchange rate table.

In France, the recycling of used motor oil is subsidized by a tax of 90FF/ton of oil produced. So, cement producers, interested in the use of tires as fuel in their kilns, have suggested a similar tax of 4.50FF/unit to fund the collection of used tires (Coulange 1991).

About 94% of cars in the US are sent to dismantlers/shredders. Scrap steel is worth $110/ton and sophisticated machines can process 300 scrap cars at a time. A typical recycling process works as follows: a dismantler removes from the car the bumpers, the catalytic converter, the battery, radiator, engine, fuel and water pumps, all fluids and transmission. Each of these items suffers a specific reclaim process. The rest of the vehicle - the steel body and everything else that was not removed - goes to a shredder that will recover the steel and the nonferrous metals[5]. American shredders collect 11 million tons of steel and 800,000 tons of nonferrous metals each year (Owen 1993).

However, collection of scrap cars for disposal, worth just $20-$40 each, creates a big hurdle. Beside the development of the technology for cost-effective vehicle dismantling and processing, a stable market for used parts and recycled material is necessary to evolve. Until then, a large amount of fluff will come out from the shredding process, from windows, tires, upholstery, with absolutely no commercial value.

2.2 Industry Experience

Although the recycling policy of some car makers is not very clear yet, most of the large firms have taken positive action to make their products less aggressive to the environment, a concern largely generated by the increasing threat of new regulation throughout the world. The Old Car Ordinance has led the way to what may become the base for EC's used car regulation. Some European car makers identified the threat very quickly, engaging in comprehensive research projects to improve the disposal process.

Other European firms, while recognizing the need to invest in more recyclable automobiles, have put less effort into solving the old car recovery problem, perhaps waiting to see the actual developments in the legislation and the results obtained by the other firms. Despite their commitment to the European market, the American and Japanese car makers have made less progress (on average) than their European counterparts. This is quite predictable since the environmental regulations in their home markets are more concerned with the reduction in fuel consumption and in the emission of pollutants. Nonetheless, some remarkable achievements have been collected by many of them. Let's examine some of this effort:

2.2.1 BMW

Following the pressure at home to be prepared to reclaim its products at the end of their useful lives, BMW invested in several countries trying to establish networks for recycling. In 1991 it established the first car recycling pilot plant in Germany, in its Landshut component plant. The project was set to last 2 years with the purpose to develop an efficient process for dismantling and recycling old cars and to define guidelines for the designing of cars that would be easy to recycle.

Simultaneously, the concepts Design for Recycling and Design for Disassembly were adopted. Engineers should select materials free from harmful substances and easy to recycle. Variety of materials should reduce; PVC, duromers and metal-plastic combinations should be avoided. Parts are color-coded for new plastic (green) and recycled (blue) for future identification. All plastic parts

[5] Mostly aluminum, zinc and copper.

above 100g are identified. At the time the project started, Landshut already reconditioned 16000 engines/yr., 8000 rear axles/yr., 13000 starters/yr., lights and water pumps, beside reclaiming precious metals from 8500 cat converters/yr. worth DM 300 to DM 400 each.

Initially, dismantling an entire car would take 4 to 5 hours but BMW worked to cut time into 1 hour. Specially designed equipment removes fluids, discharge air bags, recover batteries and disassemble vehicles in an environmentally friendly way. The dismantling process is organized in six stages:

1. doors, hood and trunk lid;
2. interior;
3. trunk;
4. outer body work;
5. engine compartment;
6. floor pan.

Some 81.5% of the 3-series can be recycled by current methods when remanufacture of big components is taken into account. One of the obvious constraints of such project was to find market for the reclaimed materials. Recycled BMWs find customers among raw material producers (cement, rubber, plastic), tire and glass manufacturers, chemical industry and road construction companies, wishing to use granulated plastic as filler for road beds. A paper mill changed its furnaces to take tires instead of coal (Griffiths 1991d).

The Landshut pilot plant led to the conclusion that large-scale centralized disassembly units are not practicable (Griffiths 1991c). Economic reasons and transport limitations discouraged BMW to centralize its recycling activity. BMW will supply the technology to an authorized network of 100 dismantlers in Germany to reclaim old cars. The first partnership was with Pressmeier in Munich, having the capacity to process 30 cars per day, expecting to raise to 40 cars soon.

Shortly after, BMW announced plans for establishing a network of car dismantling and recycling centers in the UK. It collects damaged plastic bumpers and catalytic converters and sends them for recycling in Germany. Fifteen recycling plants, each at a cost of £250,000, are expected to operate in the UK. The first dedicated car dismantling and recycling plant in the UK was opened in partnership with Bolney Motors, with capacity to process 2500 cars/yr. It will take back for recycling all models in its current product line - even those registered several years ago. Disassembly of the new 3-Series takes 2-7 hours (£20 per hour), at an average cost of £175 per car (Griffiths 1992c, Griffiths 1991a, Griffiths 1991b).

In order to finance the costs of the operation, BMW insists that the market forces should prevail. Car owners and dismantlers will negotiate the sale price, as a function of the car's recycling cost and economic value.

Example: a 1977 BMW 525 costs DM 200 to dismantle. Sold at its market value is DM 400, the owner takes DM 200. The recycler will extract 20kg of plastic, glass, 500 kg of steel, fluids and sell it to different material recyclers. The profit will come from the sale of recovered parts like the engine, which may be worth DM 600 once repaired (Laperrousaz 1991).

Old Car Recovery at BMW

Designing New Products:

- Design for Recycling and Design for Disassembly.
- Selection of materials free from harmful substances and easy to recycle.
- Reduction of materials variety.
- All plastic parts above 100g are identified.

Developing Recovery Process:

- First automobile pilot plant in Germany to develop dismantling and recycling process and to define guidelines for designing.
- Disassembly projected to reduce from 4 hours to 1 hour per car in the pilot plant.
- Recycling yield achieved: 81.5% of the 3-series.
- Customers of recycled materials found outside the automobile production chain.

