Remanufacturing and Product Design

Designing for the 7th Generation

Casper Gray and Martin Charter

The Centre for Sustainable Design

University College for the Creative Arts, Farnham, UK

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Executive Summary

Remanufacture can offer a business model for sustainable prosperity, with reputed double profit margins alongside a significant reduction in carbon emissions (OHL, 2004) and 15% of the energy required in manufacture (Steinhilper, 2006). Remanufacture also diverts material from landfill and creates a market for skilled employment. These benefits potentially place remanufacturing as a major contributor to sustainable prosperity and a Factor 4 society.

Remanufacturing in the UK is an industry already worth £5 billion per year (OHL, 2004). However, considering that the 2003 value of manufacturing industry in the UK was £447 billion (ESRC, 2006) the actual practice of remanufacture is limited. The majority of both remanufacture and product design in the UK occurs in the South East and London. The South East is well-placed to connect these sectors and develop a model of leadership in Sustainable Consumption and Production (SCP).

The majority of remanufacturers are independent companies operating with less than 5 employees (OHL, 2004). If Design for Remanufacture were to be implemented on a wider scale then the increased profit margins for small remanufacturers in particular could result in achieving SEEDA's aims for smart growth and raised performance. The ability of design to identify and resolve inefficiencies in remanufacture is poorly understood or irrelevant to the majority of remanufacturers because as small independent remanufacturers they have little or no control over the design process. Original Equipment Manufacturers (OEMs) control the design process and could potentially control remanufacture; as such OEMs are key to establishing Design for Remanufacture however only a very few OEMs are currently engaged in remanufacture.

The relatively small take-up of remanufacturing comes despite anecdotal reports that remanufacture can be twice as profitable as manufacture (Steinhilper, 2006). The very small number of OEMs designing their business models and products to take advantage of the opportunities of remanufacture combined with a lack of cross-fertilisation between industry sectors is constraining the take-up of remanufacture. Remanufacture is poorly understood by industry and suffers confusion with other elements of 're' (recycling, repair, reconditioning etc.). Effective methods of improving awareness of remanufacture need to be identified.

Although any product that can be manufactured can in theory be remanufactured, the business case, which would make remanufacture economically feasible varies between product sectors and products. Design for Remanufacture optimises remanufacture through consideration of both the business model and the detailed product design (Nasr and Thurston 2006) however the process of Design for Remanufactured is not well-known. This report defines Design for Remanufacture as a combination of eco-design strategies including Design for Multiple Lifecycles, which leads to other design strategies such as Design for Upgrade. Two leading global

practitioners of Design for Remanufacture with subsidiaries in the UK are Xerox and Perkins Engines (now owned by Caterpillar).

Consideration of the implications of Design for Remanufacture in the South East of England requires consideration of both remanufacturing and product design industries. A basic review of remanufacturers has identified that a significant proportion of remanufacturers are in the South East (Yellow Pages, 2006), this is mirrored by the majority of product design companies being located in the South East and London (Design Council, 2005). Opportunities for the interchange and increase of knowledge, trade, investment and people in Design for Remanufacture therefore exist in the region. The promotion of remanufacture can create opportunities for sustainable prosperity and enterprise in underperforming coastal areas of the region.

Remanufacture is currently practiced in numerous industry sectors, namely the automotive and aerospace sectors; the imaging industry is also involved in remanufacture e.g. copiers and ink cartridges. Through remanufacture Caterpillar and Xerox have generated ongoing revenue opportunities from 2nd, 3rd, nth life products. At the expert remanufacturing workshop (CfSD, 2006) Xerox described that their products can have up to 7 lives i.e. 7 revenue streams!

Remanufacture is driven by market demand and legislation and these provide a context for business model design. The market is the key driver for remanufactured products, and affects remanufactured spare parts and remanufactured products in different ways. UK legislative drivers of remanufacture include the Energy using Products (EuP) Directive and the End of Life Vehicles (ELV) Directive whereas the impact of the Waste Electrical and Electronic Equipment (WEEE) Directive is unclear but does not appear to provide incentives for remanufacture. Other challenges to remanufacture consist of the Sales of Goods Act (SoGA) which discourages retailers from retailing used goods; and the poor availability of OEMs original specification information for use in remanufacture. Business and customer perceptions of used products is another key challenge to remanufacture. Research is being done internationally to explore opportunities to progress remanufacture, however this work is being carried out by only a handful of researchers.

SEEDA has the opportunity to encourage the region's global competitiveness by supporting OEMs to engage in remanufacture; this could be achieved by providing incentives and guidance or by linking them with designers experienced in eco-design strategies. Other proactive strategies are required to increase awareness of both remanufacture and Design for Remanufacture, alongside the evidence base. These may include specific university education in remanufacture for designers, the launch of an international remanufacturing conference, a regional road show on Design for Remanufacture or a practical 'how to' booklet.

Promotion of remanufacture will raise the demand for technical skills, research and development and increased levels of innovation; whilst links with international OEMs offers the opportunity to build trading links with emerging economic powerhouses. Entrepreneurial spirit can be encouraged, particularly by designers in collaboration with remanufacturers to take advantage of the opportunities of remanufacture.

In promoting remanufacture, SEEDA has an opportunity to decrease carbon emissions, reduce landfill, increase skilled employment and secure sustainable economic growth, giving the South-East the potential to increase regional activity and become a 'Factor 4' region.

Contents

1 Introduction

Remanufacture returns a used product to like-new condition; it is a process of recapturing the value added to the material when a product was first manufactured. Remanufacture results in reduced energy and material use, and production cost reductions. In the context of drivers such as the Landfill Directive, the revenue that remanufacture generates from 'waste' coupled with environmental advantages place the process as potentially a major contributor to Sustainable Development (SD) and movements towards a Factor 4 society.

Remanufacturing is an industry worth £5 billion per year in the UK and has been identified as a potential contributor to sustainable development (OHL, 2004). However the actual practice of remanufacture is limited, especially considering that the value of the UK manufacturing industry in 2003 was defined by the Economic & Social Research Council (ESRC) as £447 billion (ESRC, 2003). There are several strategies which may increase the practice of remanufacture; one of these strategies is Design for Remanufacture, which comprises of both product strategy/business model design and detailed product design.

The process of remanufacture was first brought to the fore at an industrial level by tank remanufacturing in World War I; for a time after World War II, it was profitable for all car manufacturers in the UK to engage in remanufacture. However remanufacture is still generally a niche practice today. Caterpillar, Xerox and Flextronics (who remanufacture a small number of Xerox products in Europe and a majority in the USA (Cosgrove, 2007b)) are leading global remanufacturers with a high profile, but the majority of remanufacture is carried out by much smaller organisations.

The 2004 Oakdene Hollins Ltd (OHL) report "Remanufacturing in the UK: a significant contributor to sustainable development?" provides a detailed evaluation of the state of the UK remanufacturing industry and identified future opportunities for remanufacture, highlighting that remanufacture can lead to a reduction in carbon emissions. This report investigates the links between design and remanufacture and builds on elements of the OHL report and contributions to elements of analysis by OHL. Nabil Nasr and Michael Thurston's 2006 paper "Remanufacturing: A Key Enabler to Sustainable Product Systems" brings Design for Remanufacture to the discussion and suggests the full potential of remanufacture to contribute to sustainable systems through the closed-loop economy; whereas Erik Sundin's work in "Product and Process Design for Successful Remanufacturing" brings detailed design to the fore.

This report investigates Design for Remanufacture in terms of both detailed product design and the business context in which Design for Remanufacture may operate.

2 Research Objectives

2.1 Key Study Objectives

- To understand the link between design and remanufacture

- To understand how Design for Remanufacture can lead to increased innovation and Sustainable Development (SD)
- To identify proactive strategies to further Design for Remanufacture

2.2 Research Methodology and Problems Encountered

This study into design and remanufacture was carried out using a combination of secondary and primary research. Initial, broad research into remanufacture became focussed on Design for Remanufacture as research avenues were identified.

Desk based research was planned to develop a research foundation of best international practice upon which informed questions could be framed. Information was found to be disparately spread and not always freely available; budget constraints required the purchase of documentation to be carefully considered.

Primary research was carried out in the form of a structured questionnaire, and interviews with national and international experts. The limited number of experts in remanufacturing and their time constraints placed some pressure on the study. The organisation of an invite-only, expert remanufacturing workshop considered these time pressures; the workshop successfully brought together practicing remanufacturers, researchers and industry groups to exchange experience and views on remanufacture.

There is a very limited amount of information available concerning Design for Remanufacture and even less detailing specific strategies for detailed product design. Due to the lack of information and case studies, the possible strategies of Design for Remanufacture presented in this report are an amalgamation of eco-design, and Design for Multiple Life strategies and may be at times conceptual.

Research

This report has benefited from the generous contributions of time and effort by numerous individuals and organisations. In particular, we would like to thank the following individuals and organisations for their help and support:

David Parker, Oakdene Hollins Ltd
Andy Cosgrove, Xerox
Tim Barker, Caterpillar
John Morrell, Consultant
Andrew King, Bristol University

3 Definition of Remanufacture

There are numerous elements of ‘re’: refurbishment, reconditioning, repair etc which are easily and commonly confused with ‘remanufacture’ due to similarities in the process and final product.

Over the past decade, literature and research has sought to define ‘remanufacture’. The persistent appearance of these definitions (also included in this report) demonstrates a lack of appreciation of remanufacturing as a concept and a process.

Uncertainty over the definition of remanufacture creates confusion, which restricts progress towards the increase of remanufacture. Logically, it would be hard to attribute a successful business model to remanufacture if the audience understands 'remanufacture' to mean 'recycling'.

> *'Remanufacturing is not a widely understood concept.'*
>
> Ron Giuntini, The Remanufacturing Institute, 2006

An understanding of remanufacturing has not yet been disseminated effectively into the manufacturing and associated industries. In some areas, work is in progress to increase awareness however this is still limited to only a few organisations such as Envirolink Northwest. Envirolink Northwest exist to promote, strengthen and support the environmental technologies and services sector in England's Northwest, taking a role that includes promoting remanufacture.

The misunderstanding of definitions is compounded by preconceptions resulting from a limited knowledge of certain historical practices loosely related to remanufacturing. The practice of poorly re-treading car tyres, which originated in the first part of the 20th Century, compared with modern practices, is a classic example of how an industry has to fight against preconceptions.

3.1 Remanufacture

When determining if a product is or is not remanufactured, it is essential to consider the process utilised. Remanufacturing is a process of recapturing the value added to the material when a product was first manufactured.

Used components and spare parts can be considered remanufactured if they are brought to at least Original Equipment Manufacturer performance specification from the customer's perspective and given a warranty equal to that of an equivalent new product (Ijomah, 2002). A product may be remanufactured with or without brand or product identity.

In terms of understanding the drivers and design for remanufacture, it is useful to note that remanufacture may be divided into two categories:

- Spare parts e.g. Automotive clutch, starter motor
- Products e.g. CR Scanner, Vending Machine

This distinction is necessary to understand that drivers and design issues for remanufactured spare parts and products may be different. This in turn has implications for the design of business models. The spare part industry, which consists of 2/3 of all remanufacturing activity (Steinhilper, 2006), is primarily driven by the market; this is particularly prevalent in the automotive sector. In contrast, legislation is a significant driver for products. These aspects will be further explored later in the report.

The remanufacturing process consists of 8 steps (including the essential collection of core discussed further in Section 4.2). A basic sequence is given here, but depending on the product remanufactured, the order of the steps may change (Sundin, 2004):

- Collection of core
- Inspection and identification of faults
- Disassembly of whole product
- Cleaning of all parts (and storage)
- Reconditioning of parts (and replacement with new parts where required)
- Reassembly of product
- Testing to verify the product functions as a new product

Fault identification – example of technique using infra-red at the European Research Center for Remanufacturing

Core

'Core' is the term commonly used to describe the component or product that will be retained through the remanufacturing process. 'Hulk' is a synonym for 'core', used notably by Xerox.

3.1.2 Remanufacture Synonyms

- Re-manufacture
- Second-life production ('3rd life' etc up to 'nth life' may also be used)
- Repetitive manufacture

Two other synonyms which are sometimes used to mean 'remanufacturing' are:

- Asset Recovery
- Asset Regeneration

Cleaning Process at the European Research Center for Remanufacturing

International Remanufacture Synonyms

International languages should also be considered when understanding terms related to remanufacture. Translation of terms can potentially add another level of confusion, where words which are similar to English words that are *not* 'remanufacturing' may be used to describe remanufacture. For example:

- Inverse manufacture (Japan)
- Produktrecycling (Germany)
- Rénovation (France)

Industry-Specific Remanufacture Synonyms

There are also a number of industry specific synonyms for remanufacture:

Rebuilt = Remanufactured

- 'Rebuilt' is synonymous with remanufacturing when used in connection with motor vehicle parts and systems but not the entire vehicle.

Recharged = Remanufactured

- 'Recharged' is used in connection with the remanufacture of imaging products e.g. laser toner cartridges.

Retread / Remoulded = Remanufactured

- 'Retread' or 'remoulding' is used in the tyre industry

Rewound = Remanufactured

- 'Rewinding' is synonymous with remanufacturing in the sector of electrical ("rotating electrics") equipment.

Overhaul = Remanufactured

- 'Overhaul' is synonymous with remanufacturing, particularly in the aerospace industry. The term "rotables" is also in common use for items on scheduled overhaul.

Terminology adds to the confusion about the extent to which remanufacture is practised. The Remanufacturing Institute (TRI) in the USA (2006) explains that some organisations are now using the concept of remanufacturing in their environmental literature but not the terminology. For example:

- The American Society of Mechanical Engineer's position paper on "Designing for the Environment" includes the concept of remanufacturing.
- The American Automobile Manufacturers Association include remanufacturing in the life cycle of a car in their "Key Facts about America's Car Companies: Environment"

In contrast Siemens AG Medical Solutions is an example where they use the term 'refurbished' alongside practise that may appear to adopt elements of remanufacture. However Siemens AG Medical Solutions do not remanufacture and 'refurbished' does not mean 'remanufactured' (Plumeyer, 2006); this demonstrates once more the importance of verifying terminology in every case.

3.2 Remanufacture is not…

There are many terms which may be confused with remanufacture. Remanufacture is not:

3.2.1 Recondition / Refurbish / Restore

Reconditioning restores a product functionally to as-new or almost as-new condition but may not come with a warranty that matches a new product. Reconditioning may return a product to like-new quality but the process may not disassemble and clean all of a product's components; this means it is not 'remanufacture'.

These terms may be applied to architectural interiors; predominantly for rental properties where these terms are used frequently on sales boards. These terms may also apply to antique or classic goods. Consumer products may also be reconditioned or refurbished; some are sold as 'reconditioned' with an 'as new' warranty. The closeness of this practice to remanufacture is not clear, which leads to further confusion.

3.2.2 Re-used / Used

This term is generally applied to a product that has been used previously. The product will retain the problems it acquired during its previous life as it will not have been repaired.

Refurbished Office, London, 2006

3.2.3 Repair

Repair makes a broken product operational again. An analysis of the root cause of the problem is generally not performed in the repair process which means the product may not perform like a new product. Typically, a warranty on a repair will only apply to the specific repair and not the whole item.

3.2.4 Recycled

Recycling returns a product to raw material form, which can be used as raw material for a future manufacturing process. The term 'recycling' is generally applied to consumable goods e.g. newspapers, glass bottles and aluminium cans but can also be applied to durable goods such as an engine. Recycling in this sense destroys the value added to the raw material by forming it in the original manufacturing process.

The term 'recycled' is used by some legitimate remanufacturers to describe a product that may meet the minimum remanufacturing requirements. However, a 'recycled' product may also be removed from a redundant product and resold with little or no work performed on it e.g. in the automotive sector as part of an end-of-life reclaim and reuse operation. In this instance, 'recycled' would not be considered remanufactured.

'Demanufacturing' describes a disassembly process and is often associated with recycling. Automobiles for example need to be disassembled to ensure segregation of materials such as steel, aluminium, various plastics, etc. Demanufacturing is a step of that could in theory be applied to any 're' but is not a process in its own right.

3.3 Remanufacturing in Context of 're'

The importance of remanufacturing's role in the context of all the 're's is explained by Nasr and Thurston of the National Center for Remanufacturing and Resource Recovery:

> *'Component reuse will typically result in lower overall material and energy use than component remanufacturing. However, only components that retain their value and conformance can be reused without compromising the durability or reliability of the final product.'*

Nabil Nasr and Michael Thurston, 2006

Remanufacture allows components to retain their worth, thereby placing this process as a sophisticated element of reuse and repair strategies.

'Remanufacturing is typically a more efficient means of material recirculation than recycling. Remanufacturing retains more of the energy associated with the original conversion of raw materials to finished product.'

Nabil Nasr and Michael Thurston, 2006

The importance of Design for Remanufacture in promoting remanufacture over recycling is that with old assemblies or equipment not Designed for Remanufacture, it is seldom possible to do more than recover the materials, and even this process of recycling may be difficult and costly (Graedel and Allenby, 1998, cited in Sundin 2004).

The chart below (Steinhilper, 1998)[1], compares remanufacturing with repair. The chart has been slightly updated to take into account new understanding as a result of this research:

REMANUFACTURE	**REPAIR**
Applicability	
Used products	Defective products
Defective products*	
Process	
Complete disassembly	Failure detection
Cleaning of all parts	Disassembly of some parts
Remediation of parts to as new state / Replenishment of new parts / Upgrading of parts*	Restoration or replacement of defective part
Product reassembly	Reassembly of parts
Characteristics	
Industrialised process	Mechanic's work
Overall restoration to like new condition	Individual repair of defect
Customer receives anonymous product	Customer keeps his/her own product
Like-new or lifetime warranty	Warranty covering repair work only
Upgrading/Upcycling to state-of-art technology	Product retains earlier standard

The difference between remanufacture and other elements of 're' are therefore distinct in terms of its process and positioning within the material flows loop.

Nasr and Thurston's diagram below shows how remanufacturing sits within a spectrum of reuse. It is important to understand this to realise that depending on the particular product and its lifecycle position, all elements of 're' should be considered to identify the most appropriate end-of-life strategy.

[1] Entries denoted by and asterisk (*) are entries added as a result of consultation with Morley and Parker of Oakdene Hollins Ltd (2007).

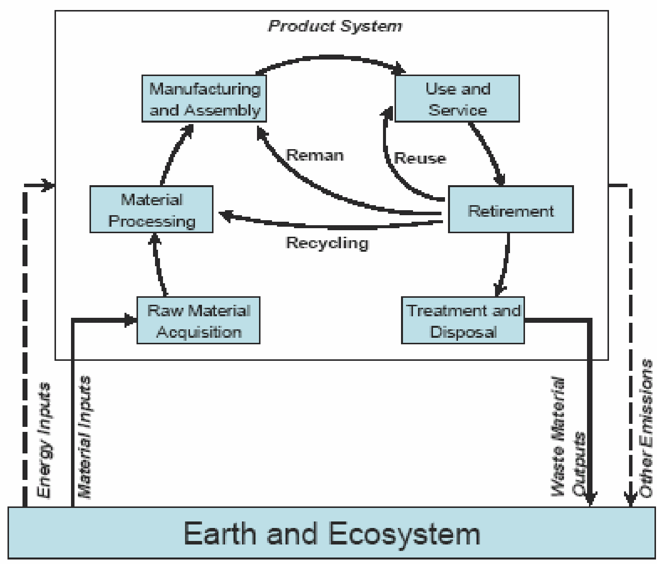


Figure 2: Closing the loop on material flows

Nabil Nasr and Michael Thurston, 2006

However remanufacture cannot be applied in isolation, to operationalise the 'circular economy' you need all the "re's"' (Charter, 2006).

4 Opportunities for Sustainable Prosperity in South East England and UK

4.1 State of Art: Where is the South East now?

The UK generates approximately 400 million tonnes of waste every year and this is growing annually by 3%. Industrial and commercial waste accounts for around 20% of total waste and over half of this goes to landfill. Remanufacturing offers an alternative to landfill or other disposal options which eliminate the value added to materials by the manufacturing process. The remanufacturing industry is estimated to be worth £5 billion a year in the UK, which places it on a par with the recycling industry (OHL, 2004).

The majority of both remanufacture and product design in the UK occurs in the South East and London. The South East, an area with a high level of consumption, can utilise its good representation of these sectors to take the lead in the new approach in Sustainable Consumption and Production (SCP) (SEEDA, 2006). However most design engineers and product designers have little knowledge of eco-design, let alone Design for Remanufacture.

4.2 Financial Opportunities: Remanufacturing and Employment

Remanufacture is reputed to lead to increased profit and creates a demand for skilled employment. Remanufacture therefore has the potential to help the South East improve its economic prosperity through raising productivity and economic activity across the region, and through releasing the untapped economic potential of all parts of the region.

Remanufacture can increase prosperity flows by bringing resources into reuse and increasing productivity. This relates to the South East's 6 drivers of prosperity given in the SEEDA Regional Economic Strategy (RES):

4.2.1 Employment

Remanufacture employs up to 50,000 men and women in the UK (OHL, 2004). Remanufacture demands skilled labour, however 3rd party remanufacturers, face economic challenges. Reduced costs through an optimisation of the remanufacture process via activities which may include Design for Remanufacture may help the preservation and creation of jobs in remanufacture. many small businesses face challenges such as costs.

4.2.2 Enterprise

Most remanufacturers are small 3rd party, engineering-oriented companies with only a few employees (OHL, 2004). These businesses have to react to opportunities in product and component remanufacture that are controlled by OEMs' original designs. Promotion of products that have been Designed for Remanufacture can increase the level of business start-up activity by increasing the opportunities for remanufacture.

Proof of the business case for remanufacture in the form of successful business models and products is required to encourage investment. This is likely to require collaboration between enterprising individuals, businesses and industrial sectors.

The UK Government's Business Resource Efficiency & Waste Programme (BREW) began in April 2005, to ensure that increases in Landfill Tax will not only incentivise businesses to reduce the amount of waste they send to landfill, but will also assist them in developing ways to achieve this.

4.2.3 Innovation and Creativity

Design for Remanufacture requires both innovation and creativity to optimise the processes of remanufacture. Promoting the optimisation of remanufacture can lead to increased research and development (R&D) and will drive the market for R&D, innovation and creative skills, and bring the South East into line with Europe's leading regions.

4.2.4 Skills

Remanufacturing presents difficulties to automation because the process is frequently concerned with batch productions of a range of components or products. This variety would mean that if machinery were to be used in disassembly etc, it would have to be frequently reset and reconfigured. This is likely to make automation prohibitively expensive for the majority of remanufacturers. Therefore remanufacturing often necessitates human intelligence and evaluation. The skilled work of the remanufacturer is reputed to lead to greater job satisfaction, particularly those involved in more creative remanufacturing (OHL, 2004), which would apply to Design for Remanufacture.

> *'[I used to mend and service machines] my job was far more interesting then.'*
>
> Ray Gould, Southern Appliances, 2006

Skill levels in the South East's workforce are relatively strong compared to most of the UK and Europe, however there are also significant variations within the region, and parts of the Coastal South East are marked by much lower workforce skills than the regional, and in some cases national, averages (SEEDA, 2006). The promotion of remanufacture would create markets for skilled employees.

4.3 Sustainability Opportunities: Remanufacturing and the Environment

Remanufacture has inherent positive environmental consequences. These relate to the four priorities for action within Prosperity and Sustainability (SEEDA, 2006):

4.3.1 Sustainable Consumption and Production

Remanufacture views 'waste' as a resource. Promotion of remanufacture can therefore benefit both economy and environment. Design for Remanufacture can optimise the process of remanufacture, increase the practise of remanufacture and therefore increase the significant economic development opportunities for the South East region.

4.3.2 Climate Change and Energy

Remanufacturing typically uses 85% less energy than manufacturing (Steinhilper, 2006). Studies performed at the Fraunhofer Institute in Stuttgart, Germany, estimate the energy savings by remanufacturing worldwide equals the electricity generated by 5 nuclear power plants. This corresponds to 10,744,000 barrels of crude oil or a fleet of 233 oil tankers a year. By requiring significantly less energy than manufacture, remanufacture can address the major concerns over continuing security of energy supplies in the face of a prospective 'energy gap' in the South East.

A rough assessment of resource impact suggests remanufacturing is also saving in excess of 800,000 tonnes CO_2 emissions per annum (OHL, 2004).

4.3.3 Natural Resource Protection and Environmental Enhancement

Through reuse of resources, remanufacture leads to a reduction in landfill, pollution and natural resource use, which can preserve the quality of the natural and built environment.

Landfill Reduction

Products that are remanufactured are kept out of the waste stream for longer thereby preserving landfill space. If remanufacture is taken to its fullest extent, where everything that is manufactured (including construction waste, packaging waste etc) is remanufactured the practise of landfill could in theory be eliminated altogether, resulting in a closed-loop society. This is clearly a long-term view, which is likely to require all products to be fully Designed for Reuse.

Pollution Reduction

Air pollution is reduced by the remanufacture of products that would have had to be re-smelted or otherwise reprocessed in manufacture. The Chartered Institute of Environmental Health (CIEH) states that industrial processes such as smelting and metals processing require oil and solvent-based fuel mixes to be burnt, releasing fine particles measuring 2.5µ or less (PM2.5s), which have been linked to a number of diseases because of their ability to enter deep into the lung. In the last 10 years experts say that PM2.5s have risen 'astronomically' in the UK (CIEH, 2005).

Raw Materials Savings

The Fraunhofer Institute determined that raw materials saved by remanufacturing worldwide in a year would fill 155,000 railroad cars forming a train 1,100 miles long (TRI, 2006).

Quality of Life

Remanufacture can also increase quality of life by contributing to environmental preservation and driving the market for skilled labour; remanufacture can thereby preserve the competitive offer of the South East and promote the economic advantages of locating in the region.

4.3.4 'Factor 4' Society

Remanufacture's cumulative benefits of energy and material savings, landfill and pollution reduction place remanufacture as a major contributor to SD. The promotion of remanufacture is therefore a significant factor in progress towards a closed-loop, 'Factor 4' society.

5 Parameters for Successful Remanufacture

In theory, any product that can be manufactured can be remanufactured but the design of some products' business model and detailed product design means that some products can be remanufactured more profitably than others.

> *'Any product that can be manufactured can also be remanufactured. However, some products are remanufactured more often than others.'*
>
> Ron Giuntini, 2006

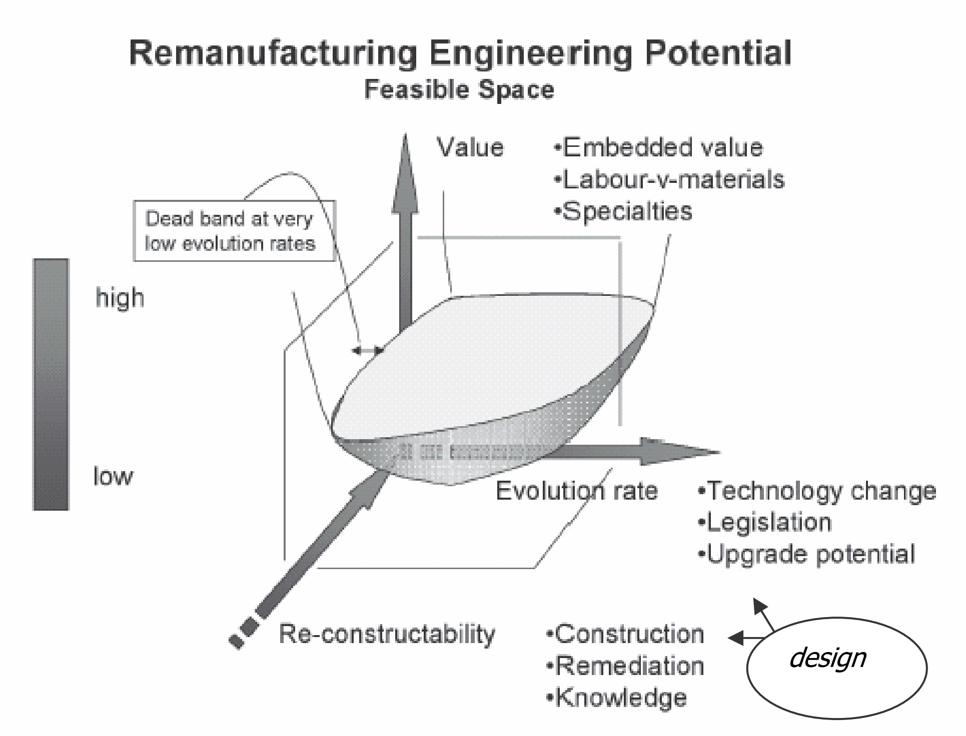
5.1 Product Parameters

The criteria required for a product to be successfully remanufactured and sold are described by William Hauser and Robert Lund (date unknown) based on 25 years of research into the remanufacturing industry:

- Technology exists to restore product. Technology must be able to extract a component without damage (Nasr and Thurston, 2006).
- Product is made up of standard interchangeable parts.
- Cost of core is low relative to savings in product cost achieved through core reuse.
- Product technology is stable over more than one life cycle.
- Sufficient market demand to sustain enterprise.
- An evaluation of disposal options and environmental impact of legislation is also necessary to determine a product's suitability for remanufacture (Nasr and Thurston, 2006).

> *'If product design permits, and there is an adequate process for return of used products (reverse logistics chain), there can be a strong business model in product remanufacturing.'*
>
> Nabil Nasr and Michael Thurston, 2006

These concepts are visually demonstrated by OHL's 'Remanufacturing Engineering Potential' model, showing a range where the parameters meet to make remanufacturing feasible.



Nick Morley, 2006

The model shows that remanufacture is unlikely to be successful when there is low value in the core, there is a high evolution rate and no return channels. Within this model, design is particularly relevant to 'upgrade potential' and 'construction' (Morley, 2006).

An overview of which product characteristics and the remanufacturing process they relate to is given below. After establishing which stage of remanufacturing is an issue for a particular product, this chart may be used as a guide to indicate what product characteristic could be improved by design.

Remanufacturing Step / Product Property	Inspection	Cleaning	Disassembly	Storage	Reprocess	Reassembly	Testing
Ease of Identification	×		×	×			×
Ease of Verification	×						
Ease of Access	×	×	×		×		×
Ease of Handling			×	×	×	×	
Ease of Separation			×		×		
Ease of Securing						×	
Ease of Alignment						×	
Ease of Stacking				×			
Wear Resistance		×	×		×	×	

Figure 24. The RemPro-matrix showing the relationship between the preferable properties and the generic remanufacturing process steps.

Erik Sundin, 2004

Of the above, Sundin (2004) found that the following four properties were most frequently found to be important for products' and components' remanufacture:

- Ease of access
- Ease of identification
- Wear resistance
- Ease of handling

The importance of 'ease of access' on numerous steps of remanufacture makes the effective application of Design for Disassembly, imperative in Design for Remanufacture.

5.2 Core Consideration

Remanufacture cannot occur without core, because without core there would be nothing to remanufacture! Core is generally collected through a specifically designed business model however the remanufacturing process relies so fundamentally on the collection of core that any steps that may help the collection of core should be utilised. If the detailed product design can aid core collection, collection should be considered in the product design process. Detailed product design for remanufacture therefore extends the conventionally understood remanufacturing process to consider core collection.

5.3 Currently Remanufactured Products

The following is a short list of some of products that match these criteria and currently remanufactured:

- Aerospace
- Bakery Equipment
- Compressors
- Data Communication Equipment
- Gaming Machines
- High end electronics and electricals
- Industrial machinery e.g. machines and tooling
- Motor Vehicle Parts (notably engine parts and tyres)
- Laser Toner Cartridges
- Musical Instruments
- Office Furniture
- Photocopiers
- Refrigeration
- Robots
- Vending Machines

Source: OHL, 2004; TRI, 2006

Remanufacturing is least prevalent in areas producing consumer goods subject to fashion or status-related purchasing decisions. It is most prevalent and holding up, in sectors of very high value or technological content such as aerospace, military and power turbines. Remanufacturing also thrives in sectors which have embraced the concept of Product Service Systems (PSS) because in these instances there are shared motives for product longevity, durability and performance. (OHL, 2004).

6 Remanufacture and Product Design in the UK

The ESRC states that to remain competitive, the UK's manufacturing sector needs to successfully move from competing on relatively low cost to competing on unique value and innovation (ESRC, 2006). Design offers manufacturing a service, which can deliver both value and innovation.

6.1 UK Remanufacturing Industry

As previously mentioned, in 2004, remanufacturing in the UK was worth an estimated £5 billion per year and employed up to 50,000 people (OHL, 2004). In contrast, the UK manufacturing industry is far bigger and employs far more people; for example in 2003 UK manufacturing was worth £447 billion and employed approximately 3,500,000 people (ESRC, 2006). This suggests there is a very significant proportion of manufactured products, which could be remanufactured if the business model and products were designed to facilitate remanufacture; but they are not remanufactured. Therefore the opportunity for increasing remanufacture in the UK is potentially high.

The majority of remanufacturers in the UK are small, engineering-oriented companies with only a few employees (OHL, 2004). As an indication of remanufacture in the

UK, a brief survey of the Yellow Pages (2006) identified 166 companies listed under 'remanufacture'. Due to the nature of advertising, the Yellow Pages is unlikely to include all remanufacturers and of the 166 listed, many are retailers of remanufactured items such as ink cartridges and not remanufacturers themselves. However the listing may be taken as indicative of the concentration of remanufacturers in the South East of England:

Location	Companies listed under 'remanufacture'
South East England (excl. London)	30
London	41
South West England	20
Wales	8
Midlands	26
North East England	3
North West England	18
Scotland	12
Northern Ireland	8
Total UK	**166**

Source: www.yell.com, 2006

Anecdotal evidence (Steinhilper, 2006) suggests that remanufacture may be up to twice as profitable as manufacture, however it is hard to confirm this due to the difficulties in accurate data collection (Parker, 2007). This may be explained by the way in which data can be realistically collected. Remanufacture is carried out mostly by small companies however data is more readily available from larger remanufacturers. Small companies may have a less predictable turnover than large companies; for example, interviews with some small remanufacturers carried out during this study, identified that small remanufacturers can face financial difficulties. Larger remanufacturers may also benefit from economies of scale and purchasing power and so their profits may be higher than profits at smaller companies. Therefore the data from larger companies can easily skew research results, especially if larger companies form an unrepresentative proportion of the overall data.

> *'We can make the same sort of margin on either product [remanufactured or not remanufactured].'*
>
> Anon, Morvend, 2007

6.2 UK Design Industry

Design for Remanufacture can optimise the process of remanufacture and logically, its practise is controlled by OEMs who initiate the design and manufacture of products. In practise design and remanufacture are linked by only a few OEMs, such as Xerox and Caterpillar.

