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Organising Reuse: Managing the Process of Design For Remanufacture (DFR)

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Abstract

Remanufacturing has become increasingly prominent as a method for waste disposal due to increasing ecological and economic pressures upon industry. As part of a project to study the design and construction of a Remanufacturing Design Platform Model (RDPM), research has been conducted into the obstacles to the widespread introduction of remanufacturing, and how these affect the process of Design for Remanufacture (DFR). In addition to several technical and engineering barriers, we have found that there are a number of operational and production-based issues that need to be overcome. This paper describes ongoing research into these issues, suggesting how they may affect successful remanufacturing operations, especially within the relationship between Original Equipment Manufacturer (OEM) and Independent remanufacturers. The paper examines the link between management and engineering, and discusses how the issues of each discipline impact upon the other in respect to remanufacturing, drawing conclusions for the resolution of these issues.

Introduction

There are several methods of product reuse, ranging from repair through to remanufacturing. These methods have been 'ranked' into a sequence by Stahl [1], who differentiated between a "fast-replacement" system, or 'open-loop' approach, characterised by short-life, incompatible goods and products lacking 'repairability', and a "self-replenishing", or 'closed-loop' system, characterised by the ability to extend product life expectancy, and the reduction of product waste. This closed-loop approach, adapted from Stahl's original, is shown in figure 1. The size of the loop determines the amount of energy required to undertake the process.

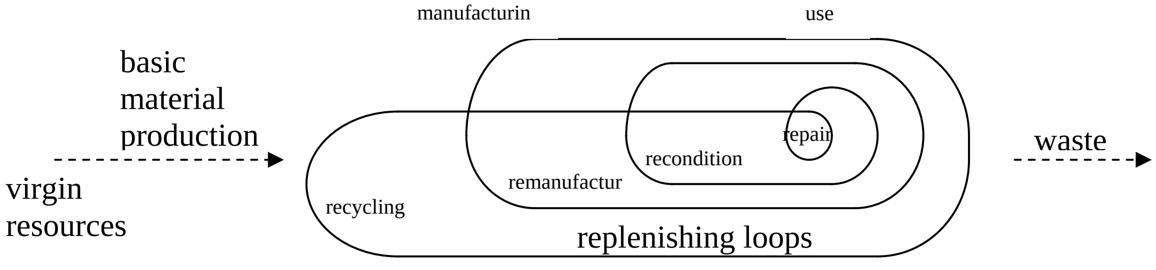

Figure 1: Stahl's 'