Remanufacturing Towards a More Sustainable Future

Remanufacturing is a concept of strategic importance that enables a significant part of the value added to a product during its initial production to be retained. It is no longer acceptable to dispose continually of strategically important materials in landfill sites or waste the energy associated with their processing. Remanufacturing is the process by which used products and assemblies are returned to their new state with minimum waste and expenditure on materials and energy. Parts that do not wear out are reused in a rebuilt product that incorporates the technological advances deemed necessary to ensure that repairs can be carried out in a timely manner and the item returned to functionality in an efficient manner. This review provides an overview of how remanufacturing reduces industrial costs. Its strategic importance is stressed and examples are given to illustrate how the concept is applied in a wide variety of industries.

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1.0 Executive summary

In the UK, and particularly in the United States, recycling has become familiar in public and private arenas as a direct result of continued legislative pressures and public awareness efforts. However, recycling remains limited to simple items such as drinks containers, steel products and paper goods, in part because recycling a more complex product, like a vehicle, results in a loss of up to 95% of the value added in the initial manufacture of that product. Remanufacturing, on the other hand, is the ultimate form of recycling. It protects the raw-material content, while maintaining much of the value added during the product's manufacture. It has the potential to contribute significantly to a more sustainable future, and has already begun to increase materials efficiency by reducing emissions of greenhouse gases.

Scope for remanufacturing has increased where industries have embraced new technologies for the restitution of components. This has enabled greater material recovery and even the retention in-house of capabilities that may have previously been outsourced. The improvement in service and margin that this affords can offset loss of business through general enhanced longevity of industrial items. Remanufacturing has a high chance of failure when used to compete in markets where price is the only basis for competition, unless a low-cost source of labour is available.

This sectoral analysis aims to build on this current thinking and examine the scope of the industry and its impact on the UK economy in the short- and long-term future. Among the prime benefits of remanufacturing are, of course, the ecological benefits, as it reduces the volume of materials entering the waste stream. Not only is there a reduction in the amount of product sent to be recycled, but the scrap which is sent to recycling from remanufacturers has a much better chance of avoiding contamination that degrades material quality. Further impacts on society are also discussed from both an economic viewpoint as well as the savings to be made in energy and raw materials.

Information is presented on the European remanufacturing industry, drawing on direct comparisons with the US market. This section highlights how enlightened remanufacturers are at the forefront of marketing novel product-service offerings, and shows how those sectors that compete on lowest price are suffering against lower-price competition, mainly from abroad. Although its societal benefits are clear, there are a number of obstacles to overcome before the full benefits of a remanufacturing programme can be appreciated. These are discussed in section 6.0. They bring several issues to the fore, including the need for commitment from senior members of management to drive it through; the criticality of the product design to enable profitable remanufacturing; and getting involved in trade groups to learn about the latest remanufacturing issues and how they are likely to affect the business.

Section 7.0 is the nucleus of the report, providing extensive information on how remanufacturing is specifically being adopted into a number of key industries. These include automotive, aerospace, consumer electronics, ink cartridges, batteries, refrigeration and industrial machinery. The review looks at how remanufacturing has been implemented in each of these sectors as well as the benefits it has brought, both from an economic perspective and an ecological one. Examples of pioneering companies that are embracing the remanufacturing model are also included to provide further insight into its increasing appeal across companies of any size.

The review ends with a set of case studies featuring some of the largest global organisations. For instance, the case study on Fenco Automotive Parts shows the different stages involved in their remanufacturing processes, while examples provided on companies such as Caterpillar, Xerox and Ford illustrate how the efficiency of business operations can be dramatically improved by a well-structured remanufacturing program.

2.0 Introduction

Remanufacturing describes the process of dismantling products, cleaning, repairing or replacing parts, and then reassembling them to a good working condition. In other words, it is recycling by producing products that are as good as original products in look and capability, from used items. Remanufacturing is synonymous with a number of other terms such as rebuilding and refurbishment, although 'remanufacturing' as a term has become commonly acknowledged as the generic industry term for this process.

Candidate products for renewal (called 'cores' in the industry) are typically brought to a factory environment

where they are disassembled. The component parts are cleaned, inspected, repaired or refurbished if useable; otherwise they are replaced. The parts are then reassembled and the product is tested to original performance specifications. In some instances it is possible for the remanufacturer to upgrade the product, adding improved controls or strengthening parts prone to failure.

> *Remanufacturing is the process of returning a used product to at least original-equipment-manufacturer performance specification and giving the resultant product a warranty that is at least equal to that of a newly manufactured equivalent.*
>
> **The Remanufacturing Institute**

Cores are the lifeblood of the remanufacturing cycle. They are often sent to the remanufacturer by retailers or distributors that sell new and remanufactured products. Customers hand over worn-out or broken products when replacements are required, and these trade-ins are sold to the remanufacturer. Some remanufacturers establish direct exchange loops with their customers. Ownership of the core usually passes to the remanufacturers, but they frequently provide rebuilding services to customers who retain rights to the product and expect to get the same item back when rebuilt.

Remanufacturing is essentially a form of recycling but offers additional benefits. Not only are the materials recycled but the value originally added to the raw material is too. When a product becomes defective, repairing it will more or less extend its useful life; remanufacturing will establish its next full life cycle. Unlike repaired products, which are returned to their original owner, remanufactured products are anonymous and ownerless until purchased.

Remanufacturing activities are applied to a large number of products. These include:

- automobiles
- automotive parts
- electric motors
- tyres
- single-use cameras
- personal computers
- industrial equipment
- office furniture
- compressors
- telephones
- televisions
- electrical apparatus
- vending machines
- photocopiers
- toner cartridges
- data-communication equipment
- gaming machines
- musical instruments
- robots
- aircraft parts
- bakery equipment.

However, remanufacturing probably has its strongest tradition and currently also its strongest representation in the automotive sector. Remanufacturing of automotive products accounts for two thirds of all remanufacturing.

Different industry segments sometimes use other terms for remanufacturing. For example, ‘rebuilt’ is used for motor-vehicle parts and systems, and ‘recharged’ for imaging products such as laser and toner cartridges. Other related terms that refer to distinctly different processes include ‘recycled’, ‘repaired’, ‘restored’, ‘reconditioned’ and ‘used’.

The Remanufacturing Institute (TRI) asserts that whether or not a product is remanufactured depends on the process utilised. According to TRI, the following conditions must be met before a product is considered to be remanufactured:

- The principal components are reused.
- Dismantling is carried out so that it is possible to ascertain component condition, wear or deterioration.
- Each part is thoroughly cleaned and examined.
- Any broken, missing or damaged items are replaced by new parts, or reconditioned so that they are as new. It may sometimes be acceptable to incorporate used items if their functionality is not affected.
- Any necessary rectification by, for example, machining, rewinding or refinishing will be carried out to restore working condition.
- A refurbished product will operate to the same standard as a new one.

3.0 Design and methodology for remanufacturing

There is a set of conditions that must be met by a company wishing to establish and maintain a successful

remanufacturing business. Above all, there must be a core – a remanufacturing entity. From a physical standpoint, the product must have a reasonably long life, and its functions should not be underpinned by a technology subject to rapid change. It should be capable of being dismantled without excessive damage, and its normal failure modes should be repairable. Failure should leave a large fraction of the product in reusable condition through refurbishment, and the cost of labour and of replacement parts must be such that the remanufactured article, after allowing for a reasonable profit, enjoys a price advantage relative to a comparable new unit.

The original cost of the product should have a large added-value component (labour, energy, capital-equipment costs) when compared with the material costs. The price of a remanufactured product should be sheltered by well-established prices for comparable new products. Also, the scale of remanufacture should be large enough to sustain specialised expertise in the business and technology of the operation.

The design of a reusable part must be such that it will last longer than just one functional life span. However, if excessive raw material is required to extend the physical life span, it could result in an undesirable impact on the environment. The life span of a reusable part should be long enough and the entire remanufacture process should result in a decrease in the total environmental impact. It is generally considered that components which are reused for remanufacturing in order to reduce environmental load should endure for a period equal to at least two functional lives.

The remanufacturing process itself is organised as an industrial process, and exists primarily within a manufacturing environment so that it can benefit from the advantages of volume production. Constant quality-level checks should be part of this, and every effort made to incorporate rationalisation of the processes used.

There are five steps in the remanufacturing process:

1) dismantling
2) complete cleaning of all components
3) component inspection and sorting
4) repair, refurbishment or replacement of damaged or worn parts
5) assembly and test.[1]

It is important that adequate quality-control systems are in place to ensure that a remanufactured product offers essentially the same performance, durability and warranty as a new item. However, because remanufacturing operations employ many of the principles and organisational techniques encountered in a modern manufacturing plant, there is a considerable amount of new know-how and thinking embodied in many reconditioned and refurbished products.

Remanufacturing can be considered to realise the same product at about half the cost of a new one. It is generally considered that a remanufactured product can be produced and sold at a cost of between 40% and 60% of the price of a new product. The consumer thus gets a refurbished product at an economic price and the manufacturer is able to return a sensible profit.

Consumer products are often manufactured nowadays with the aim of minimising opportunities for repair and replacement of parts, with the intention being in some cases to enhance the profits of the manufacturers. This manifests itself in a number of ways during the manufacturing process, from making actual repairs of products either difficult or impossible in material and engineering terms, to rendering the cost of repairs or refurbishment ineffective in relation to the cost of manufacturing a new product.

This has the obvious implication for the industry that jobs in the repair and maintenance sector are at risk if these trends evolve any further. With consumer products in particular, the high initial cost paid for a product must be justified by the life-cycle expectancy of a product compared with repair and maintenance costs and cheaper products that need to be replaced more frequently.

In a manufacturing system, the remanufacturing consideration plays a significant part in product design. Remanufactured products generally have three characteristics. First, their useful life can be extended through maintenance, refurbishment, repair and up-grading. Secondly, they can be taken apart easily so that components can be replaced or reconditioned as needed and materials salvaged for recycling or reuse. And thirdly, the product can be remanufactured so that the value added (labour, energy, materials etc.) when the product was first made can be recaptured.[2] Studies at the Massachusetts Institute of Technology (MIT) and in Germany found that 85% or more of the original

energy and materials are typically preserved in remanufacturing. Remanufacturing is more labour-intensive than the original manufacturing process, and could therefore serve as a particularly appropriate approach in developing countries.

If remanufacturing were to become more widely practised, then design for manufacture would become a more widespread principle. In that case, design for ease of dismantling, refurbishment and ease of reassembly, in addition to design for recovery of material value, could become design objectives. As original equipment manufacturers increasingly enter the remanufacturing field, this may become part of their product strategy.

In order to avoid technological obsolescence while maintaining durability of products and ensuring effective refurbishing and upgrading, a modular approach that permits easy access to individual parts and components is important. Computers serve as an obvious example here: standardised slots will accept components such as modems, sound cards or memory chips virtually irrespective of which company made them. The automobile industry, too, offers a simple illustration; DaimlerChrysler's Smart car has been designed with interchangeable body panels and other parts that allow quick replacement.

4.0 Societal impact

A burgeoning remanufacturing industry could have significant implications for the labour market. If goods do not rapidly wear out, it follows that they will not require regular replacement and hence fewer will need to be produced. Although this suggests that fewer employees would then be needed, this is not necessarily the case. Extractive-industry jobs would clearly be among the losers, but a shift to durability would also offer new opportunities. It can be argued that the use of better materials and their incorporation into durable, high-quality products is more in keeping with a smaller batch-manufacturing regime than with mass production. Consequently there is a need for an increased level of skilled labour. What is possibly more important, however, is a larger opportunity and incentive to maintain and repair products that can be remanufactured and reused rather than just thrown away. This opportunity creates more employment potential because it is labour-intensive but requires less energy than the continuous production of new products from virgin materials.

Remanufacturing succeeds when two basic economic conditions are present. First, the product core must permit the remanufacturer to avoid production costs that would have to be incurred in making a new product. The costs avoided must be sufficient to offset any additional costs arising in the restoration of the core. This represents value to the producer. The other requirement is that the resulting product must have marketable value, if buyers are to perceive worth in the product. The embedded value, or avoided cost, in the core must be sufficient to enable a remanufacturer to offer a product at a price that is competitive by comparison with the prices of new products. For the buyer, the condition of the product and its price represent comparable value, and unless there are buyers who can perceive value in the price-performance package offered by remanufacturers, remanufacturing cannot succeed as an enterprise.

It can be argued that society gains a considerable benefit from remanufacturing. It has an intrinsic societal impact because it uses less energy and resources than are required for new products; many existing parts are reused and therefore do not have to be remanufactured, and the effort required for refurbishment is significantly less than that associated with the production of new goods. For instance, it has been estimated that remanufacturing requires only 15% of the energy needed to produce a complete new item. This is the 'equivalent of 16 million barrels of crude oil or sufficient petrol to run 6 million cars for 1 year'.[3]

Additionally, remanufacturing does not significantly add to the emission of greenhouse gases – a major worry in relation to global warming and climatic changes. Using the above figures, remanufacturing potentially removes the generation of 28 million kilograms of carbon dioxide per year; this is approximately the emission level of ten 500-megawatt coal-fired power stations. Material economies are also substantial. The material saved 'would fill 230,000 railway carriages in a train 1,650 miles long'. Recycling is often suggested as an option for materials conservation, but it requires parts to be returned to their original state (such as melting aluminium scrap to produce recycled alloys). Hence, although there is a material saving, the energy demand is increased.

The OEM Product-Services Institute is a market-research and management-consulting organisation in the US that assists capital-goods OEMs and their partners to evolve into suppliers of performance-based products or services. It estimates that if it were possible for large OEMs and vehicle manufacturers to deliver up to 20% of their output as remanufactured items then the level of remanufacturing in the US would increase by 200%. This can be correlated with a 10% reduction in waste generation and energy usage throughout the manufacturing industry. Additionally, the US government has started to recognise the environmental benefits of remanufacturing. Legislation may follow, but in Europe the status of remanufacturing is more robust. For example, in 2002 15% of a scrap vehicle was allowed to be discarded, but this will fall to 5% by 2015, driving up the motivations for manufacturers to produce reusable parts. Also, German legislation covering packaging materials and waste control is establishing green policies that will improve the status of remanufacturing.

Evidence shows that the US is slowly moving in the same direction. For example the Federal Trade Commission is allowing remanufacturers to label their products as 'recycled' and 'remanufactured'. State governments have also started to follow suit. New York passed a bill in June 1998 requiring that purchase requests for durable equipment initially consider remanufactured products. It is also mandatory that 'products purchased by the commissioner or other state agencies shall be recycled or remanufactured products… provided the cost… does not exceed a premium of ten per cent'. It prohibits state agencies purchasing commodities from OEMs that place restrictions on remanufacturing. Texas, Connecticut and California have empowered similar legislation. In 2000, New York passed a tax credit to benefit companies that undertake remanufacturing.

Walter Stahel of the Product-Life Institute in Geneva reportedly estimates that the remanufacturing sector in EU member countries accounts for about 4% of the region's GDP.[4] For example, a French producer of automotive drive shafts that began remanufacturing operations in 1976 has been able to reduce energy use by 24% and cut total costs by 50% for each remanufactured drive shaft. Nevertheless, the company found that remanufacturing is twice as labour-intensive and involves higher levels of job skills. Clearly, there is an opportunity for expansion of this activity.

5.0 European Remanufacturing Industry

In many respects the European remanufacturing industry is similar to that of the US but has probably received less of an incentive from the recycling sector. Taking printer cartridges as an example, the European market for remanufactured units is currently worth an estimated €23 million per year and rapidly growing; it accounts for approximately 23% of laser-printing consumable sales. Also, Europe has fewer small recycling companies than America. This is probably a function of population density, with the average remanufacturing company processing approximately 12,000 units per annum.

Europe comprises a number of historically independent countries having individual languages and, until recently, separate currencies. The result is that an OEM product may not be evenly distributed throughout the community. For instance, Keith Moss of LaserXchange – a company that operates in Italy and France as well as the UK – states:

> *Brother is very strong in France, and Olivetti is everywhere in Italy but virtually non-existent in the UK, so the type and number of cartridges recycled will vary from one country to another. This also localises many recyclers – the vast majority do not sell products outside their native countries.*[5]

The UKCRA also claims that one area in which the European industry operates on a wholly regional level, as opposed to nationally, is with the use of empties. As stated by the association:

> *the one pan-European sector of this market is in empties, where a group of large dealers source and supply cartridges around the continent. In fact this is an area where the US has an adverse effect on Europe, as many of the cartridges collected this way are shipped to the US, starving the European market and driving up prices to unrealistic levels.*

Additionally, there is legislation such as the Waste Electrical and Electronic Equipment (WEEE) directive drafted in the European Parliament regarding the waste of electronic and electrical goods. The WEEE directive was adopted on 27 January 2003 and national legislation implementing will be in force in the near future. The Directive's primary purpose is *'[t]he prevention of WEEE and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste'.* [6] Member states

are obliged to collect on average at least four kilograms of WEEE per inhabitant per year by 31 December 2006. The member states are to ensure that adequate facilities are available for collection of WEEE and that this collection is conducted with no charge to the householder. Distributors are obliged to back WEEE equivalent to their products, free of charge. National recovery targets (see Appendix 1: WEEE national recovery targets for 31 December 2006) have been set for 31 December 2006, after which new targets must be met.[7]

5.1 Price versus quality

Several markets have recognised the role of remanufacturing, and have begun to exploit it creatively in defining new service offerings, simultaneously reducing waste of materials and resources. In general, these have not adversely affected the profitability of OEMs. Additionally, research conducted in the US has assessed the profitability of remanufacturers.[8] In many cases they show greater added value than the OEMs, and demonstrate the inherent value of end-of-life equipment.

Remanufactured products compete with new and, in some cases, with imported items. Competitiveness is mainly based on price and quality but the lower the price, the harder it is to offer a quality product. US remanufacturing companies tend to strive for quality; most large remanufacturers comply with International Standard Organisation certifications, although some mainly compete on price, thereby at some point sacrificing quality. Also, companies with strong research and development capabilities may be able to offer products that are of better quality than the originals because they can identify and correct poor design or inadequate materials.

Unfortunately, a number of remanufacturers in order to remain competitive have to sacrifice quality standards for price. In order to remanufacture a high quality product, a significant amount of investment in the remanufacturing process is required. Some manufacturers cannot compete on quality and therefore sell at lower prices without warranty. In addition, misdiagnosis of problems at the installer level can deter the use of remanufactured products, and in many instances this translates into a bad image for the remanufacturing industry.

6.0 Challenges for remanufacturing

In addition to the environmental and societal benefits, there are also significant indications that adopting remanufacturing techniques can lead to increasing and steady profit levels. However, despite this fact, there remain many barriers and obstacles that must be overcome in order for the full potential benefits of remanufacturing to be realised. These challenges are largely and most appropriately dealt with by the individual organisation. The main ones are highlighted below.

Design engineering Product design is a vital element of profitable remanufacturing because it must incorporate ease of dismantling for refurbishment as well as, ideally, a modular approach to the use of subassemblies that can easily and cheaply be upgraded to incorporate new developments and modifications that have been found necessary in the light of service experience. In this way it is possible to minimise obsolescence and maintain a competitive position in relation to new products.

Executive commitment The addition of remanufacturing to a corporate strategy requires commitment to it at an executive level in the company. GE is one of the best examples of how an organisation implemented this philosophy at a practical level. The vision was to add value to GE capital goods in service by a combined remanufacturing and upgrade service. Substantial resources were allocated to this, and as a result it is stated that 3.5% of the company's income in 2001 came from 'other than new products' and service facilities. They provided more than 60% of profits, thus demonstrating the value of remanufacturing and overhaul.

Marketing, sales, and advertising It is important that advertising and marketing should include incentives that help to maintain a base of customers who will purchase remanufactured products. In many ways, the sale of remanufactured products is just as important that of new items because they can meet customer needs by offering a wider range of options without diversifying from the principal business of the company. A sales force must recognise this too by concentrating on delivering solutions that offer product irrespective of whether it is new or remanufactured. Hence, sales incentive schemes (if they are operated) must be modified to reflect this.

Trade groups Involvement in a trade group can be very important for any company. Trade groups have a significant impact on industry by providing a unified voice or consensus of opinion that can overcome problems or make the case for changes which would be beyond the capability of individuals. Trade bodies have made the public and government aware of many manufacturing issues and championed the case for remanufacturing as a means of saving energy and strategic materials.

7.0 Sector-specific analysis

It would be wrong to assume that remanufacturing can be applied and ultimately prove successful, in every industry sector. Certainly, in cases where products, despite probable technical superiority, are competing solely on price, remanufacturing is unlikely to prove very profitable. Unfortunately this includes a large part of the manufacturing industry, particularly machines, standard engineering equipment and many consumable durables. The best examples of remanufacturing occur in those industries that address highly engineered and costly items for which technical or service enhancements can be added.

7.1 Automotive

The remanufacturing of major, high-value car components has been an established activity, largely controlled by car manufacturers, for many years. Until recently, the remanufacturing industry has been hindered by its image. It has also been damaged by the use, in the largely unregulated independent aftermarket, of parts manufactured to the lowest standards in countries with inadequate enforcement of copyright and trademark conventions. Remanufacturing is growing in importance as a weapon in manufacturers' efforts to derive revenue from the aftermarket for vehicles that are out of warranty. Franchised dealer networks cannot generally service out-of-warranty cars at competitive labour rates, but they can supply independent workshops with competitively-priced parts.

This policy makes a virtue of necessity. Without an alternative to new parts, many cars that fall victim to mid-life accidents or major component failures become uneconomic to repair. It can be argued that owners of such cars are very unlikely to purchase the same marque again, but if repairs can be carried out at substantially lower costs, the car stays on the road, provides satisfactory service and continues to generate revenue from the sale of faster-moving spare parts and labour. Franchised dealer workshops have largely abandoned the post-warranty servicing market, but their franchisors are keen to collect major parts that may fail in warranty. They can afford to reclaim major parts (e.g. cylinder heads or transmissions) from their own dealers, remanufacture them, and re-market them profitably at less than half the price of new units.

Until comparatively recently, vehicle technicians would rebuild automotive units such as starter motors for customers while the vehicle was in the workshop. This system is now obsolete because of the inconvenience to customers of having to wait for the job to be finished and having to pay extra for the additional labour. Remanufacturing can solve these problems. Estimates suggest that the entire remanufacturing industry is worth somewhere in the region of £35 billion worldwide, with the automotive segment representing £20 billion of that total. Exact figures are very difficult to find but it is undoubtedly a multimillion-pound industry. Despite this, experts agree that the industry is in decline, and to a large extent this is due to the use of better-quality oils, alloys and engineering that are available today. Fifty years ago an engine would need a rebuild after some 40-50,000 miles; a well-maintained modern engine will usually cover 100,000 miles without much problem.

The engine remanufacturing industry will probably become a niche market dealing with disasters, vintage vehicles, etc. This is a useful and profitable side of things – but it is significantly smaller. The other problem has been the pressure to reduce the cost of new vehicles. This has an obvious effect on the second-hand market, where it is becoming cheaper to change the vehicle rather than have the engine rebuilt.

The whole remanufacturing industry consisting of engines, parts, etc. (generally referred to as the aftermarket) is enormous, but it gets little support from government. The vehicle manufacturers are only interested in selling their own parts and, although changes to the block exemption[9] rules have been introduced, there is still no evidence of any major changes of strategy by the manufacturers. For example, engine and other remanufacturers could increase the amount of material they can remanufacture if they could get the relevant technical information from the vehicle

manufacturers themselves. This they either refuse to give, which is now illegal under block exemption, or they charge for. If this information were freely available it would give the industry a significant advantage.

7.1.1 Methodology

Remanufacturing starts with a returned unit that must be cleaned before it can be dismantled. These units, often termed 'cores' by the industry, are usually engines, transmissions, alternators, starter motors, steering racks etc. High-wear components such as gaskets, seals, bearings and rubber boots are invariably replaced, and the remainder is carefully examined to determine what can be reused. In a gearbox this may be just the casing, layshafts and selector mechanism, with gears and synchroniser rings being replaced as a matter of course. Reusable items in an engine include the cylinder block, crankshaft, camshaft, timing gears, connecting rods, bearing caps, sump pan, etc. but it is usual to restore the block, fit oversize pistons, regrind the crankshaft and fit new bearing shells of an appropriate size.

A remanufactured unit is usually in the region of 50% cheaper than a new item because reusing the major components reduces expenditure on labour, energy and raw materials. Bill Gager, president and CEO of the Automobile Parts Rebuilders Association (APRA), has reportedly said, 'As a remanufactured part can be up to half of what a new part would cost, it is easy to see why this sector is rapidly growing.'

Some of the cost savings are achievable because the price of initial tooling and development are not on a remanufactured product. However, it is sometimes necessary to make components that are not readily available to the rebuilder. Also, it is possible to correct specific problems endemic in the original product that are found in the light of service experience, and many OEMs frequently turn to the remanufacturing sector to help them overcome recurring failures by quickly making replacement items available. Many remanufactured items have warranties at least as good as the new products they replace and are produced under QS/ISO quality conditions.

Some vehicle owners may not consider the environmental benefits of a remanufactured item, but there are increasing pressures for eco-friendly products. For example, the Automotive Repower Council in America is reportedly developing a campaign to explain the benefits of remanufacturing. Their remit is to make consumers aware that up to 90% of replacement engines, CV joints, drive shafts, starters, alternators, etc. are available as remanufactured items.

7.1.2 Challenges

While it is not especially difficult to rebuild mechanical assemblies, it is a big challenge to remanufacture modern automotive electronics and hydraulics at a competitive cost. ABS braking systems, for instance, are very complex, but as the technology is rapidly being enhanced there is often no alternative to remanufactured units because new spare parts for early systems are no longer available. In view of this, some companies offer a rebuild-and-return service. This tracks the components through a rebuild process so that the original part is returned to the customer; many owners of classic vehicles prefer this method because it maintains vehicle originality. Engine management systems, which are fully computerised, are similarly complex. While their associated sensors (e.g. for air flow rate, temperature, throttle position, exhaust-gas oxygen content) are disposable items, the high value in an engine control unit (ECU) makes it a candidate for refurbishment or repair, particularly as relatively minor faults can disable an engine. However, the repair process is far from straightforward because most ECUs are specific to a particular engine type and manufacturer. However, as the number of individual types of ECU is large, and more versions come to market as vehicle manufacturers reduce emissions, there may ultimately be no alternative to the rebuild-and-return process.

Air-conditioning compressors Remanufacturing in the air-conditioning sector is experiencing rapid growth. It is currently estimated that the UK is remanufacturing around 50,000 air-conditioning units annually – a far lower figure than in many European countries.

The US has also experienced a significant increase in demand for reconditioned or remanufactured automotive components. In response, ACTIS Manufacturing Ltd in North America (a remanufacturer of automotive air-conditioning compressors established as a joint venture by Toyota Industries Corporation, DENSO Corporation, and Toyota Tsusho Corporation), and TD Deutsche Kilmakompressor GmbH in Europe began remanufacturing car air-conditioning compressors. The two

companies dismantle used compressors, replace worn parts and then reassemble the units for sale. In 2002, the two subsidiaries sold approximately 50,000 compressors to the US and European aftermarkets.

7.1.3 End of Life Vehicle directive

The EU's End of Vehicle Life directive (200/53/EC) is expected to have a significant impact on the salvaging of parts suitable for remanufacturing. It applies to: cars and other passenger vehicles with nine or fewer seats (including the driver's) and to light goods vehicles (maximum weight 3.75 tonnes). Its primary objective is reduction of vehicle waste by encouraging component and materials recovery for reuse or recycling. A secondary objective is to improve environmental standards associated with scrap-vehicle processing.

The major requirements of this directive for vehicle dismantlers are twofold. First, dismantlers will need to meet certain minimum technical requirements for storing and depolluting scrap vehicles. For example, prior to depollution, vehicles are required to be stored on an impermeable surface with a sealed drainage system. Secondly, dismantlers are required to encourage the reuse and recycling of automotive components and materials. This requirement relates to:

- removal methods
- storage of removed components for sale as spare parts (so that parts for obsolete vehicles can be re-covered for low-cost spares or for remanufacturing).
- materials such as large plastic items and glass which, at present, are left in a vehicle when it is shredded

7.1.4 Collaborations

The increased demand for remanufactured parts has instigated the formation of a number of key partnerships between automotive companies. One of the most recent alliances was formed in November 2003 between Cardone Industries and Delphi. Cardone is a leading automotive-parts remanufacturer with a full line of brakes, drivetrain, electronics, pumps, motors and steering, while Delphi is the world's largest automotive supplier focusing on providing OE quality replacement parts to the independent automotive aftermarket.

The primary aim of the alliance is to attain global leadership in remanufactured vehicle electronics. Initially Delphi will market an all-makes programme of Cardone-remanufactured engine-control computers (ECC) and mass air flow (MAF) sensors to the traditional independent aftermarket. Other remanufactured electronics items will be added, including ABS (anti-lock brakes) controls, body controls, cruise control, power steering, suspension controls and automatic transmission logic units. The alliance enables Delphi to expand its vehicle-electronics product portfolio and press for growth in the independent aftermarket. It is also believed that through this collaboration, Cardone will increase its business opportunities by expanding its remanufacturing operations on a global scale.

Component manufacturer Delco Remy[10] is involved in serving both the OEM and aftermarket sectors and provides its services on a global scale. In June 2001 the company acquired the North American remanufacturing business of Mazda North American Operations (MNAO). MNAO employs 70 people and is responsible for the remanufacturing of Mazda automatic transmissions, transaxles and rotary engines for Mazda's North American service requirements. As a consequence, Delco Remy provides the sales and marketing, customer parts and service and replacement parts of Mazda vehicles in the United States.

In 2000 Delco Remy opened a purpose-built remanufacturing division in Hungary designed to service the remanufactured rotating-electrics demands of the European aftermarket. The factory is based in Miscolc, Hungary and has 56,000 square feet of floorspace. It serves primarily the European market with an estimated 250,000 units annually.

In total, Delco Remy has six factories based in Europe, four of which are specifically targeting the remanufacturing market. The establishment of the Hungarian base will allow Delco Remy's UK plant to focus on the smaller-batch production of higher-tech products and higher-skilled production.

July 2001 saw the creation of ACTIS Manufacturing Ltd, a joint venture between DENSO and the Toyota Tsusho Corporation, largely due to rising concerns about the social and environmental impact of vehicle components and parts. This new entity began production in March 2002 and provides remanufacturing services for vehicle air-conditioning compressors in North America. ACTIS intends to reinforce competitiveness in the North American aftermarket for remanufactured compressors.

Wealdstone Engineering has more than 60 years experience in the area of volume engine remanufacture and is now one of Europe's leading remanufacturers, producing over 15,000 engines per year. The company remanufactures engines and major components for OE vehicle manufacturers as well as major fleet users. It has a dedicated 11,000-square-metre factory on a seven-acre site in Rushden, Northamptonshire where specialist machinery, equipment, tooling and gauging is employed in the remanufacture of engines and other powertrain products. Wealdstone Engineering is a Ford Q1 supplier with third-party accreditation to QS-9000 and ISO9000; fleet customers include the UK government and the major British bus operators.

7.1.5 Conclusion

The general feeling among automotive industry players and observers is that remanufacturing will continue to grow as it is driven by a need for lower costs and reduced air pollution. This expansion will be noticed more in the aftermarket because of pressures on the affordability of transport. There is also a view that manufacturers will work more closely with vehicle assemblers, possibly as tier-one suppliers who offer remanufactured components as new that can be recycled and built into new vehicles on the assembly track. Possible components are starter motors, alternators, air-conditioning units, clutches and brake callipers. However, demand may outstrip supply, so for the foreseeable future it would be necessary to use a mix of new and refurbished parts.

The relatively high labour requirements of remanufacturing means that it will move towards the developing countries to keep cost down. Hungary and Eastern Europe are experiencing activity now, but this is expected to extend into the Far East and Africa. This will to some extent be the result of industrial consolidation as small companies are taken over because they do not have the funding and economies of scale to compete in a global market.

Many pundits believe that vehicle assemblers will have to change in strategic terms before remanufacturing can assume its rightful place. They make profits from selling new vehicles, as well as new parts into the aftermarket, and from the sale of service and repair parts. Both profit channels feed into each other and the profits from parts in such outlets are considered to be important in order to counteract the costs associated with vehicle sales at dealer outlets where competitive pressures are squeezing margins to the limit.

Despite some companies divesting their interests in remanufacturing, others such as Delco Remy are rapidly expanding as they realise the vast potential of this market. The industry appears very concentrated, meaning that only the bigger players in the market are likely to be able to survive and expand with their own brand or work as subcontractors to others. Smaller, newer companies looking to establish themselves in the industry will find it extremely challenging.

As vehicle assemblers (manufacturers) continue to consolidate through the use of common components and platforms, model- and marque-differentiating factors are increasingly focused on visible appearance and on-board support systems for varying levels of driver comfort or convenience. This will keep assembly costs down as economies of scale are introduced by the larger remanufacturing firms in order to exploit the high volumes per part number. The commonality of engines, transmissions, brakes, suspension parts etc. will make remanufacture even more viable because rebuilt units that are identical in all but minor detail will be required by more than one franchised dealer network. To some extent this is already happened with Ford using various FIAT diesel engines, MG-Rover buying engines from Peugeot and a common platform being used for the new Ford Focus and the Volvo V40-series.

7.2 Consumer electronics

The recycling of electronic products has emerged as a result of increasing levels of waste products. There has been a step change in the ways in which this occurs. While scrap dealers traditionally collect discarded electronic products to recover precious metals contained within the products (such as gold, silver, platinum and palladium), the more modern products do not contain as much of these metals, and companies are looking for new ways in which to reuse the materials used to manufacture electronic products.

Disposal of end-of-life electronics is beset by many environmental problems. The Environmental Protection Agency (EPA) in the US highlights three key issues that must be considered: technological advancements that are increasing levels of electronic waste, the use of

valuable resources in the manufacture of goods, and the disposal of products containing hazardous substances. The following have been highlighted by the EPA.