A profile of the UK design industry puts the practitioners of detailed product design, who, if educated in Design for Remanufacture could potentially put it into practise (Design Council, 2005):

- 14,841 product & industrial design businesses in the UK, approximately 5,500 of whom are in-house teams.
- 65% (3,600) of in-house designers work in the private sector, 30% in the public sector with only a small number in charity, community or voluntary sectors.
- 20% of product and industrial design businesses are based in the South East and a further 21% are based in London.
- 79% of companies in product and industrial design have 4 or less employees; the second largest group comprises 8% of Product & Industrial design companies with 50-249 employees.
- 17% of design businesses say their main competition comes from outside the UK and 79% of product and industrial design companies report that overseas competition has increased
- 40% of design consultancies use informal mentoring to develop their staff.

To what extent Design for Remanufacture is practised in the UK is unknown but it is likely to be limited to a small number of Original Equipment Manufacturers (OEMs) who engage in the remanufacture of their own products and therefore have an incentive to increase the efficiency of remanufacture. Although consultancies may in theory be able to offer Design for Remanufacture (if they have the capability) to give clients added value, time constraints and low levels of awareness make this highly unlikely.

Awareness of eco-design, let alone Design for Remanufacture in the design industry is low. This situation is perpetuated by the lack of applied courses in eco-design and sustainable design, which results in professional designers and design students not receiving training in these areas. This lack of awareness is one of the reasons why the practise of Design for Remanufacture is limited.

6.3 Remanufacture and Product Design

The imperative for connecting design and remanufacture is established by Nasr and Thurston (2006) who state that the full societal benefits of remanufacturing (reduced energy and material consumption and reduced wastes) cannot be achieved unless Design for Remanufacture becomes an integral part of the product development process.

'Xerox has been able to maximise the end-of-life potential of products and components by incorporating reuse considerations into its design process.'

Xerox, date unknown a

Remanufacture begins with core and all core is designed prior to manufacture. Components' form, material, fastenings etc can all affect the ease with which a product undergoes the various stages of remanufacture e.g. disassembly or cleaning. Therefore Design for Remanufacture has a clear part to play in improving the efficiency of remanufacture.

In combination with other strategies, the different thought processes required for Design for Remanufacture (and more specifically Design for Upgrade) may be able to feed into innovation and new business models for UK industry. Xerox is an example of how Design for Remanufacture can benefit a business. Xerox began remanufacturing operations in the early 1990s and is now a world leader in this field.

The profitable link between design and remanufacture is however poorly understood or irrelevant to the majority of remanufacturers because as small independent remanufacturers they have little or no control over the design process. To put OEMs' involvement in remanufacturing in context, in the USA, OEMs account for less than 5% of total remanufacturing activity (Guide, 2000, cited in Sundin, 2004). Proactive ways of stimulating industry in the UK by encouraging Design for Remanufacture will be discussed later in this report.

7 Design for Remanufacture

Consideration of design and remanufacture brings to the fore three questions regarding Design for Remanufacture:

- What is 'design' in the context of remanufacture?
- What can detailed product design do for remanufacture?
- How can the practice of Design for Remanufacture be enabled?

The actual process of detailed product Design for Remanufacture will be discussed in the section 'What is Design for Remanufacture?'.

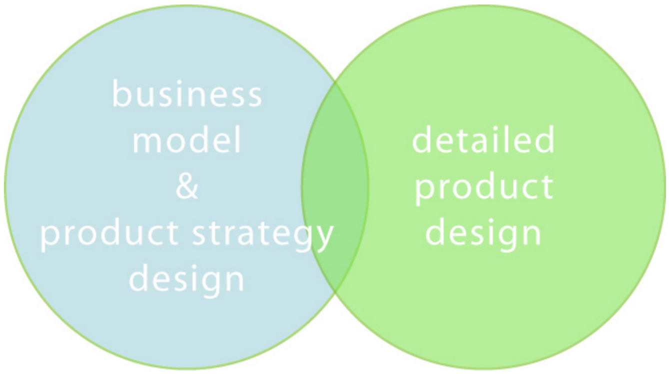
7.1 Design in the context of remanufacture

Remanufacture is affected by the physical characteristics specified during the design phase, whether the product has been Designed for Remanufacture or not. Product Design for Remanufacture is enabled by business models which recognise the benefits of remanufacture.

We can therefore consider Design for Remanufacture on two levels:

- Product strategy, including sales, marketing, service support, reverse logistics/core collection.
- Detailed product design and engineering, including core collection and functional design.

The two inter-related levels of Design for Remanufacture



Some aspects of remanufacture may span both levels. For example, core collection mechanisms may require the design of the business model to facilitate collection e.g. PSS as used by Xerox, or financial incentives for the core's return as used by Caterpillar; but the detailed product design may also communicate information including collection methods to all stakeholders, using graphics for example.

Generally the discussion of Design for Remanufacture technologies focuses on the detailed product design issues (Nasr and Thurston 2006). This report investigates both these aspects of Design for Remanufacture; this section will primarily explore detailed product and engineering; further sections explore the drivers and challenges that relate to the business model design for remanufacture.

A consistent understanding of the job roles related to detailed design and remanufacture is also useful to demonstrate that different roles may be able to feed different skills into the different aspects of Design for Remanufacture:

Product Design

'Product Design can be defined as the idea generation, concept development, testing and manufacturing or implementation of a physical object or service…Product Designers conceptualise and evaluate ideas, making them tangible through products in a more systematic approach [than Industrial Design]. The role of a product designer encompasses many characteristics of the marketing manager, product management, industrial designer and design engineer.' (Wikipedia, 2006g)

Engineer

'An engineer is someone who is trained or professionally engaged in a branch of engineering. Engineers use creativity, technology, and scientific knowledge to solve practical problems. People who work as engineers normally have an academic degree (or equivalent work experience) in one of the engineering disciplines.' (Wikipedia, 2006h)

Design Engineer

'A Design Engineer is a general term that covers multiple engineering disciplines - Electrical, Mechanical and Civil Engineering are the basic three. The Design Engineer is responsible for the design and development of new products, equipment or facilities.

The Design Engineer is distinguished from the designer / drafter by virtue of the fact that a Design Engineer sets the direction of the design effort. The Designer/Drafter is usually directed by the Design Engineer.' (Wikipedia, 2006f)

7.2 What Can Detailed Product Design do for Remanufacture?

The most effective way to boost remanufacture is through the product and process design approach (Amezquita and Bras, 1996, cited in Sundin, 2004). Design for Remanufacture can identify and prevent inefficiencies in remanufacture.

In contrast, it is important to note that it is also possible to design products to ensure they cannot be remanufactured. Some OEMs who want to prevent 3rd party remanufacturers may actively prevent remanufacture of their products using assembly techniques such as ultra-sonic welding, which may make it impossible to disassemble a product without destroying the very components that are sought.

> *'GE Medical Systems wanted to test out the profitability of a voluntary take-back and remanufacture of their used equipment. To test it, a manager was asked to run a pilot in an old plant for a year, after which period he had to report if it was profitable. The reply was: "Yes, we can break even, but if the products were designed for remanufacture, then we could have made a lot of money.'*
>
> Walter Stahel, The Product-Life Institute, speaking at the Remanufacturing Stakeholder event (2007)

7.2.1 Remanufacturing's Design-Related Needs

Remanufacture can be twice as profitable as manufacture (Steinhilper, 2006) but profit generation remains a priority for remanufacture as shown by a survey of remanufacturing executives. This survey revealed that 60% cite the increased pressure to reduce lead times continuously as the biggest threat to their remanufacturing activities (Guide, 2000, cited in Sundin 2004).

A survey of Electrical Rebuilders

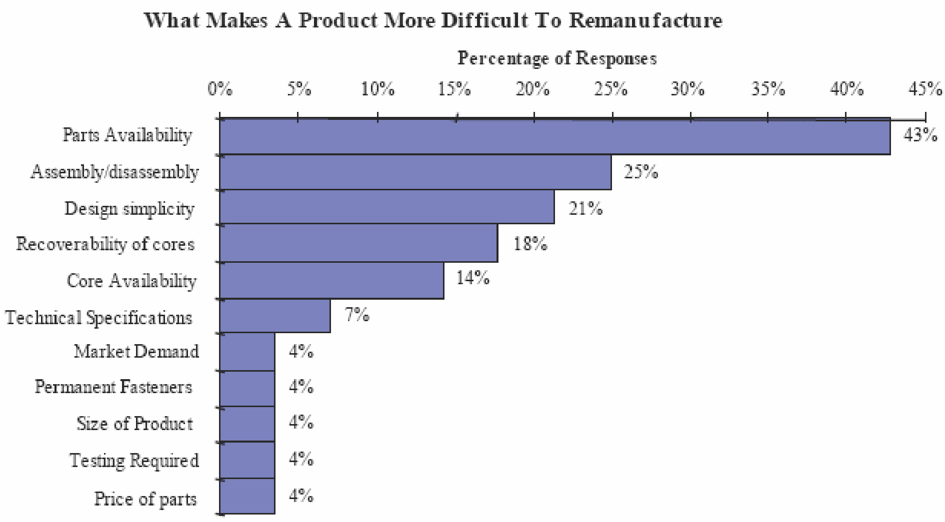


Figure 1 – Responses to Question 1: Difficulties To Remanufacturing

Richard Hammond et. al, 1998

Design for Remanufacture can optimise remanufacture, making profit margins greater. A survey of American automotive remanufacturers showed the main issues with regard to Design for Remanufacture can be grouped as concerning (Hammond et. al, 1998):

- Complexity
- Fastening methods
- Means of assembly and disassembly
- Increased part fragility

Design for Disassembly relates strongly to all the above, by allowing ease of disassembly which results in faster disassembly times and greater recovery of intact parts. Design for Disassembly is therefore an important component of Design for Remanufacture. In instances and for products where remanufacture is suitable, Design for Remanufacture may improve the efficiency of remanufacture by:

- Reducing disassembly and reassembly times and thereby also reducing inspection/evaluation time and costs
- Specifying materials and forms appropriate for repetitive remanufacture
- Building mechanisms into the product or component to ensure the return of cores.

7.2.2 Difficulties in Ranking Design and Remanufacturing Process Issues

It is difficult to obtain a clear ranking of design and remanufacturing process issues and this may hinder the development of methods for assessing a product's remanufacturability (Hammond et. al, 1998).

The target of any design effort might change depending on the product type, infrastructure and where the product sits within the spectrum. Hammond et. al (1998) say that, a large source for the variations appears to originate from the different perspectives about remanufacturing. This is a result of differences in the scale of businesses and the type of customer primarily serviced.

7.2.3 Design for Remanufacture in Context

Although Design for Remanufacture may contribute to improving the efficiency of remanufacture, it is important to note that Design for Remanufacture is not always the best option, either environmentally or economically. For example, from an environmental perspective it may be better in some circumstances to promote other strategies such as reuse, whereas fast-moving consumer goods may best designed for recycling.

In some cases, other strategies concerning the business model may have a greater impact in stimulating the remanufacture of a particular product than detailed product design. A few of these options may concern:

- Reverse logistics
- Collection of core parts
- Reducing the rejection of remanufactured products

7.3 Enabling Design for Remanufacture

Research in compiling this report has revealed that the pressures of time to market and cost outweigh other aspects such as eco-design which may be considered non-essential (aside from compliance with legislation). It is reasonable to assume that Design for Remanufacture is therefore not a priority for the vast majority of companies in the normal business model.

Business model design that recognises the value of improved efficiency in remanufacture (and therefore Design for Remanufacture) is required in situations where Design for Remanufacture is appropriate. This requires examples of successful remanufacture and the role of Design for Remanufacture in achieving it.

The strategies useful in implementing sustainability into environmental management systems (EMSs) and business model design for sustainability are well-documented in other publications and as such, are not explored fully in this report.

> *'During the design process, the end-of life option (reuse, remanufacture, recycle, or treat and dispose) for each module, component, etc. should be evaluated… The end-of-life assessment should be an iterative (or synchronous) process with product and manufacturing system design.'*
>
> Nabil Nasr and Michael Thurston, 2006

8 What is Design for Remanufacture?

Design for Remanufacture is a combination of design processes whereby an item is designed to facilitate remanufacture. Design for Remanufacture is guided by an assessment of product or component value over time. This value may vary depending on the market and material demand and supply, legislation and technological improvements.

As part of a business model, Design for Remanufacture can reduce the constraining issues and preserve the facilitating properties for remanufacture. Design for Remanufacture therefore can therefore play a part in optimising the process of remanufacture. Design for Remanufacture requires two stages:

- Evaluation of the product and its relation to the remanufacturing process to discern what Design for 'X' methods are required. This may be done using the criteria given in Section 4 'Parameters for Successful Remanufacture'.
- Application of the selected design techniques to optimise the process of remanufacture.

Design for Remanufacture incorporates these characteristics into particular design steps or Design for X strategies, which are described in this section. These steps are related and frequently overlap. They are considered as separate here for the sake of clarity. The Table below links the Design for X strategies with their corresponding remanufacturing steps (including core collection).

DESIGN STRATEGY	**REMANUFACTURING PROCESS**						
	Core Collection	Inspection	Disassembly	Cleaning & storage	Remediation	Reassembly	Testing
Design for Core Collection	√	√					
Eco-Design		√	√	√		√	
Design for Disassembly		√	√	√	√	√	
Design for Multiple Lifecycles				√	√		
Design for Upgrade					√		
Design for Evaluation		√					√

Depending on the product, Design for Remanufacture may concentrate on a particular problematic stage of the remanufacturing process e.g. disassembly which may make remanufacture of a particular product uneconomical. However taken to the full implication of the phrase, Design for Remanufacture can optimise the entire process and system of remanufacture.

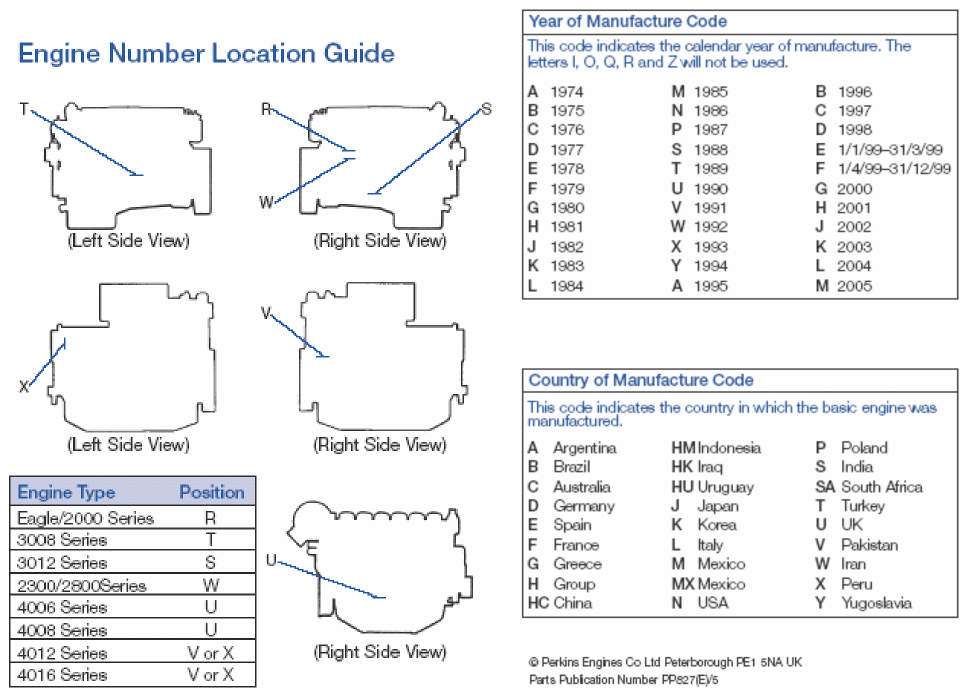
8.1 Design for Core Collection

Core return relies on both the business model and detailed product design. The business models of Xerox and Caterpillar for core collection will be described in later sections.

Detailed product design can also visually communicate end-of-life processes. For example, this may include labels positioned on packaging, the product's exterior or inside the product. The positioning of the label will depend on the intended viewer, how they may view it and how they will use the information. Labels may also incorporate radio frequency identification (RFID) to allow a vast array of information to be held.

Graphical communication, packaging or even the form of a product may also be able to communicate collection. The basic concept of using graphics to simply communicate product information is demonstrated by Perkins guide for identifying engine type:

An example of visual communication of product information at Perkins



Engine Type	Position
Eagle/2000 Series	R
3008 Series	T
3012 Series	S
2300/2800Series	W
4006 Series	U
4008 Series	U
4012 Series	V or X
4016 Series	V or X

Year of Manufacture Code

This code indicates the calendar year of manufacture. The letters I, O, Q, R and Z will not be used.

A	1974	M	1985	B	1996
B	1975	N	1986	C	1997
C	1976	P	1987	D	1998
D	1977	S	1988	E	1/1/99–31/3/99
E	1978	T	1989	F	1/4/99–31/12/99
F	1979	U	1990	G	2000
G	1980	V	1991	H	2001
H	1981	W	1992	J	2002
J	1982	X	1993	K	2003
K	1983	Y	1994	L	2004
L	1984	A	1995	M	2005

Country of Manufacture Code

This code indicates the country in which the basic engine was manufactured.

A	Argentina	HM	Indonesia	P	Poland
B	Brazil	HK	Iraq	S	India
C	Australia	HU	Uruguay	SA	South Africa
D	Germany	J	Japan	T	Turkey
E	Spain	K	Korea	U	UK
F	France	L	Italy	V	Pakistan
G	Greece	M	Mexico	W	Iran
H	Group	MX	Mexico	X	Peru
HC	China	N	USA	Y	Yugoslavia

www.perkins.com, 2006

8.2 Eco-Design

The aim of integrating environmental considerations into product design and development is to reduce products' adverse environmental impacts throughout a product's lifecycle (BSI, 2002) and is detailed by ISO TR 14062. Specifically, Design for Remanufacture suggests designing with a product's end-of-life in mind, however there are lifecycle considerations that may also impact on the process of remanufacture. Examples of possible eco-design approaches that may impact on Design for Remanufacture are (BSI, 2002) shown in the following sections 7.2.1-

7.2.6. Eco-design's backbone is lifecycle thinking and management, however examples of specific eco-design strategies which can support lifecycle thinking are shown in sections 7.3-7.6.

8.2.1 Improvement of Materials' Efficiency

This technique asks whether environmental impact can be reduced by minimal use of materials, use of low impact materials, use of low impact materials, use of renewable materials, and/or use of recovered materials. The specification of minimal materials may reduce time and complexity of remanufacture.

8.2.2 Improvement of Energy Efficiency

This technique considers total energy use throughout the product's lifecycle, and questions whether it is possible to reduce energy in use, use low impact energy sources, use energy from renewable sources. Design for Remanufacture may specify materials which require low energy in manufacture and may also reduce the energy costs of remanufacture. Business models Designed for Remanufacture may specify the use of renewable energies in remanufacture.

8.2.3 Reduced Land Use

This aspect of eco-design may be particularly relevant when land-consuming infrastructure is utilised in the product system. Both detailed product design and business models may investigate reducing the physical footprint of a remanufacturing facility to reduce costs and increase production efficiencies. Reduced land-use may result in smaller remanufacturing facilities and therefore reduced costs for the remanufacturing operation.

8.2.4 Design for Cleaner Production and Use

This aspect promotes the use of cleaner production techniques, avoiding the use of hazardous consumables and auxiliary materials and using an overall systems perspective to avoid decisions based on a single environmental criterion. The avoidance of hazardous chemicals in production may eliminate the need for such chemicals in remanufacture. The avoidance of potentially hazardous substances in the product may protect human health, safety and environmental aspects during remanufacture.

8.2.5 Design for Optimising Functionality

Considering opportunities for multiple functions, modularity, automated control and optimization may promote remanufacture by the use of common and/or modular parts.

Design for Durability is another aspect of Eco-design and will be considered in the following sections.

8.2.6 Design for Reuse

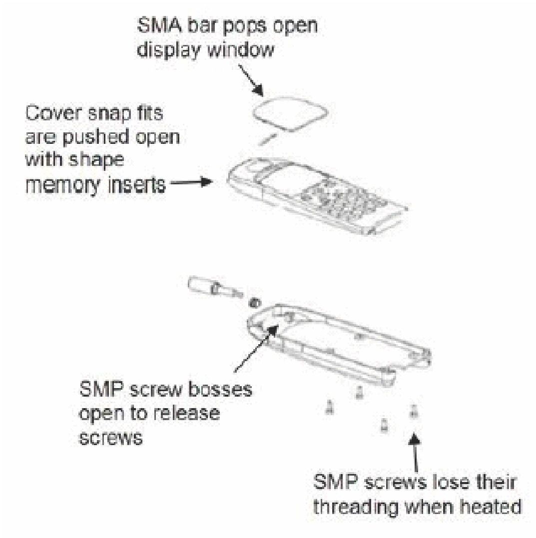
Design for Reuse, Recovery and Recycling may be the broad eco-design approach that most clearly relates to a product's end-of-life and may therefore increase the speed and reduce the costs of remanufacture is Design for Reuse.

Design for Disassembly is likely to be an essential component of any efforts to recover intact components and materials; it is therefore an important aspect of Design for Remanufacture.

8.3 Design for Disassembly

Design for Disassembly is an important enabling component of end-of-life procedures. The elimination of hazardous materials is an aspect of eco-design that facilitates Design for Disassembly and remanufacture by reducing the safeguards required. Aside from those specified in legislation, various 'black', 'grey' and 'white' lists of materials are freely available on the internet from organisations such as Volvo.

Active Disassembly using Shape Memory Alloys and Shape Memory Polymers



Active Disassembly Research Ltd, 2007

The impact of Design for Disassembly on assembly and reassembly times is contentious with some sources citing it as slowing assembly times and others saying it reduces time required for assembly. Essentially in terms of remanufacture, Design for Disassembly enables the removal of parts without damage and can therefore reduce the remediation process and requirements for new, replacement parts.

Research into disassembly is being done by a few organisations in the UK such as Active Disassembly Research Ltd. The Nokia Research Centre is also investigating disassembly mechanisms and has developed a prototype phone with a built in "active disassembly" mechanism, designed to aid the recycling of materials at the end of the phone's life (Kurk and McNamara, date unknown).

In the Automotive industry, Hammond et. al (1998) identify that corrosion/rust is the biggest hindrance to disassembly. From a detailed design perspective, the problem of corrosion could be helped by, for example, better isolation of parts from the elements, the specification of non-corrosive materials or the use of different fastening mechanisms to name.

A survey of Electrical Rebuilders

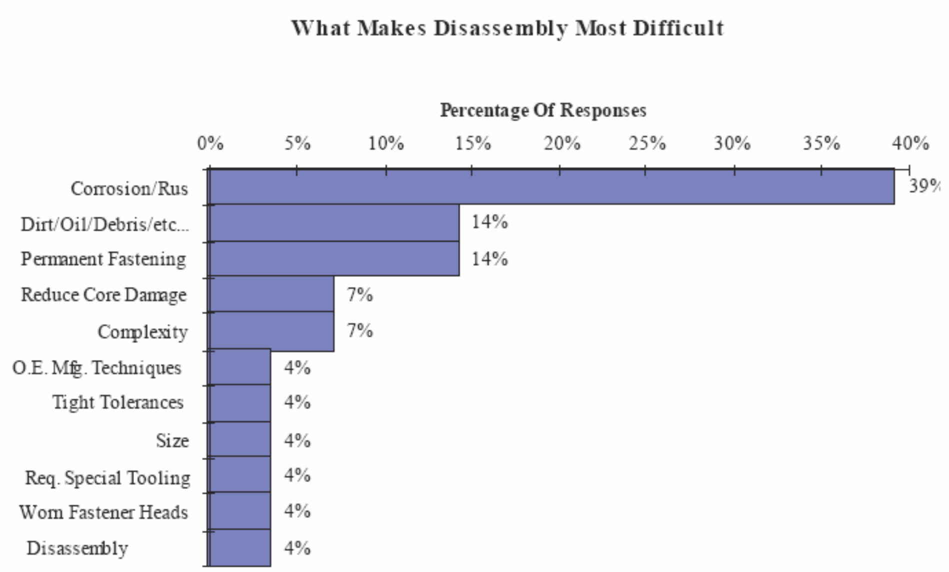


Figure 3 – Responses to Question 3: Difficulties To Disassembly

Richard Hammond et. al, 1998

The lack of skills is the biggest to hindrance for reassembly in the Electrical Rebuilders section of the automotive industry (Hammond et. al, 1998). This could suggest employees need greater training, but also makes the case for simpler product designs leading to more intuitive reassembly procedures.

A survey of Electrical Rebuilders

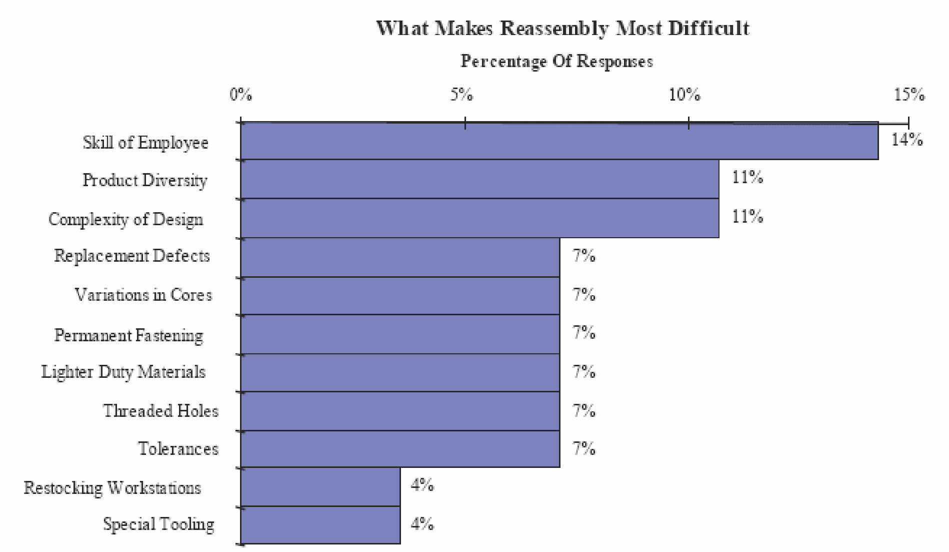


Figure 7 – Responses to Question 7: Difficulties to Reassembly

Richard Hammond et. al, 1998

8.4 Design for Multiple Lifecycles

Design for Multiple Lifecycles includes consideration of:

- Cleaning
- Product reliability
- Durability
- Remediation

However Design for Multiple Lifecycles is not necessarily required for all products or components. Nasr and Thurston (2006) argue that some components may be designated, by design, for single or multiple reuse, for single or multiple remanufacturing, for recycling, or for disposal. Depending on the product sector, multiple life spans may infer product upgrade. In this report, Design for Upgrade will be considered separately from Design for Multiple Lifecycles.

Design for Reconditioning may reduce the use of forms that gather dirt

8.4.1 Design for Cleaning

The component's physical form should enable appropriate cleaning. Such physical structures may mean that materials do not accumulate on the part during its lifecycle, resulting in better performance and reliability. In some product applications this could be actually be negative in terms of a particular component's functionality; in these cases the designer must make a judgement.

The graph below suggests the priority areas that Design for Remanufacture may tackle regarding cleaning in the automotive industry.

A survey of Electrical Rebuilders

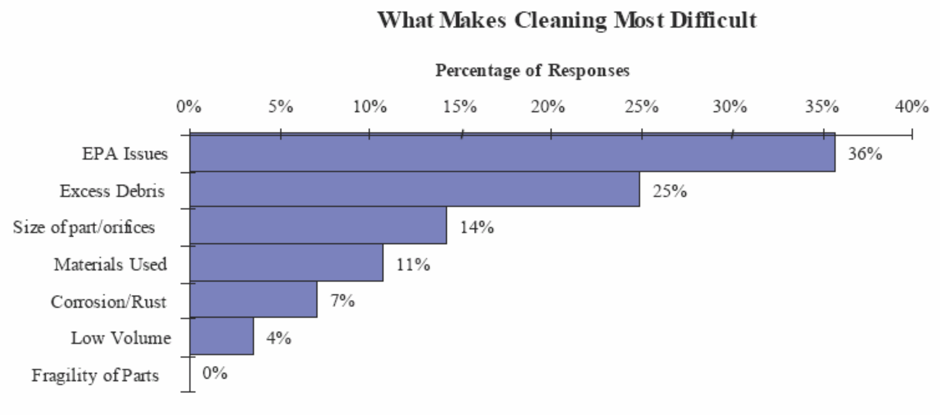


Figure 4 – Responses to Question 4: Difficulties to Cleaning

Richard Hammond et. al, 1998

8.4.2 Design for Reliability & Durability

> *'Environmentally, there is a need to decrease the duration of remanufacture and the frequency a product is remanufactured."*
>
> Ron Giuntini, 2006

Design for Reliability includes specification of materials fit for purpose, and also communication to the user, or a person acting for the manufacturer, when testing or check-ups are required. This communication may be done by a system of manual notification e.g. by a letter that is automatically sent out according to the product's average life span. A more product-personal and technologically sophisticated method may be available, depending on the product and its usage e.g. automotive mechatronics where the product may record its life and history and report back to an engineer that it may need replacing.

Even though remanufacture generally uses considerably less energy than manufacture, if a product or component is more reliable it will require remanufacture less often and therefore less energy will be used; giving an environmental saving.

Design for Durability requires the specification of materials appropriate to intended usage over the lifetime of the product however these materials may not themselves have to last the full lifetime of the product, but in this case they should be selected to enable remediation.

8.4.3 Design for Remediation

Design for Remediation will include the specification of component materials and consideration of other materials likely to be encountered in the lifespan of the product e.g. oils. Where applicable, cleaning substances for those materials should also be identified and specified simultaneous to the design process.

A survey of Electrical Rebuilders

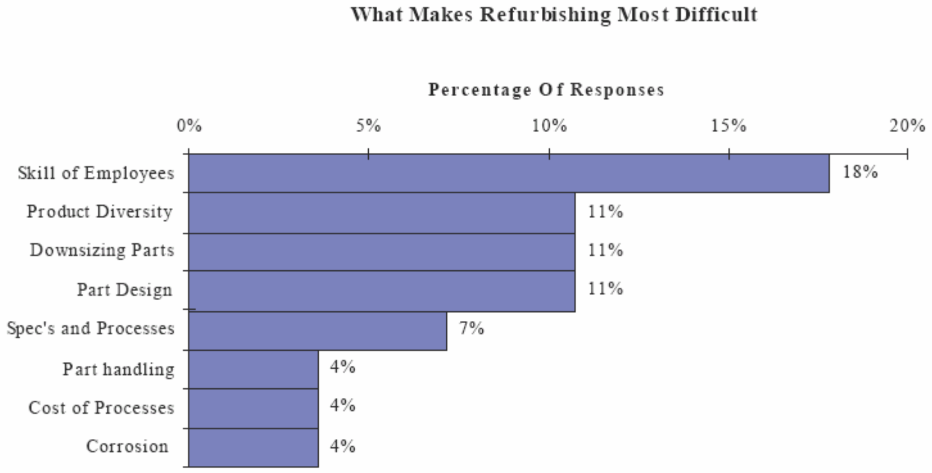


Figure 6 – Responses to Question 6: Difficulties To Refurbishing

Richard Hammond et. al, 1998

8.5 Design for Upgrade

Design for Upgrade is applicable in cases where components or products have a market life that brings them into the realms of technological change. As such, Design for Upgrade may be considered a component of Design for Multiple Lifecycles. The increasing rates of technological/aesthetic change in the consumer markets, make design for upgrade particularly relevant to remanufacturing in this sector. Upgrading product function to meet customer requirements can prolong the functional life of products (Sundin, 2004).

Although Design for Upgrade is very closely related to Design for Multiple Lifecycles, for clarity, it is useful to consider Design for Upgrade separately. Design for upgrade comprises:

- Platform Design
- Design for Optimum Life

A Xerox copier, remanufactured into an upgraded copier

Xerox, date unknown b

8.5.1 Platform Design

'Platform' or 'Modular' design is used to cluster components with similar technical and market life. In platform design, essential components can be grouped in platforms and those that are likely to become faulty or defunct can also be grouped; creating platforms upon which the next generation can be based.

In order to preserve the useful aspects of components, platform design may actually require more components rather than less, which would allow defunct aspects to be removed whilst retaining the useful aspects.

8.5.2 Design for Optimum Life

Design for Optimum Lifespan requires communication to the customer of when the optimum lifespan has been reached. 'Optimum' may be used in the context of environmental impact, functionality and/or profit and may apply to one or more products, however the three areas are linked and can to an extent run in parallel.

In contrast, Harrison (2006) states 'Ideally all the redundancies should happen at the same time.' This would ensure that the full value had been achieved from the product over the lifespan, and enable all of the components to be remanufactured at the same time.

> *'Other components that may incur variable levels of degradation during product use cannot necessarily have a predetermined end-of-life strategy.*
>
> *These components must first undergo a condition assessment process to determine the residual life and value. For these components, the end-of-life decision criteria should be spelled out during product development.'*
>
> Nabil Nasr and Michael Thurston, 2006

Examples of how Optimum Life may be communicated to the user may be:

- Functional Obsolescence. A single key redundancy could happen to bring the product in for remanufacture. In this case the other components could just be reused.

- Aesthetic obsolescence. In consumer markets, it may even be possible to use aesthetic obsolescence as a means of communicating lifespan for remanufacture.
- RFID may be used to inform the customer or supplier that replacement / upgrade is required.

8.6 Design for Evaluation

The inspection of a product to establish its current status and history is necessary in order to apply appropriate methods for remediation.

A survey of Electrical Rebuilders

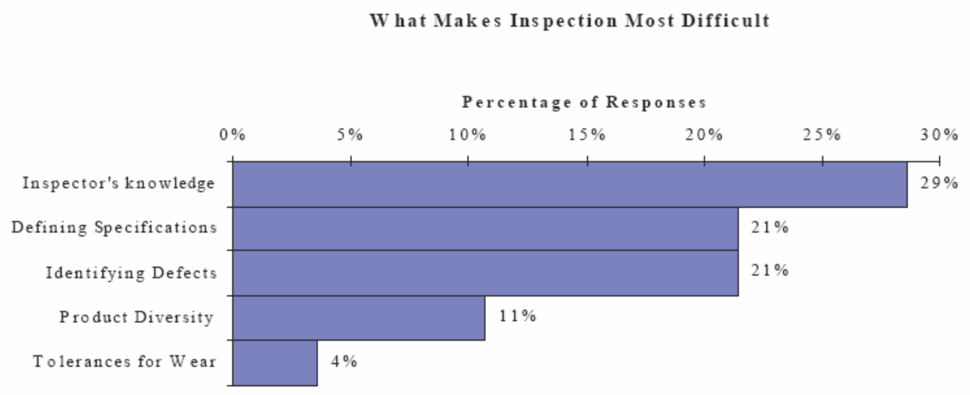


Figure 5 – Responses to Question 5: Difficulties to Inspection

Richard Hammond et. al, 1998

In Hammond, et. al, (1998), the inspector's knowledge of the inspected parts and required quality was a big issue. Other aspects such as the ability to define specifications could be resolved by legislation such as the Freedom of Information Act, or detailed design activities.