Development of Networks in Several Countries:

- Germany, UK, US, France, Holland

Following its moves in Germany and in the UK, BMW is already planning on establishing car dismantling facilities in France, Holland and the US, some of them in cooperation with Renault. In The Netherlands, BMW collaborates with De Mosselaar BV of Dogen, who dismantles 40 cars/shift for parts salvage, while selecting plastic components, tires, and glass for recycling. In the US, BMW is on a two-year pilot program with the Automotive Dismantlers and Recyclers Association. The company offers US owners a $500 credit toward one of its new or used cars, against an old car for proper recycling (Owen 1993).

2.2.2 Volkswagen

Volkswagen started a pilot facility in Leer, committed to achieving a 90% recycling level. There, disassembly has the following sequence (Griffiths 1992b, Siuru 1990):

1. Remove fluids for recycling;
2. Remove assemblies in better state, such as engine and transmission, for rebuilding;
3. Remove plastic bumpers. They are shredded into small pieces, cleaned and granulated to use as raw material for new bumpers (like-for-like).
4. Send other plastic parts to recycling facilities;
5. Remove batteries for dismantling and recycling;
6. Send remainder to a shredder (body and damaged assemblies).

VW is determined to achieve like-for-like recycling of plastics. It has cooperated with Bayer to demonstrate that Novodur, a newly developed thermoplastic used in radiator grills, is recyclable. The used grills are crushed, cleaned and combined with fresh material to make new grills, in a process much too similar to what is successfully done with bumpers made of PP. The final product meets the quality standards holding paint and retaining mechanical properties.

As a result, VW announced that the new Golf is the world first car designed for recycling, but disposal costs of 300-400DM per car raises the question of who should bear the burden. Nonetheless, it will take back all of them to dedicated plants, at no cost for the owners, and strip them for disposal. The new Golf is 77% recyclable, but should reach a 92% recyclability level once the entire procedure is implemented (Taylor 1993).

2.2.3 PSA

PSA, manufacturer of Peugeot and Citroën, invested 20 million FF in a pilot unit in Saint Pierre de Chandieu to dismantle 300 cars per month. In this program, it develops a materials separation process for economically efficient recycling of plastic parts, especially bumpers and fuel tank. Meanwhile, it studies the generalized use of PP, already used on bumpers and shock absorbers, instead of other plastics. Already, 90% of all plastic parts are made of just 7 polymers (Laperrousaz and Counas 1991).

In the process, the vehicle is disassembled in 3 to 5 hours and all negotiable parts are sold. The metals can be sold at market price, presently around 600FF/ton. Tires and several plastic parts have been negotiated with a cement plant for 320FF/ton to be used as fuel. The fluff that remains is discharged at a cost of 130FF/ton. The plant reuses, recycles or incinerates almost 95% of each car processed (Taylor 1993, Coulange 1991). The account works as follows (in FF/car):

Revenues		Expenses	
Steel body	150	Price paid for old car	450
Copper (from cables) and lead (from battery)	700	Disassembly and treatment cost	400
Total	850	Total	850

2.2.4 Adam Opel

At GM's German subsidiary, some of the advances in product recovery are in the plastics recycling, due to the choice of PP for bumpers and battery cases. Adopting design for disassembly, the sport's model Calibra has rear bumpers attached with a special wedge clamp and a reduced number of bolts providing great improvement in disassembly time.

Fenders and wheel arch lining are made from plastic recovered from used battery cases, bumpers and production scrap. The scrap is granulated, dyed black and molded. The recycled material is 99.5% pure, meeting the high quality standards of new cars. Soon, soundproofing, floor mats and air cleaning housing will be made from reprocessed materials (Siuru 1990).

Disposal costs are in the range of 300DM to 400DM per car. However, Opel announced that it will take back for recycling the new Opel Astra at no cost to the last owner at the end of its useful life (S&T Perspectives 1992).

2.2.5 Daimler-Benz

At Mercedes, much of the effort has been on designing efficient materials recycling processes and finding application for recycled materials using the cascade approach. For example, reprocessed plastic is used for much of the interior lining. Old rags and shredded paper are used to make the inside of glove compartments, and recycled PVC to make floor mats. Regarding fluids, it has adopted a like-for-like approach in the development of a comprehensive coolant-recycling procedure. Since the 70's, the firm has included reprocessed oils on the list of materials approved for use in their cars (Siuru 1990, Taylor (1993).

The firm investigated two methods for recycling batteries: the first proposes that the battery should be destroyed and parts separated according to the basic constituents for recycling. The second proposes melting the entire battery in a furnace, using the plastic case as fuel, resulting in raw lead. This approach is possible only if the battery is free from PVC, which would turn into hydrochloric acid in the combustion.

The use of plastics increased from 2% to 10% in the last 20 years. Forecast of increasing to 20% in next 20 years is now contained by the philosophy that materials chosen have to be disposed of or reused at the end of their service lives (Huber 1991).

2.2.6 Chrysler, Ford and General Motors

In the United States, the Environmental Protection Agency has maintained its priority of reducing fuel consumption and emissions. Also, in the state of California, a market of one million cars per year, zero-emission vehicles (ZEV) must have market-share of 2% (1998) and 10% (2010), a regulation with considerable effect over the rest of the US. These requirements receive most of the attention on automobile research in the US and in Japan today.

Nonetheless, GM, Ford and Chrysler have formed in Detroit the Vehicle Recycling Partnership to explore automobile recycling opportunities. One of the outcomes has been a uniform code for labeling plastic parts of more than 100g for easier identification at the end of the vehicle's useful life (Taylor 1993).

More recently, Ford has used GE Plastics technology to cascade old bumpers into housing for tail lights of new models, in a process considered cost effective. Over one thousand Ford suppliers in the US received the guidelines on design for recycling and material selection to ensure recyclability of new models as they are designed (Owen 1993).

2.2.7 Mazda, Nissan and Toyota

Constructors have announced programs to recycle the four million cars disposed in Japan each year: the goal is to reach 100% recycling level (Laperrousaz and Counas 1991).

Mazda has developed a chemical method for recycling plastic bumpers and fuel tanks, obtaining 600g of oil from each 1kg of PVC. While this cannot be expanded commercially, it is recycling bumpers from cars sold in Europe in a plant in Germany.