- Discarded electronics are a fast growing waste stream. Technological change is quickly rendering current electronic designs obsolete. For instance, the majority of PCs that become obsolete end up in storage. Of the remainder, the bulk are disposed of, and probably fewer than 6% are being recycled.
- Electronic products are made from valuable materials, including precious and other metals, engineered plastics and glass, all of which require energy to source and manufacture. They are also a tremendous waste of valuable resources. Many electronic products contain parts that could profitably be refurbished and reused with little effort.
- Electronic products may contain hazardous or toxic substances. Some electronic products (notably those with cathode ray tubes, circuit boards, batteries and mercury switches) contain hazardous or toxic materials such as lead, mercury, cadmium and chromium, as well as various types of flame retardants. In particular, glass screens or CRTs in computer monitors and televisions can contain as much as 27% lead. Some estimate that because many batteries (such as car batteries) are now removed from waste, electronic products represent the largest remaining contributor of heavy metals to the solid waste stream.[11]

There are environmental and societal benefits to reusing or recycling scrap electronics. For example:

- Electronics reuse and recycling can divert bulky equipment from landfills and incinerators.
- Reuse and donation of electronic products extends their useful life and affords individuals or organisations that could not buy new equipment the opportunity to make use of second-hand equipment.
- Products that are configured or designed to use a greater recycled content need fewer virgin resources and require less energy to make, thus reducing pollution. Energy savings also translate into reduced greenhouse-gas emissions, but if reuse is not an option, recycling creates a supply of parts and materials that can be employed to refurbish older products or manufacture new ones. [12]

7.2.1 Mobile phones

Concern has been expressed about the environmental impact associated with the production, use and disposal of mobile phones. Significant technological advances have been made in recent years leading to the introduction of G3 devices, but design life appears to be shortening. At the time of writing (summer 2006), there are two and a half billion mobile phones in use across the world. Five years ago, the worldwide number of redundant mobile phones was already expected to exceed 500 million.[13] Incinerating or using landfills for mobile phones is extremely hazardous since disposal of its component parts – batteries, printed circuit boards, liquid crystal displays, plastic housings – causes the release of potentially harmful substances such as those from heavy metals or halocarbon materials. The difficulty for mobile phone remanufacturers is that the components are tightly fitted into a small shell, so that dismantling for component recovery and remanufacturing is not easy.

The recycling of components other than batteries is not a widespread activity, but mobile phone remanufacturing has become a reality in Europe and America. Some third-party remanufacturers of mobile phones are generating profits by reselling them into emerging markets but many OEMs are unsure about pursuing remanufacturing as a core business activity. The US has pioneered mobile-phone remanufacturing and is certainly more advanced in this activity than Europe. The US began remanufacturing mobile phones in the early 1990s through charity recycling systems that are an important method of collecting unwanted phones.

Collaborations have been developed throughout Europe to create similar concepts for the reuse of mobile phones. However, this is much less well established in Europe, and such organisations (including used-phone operators, network providers, commercial institutions and non-profit organisations) focus mainly on actual re-sale rather than the technological remanufacturing processes that take place in America. Phones are re-distributed to Eastern Europe, Africa and Asia. In addition to the initial market potential that exists in these regions for actual handsets, they also offer opportunities for other types of company, OEMs involved in infrastructure for example, where the embryonic and growing markets provide more opportunities than the more saturated developed countries.

In the US, where the greatest potential for remanufacturing exists, several different standards such as TDMA, CDMA, IDEN and GSM are in operation, resulting in a market with wide variability. Technological

and logistical challenges are high due to the variety of handset types collected. Most of these standards, but not GSM, are not globally circulated, which makes resale opportunities more difficult. Conversely, the European market has only two GSM standards, which makes for a much more stable market and a positive impact on the potential production of remanufactured mobile phones. Several emerging markets have consequently decided to implement the European GSM standards to encourage the growth of this supply chain. Remanufacturers making a bigger push to acquire more mobile phones in Europe (and therefore moving away from the American market) could thus become an important trend in the industry.

The remanufacture of mobile phones has an obvious impact on OEM handset and infrastructure manufacturers, as well as network and service providers. The way in which the industry develops is very dependent on three elements, according to the US-based professional Institute of Electrical and Electronics Engineers (IEEE). These are: Who will remanufacture? Where will the acquisition markets be? and, Which markets are going to be served?

It is possible that third-party remanufacturing could represent a threat to the market share of handset OEMs. However, taking into account the fact that most remanufactured-handset users are first-time customers who were originally not attracted to mobile communications due to the high price of new handsets, but may wish to upgrade to new handsets later, it is thought that market shares may increase in the medium term. One option is for remanufacturing to be carried out by the handset OEMs themselves, which may well be more effective, since technical and logistical problems have less of an influence. This is especially so for the European market where the WEEE directive makes handset OEMs responsible for take-back and end-of-life treatment; so significant, readily available opportunities exist for remanufacturing with OEM participation.

7.2.2 Personal computers

Most PCs become redundant well before the end of their useful life, but there is surprisingly little remanufacturing of them. What little there is results in machines of extremely low value, which may be of interest to some bulk purchasers such as schools and hospitals. Little is being returned to premium users, especially businesses. To a large extent this is due to intense price competition from new goods that are heavily marketed and coupled to a software industry feeding a climate of planned obsolescence.

Some refurbishers of PCs exist for the redistribution of used IT equipment to schools, other institutional purchasers and disadvantaged purchasers. This amounts to around 50% of equipment disposed of. However, remanufacturing is even lower; this is largely because the rate of evolution in the speed and capacity of PCs leaves a low residual value for disposals. In addition, PCs are often cascaded within the home for low-level and child use, and this can also exacerbate loss of utility. There are signs, however, that the PC market is beginning to saturate. Under such conditions suppliers, under threat of declining margins, will need to differentiate their products. A feasible way of doing this could be to remanufacture to create layered markets of higher and lower specification. This will require significant improvements in the warranty offered on such goods, an aspect that has already been demonstrated in The Netherlands. The benefits of PC remanufacturing are highlighted in Appendix 2: Advantages of PC recycling.

7.2.3 Photocopiers

In contrast to the PC market, there is a well-established market for the remanufacture of photocopier equipment. A wide range of models continue to be used for photocopying, including OEM, contract and independent remanufacture; many operators have successfully integrated remanufacture as an expansion of their business options, offering a continuum of purchase, hire, upgrade, remote service, billing and pay-per-use, and profit sharing – some of the most sophisticated service models in business.

For instance, Xerox remanufactures equipment and parts from returned machines, thereby reducing energy consumption and preventing the disposal of valuable equipment. Its products are designed with remanufacturing in mind, and therefore the company can offer the same warrantee for remanufactured equipment as that given with new machines. Xerox claim that 90% of their products are remanufacturable. This, they say, has only been possible by virtue of their allowing 'joined-up' design – product designers working with manufacturing engineers to optimise build features that facilitate cost-

effective remanufacture. The company says the results amount to 'several hundred million dollars a year.'

Hewlett-Packard uses material-identification codes to mark all plastic parts according to ISO 11469. It also moulds user instructions into plastic casings rather than affix a paper label. Labelling the materials used in its products and reducing reliance on paints and coatings helps make the sorting and recovery of secondary materials more cost-effective.

7.3 Printer cartridges

Printers linked to a PC or to a network can consume a substantial number of printer cartridges. It has been claimed that in a year the average user can spend more on consumables than the cost of the printer. So it is not uncommon for toner or colour cartridges to be purchased from third parties rather than the OEM. There are three basic options when an ink-jet or toner cartridge is expended:

1. Purchase replacement cartridges of the same make as the printer. This is often an easy option because most printers are supplied with all the information needed to obtain consumables. It should offer the best quality but at a price premium.
2. Buy cartridges made by another company to fit the printer or remanufactured units. Compatible printer cartridges usually cost only 50% of the price of OEM versions, while a remanufactured unit typically costs 30% of the OEM price because many components and mouldings are reused rather than scrapped.
3. Use an inkjet refilling kit. These comprise a syringe for inserting ink into the empty cartridge, plus a quantity of appropriate ink. The cost of this option can be as low as 10% that of a new OEM cartridge.

According to the UK Cartridge Remanufacturers Association, a remanufactured cartridge should be a quality, reliable product that is virtually indistinguishable from the original. There are reportedly over 100 remanufacturers in the UK, and it is estimated that remanufactured cartridges can undercut OEM products with such negligible difference in quality that cartridge remanufacturing is fast becoming a multi-billion-pound business. The association reckons that over 1.5 million remanufactured cartridges are sold in the UK each year.

This has resulted in OEMs attempting to persuade customers to purchase replacement cartridges directly from them or their dealers. Tactics include warning that the use of aftermarket consumables will invalidate any warranty given with the printer, although it is doubtful if this is a valid argument provided no damage is occasioned. Additionally, some printer manufacturers have offered discounted prices on their replacement cartridges provided the used items are returned to them and not a remanufacturing company. In 1996, several printer manufacturers began inserting chips into their cartridges to prevent the use of third-party remanufactured items or reuse of the cartridge casing and mechanism. These 'killer chips' will detect when a cartridge is empty and electronically tag them as such so that they cannot be used again even if they are refilled. This makes considerable work for remanufacturers minded to circumvent them. Some OEM companies claim killer chips are not restrictive because, in their opinion, a printing system comprises the printer plus original–pattern cartridge filled with original ink to their specification; and, they argue, using remanufactured components will result in lower-quality products.

