ABSTRACT NO: 008-0130

REMANUFACTURING – A COMPARISON OF BUSINESS DEFINITIONS AND OPERATIONAL REQUIREMENTS

Mark Errington
University of Exeter

Stephen J Childe
University of Exeter

Corresponding Author:
Mark Errington
Harrison Building
North Park Road
EXETER, EX4 4QF
m.errington@exeter.ac.uk
+44 (0) 1392 263613

POMS 19th Annual Conference
La Jolla, California, U.S.A.
May 9 to May 12, 2008

ABSTRACT

International associations for *remanufacturing* state that the term that can be used interchangeably with *reconditioning* and *rebuilding*. Practitioners of remanufacturing regularly oppose this definition and state that there are key differences in the quality of the product produced. It is important that this definition is clarified to support further research.

This paper argues that the debate rages so fiercely because the two concepts arise from different viewpoints. A remanufacturing process may include reconditioning as one of the stages and whilst the workshop processes may appear to be identical, the remanufacturing business is not about disassembly, repair and cleaning but about the collection of sufficient information to guarantee the reliability of a product.

This paper concludes that in some cases it may be possible to replace some of the physical processes involved in remanufacturing with information-gathering techniques. This has the potential to greatly reduce the operating costs of remanufacturing processes. More research should be carried out in order to establish how information gathered during a product's first life can be used to improve the efficiency of remanufacturing processes.

Key words: remanufacturing, definitions, reconditioning, information, process

INTRODUCTION

Due to global warming and the imminent peaking of world oil production (Richard and Walter, 1999, Bentley, 2002) closer attention is being paid to the impact of manufacturing on the environment and its energy consumption. There is now an increasing amount of legislation being developed by the European Union aimed at reducing energy use as well as our impact on the environment. As more and more countries join the European Union, more manufacturers will be required to comply with this legislation. This includes so-called producer responsibility legislation

including the WEEE directive (EU, 2003), End of Life Vehicles Act (EU, 2000), Packaging and Packaging Waste Directive (EU, 1994) and the Batteries and Accumulators Directive. (EU, 1991) This legislation requires the producers of certain products to be responsible for their disposal at end of life.

Producers are not only responsible for retrieving the used products from their end users but are also responsible for recycling them whilst meeting certain minimum recycling rates. With limited room remaining in landfill sites material recycling is often preferable to land filling, however most of the value added during manufacture and energy embodied in the product is lost.

In order to take back post consumer products it is necessary to create a reverse supply chain. In cases when this is integrated into forward manufacture in such a way that old products are used to produce new, at any level, this leads to a closed-loop supply chain.

Many consumer products are still working at their end of life, and there are an increasing number of companies that collect these products and return them to market both in the UK and abroad. They provide a cheap alternative to buying new products and appear to have been very successful both in not for profit and for profit organisations.

Other products reach their end of life because of an accumulation of rectifiable faults, the wearing of a small number of components within a product or sometimes because of their age or amount of use. It has been shown that there has been a long tradition of remanufacturing in the auto parts industry (Hammond et al., 1998). Recently manufacturers in other industries such as Hewlett Packard (Guide et al., 2005), Oce (van Nunen and Zuidwijk, 2004) and Xerox (Maslennikova, 2000) have started to take advantage of this way of doing business and have started to run large

remanufacturing operations. It is regularly stated that remanufacturing is 80% more energy efficient and 60% more cost efficient than traditional manufacturing. For this reason a large amount of attention is being paid to these types of processes by old and emerging economies alike.

RETURN TO MARKET DEFINITIONS

Definitions for remanufacturing have emerged from the sectors in which it is most mature. In these sectors, remanufacturing is typically carried out on mechanical items which have often failed due to wear out. The definition for Remanufacturing provided by the Automotive Parts Rebuilders Association (APRA, 2008), which was established in 1941, appears to confirm this. It states that remanufacturing is the renovation of used vehicle parts in accordance with the generally accepted state of the art so that they can perform their function similar to new. It goes on to state that remanufacturing regularly consists of dismantling the used aggregate into its components, checking these components, repairing defective components, cleaning all components, reassembling the aggregate, readjusting as necessary, and submitting the product to a final test.

It is thought that one reason for the slow take up remanufactured products might be consumers' misconception that a returned product is always inferior to a new one. It is possible that this is due to the large number of terms that are used to describe products that are returned to market interchangeably.

Case study research has been carried out related to this project. It has been identified that some industrial customers of remanufacturing firms do not seem to distinguish between remanufactured and reconditioned products leaving remanufacturing firms losing contracts to reconditioning companies. This problem has been compounded in the automotive industry where the British standard for remanufactured engines (BSI, 2002) starts by stating that for the purposes of the standard, the term reconditioning will be interchangeable with remanufacturing.

This is not the only are where several terms are used interchangeably that can mean different things to different organisations. The table below shows and overview of terms that can be used interchangeably with remanufacturing as outlined by associations established to assist the industry. In addition to this the table also shows terms that are not considered to be synonymous with remanufacturing by the various organisations.

	Remanufacturing	**Not Remanufacturing**
The Centre for Remanufacturing and Reuse, UK (The Centre for Remanufacturing and Reuse, 2008)	----------	Reconditioning Refurbishing Overhauling
The Remanufacturing Institute, USA (The Remanufacturing Institute, 2008)	Rebuilt	Recycled Repaired Restored Reconditioned Used
Automotive Parts Rebuilders Association US & Europe (APRA, 2008)	Rebuilt	Recycled Repaired Restored Reconditioned Used
Code of practice for remanufacture of spark and compression ignition engines (BSI, 2002)	Reconditioning	Exchange Factory Rebuilt Repaired
Remanufacturing: The Ultimate form of Recycling (Steinhilper, 1998)	Rebuilding Refurbishing Reconditioning Overhauling	---------- No mention

Table 1 - Interchangeable Terms for Remanufacturing

It can be seen from Table 1 that the different organisations have different and often contrasting opinions about the term remanufacturing. Many different terms that are used by different organisations to mean remanufacturing, it is thought that this may often be due to historical reasons. In the book Remanufacturing: The Ultimate Form of Recycling (Steinhilper, 1998) a comment is made that the term remanufacturing was starting to become distinct different from other return to market operations. The author states that remanufacturing is becoming the standard term for restoring used products to 'like new' condition. The more recent references in Table 1 seem to show the acceptance of this definition with a clear distinction between remanufacturing and other return

to market operations. The only exceptions to this are the terms reconditioning in the UK and rebuilding in the USA. The Automotive Parts Rebuilder's Association prefers to use the term rebuilt as it gives more description about what process is carried out on the product. This is perhaps the same reason as why reconditioning has been given the same standing as remanufacturing in the British standard for engine remanufacturing.

OTHER RMO DEFINITIONS

There is a clear and established need for more robust definitions for return to market operations. This problem has been addressed several times in the past decade by various organisations and researchers across the world.

There has been an attempt to define the processes depending on the level of disassembly require in order for an operation to be carried out (Thierry et al., 1995). A table of definitions is shown in Table 2.

	Level of Disassembly	**Quality Requirements**	**Resulting Product**
Repair	To product level	Restore product to working order	Some parts fixed or replaced by spares
Refurbishing	To module level	Inspect all critical modules and upgrade to specified quality level	Some modules repaired/ replaced; potential upgrade
Remanufacturing	To part level	Inspect all modules and parts and upgrade to as new quality	Used and new modules/parts combined into new product; potential upgrade
Cannibalization	Selective retrieval of parts	Depends on process in which parts are reused	Some parts reused; remaining product recycled/disposed
Recycling	To materials level	High for production of original parts; less for other parts	Materials reused to produce new parts

Table 2 - Return to Market Definitions (Adapted from (Thierry et al., 1995)

This method appears to work well however it assumes that the failed component in the case of repair is easily accessible. This may be the case for a repair such as a fuse replacement but is rarely the case for components which are known to wear. It may not be possible to access these without a more extensive amount of disassembly. This is also unlikely to be the case when the component that caused the product failure was not expected to fail. The module level disassembly level for refurbishing is also not always correct. Likewise Remanufacturing does not necessarily require

complete disassembly however this is more often than not the case. The quality levels shown in the table are the most important from a customer's perspective.

The European Working Group on Reverse Logistics, REVLOG, has produced a set of definitions for the five main return to market operations. These are as follows (RevLog, 2008);

- ***Direct Reuse*** *This type of recovery involves products which do not receive repair or upgrading but are cleaned and brought to a state where they can be directly reused by the customer. Examples are pallets, bottles, etc.*
- ***Materials recycling*** *In this type of recovery, the product does not retain its functionality. The purpose is to use some or all of the materials from the returned goods. The recovered materials may be utilized in the production process of the original product or may be inputs of other industries.*
- ***Repair*** *The product/component is brought into the working state after this recovery operation. The quality of the repaired good is generally lower than the quality of a new good.*
- ***Refurbishing*** *The product/component is upgraded such that it meets higher quality and/or operational standards than the original product.*
- ***Remanufacturing*** *In this type of recovery operation, the products are completely disassembled and all modules and parts are examined in detail. Worn out components are either repaired or replaced with the new ones. If required and feasible, model upgrading is performed on some technology modules. The remanufactured products receive a high quality assurance and are mostly delivered to customers under new product warranty contracts. In principle, remanufactured products can be sold at the same market as the original product.*

These definitions add to our understanding of the processes however the impression is still created that in order for a product to be truly remanufactured it must first be completely disassembled. While this is often the case for mechanical products that have failed due to wear out it may not be the case for products that have failed soon after manufacture or in the case of electronic products which are rarely discarded due to wear out.

The most commonly used definition found in the UK was produced by (Ijomah et al., 2005). It has been adopted by the Centre for Remanufacturing and Reuse and describes remanufacturing as follows.

> *"Remanufacturing is the only process where used products are brought at least to Original Equipment Manufacturer (OEM) performance specification from the customer's perspective and, at the same time, are given warranties that are equal to those of equivalent new products"*

This definition is perhaps the most useful of the ones outlined in this paper. It was developed during the author's production of comprehensive business process diagrams for remanufacturing processes (Ijomah and Childe, 2007). It is product quality rather than process based. This is important as it works for both mechanical and electronic products where complete disassembly may not improve the reliability of the product. It is also unclear where terms such as reconditioning and rebuilding fit into the definitions detailed above. Reconditioning is a term commonly used in defence contracts in the UK often considered to be interchangeable with remanufacturing by the customer. These are key processes that need to be understood by customers as well as those carrying out the operations in order to develop less ambiguous contracts for return to market operations.

Some definitions make a real distinction between remanufacturing and other return to market operations in terms of the quality of the product being produced, its anticipated reliability and the warrantee offered with the product. In the opinion of the authors this shows that there are two key processes running in parallel which form part of a remanufacturing process. The first is the physical strip down and rebuilding of the product to the level required for the necessary operations, inspections and tests to be carried out. This process may be indistinguishable from a reconditioning, rebuilding or refurbishing process. The second is the collection of information in order to access the reliability of a product and hence its expected life and the prediction that it will perform 'as new'. During more established remanufacturing processes this is carried out through a number of inspection and testing procedures before, during and after the strip down and rebuilding process.

On the surface it may appear that a reconditioning or rebuilding process can also be called remanufacturing and this may indeed be the case for some processes. The act of stripping down and rebuilding an automotive component, and replacing worn parts may be sufficient to predict its reliability accurately and hence offer a warrantee. Where these terms cannot be used interchangeably is in products with non mechanical faults. It is unlikely, for example, that stripping down and rebuilding a computer enables a product inspector to gain any additional information about the state of the product and/or its reason for failure. If a personal computer was stripped down and rebuilt in the same was as an engine or generator it may be less reliable than before it was processed.

The fact that a computer should not be disassembled should not mean that it cannot be described as remanufactured once it has been processed. The requirements for remanufacture are the two key processes that were identified earlier a mechanism for finding the failures and potential future failures in the product and a mechanism for repairing them. Once these two processes have been carried out it is clear that products meeting the most commonly used definition (Ijomah et al., 2005), and accepted by the UK remanufacturing industry, can be produced.

RESEARCH OBJECTIVE

It has been shown that there are a number of different and regularly used definitions for remanufacturing. The roots of these definitions often come from the processes which they describe such as rebuilding or repairing. Definitions for remanufacture are becoming more reliability based. It is thought that a product can be remanufactured without necessarily carrying out a complete disassembly and rebuilding of it.

It has been stated that one of the major weaknesses of previous operations management research in remanufacturing is that little has been done to document present industry practices in case studies or

surveys (Guide et al., 1999). This research will use cases to compare the remanufacturing of mechanical products that have been remanufactured for many years and electronic products for which remanufacturing is in its infancy. It will look at how the decision is made to remanufacture a product and how information is collected about the product in order to sell it with a full warrantee once it has been processed.

The aim of this research was to develop a deeper understanding of what allows the reliability of a product to be estimated during the remanufacturing process. It also aims to compare remanufacturing processes for mechanical and electronic components. The reason for the return of a product, the method of remanufacture and the information contained within the product can all play a part in the way they are remanufactured.

METHODOLOGY

Case study research was carried out in four remanufacturing operations, two computer remanufacturers and two automotive part remanufacturers. The automotive remanufacturers have both been operating for several decades whereas the computer remanufacturers were established more recently.

Rigour was ensured in the case studies through the following of a framework for case research (Voss et al., 2002). Discussion points were developed from the literature and were further developed using the findings from other interviews. Cases were selected to represent two very different types of remanufacturing operations. These include an OEM partnership, third party remanufacturers as well as for profit and not for profit companies. Interviews were carried out on site with operations managers, the results were triangulated through visits to the factory floor and further interviews with production staff. After each visit, the case notes were sent to the interviewees promptly after the interviews to verify their accuracy.

CASE STUDIES

In this section a discussion will be made about 4 case studies of companies all based in the UK. The real names of these companies have been hidden and for the purposes of this paper will be referred to as CompCo, PCCo, ClutchCo and GearCo. Both CompCo and PCCo remanufacture used business computers. CompCo operates as a not for profit company whereas PCCo operates as a profit making business. Both process large volumes of machines and are well established. ClutchCo and GearCo carry out replacement auto part remanufacturing and both have been operating for a large number of years.

GearCo

GearCo is a remanufacturer of automotive drive trains. They remanufacture engines, transmissions and gearboxes as an OEM approved remanufacturer. There are other companies that recondition parts known to GearCo however this is not to the same quality standard and is not carried out working with OEMs.

The Remanufacturing Process

A core is taken from the store when an order is received. An initial inspection is made for obvious damage which would make the core uneconomical to repair e.g. a cracked case. The core is disassembled and cleaned using a three stage cleaning process. A glass bead blast is used as well as a high pressure and low pressure chemical clean. Parts that are always replaced, e.g. bearings, are removed and scrapped. Other parts are inspected for reuse potential. The reason for failure of a returned core is not always obvious. Experienced inspectors access parts against criteria set in conjunction with the OEMs. For some parts a decision is made based on measurements of the item and for others a decision is made of the basis of the amount of wear it has experienced. This can be used to estimate the amount of life remaining in the part. For these products there are no parts at all that are never replaced.

Some of the smaller parts are removed from the core and sent through a separate cleaning and inspection procedure.

The main parts are placed in a tray together. An inspector utilises a computer based system to establish which parts are required for replacement and to generate a stores order for them. It is at this point the failed parts are removed and scrapped.

All of the replacement parts that are used are supplied by the OEMs or OEM approved suppliers. Parts are never repaired. Non-OEM parts could be used however the remanufactured gearbox would not be able to carry a full OEM warranty.

Once assembled the unit is put through a testing procedure developed in conjunction with the OEM. The gearboxes are run with and without load and analysed for noise and operation. Acceptable limits are set in conjunction with the OEM. 100% of the units produced are inspected in this way.

ClutchCo

ClutchCo supplies 1300 types of clutches used in cars in the UK and Europe. Half of these models come from remanufacturing, and half are new imports. The imported clutches account for 80% of the total clutch sales volume. The remaining 20% of clutches are remanufactured by ClutchCo. This strategy allows the company to hold less stock of slower moving parts at the same time as allowing it to have full market coverage. ClutchCo accepts that its remanufacturing area may now be running at a loss. However it estimates this cost to be less than keeping the large stocks of slow moving parts that would be necessary if it was to import them from China.

As an independent remanufacturer ClutchCo has found little cooperation from the OEMs of the products it remanufactures. This is despite the legal obligation of the OEMs to cooperate. In order

to develop a remanufacturing process, ClutchCo purchases OEM clutches and reverse engineers them. They have found this to be a more effective method than obtaining information from the OEMs directly. None of the clutches that are remanufactured by ClutchCo are supplied to OEM manufacturers.

Clutch Remanufacturing Process

After the cores arrive at the plant they are sorted. They are sorted by part type, against approved samples, and are visually inspected for any obvious damage which would make them unusable. The main fault inspectors are looking for is excessive wear to clutch diaphragms. Excessive wear would mean that the reassembled clutch would be unlikely to last a full second life.

After inspection, the cores are formed into production batches and are stored in the warehouse.

Core product is collected from the warehouse and washed using a caustic solution. The cover of the clutch is removed and all parts are cleaned in order to make them appear as new. Inspection of the clutches component parts is carried out. They are ground and repaired or scrapped as necessary.

The clutch is then reassembled, tested for clamp load and clearance and then ink jet sprayed with its part number and batch code.

PCCo

The mission of PCCo is to extend the life of office equipment. They offer a wide range of services ranging from collection and auditing of unwanted equipment to the supply and installation of refurbished equipment.

The majority of the work PCCo undertake is to dispose of used IT equipment. Where possible they do this through remanufacture and resale of the equipment. After processing it is sold with a 14-day

‘no quibble’ guarantee and a one year warrantee against failure. This warrantee can be extended as far as required at a cost to the customer. Despite this very liberal returns policy, only 2% of equipment supplied to customers is returned. This shows that it is very high quality and as reliable as new equipment. Customers are very happy with the equipment supplied and many give repeat business.

The PC Remanufacturing Process

Items that are deemed to be unmarketable are separated from the batch of equipment and are sent directly to a recycler. Items for which this is done currently include 15” CRT monitors.

The remaining items are sent to the remanufacturing facility. On arrival a batch number is allocated to the equipment and a unique tracking number is given to each piece of equipment. Information regarding the type of equipment, manufacturer and model number is stored against the tracking number at this stage.

The batch is then sent to the workshop where it is processed. Equipment is connected to a network which automatically audits and tests it. The network stores data about the equipment, carries out data erasure in accordance with the UK government standards and creates a record of the wipe. Software is used to carry out a fault diagnosis of the equipment.

The majority of equipment is found to be working. The exact amount varies depending on its source but the average is similar to the 80% figure quoted for Germany (Steinhilper, 1998). A visual inspection is made and the equipment is cleaned as necessary.

Information collected during the diagnostic ‘bench’ test is used in order to determine the remanufacturability of the equipment. This is restricted by value, functional state and age. A triage

principal is used to sort the equipment into 3 streams. These are reuse, recycle and carry out further tests. Diagnostic information, collected during the bench test, is then used in order to calculate a repair cost for the equipment. This consists of the cost of parts and labour required to process the equipment as necessary.

After the decision is made to continue processing an item then it is repaired before being packaged for sale.

CompCo

CompCo remanufactures between 1,400 and 1,700 computers per month. The vast majority of these are desktop computers however they also process laptop computers. The standard refurbishing lead time is two weeks and stock does not spend much time in the warehouse. CompCo works on a not for profit basis and provides computers to educational establishments and NGOs in various locations throughout the developing world.

Computers are sorted at source as much as possible. Only high specification, working machines are accepted. Computers that are found to not work or to be the wrong specification are recycled with the cost, plus a premium charge, borne by the donor.

CompCo believes that the computers it supplies should have a working life of 3 to 5 years. Their computers have been found to perform well and meet this requirement. The computers also appear to out perform new equipment. They think that this is due to the good quality brands of machines that they deal with and the 'proven' reliability of the machines after years of use.

CompCo Remanufacturing Process

Computers arrive at the warehouse in an unknown state. Information on the condition of the computers is sometimes given by the donor but it usually turns out to be inaccurate. For this reason

all of the decision making about the suitability of a machine for remanufacture is made on the basis of a visual inspection, the model of the computer and an estimation of its age. This is used to approximate the amount of usable life a computer will have once it is fully working. If it is decided that a computer is not suitable for remanufacturing it is sent for materials recycling.

During the next stage of the process, the data wiping, the machine specifications are found using diagnostic software. Based on this it is decided if the computer is suitable for reuse as it or if it requires upgrading or in some cases it cannot be used.

There are no standard part replacements made but computers are cleaned and brought back to a working condition before they are shipped.

Case Study Summary

It has been shown that the four remanufacturing companies described here operate in quite different ways. They do however have a number of key similarities.

- According to the widely accepted definition for remanufacturing, (Ijomah et al., 2005) they all carry out remanufacturing processes.
- All of the companies start with a used product and finish with a physical product and offer a full warrantee at least as comprehensive as would be provided with the product if it were new.
- All of the companies have a system for discarding unreliable products at various stages of their processes.
- All of the companies have an information processing system that runs in parallel to the physical process in order to ensure the reliability of the final product and hence its warrantee.

As anticipated, there was found to be a major difference between the processes carried out by the computer remanufacturers and the automotive part remanufacturers. In the case of the computer

remanufacturers disassembly is carried out to facilitate repair only as and when it is necessary. All other operations required to guarantee the reliability of the product can be carried out without disassembly. In addition to this the vast majority of the computers that are remanufactured by the companies studied are fully working and so disassembly would serve no purpose at all in the majority of cases. This is due to the fact that the predominant reason for discarding was not due to wear out or failure but due to the product being no longer fit for purpose in its current setting.

In the case of the automotive part remanufacturers every core that is processed is disassembled to the lowest level. This is necessary in order to assess the state of all of the components within the assembly and to carry out repairs and replacements where necessary.

The following table shows how information and processes are used to make the decision that a reassembled product will be sufficiently reliable to meet its warrantee requirements after it is processed.

	Disposal		**Quality Control**	
Company	**Dispose of Cores that will never meet warrantee requirements**	**Disposal of unusable parts/cores**	**Bring back to as new condition process**	**Final Testing Procedure**
CompCo	Demands made of organizations supplying cores	System specifications analysis	Replacement of parts determined by software	Repair tested
PCCo	Sort at source, direct disposal based on type, age	System specifications analysis	Replacement of parts determined by automatic bench test	Electrical safety compliance test
GearCo	Visual inspection for major damage	Part specification analysis	Part replacement determined by visual inspection	Test under load as developed with OEM
ClutchCo	Visual inspection for major damage	Part specification analysis	Part replacement and repairs determined by visual inspection and standard replacements	Load, clamp and clearance test

Table 3 - Summary of Findings from Cases

The strategies of all of the case companies include two key issues. Firstly there are processes where the aim is to dispose of items and products that will reduce the overall reliability of the population of the products they produce. Secondly they carry out processes in order to gain confidence that the individual items within the population will perform as required.

CONCLUSIONS

Traditionally remanufacturing has been carried out largely on mechanical products in the automotive and defence sectors. Various definitions and terms have been developed that attempt to explain this remanufacturing process adequately. Mechanical products are almost always returned in a non-functional state. Even if the products were functioning then it would be wrong to assume that they could complete a full second useful life without failure. There are many products now, for example computers, that often reach the end of their first life in a fully working state and can complete another full life, often years, before wear out. Information can be collected from some of these products without disassembly to estimate their remaining life, find any faults and to analyse their exact specifications. The definitions developed for remanufacturing by the Automotive Parts Rebuilders Association, and The Remanufacturing Institute do not regard this as true remanufacturing as the core is not necessarily stripped down to its component parts.

Definitions developed more recently conclude the opposite. The products have been subjected to specific processes developed in order to bring the product to a functional state and to assure their reliability. These products can therefore be classed as remanufactured, so long as the remanufacturer is sufficiently confident that they will continue to perform and predicted. In order to assure this they must offer a full warrantee as would be sold with the product if it was a new item.