At Nissan, all plastic parts over 100g are marked for identification; thermoplastics, rather than thermosets, are used as much as possible. A dismantling workshop in Holland is studying means to reduce the number of plastics used in Nissan cars.

PP is the raw material for bumpers in Nissan to allow like-for-like recycling in Japan. Unlike the successful recycling of *black* bumpers by Volkswagen, the *color* bumpers usually demanded by the Japanese customer were found hard to recycle: shock resistance was compromised, causing cracks and streaks. Once Nissan found the technical solution to remove the paint without generating toxic waste, it started to collect bumpers in and around Tokyo to recycle. A similar program is being introduced in Germany to recycle 47,000 bumpers annually.

Photocopy Machine Remanufacturing at Rank Xerox

Process:

1. Delivery trucks return with used machines to be remanufactured.
2. Reclaimed units are separated by models, inspected and disassembled.
3. of parts are repaired for reassembly or as spares.
4. Reusable parts are cleaned and the surface is finished.
5. Parts that are not reusable are recycled.
6. A blend or used and new parts enter the assembly of "new" products.

Parts Recovery Yield:

100% chassis, electric motors and electronic boards.

66% optical elements

33% parts subject to wear (bearings).

3% in weight must be disposed or incinerated.

Toyota, too, has a recycling program for used bumpers collected in Germany. Used PP bumpers are crushed by Plalloy (Netherlands) and the material is reused to make new bumpers (S&T Perspectives 1992, Owen 1993).

2.3 Remanufacturing Photocopy Machines

Copy machines are among the products with most successful remanufacturing experience. The reason for this success could be either the environment where it works - the business office, less demanding on fashionable updates, or its operation - stationary, subject to moderate wear. The actual reason is not very clear yet so we will examine one successful example in Europe.

2.3.1 Rank Xerox

Rank Xerox started in 1988 a recycling plant in the Netherlands that, by 1992, was reconditioning 1 million parts from small and medium size photocopy machines each year. These parts are used to produce 20000 copiers for the British and the German markets each year. The collection is done by some of the same trucks used to deliver the products out of that plant. They bring back used copiers and parts to be remanufactured and reused. In 1993, copy machines entirely made of used or reconditioned parts were introduced in the French market. Remanufactured copiers are sold at a 20% discount over the price of the new machines, hoping to hold 30-35% of the market share of small to medium copiers.

Each copier is composed of 6000 components. More than 50% of its weight is repaired for reuse either as part of a new machine or as spares. The reclaimed units are separated by models and, after a preliminary inspection, are completely disassembled according to detailed instruction sets developed for each type of machine. Nearly 100% of the chassis, electric motors and electronic boards are reconditioned and reused, whereas just 2/3 of the optical elements and 1/3 of the parts subject to wear, like the bearings, can be recovered. Reusable parts are cleaned and the surface is treated according to its application to obtain a newness look. Parts that are not reusable are recycled and just 3% in weight must be disposed or incinerated (Meyer 1993).

Processed used parts enter the assembly of "new" products, with the addition of some new parts that couldn't be obtained from the reclaimed machines. Remanufactured copiers are not treated as second-hand products: they are subject to the same quality requirements and total satisfaction policy. If the customer is dissatisfied with the equipment during the validity of the 3-year warranty, he is allowed to ask for its substitution. At Rank Xerox, the quality is certified by ISO 9002 and the environmental responsibility is recognized by the Blue Angel certification given by BMU to several of Xerox products. The next step is to extend the remanufacturing process to its line of large copiers and printers.

2.4 Remanufacturing Personal Computers

A study done at Carnegie-Mellon U. predicts that more than 150 million PCs will find their way into the landfills in the US by 2005. Another study estimates that 800,000 PCs are thrown away in the UK every year. Although the computer industry is a lot more fragmented than the photocopier industry, the volume involved should give hope to a successful remanufacturing program. That is not the case yet. The practice of upgrading computers allows users to delay replacement so much that, when time comes, the machine will be too obsolete to allow reuse of most parts.

If designers adopt a modular structure, it is likely that remanufacturing will be an even less profitable task. Until now, users could upgrade their computers adding RAM or some accessories (modem, numerical processor, etc.). With the modular design, the substitution of a hard disk by the user will become a simpler task. Even microprocessors will be changed for a faster one when it becomes available (Foremski 1993). Hence, when users eventually dispose of PCs, the reclaim process will be limited to the material that they contain. Since each part in the PC will be obsolete, remanufacturing will have to occur at the component level, if technically possible.

2.5 Small electronic equipment

The remanufacture of small equipment, be it electronic or not, is quite challenging because of the high volume necessary to make the process profitable. Obviously, the more efficient processes will require lower volumes to achieve economies of scale. This seems to be the case with disposable cameras.

2.5.1 Disposable cameras

Design for disassembly of the disposable camera Kodak Fun led to process change to allow for the mass remanufacturing of the product. Kodak picks up, free of charge, used bodies from development labs. The camera's plastic front and rear covers and film spools are ground, melted and molded into new camera parts. Battery is easily removed. Main camera frames are cleaned, tested and reused to assemble new cameras. A code within the camera records number of cycles that the frame has been through; eventually it will be ground and melted too. The electronic flash is inspected and reused up to 10 cycles. Lens and polycarbonate housing cannot be reused because of quality demands: they are sold to toy manufacturers. Even the cardboard used to pack the returned camera is burned to generate electricity. Consequently, 84% to 92% of the original camera is reused, diverting 31 tons of plastic from the European waste stream each year (Owen 1993).

Disposable Camera Remanufacturing at Kodak

Process:

1. Used bodies collected from development labs.
2. Plastic front and rear covers and film spools are ground, melted and molded into new parts.
3. Battery is easily removed.
4. Main camera frames are cleaned, tested and reused.
5. Code within the camera frame records number of cycles.
6. Electronic flash is inspected and reused up to 10 cycles.
7. Lens and polycarbonate housing are sold to toy manufacturers.
8. Cardboard is incinerated to generate electricity.

Outcome

- 84% to 92% of the original camera is reused.
- Same quality standards as cameras made from scratch.
- Remanufactured and new cameras can't be distinguished ⇨ same price.