Detailed product design for evaluation may provide information regarding embedded condition or usage monitoring. This could be done through:

- Embedded data recording, or RFID which may be updated during product servicing etc.
- Sacrificial parts. The application of sacrificial aspects to a component, which would wear during use and thereby give an indication of the components' treatment over time.
- Traditional data recording of the products' multiple life history. Xerox for example keep accessible data of all their products previous lives.

8.6.1 Six Sigma

Six Sigma techniques allow remanufacturers to guarantee the quality of their remanufactured goods and are oft cited by remanufacturers as being applied to their remanufacturing operation. Six Sigma focuses on the processes themselves, ensuring that they are carried out better and faster and consequently, at lower cost.

9 Overview of the leading UK organisations and practitioners

Remanufacturing is practiced by OEMs, sub-contractors and independent remanufacturers to some extent in each industrial sector.

OEMs are starting to engage in remanufacturing, often through 3rd parties. Five years ago most OEMs were not interested in remanufacturing, and may have described remanufacturers as 'pirates' but now OEMs are seeing the value (Giuntini, 2006).

> *'the product developer/manufacturer can get the most benefit from sustainable design practices by maintaining product responsibility throughout the product life cycle.'*
>
> Nabil Nasr and Michael Thurston, 2006

However as previously mentioned, OEMs in the USA, account for less than 5% of total remanufacturing activity (Guide, 2000, cited in Sundin, 2004). It should also be noted that many OEMs (such as the B2C automotive industry) will not publicise their involvement in remanufacture to customers; this poses difficulties in understanding the real practice of remanufacture.

OEMs engaged in remanufacture are likely to encourage the use of 'genuine' parts remanufactured by the OEM themselves e.g. Perkins Engines.

9.1 Xerox

Xerox's comprehensive process for taking back 'end of life' photocopiers, printers, scanners from customers was established in the early 1990s, creating a remanufacture and parts reuse programme that forms the foundation of waste free initiatives.

Xerox take advantage of remanufacture through the design of their business model, making them global leaders in this field. Xerox's Production Systems Group (PSG) work to strict corporate targets e.g. in 2003 95% of all waste produced was recycled, which equates to 175,000 tonnes and increases year on year.

'The very nature of [Xerox's] business is to reuse existing components.'

Xerox, date unknown a

Remanufactured output now accounts for 25% of Xerox's output despite double the labour cost compared to new equipment. Globally, it is estimated to have saved $200m and recovered over 25,000 tonnes of materials from landfill. Xerox have some design functions in Welwyn Garden City, UK, but design for the global market.

9.1.1 Remanufacture

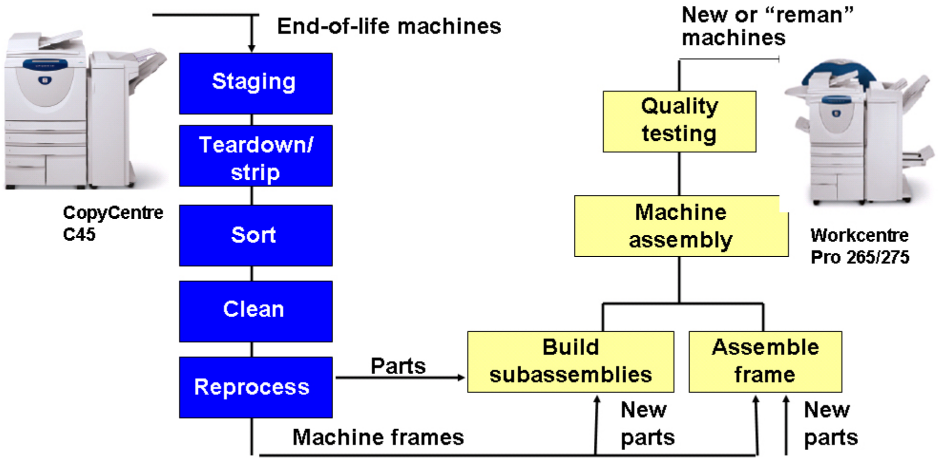
Xerox Remanufacturing Plant, Dundalk, Ireland. (Xerox, date unknown a)

At the Xerox Dundalk, Ireland site, remanufacture and 'new' production is not split making it difficult to ascertain the exact profitability of remanufacture. However it is safe to assume that remanufacturing at Xerox is a profitable business, where Xerox are able to generate up to 7 revenue streams from 2nd, 3rd, 4th, 5th, 6th and 7th life products. It is also notable to say that consumables are more profitable than original products (Cosgrove at CfSD, 2006).

Xerox use 3rd party remanufacturers where it is more efficient to do so depending on location and Xerox's business priorities in that area. Xerox predominantly out-source to Flextronics. Flextronics only remanufacture one product in Europe but remanufacture the majority of Xerox products in the USA (Cosgrove, 2007b).

The remanufacturing process starts with the business model which leases machines to customers rather than selling them. Xerox takes old machines back from customers after 5 years or more, depending on the number of copies the machine has taken.

An overview of Xerox's remanufacturing process

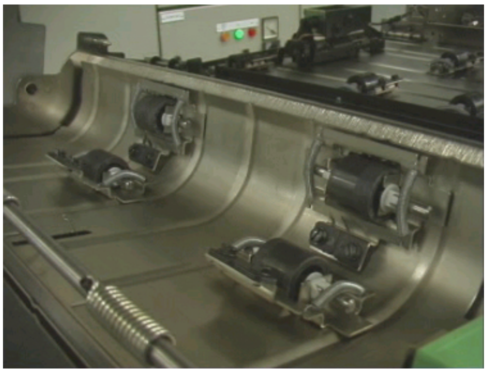


Xerox, date unknown b

Once a product reaches the Xerox remanufacturing plant it undergoes the remanufacturing process (Xerox, date unknown a)

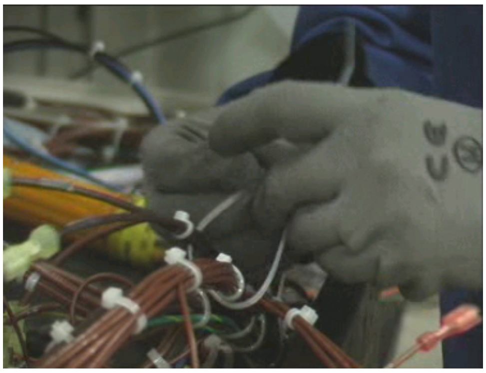
The products to be remanufactured are taken to the CO_2 spray booth where they are blasted using the principle of dry ice and compressed air.

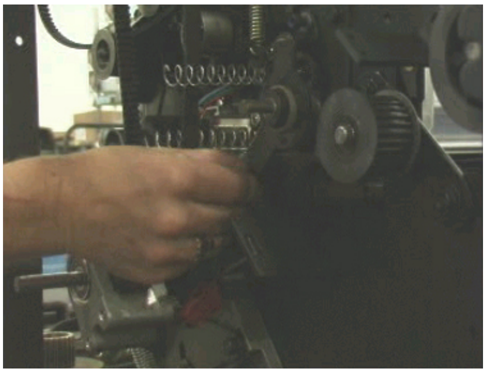
The cleaned carcasses are then taken to the spray booth where they are re-sprayed as new.




Other smaller parts are put through an ultrasonic cleaning process. They are rinsed in several tanks containing a solvent while also being bombarded with ultrasonic.

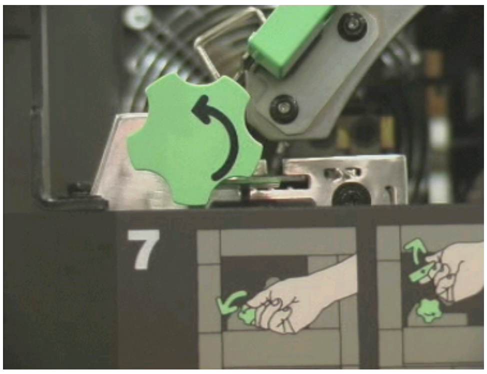
These are stripped down into up to 8,000 individual parts. Up to 80% are reused and those which are not are recycled.



Skilled and trained people take these parts and build up the new carcasses from scratch.





The final stage of the process is securing the panels onto the carcass.



Xerox's drive to remanufacture is driven by marketing and asset recovery. Collection of used equipment remains a key question for Xerox.

9.1.2 Design

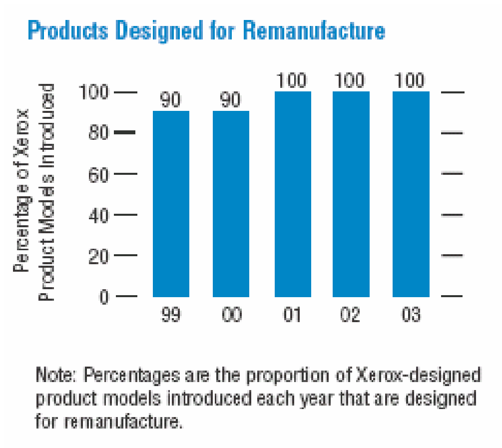
Xerox's Design for Remanufacture process starts with strategic intent. Lessons can be learnt from their approach. The company or organisation must evaluate the feasibility of remanufacture and identify it as a strategic enabler. This applies to many elements:

- Cost
- Pricing
- Customer requirement
- Environmental benefit
- Product diversification
- Market positioning
- Asset management, etc.

> *'Xerox products are designed to reduce environmental impacts in all phases of the life cycle. We design our products for remanufacturing and design imaging supply items for return, reuse and recycling. These early decisions mean that once the product's supply item or the product itself has reached its end-of-life, we maximize the assets and minimize the waste.'*
>
> Jack Azar, Xerox VP for Environment, Health & Safety. First Sustainable, 2004

Once the business model is defined, the design teams can design the products with the full life cycle requirements understood.

Machines at Xerox are designed for disassembly and contain fewer parts because of this. Parts are also designed for durability over multiple product lifecycles. As a result each new generation of Xerox products offers increasing functionality while conserving energy and materials, and requiring fewer hazardous substances throughout the product lifecycle. (Xerox, date unknown)



EHS Report 2004 (Xerox, 2004)

Since the early 1990's the strategy within Xerox has been to remanufacture certain product platforms. The designers use a common platform approach to ensure that the main engine of the machine and peripheral equipment is common across many different models. This ensures the minimum amount of unique parts and obsolescence. The production systems will have a life cycle of about 15 years but during this time the equipment may be remanufactured many times, this will include remanufacture to the same as specification or in many cases capacity/software upgrades to a better than specification. (Cosgrove at CfSD, 2006).

9.2 Perkins Engines

Perkins Engines make and remanufacture diesel engines and transmissions for armoured fighting vehicles, mobile diesel generator sets, naval and marine propulsion engines and generator sets, construction equipment.

> *'Perkins engines have earned a reputation for ease of service along with low costs of maintenance and repair. Their rugged and simple design enables local repairs to be made with a large global network of distributors.'*
>
> www.perkins.com, 2006

Perkins Engines was formed by Frank Perkins in 1932 in Peterborough, UK. Perkins Engines works in the industrial plant sector and is located in Shrewsbury, Shropshire, UK. The company was sold to Massey-Ferguson in 1959 and later became part of LucasVarity. In 1998 Caterpillar Inc. purchased the Perkins Engines Company Ltd from LucasVarity Plc for $1.35 billion. Perkins and Caterpillar engines are in service in both combat and logistics vehicles with over fifty armies around the world (www.army-technology.com, 2006).

By buying an existing plant in the UK, Caterpillar were able to enter the European market. Having a facility closer to its European customers offers the following benefits to Caterpillar:

- Significantly improves Caterpillar's response time
- Allows more customised products to meet regional customer needs
- Reduced transportation costs

Operations in Shrewsbury are beginning with the remanufacture of Caterpillar and Perkins diesel engines and components from all over Europe, Africa and the Middle East.

9.2.1 Remanufacture

In January 2004, the Caterpillar Perkins plant in Shrewsbury switched from manufacturing new diesel engines to remanufacturing. To give the scope of the impact of Perkins Engines, worldwide one in five tractors is powered by a Perkins engine. A multi-million pound factory re-fit was carried out including substantial investment in new machinery.

9.2.2 Design

The business model of Perkins Powerparts has been designed so that all products carry a 12-months warranty from date of purchase, which Perkins' website describes as 'unequivocal'. The warranty will indemnify the purchaser for the following costs associated with making the repair.

Detailed design is carried out by Caterpillar in the USA. The geographic separation of detailed design and remanufacture could potentially pose communication difficulties.

Packaging design emphasising Perkins' genuine parts

www.perkins.com, 2006

9.3 Milliken Carpets

Milliken are the first major carpet manufacturer to offer a true remanufacture capability on a carpet system. This has required the development of a unique modular carpet product. Milliken sell their product globally.

9.3.1 Remanufacture

Milliken's remanufacturing operation is driven by the market and legislation. Remanufacturing at Milliken was developed initially as the result of the vision of the technical director of Milliken Carpet in the USA, in anticipation of social and business environment trends concerning reuse and recycling, and the need to reduce resources. Observation of other industries being subject to increasing legislative constraint on their activities led Milliken to consciously adapt its manufacturing technology and range to enable its own products to be recycled.

> *'Life-cycle costing of the remanufactured product [Milliken's] shows clear benefits over newly manufactured items. Even better, the margin on the remanufactured product, despite the lower market price, is still very attractive.'*
>
> www.sustainablecarpets.com, 2006

However, remanufactured products currently account for only a small percentage of Milliken's sales.

9.3.2 Design

Milliken's remanufactured carpet range has been designed so that unwanted carpet tiles can be recovered, cleaned, retextured, and restyled in preparation for reuse, either within the same company or at another location. The cost is about half the cost of new carpet (Blum-Evitts, 2000). Milliken have also developed a glue-free carpet installation system called TractionBack™ which is available on all modular carpet products manufactured by Milliken. This is a high-friction coating applied to the backing of the modular carpet tiles. The coating allows the tile to be installed without using wet adhesive or "peel and stick" adhesives. The absence of adhesive reduces contamination and makes reprocessing easier. Milliken's remanufacturing process allows the carpet to stay intact, eliminating carpet waste.

9.4 InfoTeam

9.4.1 Remanufacture

InfoTeam International Services became the main assembly and repair centre for Sony UK and Sony Entertainment Europe in 1996. It has succeeded in retaining this prestigious contract, an achievement in the competitive outsourcing market. InfoTeam are currently remanufacturing a Sony games console. Sony have an interest to remanufacture the units and sell them to secondary markets because every game sold is additional profit (Leppard, 2006).

9.4.2 Design

InfoTeam are involved in the remanufacture of others' products and as such are not involved in the design of those products.

10 International Remanufacturing Activities

International differences in the practice of remanufacturing are driven by numerous factors including geography and culture. The historically independent countries and languages which make up Europe mean that OEM products are not spread evenly.

10.1 Key International Remanufacturing Practice

10.1.1 US Military

The US military is the biggest remanufacturer in the world (Giuntini, 2006).

Remanufacture

An example of the US military's eagerness to take advantage of the benefits of remanufacture was demonstrated in June 2005, when BAE Systems was awarded a series of delivery orders and contract modifications worth $1.127 billion from the U.S. Army Tank-automotive and Armaments Command (TACOM). The contract was to remanufacture and upgrade more than 500 Bradley Combat System vehicles.

> *'The military don't care if the product is 'new' or not.'*
>
> Ron Giuntini, 2006

Design

The extent to which the US military engage in feedback between design and remanufacture is unknown.

10.1.2 Caterpillar

Caterpillar's global remanufacturing business is currently one of the largest in the world in volume terms, recycling more than 50,000 tonnes of products (over 2.2 million end-of-life units) each year. Through their large scale activities, Caterpillar have helped change the business of remanufacture (Giuntini 2006).

> *'President Bush Supports Remanufacturing…*
>
> *In cooperation with relevant international organizations such as the OECD, we will seek through this initiative to…Reduce barriers to the international flow of goods and materials for recycling and remanufacturing, recycled and remanufactured products, and cleaner, more efficient technologies, consistent with existing environmental and trade obligations and frameworks'*
>
> www.whitehouse.gov, 2004

Remanufacture

Caterpillar first entered remanufacturing in 1972 due to a favour Caterpillar reluctantly did for Ford Motor Company: to lower its own costs, Ford's truck-making subsidiary wanted a source of rebuilt engines, which generally sell for half the price of new ones. Caterpillar's first remanufacturing plant was quickly overworked and Caterpillar soon realised the business benefits.

Caterpillar Remanufacturing Services is one of Caterpillar's fastest growing divisions - annual revenue is over $1 billion and is reputedly growing at 20% a year.

In 2005, Caterpillar spent $1.5 billion on purchasing remanufacturing facilities around the world so that Caterpillar could remanufacture in those markets. Caterpillar now has remanufacturing facilities across the globe, including Shrewsbury, UK and Nuevo Laredo, Mexico; Shanghai, China was the 14th facility and opened in early 2006. Caterpillar has been operating in China for almost 80 years. In 2005, its remanufacturing division generated over $1 billion in revenue.

Design

This revenue is in part preserved by Caterpillar branding. Any part which is remanufactured by Caterpillar is given a designed "reman" logo. This branding distinguishes Caterpillar remanufactured parts and those of 3rd parties, thereby preserving trust and creating ongoing demand for Caterpillar-branded remanufactured products.

By engaging in remanufacture, Caterpillar can increase the possibility of achieving feedback from remanufacture and design of the original products.

10.1.3 Flextronics

Flextronics offer full-spectrum design, manufacturing, remanufacturing and logistics services vertically integrated with world-class component capabilities to help OEMs create market leading products. Flextronics remanufacture only a very few of Xerox's products in Europe, but in the USA they remanufacture a large proportion of Xerox's products.

Remanufacture

Flextronics' Reverse Logistics expertise lies in:

- Consumer and midrange products
- High volume, with low to medium complexity
- Printers
- PDAs
- Mobile phones
- Consumer medical devices
- Notebooks
- PCs
- Set top boxes
- Highly complex infrastructure products

Examples of the services Flextronics provide in the area of remanufacturing include:

- Component warranty management
- Part harvesting
- Failure analysis
- Spares planning
- Remanufacturing
- A to B replenishment

Speed of service delivery is critical in the After Market sector. To this end, Flextronics provides same day turn around on repair of products such as notebook PCs. Throughout all of Flextronics Logistics' operations, they are committed to continuous improvement driven by a Six Sigma platform.

Design

By offering integrated reverse logistics solutions Flextronics can provide feedback loops into design, engineering, assembly, distribution and customer service.

10.1.4 Hanover

Hanover is a supplier of new, used, remanufactured, OEM and aftermarket parts and equipment for maintenance, repair and overhaul of equipment for natural gas compression. More research into Hanover's remanufacturing activities is required.

> *'[Hanover] is probably the most intensive remanufacturer in the world'*
>
> Ron Giuntini, 2006

10.1.5 Siemens AG Refurbished Systems – a comparative example

Siemens Medical Systems refurbish (not remanufacture) some product lines. This example is given to demonstrate that the importance of customer assurance of quality applies to all elements of 're' and is not unique to remanufacture.

Since 1998, Siemens Medical Systems has offered to take old devices back from its customers for the process of refurbishment. The 'refurbished' Siemens product is likely to be sold with a reduced warranty and would not be considered to meet the quality standards of a new Siemens product.

> *'During comprehensive refurbishment of used systems, only original parts are used. We apply the same strict quality standards as for new systems'*
>
> Hans-Peter Seubert, Manager, New Product Group. (Siemens, 2006)

In 2000, the Refurbished Systems product group was established to market used systems. In the past year, Siemens say nearly 800 refurbished systems with the "Proven Excellence" quality seal have been sold worldwide.

The Siemens Medical Solutions Refurbished Systems division offers refurbished medical equipment from several different modalities. Through the Siemens "Proven Excellence" programme, all systems undergo an in-depth refurbishment process to ensure the high quality which they claim only the original manufacturer can offer. These refurbished systems are offered to customers world-wide.

The Siemens "Proven Excellence" Logo. Designed to instil customer confidence in Siemens' refurbished products

Siemens, 2006

10.2 Key International Research Expertise

Design for Remanufacture where practised at all, is likely to be limited to a small number of OEMs who engage in the remanufacture of their own products and therefore have an incentive to increase the efficiency of remanufacture. Information on international Design for Remanufacture activities is therefore difficult to access.

There is research occurring as to how the remanufacturing process may be optimised for specific products e.g. by Rolf Steinhilper at The European Research Center for Remanufacturing, there appears to be little work being carried out on Design for Remanufacture.

As an example of international activities, a brief overview of some international research expertise is given here:

10.2.1 UK

Organisation:	Oakdene Hollins Ltd
Aim:	Supported by Defra, OHL aim to act as a focal or coordination point for the understanding of remanufacturing issues. OHL aim to target research going forward and offer operational support to initiatives that have a direct impact on remanufacturing practices.
Sector:	Non-sector specific
Leader:	David Parker

10.2.2 Germany

Organisation:	European Research Center for Remanufacturing, Bayreuth, Germany.
Sector:	Car Mechatronics
Leader:	Professor Rolf Steinhilper

10.2.3 USA

Organisation:	US National Center for Remanufacturing, Rochester, N.Y., USA.
Sector:	Office & Industrial Electronics
Leader:	Professor Nabil Nasr

10.2.4 China

Organisation:	National Key Laboratory for Remanufacturing, Beijing, China
Sector:	Mechanical & Surface Treatment
Leader:	Professor Zhu Sheng

10.2.5 South Africa

Organisation:	National c/o Life Cycle Engineering University, Pretoria, South Africa
Sector:	New markets for remanufactured products
Leader:	Professor Alan Brent

10.2.6 Korea

Organisation:	Korea Institute of Industrial Technology (KITECH) & Korea National Cleaner Production Center (KNCPC)
Sector:	Automotive, electronics, etc
Leader:	Unknown

10.2.7 International

Organisation:	Fraunhofer - Institute for Experimental Software Engineering (IESE)
Sector:	Processes, methods, and techniques for developing software-based systems according to engineering-style principles
Leader:	Unknown

11 Drivers of Remanufacture

An understanding of the drivers of remanufacture gives insight into how business models may be Designed for Remanufacture. The two key drivers of the remanufacturing industry are market demand and legislation; of these two drivers, market demand is the major driver.

Drivers vary depending on whether the remanufactured item is a spare part or product, and their market (B2G, B2B or B2C). The impact of some drivers is unclear, particularly legislation such as the Waste Electrical and Electronic Equipment (WEEE) Directive, which may actually pose barriers as well as theoretically drive remanufacture. Distinct challenges will be discussed in the following section, whereas those that may be both a driver and a barrier are discussed here.

11.1 Market demand

Market demand may vary depending on the product type or market being considered. Design for Remanufacture (particularly business model design) must take the market into consideration.

11.1.1 Price

As in other industries, the more established the market, the higher the price for remanufactured products. Although remanufactured spare parts could be (and sometimes are) sold at 30-70% of the cost of new, remanufacture is shown to work best in markets when there is no discount for remanufactured items compared to new. In these cases the market has accepted the remanufacturer's offer that its goods are as good as new. The supply of core is so vital to remanufacturers that often in these markets, remanufacturers (such as Caterpillar) initially pay for cores in order to secure a good flow of high quality cores (Morley, 2006).

> *'Remanufacturing is generally less successful when remanufactured products are sold at a large discount to new.'*
>
> Nick Morley, 2007

The generally reduced production costs of remanufacture mean that remanufacture is a profitable industry, although as previously discussed the evidence for this is predominantly anecdotal. For example, Steinhilper (2006) recalls a story about a company who began remanufacturing vending machines and selling them at the same price as new, and doubled their profit margin.

11.1.2 Purchase Considerations

Procurement in B2G and B2B transactions is likely to involve a greater consideration of cost than B2C issues. Quality will also be considered by these markets in particular, in terms of fitness for purpose. Although a remanufactured product would by default be as fit for purpose as a new product, the time and thought required by purchasers and the potential obstacles posed by others, may make the simplicity of 'business as usual' i.e. buying a known 'new' product, the easiest option.

Market	Basic Purchase considerations				
	Functionality	Cost	Environment	Development time	Emotive factors
B2G	√	√	√		
B2B	√	√		√	
B2C	√				√

Buying 'new' is particularly prevalent in B2C markets where misconceptions and concerns over the quality of '2nd hand' products are diffuse. This makes B2C markets especially resistant to remanufactured products. Design for Remanufacture, may be able to contribute to changing this situation, particularly through branding.

Where the purchase is *forced* rather than *chosen* such as in the case of a spare part required to repair a broken down car, cost is a more significant deciding factor, because the expense was not planned. In this case the customer is likely to be happy to buy a remanufactured spare part, which costs less than a new part.

However, when a product is considered valuable by the owner e.g. a vehicle which is new or only a few years old, customers are more prepared to spend extra on purchasing a 'new' spare part (Steinhilper, 2006). In contrast, to spare parts, products are generally purchased consciously after a consideration of needs/wants and costs.

11.1.3 Continued supply

OEMs may be obliged to supply spare parts for products for a certain length of time after production ceases. By designing a business model which provides these spare parts through remanufacture, OEMs are able to cease production of small numbers of new spare parts for old product lines. This means remanufacture can offer a further cost saving to the OEM.

> *'If [Morvend] sell something they [generally] sell new. If a customer wants a machine that isn't manufactured anymore, then remanufactured products are useful in that way.'*
>
> Anon, Morvend, 2007

11.2 Legislation

Legislation can be both a driver and a barrier for remanufacture. The impact of legislation on remanufacture needs to be understood to design successful business models for remanufacture. Within this, it is useful to remember that the majority of existing legislation applies to products but does not apply to spare parts.

Some legislation such as the Sales of Goods Act (SoGA) appears to constrain remanufacture, whereas it is still unclear whether other, new legislation such as the WEEE Directive will promote or hinder remanufacture. This section will describe legislation which may drive and constrain remanufacture, whereas legislation which only appears to constrain remanufacture will be described in the following section 11 'Challenges to Increased Remanufacture'.

Legislation which may have an impact (whether positive or negative) on remanufacture is:

- Landfill Directive
- Waste Electrical and Electronic Equipment (WEEE) Directive
- Restriction of Hazardous Substances (RoHS) Directive
- End of Life Vehicle (ELV) Directive
- Energy-Using-Products (EuP) Directive
- Freedom of Information Act (FoIA)

11.2.1 Landfill Directive

With increasing Landfill taxes, the advantage for producers to rely on landfill is decreasing with time. Landfill is neither an environmentally or commercially sustainable option and so producers are exploring alternative end-of-life scenarios. Remanufacture is one of many alternatives to landfill and is increasingly being seen as an effective means of generating revenue.

11.2.2 Waste Electrical and Electronic Equipment (WEEE) Directive

> *'WEEE is stopping remanufacture.'*
>
> Ray Gould, Southern Appliances, 2006

The WEEE Directive aims to reduce landfill and support more sustainable development by providing the impetus to boost recycling. The UK finally passed WEEE in early 2007 and it will require all products placed on the market after 1 April 2007 to be marked with a crossed out wheelie bin symbol (Clements, 2007). The UK was one of the last two countries in Europe to implement.

> *'We are involved in remanufacture but we see no advantage to remanufacture with regards to these Directives [WEEE]'*
>
> Dr Kieren Mayers, Environmental Programmes Manager, Sony Computer Entertainment Europe, 2007

The Directive mostly affects electronic and electrical manufacturers and importers. When the Directive eventually comes into force in the UK, OEMs will be required to take responsibility for treating and recycling their new products when the products are no longer wanted by their owner. The Directive applies to new products but producers will also be made collectively responsible for goods already on the market.

The implications of WEEE for remanufacturing are still unclear. Some see it as a driver for remanufacture while some believe its emphasis on recycling actually prevents remanufacture (Gould, 2006; Parker, 2007). One reason that re-use is not encouraged is that levels of re-use are difficult to record. The Government is exploring ways of recording 'reuse' and making it count towards recovery targets but they are having difficulties in establishing an effective methodology (Harding, 2006).

> *'[WEEE] will force a lot of equipment to be scrapped and not reused in the short to medium term especially if provenance is unknown.'*
>
> Nick Morley and David Parker, 2007

Recharger Magazine (2002) stated that one of the most important parts of the WEEE Directive is Article 4 which says that Member States are required to ensure that producers do not prevent WEEE from being re-used '…unless such specific design features or manufacturing processes present overriding advantages, for example, with regard to the protection of the environment and/or safety requirements.' Re-use in this case can relate to remanufacture and this shows that WEEE does not close the door firmly against OEMs preventing remanufacture.

> *'[establishing methods for recording reuse and making it count towards recovery targets] is problematic at the moment.'*
>
> Adrian Harding, Policy Advisor (Producer Responsibility), Environment Agency, 2006

Adding to current confusion on the impact of WEEE on remanufacture, last minute revisions to WEEE include three new exemptions, two of which are potentially relevant to remanufacture; these concern:

- Repair/refurbishment
- Storage

> *'I think the WEEE Directive could provide the tipping point – not necessarily from the outset, but perhaps over time.'*
>
> Guy Leppard, InfoTeam, 2006

Under the terms of WEEE, buildings such as retail shops which may be used to store products e.g. a washing machine returned for remanufacture, have to be registered to store 'hazardous waste' (Gould, 2006). This adds to the complications of remanufacturing.

If a product has been put on the UK market before, and is remanufactured[2] and put on the market again, it has no obligation under WEEE. However, if a product is sold in another country and then imported into the UK and sold as a 'refurbished' product, it will be considered a new product and so WEEE will apply (Harding, 2006).

Further information is planned for release in very early 2007 when the DTI will publish guidance to WEEE; there will be reference to remanufacturing and whether or not it incurs producer responsibility. The Environment Agency will also be publishing information in early 2007 (Harding, 2006).

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[2] The term 'refurbished' was used by Harding (2006); in the context it was understood by the Author to have been used as a general term for re-use strategies, including 'remanufacture'.

Revisions to WEEE will be completed by 2008. These revisions potentially pose opportunities for the correction of aspects of WEEE that may be counter-intuitive to the Directive's aims to reduce waste.

11.2.3 Restriction of Hazardous Substances (RoHS) Directive

The Restriction of Hazardous Substances (RoHS) legislation removes six hazardous materials from electronics products and aims to reduce environmental impacts of waste and improve recyclability. The Directive restricts the use of a range of potentially hazardous materials in products manufactured for sale in the UK market.

By restricting dangerous substances, RoHS aids eco-design and specifically Design for Disassembly making the work of the remanufacturer safer; RoHS can therefore be seen as a facilitator of remanufacture. However markets for remanufactured products in developing countries may be negatively affected by RoHS.

In the short to medium term, RoHS will force a lot of equipment to be scrapped and not reused, especially if its provenance is unknown (Morley and Parker, 2007). The identification of provenance and components' history may be useful in preventing scrapping of potentially remanufacturable parts. Detailed product design may be able to contribute here through Design for Evaluation strategies as previously discussed.

> *'Well-meaning schemes that pass on the industrialised world's mobile phones and computers to the developing world could constitute toxic dumping by the back door, a meeting organised by the United Nations heard this week.'*
>
> Steve Freeman, 2006

11.2.4 End of Life Vehicle (ELV) Directive

The ELV Directive (2000/53/EC) is concerned with cars, vans and certain three-wheeled vehicles. The Directive was due to be transposed into national law in all Member States by 21 April 2002. The UK and most other Member States missed this deadline.

> *'With the current pressures on OEM's to meet environmental targets were optimistic that this [ELV Directive] will force their hand to remanufacture/reuse a greater percentage of end of life vehicle components.'*
>
> Kevin Haynes, OEM Contracts Manager, ATP, 2006

Around two million vehicles reach the end of their life in the UK each year. Currently, between 74-80% of the weight of a typical ELV is re-used or recycled. European Union Member States must ensure:

- Producers limit the use of certain hazardous substances in the manufacture of new vehicles and automotive components and promote the recyclability of their vehicles
- ELVs are subject to de-pollution prior to dismantling, recycling or disposal
- Treatment facilities operate to higher environmental standards and have permits if they want to deal with undepolluted ELVs
- Certain recovery and recycling targets are met by 1 January 2006 and 1 January 2015

- Producers pay 'all or a significant part' of the costs of treating negative or nil value ELVs at treatment facilities by 2007

The ELV Directive will require vehicle manufacturers to take responsibility of vehicles and therefore potentially bring remanufacture into consideration. However the Directive suffers similar issues to WEEE - no credit is offered for remanufacture. The DTI have limited interest in promoting the remanufacture of vehicles as they see a recovery route for the largest metal fraction; business models must ensure that economics can drive recovery routes for the rest (Morley and Parker, 2007).

11.2.5 Energy using Products (EuP) Directive

The EuP Directive provides a coherent framework for continuous improvement of the environmental performance of energy-using products, which avoids the adoption of uncoordinated measures which could lead to an overall negative environmental impact (Papdoyannakis, 2006). Under EuP, products will be designed, manufactured and operated with a focus on ease of end-of-life management (Craw-Ivanco, 2006).

EuP therefore is a driver of eco-design, and end-of-life strategies which include but are not limited to, remanufacture.

11.2.6 Freedom of Information Act (FoIA)

The FoIA seeks to give individuals the right of access to information held by governments and corporate bodies. In the USA FoIA allows remanufacturers access to OEMs' design specifications allowing 3rd party remanufacturers to remanufacture to original specifications.

12 Challenges to Increased Design for Remanufacture

Aside from the normal business pressures of time and money, there are numerous challenges to remanufacture. These challenges can be roughly grouped by issue:

- Markets
- Legislation
- Design
- Business
- Knowledge

12.1 Market Demand

12.1.1 Establishing Markets

Establishing markets is key to driving remanufacture. Customer belief in remanufactured products needs to be established in order for markets to strengthen. Customer belief in a product (and therefore market strength) means that 'as new' prices can be charged, enabling remanufacturers to use their larger profit margin as leverage for core return.

12.1.2 Trade Barriers

Trade barriers mean that remanufacturers may have to procure a remanufacturing plant in a particular country in order to sell remanufactured products in that country. To give an example of this, in 2005, Caterpillar spent $1.5 billion to have access to remanufacturers in different countries around the world.

12.1.3 The Open market

The open market provides challenges to remanufacture by introducing more competition into the market and complicating distribution/collection systems. For example, BT used to remanufacture/refurbish all of their products. This was possible because 15 years ago (when the market was closed e.g. when there was a monopoly) and only BT phone's could be used on the system. BT therefore had control over the products, delivery and collection and could refurbish the phones. Since the market opened up, this controlled system has been compromised (Chiodo, 2007).

12.1.4 Concept of 'New' and the Concept of 'Waste'

> *'If [commercial customers] lease they are quite happy to [lease] a new machine. Vending machines do not cost a lot of money in the grand scheme of things so it doesn't really matter.'*
>
> Anon, Morvend, 2006

Establishing markets for products will also require a challenge to the desirability of the 'new'. There is a temptation to purchase new products rather than used (Steinhilper, 2006). This is present in all markets to an extent but particularly in B2C markets. The elements of 're' need to be marketed to demonstrate their positive characteristics and eliminate misconceptions and fundamental assumptions of poor quality and low status. Financial factors also affect the decision to by new or used e.g. a new product may cost the same or less than a used product.