There have been instances of companies trying to halt the remanufacture of such cartridges. For example, Lexmark was involved in a legal battle in which it invoked the Digital Millennium Copyright Act (DCMA) and copyright law to sue Static Control Components, a company that produces toner-cartridge components, for unlawfully selling its Smartek chips to companies that remanufacture Lexmark printer cartridges. These chips enabled aftermarket suppliers to circumvent the single-use restriction Lexmark was enforcing on its Prebate cartridges by way of its own killer chip. In the district court, Lexmark obtained a preliminary injunction forcing Static Control to stop distributing Smartek chips. However, Static Control won on appeal and efforts by Lexmark to have the case reviewed have been denied, most recently in June 2005 by the US Supreme Court.

Nevertheless, the concept of refilling and remanufacturing ink and laser cartridges is still in its infancy. Research suggests that 85% of printer owners, both home- and office-based, do not recycle their cartridges. This equates to over 47 million cartridges – around 20,000 tonnes – delivered into the waste stream where it can take 400 years for them to decompose.[14]

Many companies have found that selling refilled inkjet cartridges can be highly profitable, and companies are competing with one another to devise effective ways of

accumulating empty cartridges. There are various ways of collecting them, but schools, churches and clubs are probably the most efficient. For example, a company could go to a school and put in a recycling bin for empties and say that in return for every 100 cartridges they will give the school points that they can collect which will go towards the cost of a new PC or other hardware. Office-equipment superstore Staples was one of the pioneers in this market. In August 2003, they announced their intention to raise up to $3 million for Ohio schools with a state-wide cartridge-recycling programme in the US. The company donated $1 for every eligible cartridge recycled in its stores, and in 2003 the total number of 'empties' collected was over a million. Under its 'Recycle for education' programme, the company is currently donating $3 to schools for each eligible ink or laser cartridge collected.

The collection of empties is becoming increasingly sophisticated. Some firms are setting up websites and some are offering money for used cartridges. Micro Solutions Enterprises (MSE) is one company that has a website to do this and even has a sister firm, WBi Recycling, created for the sole purpose of collecting empties. Another online 'empties' facility is the http://www.empties.com site, which has changed into an Ebay-style auction service. The founders of the website say they developed Empties.com in response to an industry demand for an easy-to-use system to quickly and accurately buy and sell empties with the potential to make significant cost savings.

UK legislation is unfortunately a significant hurdle in the potential impact of remanufacturing in this sector. Cartridge remanufacturing companies are concerned that the government's interpretation of the WEEE directive (see Section 5 for more details) will mean an extra 20 million kilograms of waste going to landfill each year. They feel that the Department of Trade and Industry (DTI) has been too easily influenced by the big printer manufacturers who are making huge profits by selling printers cheaply, but cartridges at relatively high prices. The point at issue is whether an ink cartridge should be classed as a 'consumable'.

The introduction of the WEEE Directive is thought to have a potentially significant impact on the printer-c cartridge industry. In 2003, when the directive was being passed through the European parliament, MEPs introduced a final amendment that they believed would prevent manufacturers from rendering cartridges obsolete once used. The DTI has since been considering how to turn this part of the directive into British law, and has been involved in debates about the classification of a cartridge as a consumable, debates that have resulted in an opinion that cartridges are not covered by the new Directive. Other member states, notably Scandinavian countries, have taken the reverse view and therefore require manufacturing to be done in such a way that cartridges can be reused.

However, the UK Cartridge Remanufacturers Association has pointed out that for the industry as a whole the UK's stance still allows American and Japanese ink cartridge manufacturers to insert chips to prevent reuse. This, it is claimed, not only prevents the reuse of cartridges and subsequently diminishes the potential for cheaper cartridges, but will also drive up the price of new products as competition is lessened. According to Lyra Research, one of the leading providers of market information and analysis on the imaging industry, refilled cartridges are impacting on Lexmark's market share less than other OEMs such as Hewlett-Packard, Canon and Epson because its cartridge design makes them more difficult to fill. Lyra figures show that the market has an 8% penetration on Lexmark ink cartridges, 20% on Canon and 27% on Epson.

OEMs argue that refilled cartridges are not comparable in quality to their original product and argue that this will persuade consumers to continue to buy new. Nevertheless, recent Lyra surveys suggest that mid-to-large companies are generally happy with the quality of remanufactured cartridges, with 80% stating in one survey that they perceived the quality to be equal to that of OEM cartridges. There is a clear demand for remanufactured products in this sector. According to estimates by UKCRA, only 20% of all cartridges are recovered – mostly by the remanufacturers. In theory, properly serviced cartridges could be reused four or five times, which would raise the recovery rate to 80%. UKCRA also predict that future demand could absorb 70% of cartridges that end up in landfill sites. At this level about 9,000 tonnes per annum of direct waste could be avoided.

7.4 Aerospace

The aerospace sector is of considerable economic importance to the UK. The industry is estimated to be worth almost £20bn per year with profits of around

£3bn. Aeronautical systems generally represent considerable investments for reasons of reliability and functionality. Consequently operators are highly motivated to ensure that components and systems consistently operate to high standards, potential failures are eradicated, and key systems are upgraded for improved functionality or efficiency. The indications are that the trend of upgrading and rebuilding aerospace-related machines and parts looks set to continue as development of new airframes slows to ease pressure on defence budgets. Analysts generally agree that the market for military helicopters is improving. The move away from heavy forces to light, rapidly deployable, mobile troops is driving the need for transport and utility machines, while the attack helicopter is in demand as a highly mobile, heavily-armed support asset.

At sea, the changing nature of maritime operations – intercepting drug and immigrant smugglers, policing international embargoes and servicing modern warships – means naval helicopters are being developed with greater functionality.

However, to reduce the cost of delivering additional capabilities and to ease the strain on stretched budgets, upgrades – rather than new production – have become the vogue. A proposal to upgrade 111 US-Marine-Corps-operated Sikorsky CH-53 heavylift helicopters, for instance, is estimated to cost $22–26 million per airframe, around half the cost of building new machines – a possible saving of $2.8 billion. The benefit of reusing large parts of existing airframes and associated systems is rapidly gaining popularity. It has not been a success in every instance, though; for example, after suffering setbacks, the US Navy decided to build the MH-60R multi-role maritime machine new rather than reuse components from in-service SH-60B/Fs. Elsewhere, rebuilding H-60 airframes remains a popular option. The US Army is remanufacturing 1,217 UH-60A/Ls to M standard with new Rockwell Collins glass cockpits and upgraded General Electric T700-701D engines and wide-chord rotor blades derived from Sikorsky's S/H-92. In Western Europe, the biggest helicopter-remanufacturing programmes on the horizon are the UK's Battlefield Light Utility Helicopter (BLUH) and the Surface Combatant Maritime Rotorcraft (SCMR). The British Army BLUH and UK Royal Navy SCMR programmes could be rebuilds of today's Westland Lynx airframes, integrating new systems and sensors with new-build airframes equipped with systems from existing machines.

Other recent major remanufacturing projects include:

- In September 2002, Kuwait ordered 16 AH-64D Apache Longbow attack helicopters, which will be manufactured by Boeing. The company is remanufacturing 269 ‘A’ model Apaches to the more advanced ‘D’-model standard for the U.S. Army and is building new or remanufactured Apaches for Israel, Egypt and Singapore.
- Raytheon’s expertise in cruise-missile remanufacturing sector has aided in their success in winning a contract to do further work in this area. In 2002 the company completed a $440m programme involving the remanufacture of 644 Tomahawk cruise missiles to the Block III configuration. Further work is now being carried out under another two contracts. The first, for $320.3m, was awarded in December 2001. The second, for $29.7m, was awarded in February 2002. The company began the remanufacturing work in 2003 which involves adding Global Positioning System satellite guidance to Terrain Contour Matching (TERCOM) and Digital Scene Matching Area Correlation (DSMAC) guidance.

With the development of new airframes slowing, upgrading existing helicopters or building new fuselages to the same design and installing new avionics and other systems, will continue to be a popular means of maintaining and developing a machine's capability without stretching tight defence budgets.

The very high cost of airframe, engine and system components in military and civil aircraft means that there are continuing programmes of remanufacturing and refurbishment that have increasing importance as aircraft life is extended. For instance, instruments need to be regularly removed so that they can be dismantled, cleaned and inspected, reassembled and recalibrated ready for refitting to an aircraft. Similarly, items such as control surface actuators need refurbishing at regular, defined intervals, and a modern turbofan engine is very rarely scrapped. Instead it is brought up to standard by a remanufacturing programme that involves the replacement of seals, bearings and turbine blades, plus rebuilt fuel and oil pumps etc. and then becomes available for fitment to an appropriate aircraft when required so that time on the ground is minimised. This is particularly important with civil aircraft which can only earn revenues when in the air. Airframes too are sometimes in need of partial remanufacture as patterns of crack propagation become apparent in service. Modern inspection techniques and the development of

repair schemes by aircraft manufacturers mean that sections comprising frames, stringers and skins can be replaced in short time spans, and such a programme continues with, for example, Boeing 747s that are suffering from fatigue cracking in areas of the fuselage.