Cameras manufactured with used parts are tested by the same quality standards as the other cameras made from scratch. Once assembled, remanufactured and new cameras can't be distinguished, and are sold for the same price.

2.6 Remanufacturing Machine tools

Large machine tools are generally good candidates for remanufacturing. It saves money and increases productivity through control and process upgrade of machines that are already familiar to operators. A major incentive is to keep in the shop floor a machine with which the workers are quite familiar. As a result, world class capabilities are achieved with old machines.

2.6.1 Injection presses

Heavy injection press - used on injection molding - can have their lives extended by remanufacturing and process capability enhanced by additional upgrade, delaying purchase decision of new machines for a decade or so. Rather than an environmental motivation, economic concerns drive the decision to remanufacture presses above 200 tons when they are between 10 and 20 years of use. There are roughly 28000 machines in the US that fit these characteristics, but only 400 of them were remanufactured in 91 (generating business of about $20 million to $25 million each year). The remanufacturing operation of a 200 ton press costs about 50% the price of a new machine, and a 700 ton press is remanufactured for 30% of the price of a new one.

Actually, it is generally uneconomical to remanufacture presses below 75 tons but those above 500 ton are completely rebuilt, upgraded and customized to the users need. The complete remanufacturing process requires several hundred-hours of engineering work and the same amount of manual tasks, thus suggesting that the procedure for smaller presses is less comprehensive.

The process starts with the visual inspection and first level disassembly of the machine. Each component is inspected and tagged for repair, replacement or upgrading. It is followed by an engineering procedure involving electronic, hydraulic and mechanical components, including

1. rewiring electrical connections and replacing motors,
2. inspecting ram and reboring clamp cylinder,
3. resurfacing platens, refinishing tie bars and replacing bushings,
4. upgrading hydraulics, replacing hoses,
5. replacing heater bands, installing heat shield,
6. installing position sensor, servo valve, calibrated pressure transducer,
7. adding microprocessor control system,

If necessary, the structure is reinforced and safety devices are added.

Five firms share the injection press remanufacturing market in the US, only two of them associated with OEMs. The machines are delivered with updated documentation and one-year warranty. For example: a 700ton press was remanufactured at a cost of $148k (compared to a new machine costing $322k). Direct savings on the first year (reduced ramp-up time, increased volume and revenue) were estimated around $150k, a pay-back of one-year (Toensmeier 1992).

2.6.2 Metal-cutting machines

20-year old CNC machines can have a new life with new control technology, new software and other options not available before, but the timing is crucial. Remanufacturing is more sensible when the firm starts a new production program involving tougher quality specifications, or when the machine is moved to another plant - since the disruption is already there, anyway.

Remanufacture of metal cutting equipment involves the repair or replacement of controls and some components that get worn out or obsolete. The metal structure usually does not wear. The learning curve of a remanufactured machine is, obviously, shorter. The operator just have to get used to the enhanced features.

At Dayton Machine Tools, remanufacturing metal-cutting equipment includes:

1. stripping machine to base casing;
2. resurfacing and realigning ways to ensure correct geometry;
3. rebuilding or replacing the axis of the feed assembly;
4. replacing all seals, bearing, wipers, gaskets, fasteners, dowel pins and locating keys;
5. replacing worn or damaged parts;
6. remanufacturing or replacing electric, hydraulic and lubrication system to fit current standards;
7. updating safety devices.

The salvaged components used in a remanufactured machine must be repairable now and in the future. In a successful example, a 1955 machine could be substituted for a new one, to be delivered in 2 years, or remanufactured, which was estimated to take one year. It was used to

Key Advantages for Remanufacturing Machine Tools

1. less expensive than purchase (up to 60%).
2. parts of the project may be expensed, reducing taxable income
3. upgrade can be customized, up to the latest control technology.
4. same foundations, tooling, fixtures
5. cams and programs are maintained
6. maintenance and training is minimized.

Possible Disadvantages

1. risk of failure to meet specifications, budget or delivery time.
2. structure may not be adaptable.
3. key features may require excessive engineering hours to adapt to old machine.

machine the inside of large turbine housings. The cost of remanufacturing came out just below $1M, against the price of $7M for a new one. Eventually, it was eventually delivered in 10 months, and the final assembly was done at the user's plant. Before remanufacturing, each turbine was machined in 3 weeks. The second turbine to be processed after remanufacturing was finished in 3 days. Although the result is quite impressive, one must keep in mind that the machine was unavailable for the whole 10 months that it was being worked on, and the life expectancy of a remanufactured machine may be just 70% of that of a new one.

Alternatively, some firms may decide to do the remanufacturing inside. The constraints are:

1. availability of high quality maintenance personnel in excess of what is needed for the everyday work;
2. the familiarity of technicians involved with engineering drawing, their ability to make accurate measurements and to decide which parts should be replaced or reworked;
3. their ability to build and align machinery;
4. the availability of necessary tools and gauges.

Many firms have realized that they meet these constraints and can remanufacture their machines in-house. It levels the activity of maintenance personnel and keep the learning in-house (Stauffer 1990).

2.7 Reclaiming White goods

The environmental laws[6] in Germany have pushed AEG, Miele and Siemens ahead of the competition in the research for the best recycling methods for home appliances in general. Priority is given to increasing the plastics resistance to last the whole life of the product and to improving its recyclability. Hopefully, the number of plastics will be reduced to a few easily recyclable kinds that will maintain the mechanical and chemical resistance that the appliances require throughout their lives.

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[6] Find in Appendix 2 an extract of the Electronic Scrap Ordinance.

However, 800,000 tons of electronic equipment is scrapped in Germany alone each year. So, the solution lies in the source reduction: eliminating waste and by-products by eliminating the material that creates them. Efficient material and process design with improved process controls and yields, extended useful life and life cycles are necessary conditions for reducing the amount of waste. Economic considerations do not allow for cost effective remanufacturing of home appliances (Fisher 1991). Unlike automobiles, very few white goods are worn out early in their lives. The need for spare parts occur when few machines containing that part have expired their useful life and returned to the product recovery cycle. So, the market for remanufactured parts from home appliances would be extremely small.