Legislation can describe used products as waste and so the storage of used products can be determined to be the storage of hazardous waste (Gould, 2006). This definition of waste therefore acts as a disincentive to organisations engaging in the reuse of products. A redefinition of what constitutes 'waste' is required to enable further remanufacture (Statham, 2006). As discussed previously, legislation which defines waste (notably e-waste from developed countries) as containing hazardous substances has the potential to challenge some markets for remanufactured products. Design may be utilised to remove hazardous substances from products if they are discovered to be hazardous or unnecessary.

12.1.5 Lifecycle costs

Getting customers to consider lifecycle costs is a key challenge for all movements towards sustainability and remanufacturing is no exception. The price of new products needs to reflect the true environmental cost.

The method of payment for services such as repair also needs to be addressed. This is particularly poignant in certain sectors of the B2C market such as white goods; for a customer to repair a washing machine, they must pay cash upfront, whereas if they were to buy new, they may be able to purchase it on credit (Gould, 2006). This is a big challenge for repair and demonstrates that the payment and reward for remanufacture should be immediate.

12.2 Legislation

As described, the impact of legislation on remanufacture is varied; in particular the impact of WEEE and RoHS on remanufacture is uncertain. The Trade Descriptions Act (TDA), the FoIA and the SoGA are also hampering remanufacture to varying degrees. The legislative framework needs to be changed to facilitate remanufacture rather than hinder it. This primarily requires an understanding of how to measure reuse.

12.2.1 Waste Electrical and Electronic Equipment (WEEE) Directive

As mentioned previously, the implications of WEEE for remanufacturing are unclear. Some see it as a driver for remanufacture whilst others believe its concentration on recycling prevents remanufacture. Design of the business model for remanufacture could be used to prevent OEM objections to remanufacture by making remanufacture a more desirable option than 'business as usual'.

12.2.2 Restriction of Hazardous Substances (RoHS) Directive

RoHS may restrict markets for remanufactured products that contain substances that are now termed 'hazardous'. Design for Remanufacture, and in particular Design for Upgrade may be used to remove hazardous aspects and take future legislation into account.

12.2.3 The Trade Descriptions Act (TDA)

The TDA 1968 is an Act of the Parliament that prevents manufacturers, retailers or service industry providers misleading consumers as to what they are purchasing. The Act makes it an offence if a trader:

- Applies a false trade description to any goods; or
- Supplies or offers to supply any goods to which a false trade description is applied; or
- Makes certain kinds of false statement about the provision of any services, accommodation or facilities.

If a product has been remanufactured, this must be communicated to the customer in some way e.g. in the contract of sale. It is possible that potential remanufacturers, particularly in B2C markets, may be reluctant to advertise their remanufacturing activities because of perceived customer perceptions. In this way TDA may discourage remanufacture.

12.2.4 Freedom of Information Act (FoIA)

In contrast to the USA, in Europe there is a lack of access to OEMs' design specifications and this requires independent remanufacturers to reverse engineer products and parts to discover the specification data, adding to the development of time and investment costs of remanufacture.

This situation affects different industry sectors in different ways. Although it is possible to acquire data from the USA where the FoIA is more diffuse, the automotive industry is particularly challenged by the barriers of withheld information (OHL, 2004). It is difficult to determine incentives for OEMs to communicate product specification data to independent remanufacturers but if remanufacture by 3rd parties is to be encouraged, incentives for OEMs to reveal specifications must be established.

12.2.5 Sales of Goods Act (SoGA)

SoGA relates to remanufacture because it affects the retailers relationship with warranties. SoGA declares that when goods are bought, they must conform to contract. This means they must be as described, fit for purpose and of satisfactory quality (i.e. not inherently faulty at the time of sale). Goods are of satisfactory quality if they reach the standard that a reasonable person would regard as satisfactory, taking into account the price and any description. Aspects of quality include fitness for purpose, freedom from minor defects, appearance and finish, durability and safety. SoGA therefore has implications for warranties, and incentives to manufacturers to design quality goods.

SoGA applies predominantly to B2C transactions because it is assumed that consumers are reliant on the retailer's knowledge whereas businesses are assumed to have the ability to make its own evaluation that an item "conforms to contract".

> *'The rules, regulations and warranties associated with second hand goods mean that the simplest way [for retail] is to not get involved.'*
>
> Ray Gould, 2006

SoGA states that it is the retailer, not the manufacturer, who is responsible if goods go wrong. When a consumer purchases a product, the warranty is held by the retailer not the consumer. Therefore when the consumer claims for a malfunctioning part or product, that claim is against the retailer; the retailer then has to sue the manufacturer for the amount. This means that there is no direct connection or responsibility between the manufacturer and the end consumer and therefore little incentive for the manufacturers to produce reliable products.

12.3 Design Skills and Education

12.3.1 Connecting Design and Remanufacture

There is currently little connection between product design, engineering and remanufacture. This disconnect is symptomatic of historical difficulties design has faced in making its value appreciated by business.

'They ought to be giving feedback between design and remanufacture.'

David Harrison, 2006

> *'It is absolutely essential for the European Commission to press the case for environmentally friendly design – certain OEM's spin their environment credentials while their actions prove the opposite is true"*
>
> Alan Castro, Lasercare Anglia in UKCRA, 2006

In order for an effective link between design and remanufacture to occur, the potential of design to aid remanufacture needs to be better understood by all stakeholders and making both the business, as well as the environmental case is essential.

> *'As more companies begin to adopt sustainable product strategies, technologies and design practices that aid in sustainable product design (such as Design for Remanufacturing) will become more important."*
>
> Nabil Nasr and Michael Thurston, 2006

OEMs control both the design and production side and as such hold the key to connecting design and remanufacture. Despite the majority of design businesses being in-house teams, and in an ideal position to Design for Remanufacture, remanufacture is still not in the remit of OEMs who generally focus on first-life production.

12.3.2 Increase number of remanufacturable products

Not all products are remanufacturable as explained in Section 4. Consumer goods most fit the model of 'not designed for manufacture'.

Design for Remanufacture needs to connect with non-remanufacturable products on both business and detailed product design levels to change the products' framework; this may enable increased remanufacture in the future.

> *'The role of financial considerations would have to be applied before environmental lifespan optimisation could be applied to real-world situations.'*
>
> A. Chalkley et. al., 2003

Connecting design with remanufacture requires recognition from remanufacturers that the remanufacturing process' efficiency requires improvement.

12.3.3 Increase Process Efficiency

Remanufacturers need to ensure their remanufacturing process is as efficient as possible. The variety of products for remanufacture ensures that there are few rules of thumb. Typical process efficiency activities are carried out at the University of Bayreuth by Professor Steinhilper and his team. These include identifying the most appropriate cleaning materials and factory layout.

Remanufacturing with loss of original product identity encompasses some unique challenges in inventory management and disassembly sequence development. Some of the open questions relate to the commonality of parts in products of different generations, the uncertainty in the supply of used products, and their relationship with production planning (Wikipedia, 2006).

12.3.4 Education

Design for Remanufacture is sometimes defined as eco-design even by people in the remanufacturing industry. In a holistic sense this understanding might be correct if you consider the net benefits of remanufacturing activities. This confusion of terminology may show merely a relaxed use of phrases but it may also demonstrate a misunderstanding of the specific concepts of Design for Remanufacture within the industry itself.

Design for Remanufacture needs to be built into education in both product design and engineering fields to counter this. Institutions which are currently providing education in the areas of eco-design include the University College for the Creative Arts, Kingston University, Cranfield University and Loughborough University. In addition, the knowledge of Design for Remanufacture should reach such a level that it becomes inherent to designers' practice so as to not impinge on timescales or cost.

> *'Design engineers are easy to persuade [to remanufacture] you just change the parameters!'*
>
> Ron Giuntini, 2006

12.4 Business

The design of business models is key to establishing markets for remanufactured products. This fundamentally requires building the business case. The case needs to be made for the supply and procurement of remanufactured products. Government has a role to lead this drive through Green or Sustainable Public Procurement initiatives which can be used to push and pull both suppliers and markets as clarified by the Simms Report (2006).

12.4.1 Business Case

The business case for remanufacturing is not understood evenly across industry sectors. Although the business case is established in certain industries (e.g. automotive, aircraft) there are opportunities for development in other areas e.g. furniture, construction, consumer electronics.

> *'The business model is key [to linking design and remanufacture]. It has to be part of the business model. In most cases remanufacture is seen as a threat to new product development.'*
>
> Ron Giuntini, 2006

Remanufacturing in business needs to be viewed at an organisational level, whereby the business model is designed to accommodate and encourage remanufacture. This will require appropriate buy-in from executives and a business model to match, which accepts responsibility for the full lifecycle of the product. Remanufacturing therefore needs to be seen as a zone of opportunity for profit and an integral part of sustaining profit in the future.

> *'Remanufacturing is an excellent example of how environmental responsibility is not only the right thing to do, it also makes good business sense.'*
>
> Mike Baunton, Caterpillar Vice President with responsibility for Perkins *in* The Manufacturer, 2004

Entrepreneurs need to be encouraged to take advantage of the business opportunities offered by remanufacturing. Although they operate in reconditioning rather than remanufacturing, Maxitech is an excellent example of a successful IT reuse business. Maxitech provide solutions for redundant IT equipment and the training of unemployed people e.g. social enterprise. The success of Maxitech is recognised by numerous awards given to the Managing Director, Peter Paduh e.g. winner of London Business Awards' Young Business Person of the Year 2005; Maxitech was also one of the regional winners in HSBC's 'Start-up Stars 2006'.

> *'Increasing remanufacturing will entail a mind-shift from people not just thinking "how can I dispose of my goods?" but 'how can I maximise my return?'*
>
> Derek Croft, Business Development Manager, Solectron, 2006

12.4.2 OEM Engagement in Remanufacture

OEMs hold and connect many parts of the remanufacturing puzzle: design, production, business models and marketing. As such OEMs are an essential facilitator to remanufacture but are also a potential barrier.

There are numerous reasons why OEMs may choose to not engage with remanufacture. From that perspective remanufacture may be seen as a competitor to 1st life manufacturing activities. Understandably OEMs who do engage in remanufacture, will aim to convince customers to purchase their remanufactured parts rather than those from a 3rd party remanufacturer.

> *'the product developer/manufacturer can get the most benefit from sustainable design practices by maintaining product responsibility throughout the product life cycle.'*
>
> Nabil Nasr and Michael Thurston, 2006

'The Risks of Using Non Genuine Parts:

Non-genuine parts are designed using reverse engineering (copying an original component). Manufacturers of non-genuine parts do not have access to Perkins technical data and drawings so these parts are designed and manufactured in isolation from the rest of the engine.

In most cases the material specification is rationalised, so there is a real risk that these parts will not fit correctly. This can result in rapid wear, compromised performance, poor reliability, higher oil and fuel consumption and even component damage or engine failure.

Suppliers of non-genuine parts will only provide a small range of the high-volume part numbers. They will not support the complete Perkins engine range. Non-genuine parts will not be covered by the Powerpart warranty.'

www.perkins.com, 2006

Some OEMs go further to actively provide challenges to remanufacture. OEMs may introduce new technology to their products to actively prevent their remanufacture by 3rd parties e.g. in the cartridge industry. In addition OEMs may try to steer legislation to prevent remanufacture, or block remanufacture by discrediting it as low quality or promoting the environmental benefits of recycling.

However the situation of OEMs blocking remanufacture may be changing as some start to realise the business benefits of remanufacturing.

12.4.3 Management of Core

The availability of core is a major challenge to remanufacturing. The management of core needs to be built into the business system. This requires not only building core collection methods into the business model but also providing incentives to ensure that those collections are carried out effectively.

Xerox for example, provide incentives to their national managers to collect core by linking the success of core collection to annual bonuses. By retaining ownership of copiers etc through PSSs, Xerox are able to track their core, or 'hubs' as they term it. In contrast, Caterpillar ensures that core is returned by only giving the discount of remanufacture when the core is returned by the customer. This business model acts as an incentive to the customer at point of purchase, and the prospect of a discount on a future purchase

> *'Our main obstacle is the availability of core. To date all our customers find it difficult to control/manage their core. Dealers typically dispose of the worn core on receipt of new.'*
>
> Kevin Haynes, ATP Group, 2006

gives the customer reason to return, but most importantly ensures a flow of core back to Caterpillar.

Where 3rd party retailers or dealers become involved, the complexity of core collection is increased. To encourage core collection the real value of the core needs to be maintained and communicated at every point of its life. This means providing incentives to all along the chain to pass the core onto the appropriate body.

12.5 Knowledge

The availability of knowledge about remanufacturing applies to both detailed product design and business model design, and is relevant to both in terms of promoting remanufacture.

12.5.1 Definitions

Understanding of the definitions of remanufacture and other elements of 're' is confused, as discussed earlier. The misunderstanding results in misconceptions.

> *'The key to increasing [the practice of remanufacture] is to improve awareness of what re-manufacturing is.'*
>
> Jackie Seddon, Envirolink Northwest, 2006

A further misunderstanding is that most people confuse the categories of 'product' and 'spare parts' by mistake (Steinhilper, 2006). The consequence of this for business model design is that the specific drivers, markets and challenges for each can be confused and therefore opportunities missed.

12.5.2 OEM perceptions

Poor understanding of remanufacturing and knowledge of out-of-date historical references to 'remanufactured' products (the classic example being the dangerous retreading of tyres which began in the 1930s) generate embedded perceptions. These perceptions and a general lack of awareness mean OEMs are generally unaware of the commercial advantages of remanufacturing; they will therefore not design their businesses to take advantage of remanufacture opportunities.

> *'Manufacturers need to be researched to see their views on remanufacture. Some are for it, others are not, why? Commercial issues are the reason and some manufacturers see it as a threat to their new sales.'*
>
> John Morrell, 2006

The whole OEM enterprise needs to be made aware of remanufacturing through training and publicity. If remanufacturing is not built into the business model it will always been seen as an add-on. This means that internal stakeholders/customers need to be involved or else they will act as internal barrier (King, 2006b).

However, the real perceptions of both OEMs and customers about remanufacturing are not well understood.

12.5.3 Skills increase

Experience and know-how is a prerequisite to remanufacturing however the skills are not more complicated than manufacturing (Freiberger, 2006). Knowledge required:

- Old core sorting /identification

- Old core analysing
- Technical know-how in setting up machines and test equipment
- Production planning

The boundaries of this know-how are changing over time. For example, with the increasing complexity of products such as cars, 'mechatronics' (the combination of electronics and mechanics) is a significant industry sector.

12.5.4 Recruitment

There is a lack of skilled personnel for remanufacturing. Workers in remanufacturing require experience and know-how of the processes. Although aspects or interpretations of 'sustainability' are increasingly taught as part of the education syllabus, specific aspects such as remanufacturing rely on the expertise and enthusiasm of the tutor. The number of tutors in the UK with specific interests in remanufacturing is limited and in-depth training of remanufacturing is therefore not guaranteed in engineering or design courses.

Tutors with an established interest in remanufacture, such as Rolf Steinhilper at the University of Bayreuth become a focus for know-how when students leave for industry. This allows tutors to maintain a good network in the industry.

However, remanufacturers tend to be small companies rather than big name companies. Therein lies a disincentive for many new engineers and designers. This reiterates the need for OEMs to get involved n remanufacture and thereby drive the development of skills.

12.5.5 Understanding Best Practice – Internally & Externally

> *'I think most remanufacturers are small companies and engineers do not want to work for small companies'*
>
> Stefan Freiberger, University of Bayreuth, 2006

Best practice needs to be understood within organisations. There is a lack of dissemination of information between departments related to remanufacture and also between businesses operating within the same parent company. Creating links between these and incentivising people to act on these links to further remanufacture is a key challenge. The lack of knowledge and exchange amongst the international sphere reduces capacity for knowledge transfer of best practice. Identification of international markets and suppliers are also compromised.

> *'The research community has been developing design for remanufacturing technologies for quite some time, however these tools need to be more widely applied in industry in order to be refined and proven.'*
>
> Nabil Nasr and Michael Thurston, 2006

The national and international remanufacturing picture is also unclear and the number of International networks is limited. Facts and figures can become dated quickly given the rate at which new business spring up and close. International networks are also limited.

13 Potential Proactive Approaches

The numerous opportunities for sustainable prosperity that remanufacture brings can be increased and amplified by proactive promotion of Design for Remanufacture in the South East to move remanufacturing into mainstream business practice and achieve the aims of SEEDA's Regional Economic Strategy (RES).

In this section, a selection of concept approaches is discussed. It is unclear at this stage which of these methodologies would be most effective.

13.1 International Definitions

Exposure of businesses to the global remanufacturing market is hampered by the persistent confusion of terminology. A resolution of this issue would facilitate interchanges of trade, investment, people and knowledge.

> *'It would be helpful for us to have a worldwide definition of the terms refurbishment/remanufacturing and so on.'*
>
> Martin Plumeyer, Siemens AG Medical Solutions, 2006

International definitions of remanufacture could be introduced to enable greater understanding and lessen confusion. These definitions may be made ISO standards.

There are BSI standards which relate to remanufacture, but only one BS AU 257:2002 - Code of practice for remanufacture of spark and compression ignition engines, that refers to the term 'remanufacture' specifically.

Other quality management standards such as BS EN ISO9001:2000 - Quality management systems, ensure quality standards in processing. This can be applied to remanufactured machines to ensure they undergo rigorous performance and safety tests before being returned to service.