The aerospace industry is clearly well aware of the potential value of remanufacturing. Safety requirements have enforced and validated remanufacturing in this sector. As a result, transformation through adoption of remanufacturing is unlikely, and further growth will probably come organically through implementation of new remediation techniques or the imposition of new legislation such as the WEEE directive.

7.5 Industrial machinery

British manufacturers are still renowned across the world for building some of the most robust and technically competent machinery. However, price competition is intense from the American and Far Eastern markets. Consequently margins for remanufactured items are being squeezed, and preference is given to imports. It appears that in many cases purchasers are prepared to buy with short-term objectives, knowing that equipment will perform with a limited life. But selected specialised areas can still sustain remanufactured goods. One example is grinding machines, such as those manufactured by Jones & Shipman (J&S). J&S machines are industry standards, with some examples surviving over fifty years and several cycles of remanufacture. Competitors in the Far East are still unable to match this absolute quality in new equipment. Now, in response to the high cyclical nature of demand in the manufacturing sector, several companies are offering a remanufacturing and maintenance service. This is now more profitable than the sale of new equipment.

8.0 Remanufacturing in action

Today many world-class companies realise the potential of remanufacturing to boost their own productivity and competitiveness. Remanufacturing is also a business for small local companies that are the backbone of every national economy. According to the IEEE Computer Society, there are eight criteria that can be used to determine the suitability of products for remanufacturing. In each field, an evaluation of the parameters has to be made to form the basis for the decision whether to remanufacturing or reprocess.

- *technical* – suitability of the parts for disassembly, cleaning, testing, and reconditioning
- *quantitative* – amount of returning products, and their regional availability
- *value* – value added from material, production and assembly
- *time* – maximum product life time versus single-use cycle time
- *innovation* – technical progress regarding new products versus remanufactured products
- *disposal* – efforts and cost of alternative processes to recycle the products and possible hazardous components
- *interference with new manufacturing* – competition or cooperation with OEMs
- *others* such as market behaviour, liabilities, intellectual property rights.

Compelling arguments can be put forward for companies to enter the business of remanufacturing some of their products. For example General Electric, Boeing, Caterpillar, Xerox and Pitney Bowes have reportedly created business models in which remanufacturing is an integral part. Most automotive companies engage in remanufacturing and have the refurbished items sold through their franchised dealer network. Also, Eastman Kodak and Fuji Photofilm have created a massive market for disposable cameras that can be remanufactured up to 10 times after they are returned for film processing.

Many companies become stakeholders in a remanufacturing operation. Some of these are:

- users of remanufactured products who wish to reduce costs.
- OEMs whose business strategy is to use remanufacturing as a means of increasing profits
- makers of specialised equipment employed in remanufacturing processes
- suppliers of IT that supports remanufacturing.
- consultancies that can guide companies who wish to undertake remanufacturing or refurbishment and incorporate it into an appropriate business model.
- designers who can input to the concept of ‘design for remanufacture’

The following case studies demonstrate the impact remanufacturing can have on companies in various industrial sectors. The Fenco Automotive Parts example

discusses various stages involved throughout an entire remanufacturing process, whereas the examples from Caterpillar, Xerox, IBM and Printing Technology Inc. provide insight on the positive effects that remanufacturing can have.

8.1 Fenco Automotive Parts

Established in 1949, Fenco Automotive Parts is now recognised as a leader in the North American automotive aftermarket. Within its 325,000-square-feet manufacturing-and-distribution centre, the company offers over twenty distinct product lines of both remanufactured and new products. In 1992, Fenco became the first remanufacturer in North America to receive the prestigious Ford Q1 quality certification. This, together with a QS9000/ISO 9002 rating demonstrates the high quality standards achieved by the company. The case study below provides an example of the remanufacturing processes within Fenco.

Stage 1: Core retrieval Remanufacturers such as Fenwick Automotive Products require 'cores' in order to remanufacture their product. The core-retrieval process is the heart of remanufacturing; without core retrieval, it cannot take place. To procure cores, most remanufacturers institute a buy-back programme. This means that when products are sold, the purchaser is offered a rebate on a newly remanufactured part equal to the value of the core. Generally, remanufacturers require that the cores be returned in their company's box, otherwise they are not accepted.

Stage 2: Sorting of the cores This stage requires a great deal of organisation and planning. When the cores are sorted, workers ensure that the boxes are scanned so that the part number and the type of product are documented. The workers unload the cores, scan the boxes onto conveyors and the sorting equipment, and then take the cores to their proper bin to unload the parts. The facility is quite large and the owners have to ensure that there is enough room for all the part numbers of which there are literally hundreds to thousands, depending on the item.

Stage 3: Core inspection At this stage, the remanufacturer has to inspect the cores to make sure that they are reusable. Any core that does not meet required specifications is immediately rejected and labelled as scrap. The remanufacturers have to absorb the cost of cores that are unusable. Some remanufacturers pay the total stipulated amount to clients, while others discount payment. Core value recognition mainly depends on market conditions. When core availability is short, full credit is given to assure future returns. Many manufacturers tend to sell the scrap parts to recyclers, so that the part does not return to the market.

Acceptable cores move forward to the cleaning phase where accumulated grime, dust and other foreign agents are removed before the remanufacturing process begins. Sophisticated machines are utilised to clean most of the parts, but in many cases they are manually cleaned. Regardless of whether a part is cleaned manually or automatically, each part is re-inspected to ensure acceptable quality.

Stage 4: Assembly and remanufacturing Once cleaning and inspection are completed, the core is ready to move forward to be remanufactured. Using brake callipers as an example, remanufacturers supply numerous part numbers to various channels of distribution. Specific cores are used to remanufacture different part numbers. Skilled technicians install new pistons in the core and add new hardware (when required). After each part is remanufactured, a quality-control check is conducted to ensure the part performs at OEM levels. The part is then packaged ready to be shipped to its required destination.

8.2 Caterpillar

Caterpillar is one of the largest engine manufacturers in America and has had a manufacturing presence in Europe for more than 45 years, which expanded in 1997 when the company acquired the assets of Perkins Engines. The company has a long history of expertise in remanufacturing, beginning in 1972, when they entered the field to meet the needs of customers for commercial vehicle engines in America. This remanufacturing programme rapidly expanded and now offers a full line of engines, components, transmissions, hydraulics and other related products throughout the world.

A new remanufacturing operation at Shrewsbury was set up in 2004 and the site switched from manufacturing new diesel engines to remanufacturing. A multi-million-pound factory re-fit has been undertaken, complete with

substantial investment in new machinery. Six-sigma techniques are applied at this new operation to maximise customer value by ensuring that all remanufacturing activity is fact-based and data-driven. The programme is designed to benefit customers and contribute to the overall growth, cost-reduction and quality improvement targets for the whole company. ISO 9002 accreditation ensures a high-quality output.

8.3 Xerox

One of the most widely reported remanufacturing systems is that of the Xerox Corporation, a global company offering products and services for printing, publishing, copying, storing and sharing documents. Xerox has recovered used equipment since the 1960s, but developed a more formal remanufacturing system in the late 1980s and early 1990s to maximise the profitability of remanufacturing operations. Today, Xerox has remanufacturing programmes for used photocopiers and print and toner cartridges from all around the world. It has remanufacturing facilities in the U.S., the UK, the Netherlands, Australia, Mexico, Brazil and Japan. By remanufacturing used photocopiers, Xerox has saved millions of dollars in raw-material and waste-disposal costs. Remanufacturing has also helped Xerox to enhance its image as an environmentally conscious company. An example of this Xerox integrated approach is the Document Centre 265 digital copier, which has been designed to make extensive use of subassemblies and recyclable parts such that 97% of the components in it can be used again after they have been refurbished.

The Xerox site in New York extends to over 400 hectares and employs 8900 staff. Savings of $250m have been attributed to pollution control and remanufacturing of copiers or other document-handling equipment that had been owned by or leased to customers. The latter is a major income stream for Xerox, which has estimated (from 1998 figures) that parts reuse and recycling diverts 66 million kilograms of waste from landfill. Analysts claim that Xerox's success owes a lot to the fact that its products are robust, large, easy to dismantle, and valuable when remanufactured. While this may be true, the company has invested substantially over the last ten years to guarantee the viability of its remanufacturing processes.[15] The integration of remanufacturing into the company's overall business strategy has undoubtedly played its part in the company's success.