Another possibility would be to retrofit old appliances at the end of their life cycles to have the performance similar to the new products in the market, as it is done with the machine tools. However, if the rule of thumb says that remanufacturing small machine tools is uneconomical, because of the large number of manual tasks, remanufacturing home appliances would be unfeasible unless several similar ones could be grouped to be worked simultaneously, which doesn't seem likely to occur (Owen 1993).

3. Product Recovery Drivers

The decision to recover an equipment is driven by several different factors. In some cases, the machine must be refurbished because of regulatory or environmental pressures. In other instances, for example, an injection molding machine is remanufactured to extend its useful life. Here we try to differentiate these drivers according to the industry where product recovery occurs:

3.1 Product recovery as a manufacturing strategy factor

Some firms have adopted remanufacturing as part of its overall manufacturing strategy. This is quite evident when we observe the decision to remanufacture by Kodak and Xerox. Under this logic, the process must be cost-effective and the final quality of the product must be as good as that of the new one. It will not be a sustainable competitive advantage if the profitability is not sufficiently high, otherwise the firm will not maintain it voluntarily. These industries are characterized by:

- High volume production, and
- Remanufacturing parallel to conventional manufacturing.

3.2 Product recovery in the replacement economics

Remanufacturing is observed in the construction business and in several manufacturing industries, with the purpose to extend the useful life of cranes, tractors and machine tools. Here, product recovery is an out-of-routine activity that may require a complex decision making process by the user. He will seek remanufacturing bids from the OEM and qualified third-parties to extend the life of the equipment - perhaps with some upgrading - assured by a warranty contract. This choice avoids the high investment of acquiring a new machine. This process is characterized by:

- Difficult decision making process
- Expected life of the remanufactured equipment is significant shorter than the life of a new one.

3.3 Product recovery as a maintenance policy

An important use of remanufacturing is related to the maintenance policy adopted by some firms with high investment in capital goods. A typical example occurs in the airplane maintenance schedule, which extends the useful life of frame and turbines several times before the equipment is retired. Similar policies are adopted by railroad companies with their locomotives and public transportation firms with buses and subway cars.

The airplane, locomotive and bus examples have in common that they belong to firms with large number of similar or identical pieces of equipment, which allows the adoption of product recovery as part of a routine maintenance expense. Some of the main purposes are:

- Improving equipment performance (energy consumption);
- Reducing the lag to the most recent developments in the industry;
- Meeting the new regulations on safety level or environment protection;
- Meeting regulations of product renewal.

This kind of remanufacturing implies a scheduling problem that could be an interesting research topic in Operations Management.

3.4 Product recovery as an environment protection policy

Regulations may require companies to be responsible for the appropriate disposal of their products at the end of their useful life. The environmental preference relations is from entropy neutral solutions to entropy increasing solutions. Regarding the product disposal and recovery alternatives, they are the following:

remanufacturing $\succ$ recycling $\succ$ incinerating $\succ$ dumping

Dumping causes long term damage to the environment: when a used product containing material that could be reused is dumped, new resources must be drawn from the environment, reducing long term society's wealth. On the short term, landfills are reaching capacity and being closed in several industrialized countries.

Incineration for energy production remains the main recovery process for materials like tires and some plastics. Incinerating plants generate electricity like other thermoelectric plants fueled by coal, oil or nuclear energy. However, it is a *final* reuse of the material. For example, burning plastic is a wasteful procedure because, although 1kg of polypropylene takes 2 liters of oil to be produced, it delivers the energy that could be obtained from just 0.8 liters of oil. But the main concern of incinerating is with the emission of pollutants, which limits its applicability to a handful of plastics whose emissions are tolerated.

driver	decision making		execution by	example
	who decides	frequency		
manufacturing strategy	OEM	periodic	OEM	photocopiers
replacement economics	owner or operator	at the time of replacement	owner, OEM or refurbishing company	machine tools
maintenance policy	owner or operator	periodic	owner, OEM or maintenance company	locomotives
environmental concern	OEM or regulator	at the end of the useful life	OEM or recycling organization	paper, glass, plastic

We have discussed the recycling and remanufacturing practices of several firms in Section 2. In practice, the firm's motivation is a mix of more than one driver, but the final decision must be economics oriented, if it is expected to last.

4. Product Identity in Remanufacturing

Any piece of equipment can be identified by a serial number that remains with it for its whole life. Hence, one simple way to classify a remanufacturing process regards the identification of the equipment at the end of the process. Basically, the remanufactured machine may retain or lose its identity.

4.1 Remanufacture with retention of identity

An airplane whose interior is refurbished, the body is painted, controls are upgraded and turbines are overhauled is definitely a recovered equipment. Airplanes are required to retain their original identity even after recovery: the serial number remains unchanged. Locomotives, airplanes, large machine tools are some examples of equipment which usually don't lose their identity when they are remanufactured, either because of customer requirements or safety regulations.

The remanufacture of a large equipment is a customized procedure. The low volume does not allow batching. The small pool of returned products prevents the build up of a stock of reconditioned parts or modules to be used in a new assembly. Keeping track of the identity of the machine is typically a non-issue. Hence, modeling this kind of remanufacturing operation requires a specific set of constraints that recognizes the retention of identity.

4.2 Remanufacture with loss of identity

The limitations regarding the remanufacture of machine tools induce the conjecture that customized remanufacture of small equipment is not viable. Indeed, the successful remanufacturing of not-so-valuable items involve high volume operations (as occurs with Xerox mid-range and small machines). We speculate that smaller equipment usually lose their identity when they are remanufactured.

Clearly, it is possible to retain the identity of some major modules in this process but, the priority will be on the number of cycles that a given module has been through or some equivalent way to measure the age of the product. The remanufacturing cases with loss of identity should provide the more interesting research questions in Production and Operations Management.

Identity Retained	New Identity
• A customized process. A single machine is disassembled and inspected to separate low-wear modules and parts.	• A disassembly line inspects and separates modules and parts that can be re-used from those that have to be recycled or disposed.
• Modules with high value added are reconditioned and/or upgraded.	• An inventory of reconditioned parts is built.
• New parts and modules complete the materials requirements.	• New parts complete the materials requirements.
• The machine is reassembled with some new parts beside its own reconditioned modules.	• A reassembly line makes products composed of used and new parts.