13.2 Design for Remanufacture - Product case studies

Further examples of successful remanufactured products and business models are required, particularly in industry sectors where remanufacture is scarce. These may include such industries as marine, leisure and furniture.

Product case studies would benefit from a combination of skills and collaborating to innovate across regional, national and continental borders. Product case studies may seek to develop and provide guidance of the Design for Remanufacture process and its specific application to different product areas, thereby raising skill levels to match improvements elsewhere in remanufacture in the global economy.

Due to the traditional barriers to remanufacture and therefore Design for Remanufacture, these case studies may provide entrepreneurial opportunities for design-entrepreneurs in all sectors that seek out new opportunities and new markets, rather than relying on existing products, processes and supply chains.

13.3 Education

Currently there is no known education on Design for Remanufacture in the South-East, making knowledge and application zero or relative zero. With education, designers and particularly design engineers, can gain the skills required to practise Design for Remanufacture with fluency so that the process does not negatively impact on development time or costs.

Bristol University and Bath University hold skills in remanufacture but these are rare examples in the UK. Skill levels in remanufacture and Design for Remanufacture need to be raised; building levels of collaboration with other EU regions with complementary expertise in remanufacture would help this process.

Building the demand and capacity for remanufacture may be achieved through promoting Modules on Design for Remanufacture in education. This may be complemented through collaborations in the form of work experience to innovate across regional, national and continental borders, thereby raising skill levels to match improvements elsewhere in the global economy.

13.4 Research

An anonymous study is currently being carried out by academics working in remanufacturing around the world. The study is being run by Andrew King at Bristol University and uses a web version of the Delphi Technique to establish the best research questions and then gather existing evidence/findings and ways forward.

> *'What is (I judge) particularly needed is a way of bringing researchers outside of the engineering/business world into a research network. Surely policy studies, sociology, marketing, legal, politics, economics all need to be involved too.'*
>
> Andrew King, 2006b

Researchers from outside of the engineering/business world, such as sociology, marketing, legal, politics and economics need to be brought together (King, 2006b) to understand real perceptions and expectations. Notably this is necessary to discover what OEMs and customers really think about "second hand", "new" and a product's unknown history, and what the root causes of deeply held perceptions may be.

13.5 Dissemination

There is very little research into remanufacture or Design for Remanufacture and so there are correspondingly few articles in the manufacturing or design press. Exposing many more of the region's businesses to the global market through dissemination which offers interchanges of trade, investment, people and knowledge would promote awareness and raise skill levels in remanufacture and Design for Remanufacture.

Examples of the current very low dissemination levels are:

- Recharger magazine for the printing industry www.rechargermag.com
- Trade fairs e.g. Remax 2005, World Expo 2006, annual events for the

Recharger Magazine: a current mode for dissemination of remanufacture in the imaging industry.

recycling of imaging products e.g. remanufacture of ink cartridges; held since 1994.

These methods are specific to niche remanufacturing sectors e.g. remanufactured ink cartridges and as such are unlikely to lead to cross-fertilisation. There is also a very limited number of broader instances of dissemination of remanufacture:

- Conferences e.g. Nabil Nasr and Michael Thurston's keynote presentation at 'IEEE 2006'.
- 'Remanufacturing: The Ultimate Form of Recycling' by Rolf Steinhilper's 1998
- Reports e.g. Oakdene Hollins Ltd's 2004 report 'Remanufacturing in the UK: a significant contributor to sustainable development?'
- Organisations e.g. The Remanufacturing Institute. A not-for-profit organisation in the USA.

The dissemination of targeted and marketed evidence is required, including:

- Case studies and information
- What has worked and why
- What has not worked and why

New modes of dissemination could include:

Exhibition

A specific remanufacturing conference or exhibition to showcase and award remanufactured products across different industries. The exhibition might comprise of national and/or international activities. An exhibition could be specific to remanufacturing; or a 'plug-in' to a manufacturing exhibition - in this case the interface between remanufacture and manufacture must be considered to avoid conflict.

Mentoring Club

A 3rd party mentoring club offering specific and cross-sector advice and advising companies of opportunities in remanufacture and relevant weaknesses in their current operations.

Workshops

Workshops could explain technical processes.

Publications

A book could written and distributed cross-sector, demonstrating:

- General remanufacturing information/statistics contrasted with sector information.
- Lists of potential suppliers for remanufactured products.
- How to remanufacture. Including case studies of business models designed for remanufacture, and Design for Remanufacture processes.

“Reman” Retailer

A shop retailing solely remanufactured products with a reputation for reliable, guaranteed remanufactured products could potentially provide a single, trusted point of contact for procurers.

“The Product Re-Life Centre”

OHL is developing a concept for the promotion of product re-life as a prototype attempt to coordinate research, policy, innovation and support. OHL are leading a project funded by BREW which will examine remanufacturing and how it could contribute to the sustainable production and consumption economy. The work is currently planned to comprises these key activities:

- Understanding the real and perceived positives and negatives of re-using products.
- Determining under what circumstances re-using a product is a better environmental option than recycling it and buying new.
- Compiling a series of case studies that describe the environmental and business impact of remanufacturing, and leading practitioners.
- Proposing and testing a range of policies and actions that might increase the up-take of remanufactured products, both in the UK and elsewhere.

14 The Future of Remanufacture

The information available on remanufacture and other reuse strategies has increased in the last few years and government sponsored activities would suggest that it is now being more seriously considered for its environmental and commercial benefits. It is however difficult to state whether the remanufacturing industry is in growth or decline, but it is can be seen that remanufacture is still marginal compared to the manufacturing sector.

14.1 Markets

Remanufacturing is growing in South East Asia (SE Asia). In Thailand for example, Western ‘waste’ is being collected for reprocessing. In simple terms, these practices increasingly direct material flows away from the West and increase the relative manufacturing strength and capability of South East Asia.

However these instances give businesses in the South East the opportunity to build trading links with these emerging economic powerhouses, through the development of trade, investment and collaboration in education and innovation.

14.2 Legislation

EuP, RoHS and the ELV Directives look set to promote end-of-life options such as remanufacture. WEEE may help emphasise the business case for remanufacture but the implications of the Directive for remanufacture are still not fully understood.

14.3 Design for Remanufacture

Research into remanufacturing is limited but design is one area which has, relatively speaking, received attention recently, however the reality of this interest is research being carried out globally by a handful of people. Recent examples include this study, Erik Sundin's work on product and process design for remanufacturing, Nabil Nasr and Michael Thurston's research at The Rochester Institute, and Andrew King's work at Bristol University. Levels of Design for Remanufacture education in engineering and design courses at university level are very low and it is unclear if they will increase; although it is reasonable to presume that the increasing emphasis on sustainable design, will on some level raise awareness of Design for Remanufacture.

14.4 Original Equipment Manufacturers

OEMs are increasingly becoming involved in remanufacture, notably through out-sourcing through organisations such as InfoTeam. Although the engagement of OEMs in remanufacture has the potential to form positive links between design and remanufacture, out-sourcing has the strong potential to distance those links between design and remanufacture. In order to establish efficiencies in successful remanufacture OEMs and any sub-contractors must ensure feedback mechanisms are maintained.

15 Conclusion

Remanufacturing is a process of recapturing the value added to material when a product is first manufactured. By reducing energy use, carbon emissions and creating skilled employment, remanufacture offers a significant contribution in the move toward a sustainable society. Design for Remanufacture optimises the remanufacturing process and business model and can therefore increase competitiveness and innovation.

Remanufacturing is not an existing science however it is also not rocket science. Despite this the proportion of remanufacture in the UK compared to overall manufacturing activities is small, with just 166 companies listed under 'remanufacture' in the Yellow Pages. The proportion of OEMs engaging in remanufacture is small and it is only OEMs who are able make the connection between design and remanufacture.

15.1 Linking Design and Remanufacture

There is currently little Design for Remanufacture being practised. Those who remanufacture are commonly small organisations who have no control over the design phase. In general terms, those OEMs who control design (either in-house or through a design consultancy) do not engage in remanufacture. Therefore the optimisation of remanufacture through Design for Remanufacture seldom occurs, with the exception of some notable OEMs such as Xerox and Caterpillar.

15.1.1 OEM involvement

OEMs hold the key to creating markets for remanufactured products and linking design with remanufacture. The evidence base for remanufacture needs to be strengthened across sector and this will require a better understanding of remanufacturing in the UK and internationally. This information needs to be disseminated both horizontally and vertically.

Dissemination of this information and further examples of remanufacture can be used to promote the business case in which producers are directly linked to the end user by the producers' continued engagement with the product. One method of enforcing this would be to change retail law to link the producer and customer directly by warranty.

Warranties and business models that lead to successful remanufacture need to be promoted and encouraged. Design for Remanufacture needs to be used in this respect to increase the number of products that can be manufactured.

15.1.2 Understanding Design for Remanufacture

Design for Remanufacture concerns both the design of business models and detailed product design. Detailed product Design for Remanufacture consists of an interrelated group of design strategies, which pragmatically build upon the foundation of eco-design strategies to capture the commercial opportunities of multiple lives and upgrading. However Design for Remanufacture is a grey area and in order to proactively promote it, Design for Remanufacture needs to be clearly defined and proved.

For the evidence base to be built, more product designers, engineers and design engineers need to gain the skills required to evaluate a product's relationship to remanufacture and understand how to effectively apply Design for Remanufacture strategies. In this, functionality is certain to take precedent over remanufacturability in the vast majority of cases and this suggests that the frame of reference for design should be changed to take other aspects e.g. environmental performance, into account. Whilst this is unlikely in the current social paradigm, alternative methods to Design for Remanufacture without compromising functionality need to be identified.

Design for Remanufacture suffers the same barriers as eco-design in general, including apathy, suspicion and ignorance of the potential for generating ongoing profit. The value of design in the remanufacturing process needs to be better appreciated and acted upon by all stakeholders in remanufacture, but notably OEMs who have the ability to control both design and remanufacture.

Design for Remanufacture also encompasses the design of the business model. Business models must take retail laws into account to ensure that the products can be stored and processed cost-effectively with minimal hassle to stakeholders – notably the retailer. This will require consideration on the business model side.

The detailed design process will require engagement by product designers, engineers or design engineers. The way that these professions connect with Design for Remanufacture and how they can interact further to combine their skills requires further exploration and testing by industry.

15.2 Design for Remanufacture – the benefits

Design for Remanufacture of both product strategy and detailed product design can lead to reduced carbon emissions, landfill and secure, skilled employment. The very concept of remanufacture implies closed-loop systems, which could, in the distant future lead to the replacement of virgin manufacture with ongoing remanufacture.

The implications of a closed-loop remanufacturing system for business, society and sustainable development need to be explored.

Remanufacture is reported to be up to twice as profitable compared to manufacture, however the profit varies according to product and sector and the figures remain unconfirmed. Design for Remanufacture can optimise the remanufacture and broaden the range of products that can be economically remanufactured.

However Design for Remanufacture is not widely practised because of numerous barriers and so the efficiencies resulting in reduced CO_2 emissions and increased profit through innovation and new product development remain largely unexploited.

15.3 Design and Remanufacture – the barriers

The linking of design and remanufacture faces significant hurdles alongside the traditional barriers to sustainability. These additional barriers can be termed as:

- Definitions and understanding
- Preconceptions
- OEM engagement

15.3.1 Definitions & Understanding

There is common misunderstanding of the definition of remanufacture and confusion with other elements of 're' (reconditioning, repair, recycling). Confusion and misunderstanding devalues appreciation of the evidence base for remanufacturing, dilutes the message and therefore the potential for increased remanufacture. Definitions require addressing through the official publication of international remanufacturing standards and process, by an organisation such as ISO and/or national standards bodies e.g. in the UK BSI.

15.3.2 Preconceptions

Customers are believed to have preconceptions about remanufacture, but aside from the historical references of poor quality e.g. retread tyres from the 1930s, the root causes of these perceptions in both OEMs and in society as a whole are unclear. Therefore there is a possibility that current understanding of others' opinions may be based on assumption rather than fact. OEMs' and customers' perceptions and the root causes of them need further research to allow more effective design of business models.

15.3.3 Market Development

The market for remanufactured products (as opposed to spare parts) needs to be developed through the business model design and detailed Design for Remanufacture. This will also require a confrontation with the widely held temptation for the 'new'. As is the case in other spheres of sustainability, this demands a realignment of pricing to reflect lifecycle costing. How the lure of the 'new' can be extinguished requires investigation, particularly in terms of perceptions and root causes.

15.4 Implications for SEEDA

SEEDA's Regional Economic Strategy (RES) (see www.seeda.co.uk/res) lays down a framework for sustainable prosperity. Remanufacture can offer prosperous business opportunities to entrepreneurs and OEMs alike in conjunction with reductions in energy use and CO_2 emissions.

Design for Remanufacture optimises the process of remanufacture making remanufacture more profitable. Proactive strategies to further Design for Remanufacture are likely to involve resolving understanding and awareness of remanufacture and generate trust in remanufacture.

The publication of an official definition such as an ISO standard could resolve confusion over definitions. These definitions may usefully extend to the actual design process for Design for Remanufacture to aid designers and engineers, whilst making remanufacturers aware of what could be done to improve their process.

Fundamental to encouraging remanufacture in the UK is to engage OEMs with both business models that are Designed for Remanufacture and that promote detailed product Design for Remanufacture. Increasing OEMs' engagement in remanufacture and then optimising remanufacture through Design for Remanufacture, may be achieved by generating a trustworthy evidence base for remanufacture. An evidence base could showcase products Designed for Remanufacture and compare them with equivalent products not Designed for Remanufacture. At first, this could feed into Design for Remanufacture standards and definitions; it could then be used to demonstrate the Design for Remanufacture process and techniques through example, ensuring that designers can acquire knowledge in this field. Importantly, an evidence base of products Designed for Remanufacture, could publish reliable financial reports of remanufacture to show the economics of remanufacture versus manufacture.

These strategies may provide OEMs with a greater and accurate understanding of remanufacture, sufficient to incentivise some to engage in not only remanufacture, but Design for Remanufacture.

SEEDA's promotion of remanufacture through profit optimisation via Design for Remanufacture and the proactive strategies listed in this report will allow SEEDA to meet the aims of its RES: innovation, sustainable economic growth and Sustainable Development and contribute to the transformation of the South East into a Factor 4 region.

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17 APPENDIX I

17.1 CfSD Expert Remanufacturing Workshop

Date held:	27th November 2006
Location:	The Brunei Gallery, SOAS, London, UK.
Organised by:	The Centre for Sustainable Design www.cfsd.org.uk
In association with:	Oakdene Hollins Ltd www.oakdenehollins.co.uk
Sponsored by:	South-East England Development Agency (SEEDA) www.seeda.co.uk

The workshop aimed to exchange and further expert knowledge contributing to sustainable development in the south-east region. After evaluating published research and questioning experts, the following questions remained to be discussed:

- **Design & Management of cores** How can relationships between design and remanufacture be forged?
- **Leap-frogging best practice:** How can best practice International remanufacturing activities be identified and how can the UK 'leap-frog' these International and cross-sector activities?
- **Policy & Business Case:** What incentives are required to effectively initiate and sustain remanufacture in both supply and demand?

17.2 Agenda

Chairman: Martin Charter, Director, The Centre for Sustainable Design

09.00 Registration

09.45 Introduction

Martin Charter, Director, The Centre for Sustainable Design

09.55 3 minute introductions by all delegates

10:40 The Business Case & Opportunities for Remanufacturing

David Parker, Head of Remanufacturing, Oakdene Hollins Ltd

11:00 Key Challenges for Remanufacturing

Casper Gray, Associate, The Centre for Sustainable Design

11:20 Coffee and networking.

11:40 Remanufacturing Visual Display Screens

John Morrell, Consultant

12:00 Remanufacturing at Xerox

Andy Cosgrove, EHS Manager, Xerox

12:20 Lunch (Cold buffet). (Room B202)

13:20 Workshop Introduction, objectives and outcomes

Martin Charter, Director, The Centre for Sustainable Design

13:30 Workshop 1 – Design & Management. (Room B202)

Workshop leader: Casper Gray, CfSD

Workshop 2 – Leap-frogging best practice. (Room B203)

Workshop leader: David Parker, Oakdene Hollins Ltd

Workshop 3 – Policy and Business Case. (Room B204)

Workshop leader: Martin Charter, CfSD

14:45 Coffee and networking. (Room B202)

15:05 Workshop 1 - Present findings

15:20 Workshop 2 - Present findings

15:35 Workshop 3 - Present findings

15:50 Discussion & Conclusions

Chair: Martin Charter, The Centre for Sustainable Design

16:45 Comments from the Chair

17:00 Close

17.3 Delegate List

Name		Job Title	Organisation
Clare	Brass	Consultant - Design programme for Business	Design Council
Martin	Charter	Director	CfSD
Andy	Cosgrove	EHS Manager, Ireland	Xerox
Casper	Gray	Associate	CfSD
Prof. David	Harrison	Lecturer / Head of Research	Brunel University

Malcolm	Hemming	Manager, Environment Health & Safety	Xerox
Dr Andrew	King	Lecturer in Engineering Design	Bristol University
Guy	Leppard	Business Development Director	InfoTeam
John	Morrell	Consultant	John Morrell
David	Parker	Head of Remanufacturing	Oakdene Hollins Ltd
Charlie	Rea	Knowledge Transfer Manager	Resource Efficiency KTN
Guy	Robinson	Co-director	Sprout
Jenni	Rosser	Deputy Manager, Cleaner Design & Electronics	Envirowise
Robin	Snook	Project Manager	London Remade
Timothy	Woolman	Sustainable innovation Coordinator	CfSD