8.4 IBM

In late 1998, IBM established as part of its Global Financing division the Global Asset Recovery Services (GARS) organisation, whose mission is to provide a single global focus for managing the disposal of returned, surplus or excess computer and related equipment.[16] With approximately 10,000 used computers being returned each week at the end of corporate-lease agreements, and products ranging from PCs to servers, the concept of a centralised effort was a key decision. By optimising the recovery and use of systems and parts, GARS is able to help IBM lower cost, increase profit and improve service to the customer while enhancing and supplementing its environmental programme.[17]

Some of the division's objectives are to:

- provide management of excess materials to optimise asset recovery and utilisation
- develop and implement disposition criteria and decisions
- manage returns inventory including parts balancing initiatives
- develop, coordinate and execute secondary sales
- development and manage remanufacturing, refurbishment and demanufacturing processes, including related information systems

The responsibility also includes deployment of an integrated returns process to support the required dispositioning processes. This aspect relies heavily on timely and efficient execution of reverse logistics operations and affects environmental performance directly. GARS manages these logistics by focusing on two critical items. The first relates to physical aspects of the process. This involves the transportation of material to designated centres, receipting the returns into inventory, and dispositioning the material for either remanufacture or disposal. The second item involves gathering and utilising the information needed to manage the physical activities to recover maximum value.[18]

A key part of this organisation in the US is the Asset Recovery Center in New York. This Centre, established in 1994, has processed over 100 million kilograms of equipment and material up to the year 2000. Being the largest demanufacturing operation in IBM, it has seen a broad range of both IBM and OEM returns. Consequently, the data and knowledge gained from its

dismantling and recovery processes have been key to both demanufacturing productivity improvements and landfill reduction. From a productivity standpoint, the organisation has shown a three-fold improvement as measured in kilograms processed per person since 1994. Additional environmental benefit is gained through the extensive use of recycling and reclamation vendors for residual commodity and material disposal after processing. As a result, the disposal of material to landfill has decreased from approximately 10% to less than 2.5%.[19]

IBM's vision is to transform GARS into an e-business. Developing the processes to expand into parts remarketing for OEM customers is one aspect. Providing a supply of industry standard parts or refurbished parts instead of automatically purchasing new and generally more expensive items is another. Likewise, giving customers the capability to obtain parts through service contracts rather than by owning inventory can provide them with not only reduced inventory costs but also reliability of supply within a committed cycle time. These activities capitalise on GARS expertise, established infrastructure and reverse logistics, and can help customers further integrate their supply chain and benefit the environment through increased systems and parts reuse.

8.5 Ford Motor Company

Motor company Ford has entered into an agreement with one of its American suppliers for the return and remanufacture of its toner cartridges. In 1996, when the agreement was put in place, the US Environment Protection Agency reported how Ford had estimated that the following benefits were realised:

- 30,000 kg of toner cartridges were remanufactured in 1996.
- In 1996, cost savings of $180,000 were realised from avoiding disposal costs.
- Since the concept began in 1991, Ford is thought to have collected a total of 150,000 kg of toner cartridge for remanufacture, saving $1.2 million.

Empty toner cartridges are collected through numerous means, including collection centres co-ordinated by employee volunteers and exchange programmes, whereby the supplier credits Ford for each cartridge returned. Ford then buys back the remanufactured cartridge for a discount on the cost of a new one. One of the key reasons for the success of the programme, according to Ford, has been the education provided to employees, raising their awareness and gaining their involvement.

9.0 Conclusion

Remanufacturing has a long history in the UK, and continues to be practised across a whole range of industrial sectors, some growing and some in decline. Theoretically, remanufacturing can contribute to more eco-efficient and sustainable product systems. However, the contribution that remanufacturing can make will be limited by the suitability of products for remanufacturing. It is widely acknowledged that remanufacturing has the potential to make quantifiable impacts on the level of sustainable consumption, and there are steps that all stakeholders can take to enable this. Foremost among these are the elimination of legal impediments such as:

- denial of access to manufacturer design information
- banning of remanufactured components in new goods
- redefinition of what constitutes waste.

Removal of these will increase competition and force the evolution of improved services including remanufacturing. If remanufacturing is to be more widely adopted there will need to be a push for freedom of information, a lifetime warranty to spur design fitness, and a liberalisation of the distinction between waste and resources to encourage trade in exploitable materials. Further success of remanufacturing will also entail concerted efforts by companies and industries to maintain high quality standards and establish a solid reputation for quality through branding.

Perhaps the greatest barrier to widespread, recognisable and acceptable remanufacture lies with the public perception of the actual quality of remanufactured goods. In some people's opinion, 'remanufactured' is just another term for something that is second best. The impact of negative public perception cannot be underestimated, and it will persist as long as the economy remains oriented towards the idea of single use. However, if the right information can be disseminated through the proper channels to provide a better understanding of the nature of the industry, then we stand a far better chance of giving companies the chance to find new opportunities for growth and

ultimately provide them with the knowledge and resources they need to extend the investments that have so far been made in durable goods through remanufacture.

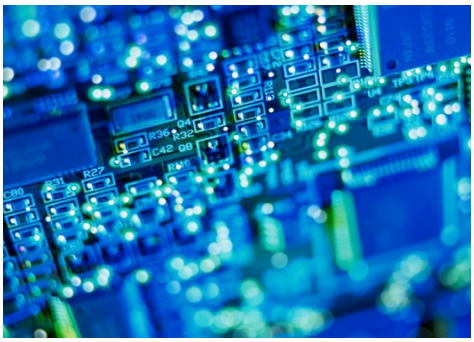
In today's economy, product life cycles are becoming global business. A product invented in Europe might be developed in the United States, manufactured in Asia, sold back to Europe or the U.S., disassembled in Mexico and some of its components might be remanufactured and reused in Hong Kong to be resold again in Europe. However, as transportation efforts and emissions not only have considerable cost, but also impact on the environment, this should not become the norm. Various different approaches to achieving successful and multiple product cycles by remanufacturing have to be found and applied.

10.0 Appendix 1: WEEE national recovery targets for 31 December 2006

Category	Recovery target (by average weight per appliance)	Recycling/ reuse target (of components, materials and substances, by average weight per appliance)
Large household appliances	80%	75%
Small household appliances	70%	50%
IT and telecommunications equipment	75%	65%
Consumer equipment	75%	65%
Lighting equipment	70%	50%
Tools	70%	50%
Toys, leisure and sports equipment	70%	50%
Medical devices	Target to be set by end 2008	Target to be set by end 2008
Monitoring and control instruments	70%	50%
Automatic dispensers	80%	75%
Gas discharge lamps	No target	80%

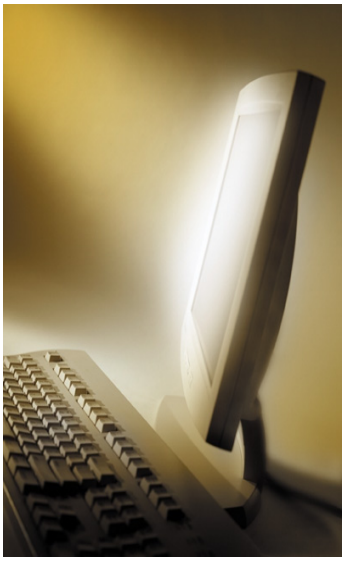
(Croner's Environmental Management, 2003)

11.0 Appendix 2: Advantages of PC recycling



Circuit boards

Most circuit boards and some hard drives can be marketed for resale as operational parts. Unusable circuit boards are broken down into a powder and separated into fibreglass, metals and precious metals through a process called fire assay.

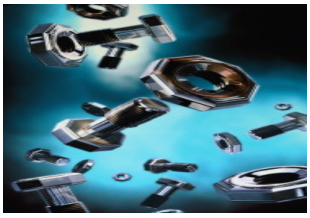


Plastic housings

Plastic housings are separated from the electronic equipment, and materials such as labels and foam insulation are removed through air classification. Unfortunately, plastic housings on computers and monitors will not fit on newer equipment. At present, these plastics are difficult to market because they contain mixed or unmarked resins that cannot be readily identified or separated, as well as some additives such as flame retardants that complicate recycling. Efforts are under way to find higher value applications for these plastics in products such as flooring, computers and automotive parts.

Small plastic components

The small plastic parts inside computers are typically made from uniformly coloured, high-density polyethylene (HDPE). This makes them easier to remove, grind and process. Recyclers must ensure that other materials (e.g. metals) or different resins are mixed in with these plastics. Even a small amount of contamination can cause a buyer to reject an entire load.



Screws, clips, small metal parts

Screws, clips and small metal components are sorted and separated magnetically into ferrous and nonferrous groups. The metals are sold as scrap.

Monitors

Monitors are handed over to a separate de-manufacturing line, where workers remove the plastic housings, metal supports, and circuit boards. The cathode ray tube (CRT) itself is a funnel-shaped, leaded glass tube with a metal frame inside. The funnel is separated from the front panel glass and the CRT is then crushed. The leaded glass and metal are then separated. The glass is screened, processed, and inspected for contaminants. Much of it can be sold to CRT manufacturers for use in new CRT glass, however the metal is sold for its scrap value.

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