5. Conditions for Successful Remanufacturing of Durable Products

Facing the evident difficulty of recovering computers, home appliances and other electronic products, and the success enjoyed by Rank Xerox and Kodak in their endeavors, we suggest the existence of two conditions for achieving successful remanufacturing:

5.1 Close Relationship with Clients

Both firms maintain close relations with their clients, which facilitates the prompt and cost-effective return of the used product. Xerox obtains this relationship with the long term maintenance contracts. Kodak, by supplying the laboratories with the consumable materials for film development. The reverse distribution is performed regularly and cost-effectively by both firms on the same vans that supply their clients with new parts and products.

A large constraint to proceed with the reclamation of electronic equipment and many other items lies on the logistics of collection. Some competing solutions to this problem are:

1. Distributors and manufacturers alike should be forced to accept the product back at the end of its life cycle. The cost of collection and recycling of the used product would be anticipated in the price of the new product, like an overhead (proposed by German laws).

2. A "deposit" should be charged from the buyer of the new product, to be reimbursed at the time the product is returned. Customers returning products at exceedingly bad state would be charged an extra fee to compensate for the excess cost to dispose of the product, instead of having the deposit reimbursed. A similar process is adopted in Norway.

3. Dismantlers would pay market prices for the returned equipment, which eventually might be negative. This market price would be adjusted by economic potential of the product being recycled: the state of the components and the possibility to reuse some modules.

4. Leasing contracts would prevail - to assure the return of the good at the end of its useful life at a pre-specified state - keeping product's ownership with the firm.

These proposals ensure the product return either by forcing the firm to act or by financing the logistics. Either way, they impose high burden on the firm and generate significant imbalances in the economy.

5.2 Stable Product Technology

Both products have technology that is stable with respect to their useful life, which allows for reuse of most components with low wear. Xerox obtains it by a modular product design with high commonality. Kodak, by the short life of the disposable camera (a few weeks). Consequently, in both firms, when a used product returns to the plant, several parts have had little wear, and can be reused without compromising product's quality or appearance.

It becomes evident that it is hard to implement remanufacturing with high percentage of reused parts in new products where fashion or technology development are fundamental marketing issues. But ecological demands will assure the implementation of remanufacturing in association with materials recycling.

Condition:	prompt and cost-effective return of the used product	products have stable technology with respect to their useful life
Xerox:	long term maintenance contracts	modular product design with high commonality
Kodak:	laboratory supplies for film development	short life of the disposable camera (a few weeks)

6. Some Research Issues

Based on the cases discussed in Section 2, we conclude this paper by identifying two families of problems for research in product recovery.

6.1 Product Recovery and Scheduling Subject to Stochastic Returns

Figure 1 illustrates the difficulties inherent to the bill-of-material of a single product made of n parts.

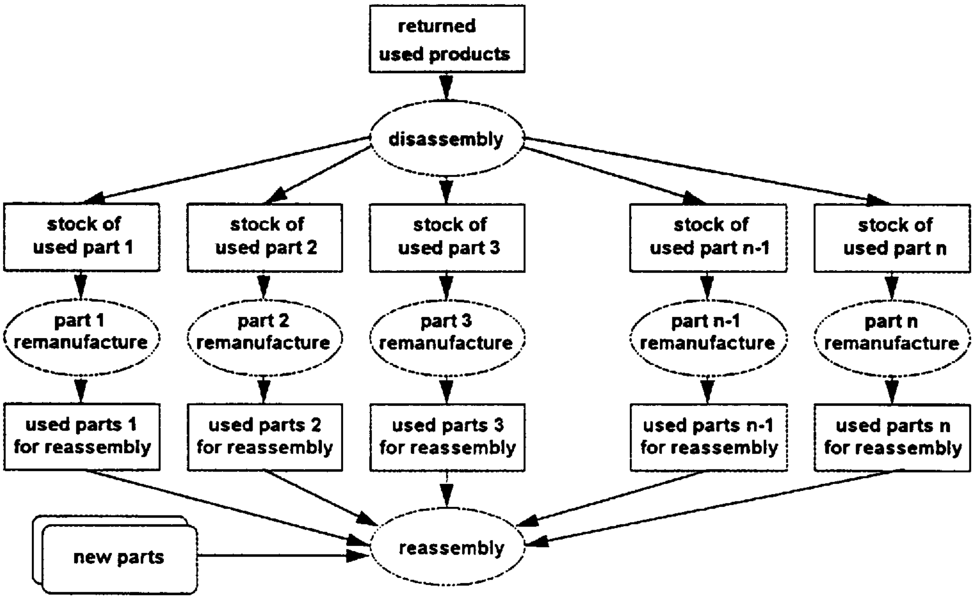
6.1.1 Questions:

1. What should the inventory policy be to manage a multi-product remanufacturing process with commonality of parts?
2. How can we deal with the uncertainties in forecast return, forecast demand and quality yield rate?
3. What are the effects of having an imperfect inspection process?
4. How should we adjust inspection criteria to recognize the different needs at different stages in the life-cycle of the product?
5. If the supplier is able to set the replacement cycle, how long should it be? If it is not, what pricing scheme would ensure maximum profit?

6.1.2 Variables:

Some of the variables involved (depending on the question we want to answer) would be: number of parts, inspection yields, commonality, stage in life-cycle, number of products, quality policy, etc.

Figure 1



6.2 Product Recovery and Market Structure

6.2.1 Questions:

1. In the case of materials recycling in which the collection is controlled by the OEM, should the used part be processed by the OEM, the parts manufacturer or the raw materials supplier?
2. How does the market structure (monopoly or oligopoly of OEMs) affect this problem?
3. Under what conditions should the OEM integrate the product recovery process, instead of subcontracting it?
4. What tasks should the OEM not integrate (among collection, disassembly, materials recycling, production of new part from used materials, assembly)?
5. Should the used part be processed by the OEM, the parts manufacturer or the raw materials supplier?