Remanufacturing processes for computers use methods other than disassembly to ensure the reliability of the products. There is potential for these techniques to be used to remove the need for

and cost of complete disassembly in the remanufacturing of some other products. This may be through utilisation of information from the product itself through green ports or perhaps directly from the previous user as is the case with CompCo. Further research should be carried out to look at which factors affect a product's suitability for this type of process. It should also look more closely at how information is managed within the remanufacturing process and access the potential for use of other information sources, such as end user condition reports, to reduce the need for costly disassembly operations.

REFERENCES

APRA (2008) www.apra.org. 15th February 2008.

BENTLEY, R. W. (2002) Global oil & gas depletion: an overview. *Energy Policy,* 30**,** 189-205.

BSI (2002) BS.AU.257.2002 Code of practice for remanufacture of spark and compression ignition engines. British Standards Institute.

EU (1991) Council Directive on Batteries and Accumulators Containing Certain Hazardous Substances. *91/157/EEC.*

EU (1994) European Parliament and Council Directive on Packaging and Packaging Waste *94/62/EC.*

EU (2000) Directive of The European Parliament and of The Council on End-of Life Vehicles. *2000/53/EC.*

EU (2003) Directive of The European Parliament and of The Council on Waste Electrical and Electronic Equipment (WEEE). *2002/96/EC.*

GUIDE, V. D. R., JAYARAMAN, V. & SRIVASTAVA, R. (1999) Production planning and control for remanufacturing: a state-of-the-art survey. *Robotics and Computer-Integrated Manufacturing,* 15**,** 221-230.

GUIDE, V. D. R., MUYLDERMANS, L. & VAN WASSENHOVE, L. N. (2005) Hewlett-Packard Company Unlocks the Value Potential from Time-Sensitive Returns. *Interfaces,* 35**,** 281-293.

HAMMOND, R., AMEZQUITA, T. & BRAS, B. (1998) Issues in The Automotive Parts Remanufacturing Industry - A Discussion of Results from Surveys Performed among Remanufacturers. *Geogia Institute of Technology*.

IJOMAH, W. L. & CHILDE, S. J. (2007) A model of the operations concerned in remanufacture. *International Journal of Production Research,* 45**,** 5857 - 5880.

IJOMAH, W. L., CHILDE, S. J., HAMMOND, G. P. & MCMAHON, C. A. A. M. C. A. (2005) A Robust Description and Tool for Remanufacturing: A Resource and Energy Recovery Strategy IN CHILDE, S. J. (Ed.) *Environmentally Conscious Design and Inverse Manufacturing, 2005. Eco Design 2005. Fourth International Symposium on.*

MASLENNIKOVA, I. (2000) Xerox's Approach to Sustainability. *Interfaces,* 30**,** 226-233.

REVLOG (2008) http://www.fbk.eur.nl/OZ/REVLOG/Introduction.htm. 14th February 2008.

RICHARD, C. D. & WALTER, Y. (1999) Encircling the Peak of World Oil Production. *Natural Resources Research,* 8**,** 219-232.

STEINHILPER, R. (1998) *Remanufacturing: The Ultimate Form of Recycling,* Stuttgart, Fraunhofer IRB Verlag.

THE CENTRE FOR REMANUFACTURING AND REUSE (2008) www.remanufacturing.org.uk. 15th February 2008.

THE REMANUFACTURING INSTITUTE (2008) www.reman.org. 15th February 2008.

THIERRY, M., SALOMON, M., VAN NUNEN, J. & VAN WASSENHOVE, L. (1995) Strategic issues in product recovery management. *California Management Review,* 37**,** 114.

VAN NUNEN, J. A. E. E. & ZUIDWIJK, R. A. (2004) E-Enabled Closed-Loop Supply Chains. *California Management Review,* 46**,** 40-54.

VOSS, C., TSIKRIKTSIS, N. & FROHLICH, M. (2002) Case research in operations management. *International Journal of Operations & Production Management,* 22**,** 195-219.