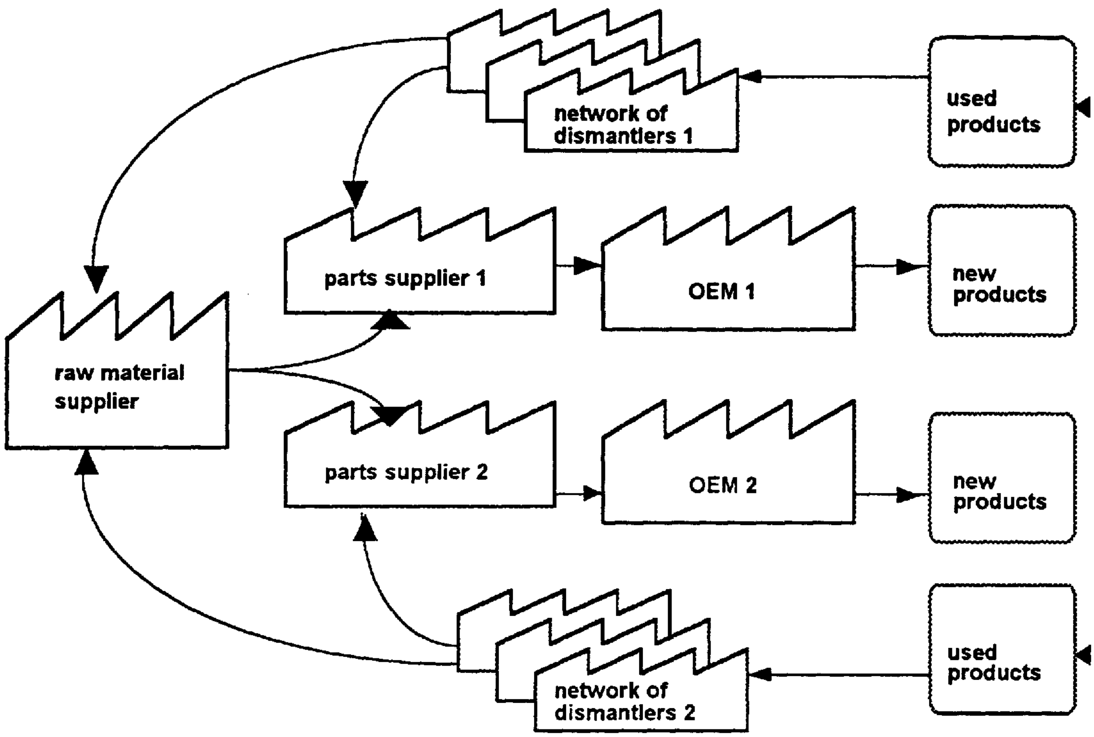
6.2.2 Variables:

Among the variables necessary to study this problem are the market structure (monopoly or oligopoly), price of raw material, price of used and new part and supply chain relationships.

6.2.3 Environment:

This problem touches the decision by BMW to decentralize collection and to adopt like-for-like recycling of bumpers. But the firms involved in the collection and disassembly are not related to the parts manufacturers. Details of the supply chain relationships are necessary to solve this problem realistically. Figure 2 shows the market structure representing this problem:

Figure 3



Appendix 1 - Definitions

These are some of the processes related to product recovery management. These definitions are based on, but not limited to, the works of Thierry et al. (1993), Sprow (1992), Toensmeier (1992), McConocha and Speh (1991) and Stauffer (1990).

Repairing and Reconditioning Parts and modules are repaired by eliminating the cause of their failure. The repair of a few parts may suffice to return an equipment to an operational state. The process has limited objectives, in the sense that there is no intervention in systems that have not failed. Reconditioning is the basic work of repairing general problems in the machine. Belts, hoses and fluids are substituted, hydraulics are checked, panel wiring is checked and reorganized, major assemblies are inspected. It may cost 40% to 50% of a small machine and be covered by a short warranty.

Rebuilding When a machine is rebuilt, it is engineered to the operating conditions of when it was constructed. Rebuilding merely restores the machine to the original specifications. It includes the examination of gears, drives, etc. There is a compromise between life expectancy and cost. Many used parts will be untouched. Only those clearly outside specifications.

Refurbishing When the whole equipment is subject to a thorough revision, with substantial elimination of small defects and, sometimes, some esthetic improvements, we may be dealing with refurbishing. It is often practiced in the public transportation industry (airplanes and buses), both to maintain a newness appearance during the entire useful life of the equipment and for safety reasons. A refurbishment decision does not imply that the equipment is broken and should not be confused with preventive maintenance.

Overhauling When an entire module goes through a repair or upgrade due to a major breakdown or excessive wear, we may be dealing with an overhaul. The prototypical examples occur in truck engines and in airplane turbines. Overhauling is similar to repair in its limited approach: only the affected module is reviewed. However, rather than fixing a lower level component within a module, the whole module is fixed or substituted.

Remanufacturing When the entire equipment is disassembled at the module level and, eventually, at the component level, to repair or substitute components and modules that are worn out or obsolete, we are dealing with remanufacturing. Parts subject to wear or clogging are replaced and the structure is inspected for soundness. The whole equipment is refurbished and critical modules are overhauled or substituted. A machine of today is built on yesterday's base, receiving all the enhancements, expected life and warranty of a new machine. All bugs that eventually existed in the original design are eliminated. Remanufacturing allows for the customization of the machine to the user's new requirements.

Upgrading or Retrofitting When new systems that enhance performance or new features are added to a machine that is solid, we are dealing with an upgrade or retrofitting. A remanufacturing process must incorporate upgrading when the equipment shows obsolescence. Systems with older technology are substituted, improving performance or reducing the equipment's negative impact on the environment.

Recycling Recycling is the term generally used to describe a materials recovery process. Broadly speaking, remanufacturing would be one form of recycling. We prefer a stricter definition in which recycling is the recovery process in which the equipment is reduced to its raw materials, losing its functional form. In recycling, most of the equipment's value-added is lost. Recycling can be done in combination with remanufacturing, in order to salvage the material used in parts and modules that cannot be reused or repaired.

Cascade Recycling It is the process of recycling in which the material loses some of its original qualities. Generally, it is related to the difficulty of recycling plastics without loss of the original mechanical properties. It opposes to *like-for-like recycling.*

Refilling Among consumer goods, refilling is probably the most common product recovery process. It has been used in the distribution of beverage (wine, beer, soft drinks and milk) for many years. More recently, it has reached the cartridges for laser printers and the cassettes for video recorders.

Incinerating At the bottom of the product recovery hierarchy is incinerating. Some materials can't be recovered with the technology available, which leaves incinerating as the single alternative to dumping. Incinerating does not allow the material recovery but provides some energy recovery. Tires and some plastics are often incinerated but its use is limited by the type of gas emissions that the material will produce, which might be toxic.

Appendix 2 - Electronic Scrap Ordinance

The Electronic Scrap Ordinance regulates the electronic waste management in Germany and may serve as a model for waste management regulation in the rest of the EC. This selection of paragraphs illustrates the difficulties that managers will face to meet this regulation, Bundesminister fuer Umwelt (1992b).

1. Goals of Waste Management

Waste from used electric and electronic equipment or equipment parts should be avoided and reduced in that

1.1. electric or electronic equipment or equipment parts are to be manufactured out of environmentally compatible and recyclable materials;

1.2. electric or electronic equipment or equipment parts should be manufactured so that they are easily repaired and disassembled;

1.3. a collection system for used electric or electronic equipment or equipment parts should be established which is easily accessible to the end-user and achieves a high return rate;

1.4. returned used electric or electronic equipment or equipment parts are to be delivered for reuse or recycling;

1.5. returned non-recyclable used electric or electronic equipment or equipment parts should be delivered to the appropriate waste disposal facility.

2. Area of Application

2.1. Persons subject to this regulation

2.1.1. manufacture or label a brand of electric or electronic equipment or equipment parts (Manufacturers)

2.1.2. bring into commerce electric or electronic equipment or equipment parts, no matter in what trade category, also as an importer (Sellers)

3. Definitions

3.1. Electric or electronic equipment in the sense of this regulation are machines containing electric or electronic parts:

3.1.1. office computers, printers, copy machines, telefaxes and telephones;

3.1.2. televisions;

3.1.3. air conditioners, heaters, stoves, dishwashers, washing machines, dryers;

3.1.4. radios, record players, CD players, speakers, combination systems, etc.;

3.1.5. coffee machines, microwaves, vacuum cleaners, electric tools, etc.;

3.1.6. laboratory and medical equipment;

3.1.7. ATM and other money transaction machines;

3.1.8. picture and sound recording and playback equipment;

4. Duty of the seller to accept returns

4.1. The seller is required to take back used electric or electronic equipment or equipment parts from the end user without charge.

4.2. The seller can limit its responsibility to equipment or equipment parts of a particular brand which it carries in its product line.

4.3. The duty to accept return is limited to the number of appliances that the end-user would normally throw away as a result of a new purchase of an equipment of the same type.

5. Duty of Manufacturer to Accept Returns

5.1. The manufacturer is required to take back used electric or electronic equipment or equipment parts from the seller without charge.

5.2. The manufacturer can limit its responsibility to equipment or equipment parts of a particular brand which it carries in its product line.

6. Location of Returns

The location of return is a point of sale or the delivery location of the new equipment that will replace the used one.

Appendix 3 - Old Car Ordinance

The Old Car Ordinance was drafted in August 1992 and is under discussion by the German Cabinet. Once approved, this regulation is expected to have profound effect over the automobile disposal laws in the rest of the European Community. This selection of paragraphs illustrates some of the managerial challenges implied by the ordinance, Bundesminister fuer Umwelt (1992a).

1. Waste-economic Aims

Waste from the disposal of automobiles have to be avoided and decreased in a way that

1.1. automobiles and their construction-, spare-, exchange parts as well as accessories are being developed, designed and produced in a way that they reach a service life as long as possible ... (and) construction parts can be reused or recycled materially, if technically possible;

1.3 reusable construction parts are being utilized again in the automobile manufacture or as spare parts after the dismounting, that construction parts, which cannot be used again, are preferably recycled materially in the course of which the obtained recycled materials are applied to the automobile manufacture.

2. Field of Application

2.1. Persons subject to this regulation

2.1.1. produce or import automobile, spare parts or accessories (Producers);

2.1.2. bring into commerce automobile, spare parts or accessories , no matter in what trade category, also as an importer (Sellers).

2.2. Furthermore, the last owner of an automobile is also subject to the orders of this regulation.

3. Definitions

3.1. Automobiles, in the sense of this regulation, are passenger cars, caravans and commercial vehicles.

3.2. Old cars, in the sense of this regulation, are automobiles which are finally being shut down at the vehicle registration office or which are regarded to be definitely withdrawn from traffic.

4. Withdrawal Obligations

4.1. The automobile producer is obliged to take back old cars from the last owner. This obligation is restricted to old cars of his automobile brands.

4.2. Withdrawal places have to be installed at least as tight as the marketing network.

4.3 The collection has to be principally carried out free of charge for the last owner.

- Exploited wrecks (old cars from which parts necessary for the operation have been removed;
- Old cars which are contaminated with matters which thus impair the material recycling or disposal;
- Cars involved in an accident where a dismounting is technically impossible;
- Cars registered before the coming into force of this regulation are not taken back free of charge.

4.4 Sellers of spare or exchange parts, accessories and other construction parts used for the operation of already registered cars are obliged to take back a similar used part from the final user, free of charge, when selling corresponding equipment.

7. Authorization of third parties

In order to meet the obligations fixed by this regulation, producers and sellers can use third party. By asking third parties to take care of their recycling, the producer has prove that the recycling company meets the demands of the Waste Law and of this Ordinance.

8. Accountability of the producers and sellers

Until the end of the year, producers and sellers have to resent a proof about the recycled materials used in the automobile manufacture and in other fields of application as well as about the materials transferred to another disposal to the appropriate authority.

9. Obligations of the last owner

The last owner of an old car has to leave it to the producer or a third party authorized by him or another recycling company in a way that an environmentally compatible disposal is guaranteed.

Appendix 4 - Exchange Rate Table

Approximate exchange rates between the currencies appearing in this paper.

	US$	FF	DM	£
US$	1	0.20	0.65	1.55
FF	5.30	1	3.40	8.20
DM	1.55	0.30	1	2.40
£	0.65	0.12	0.40	1

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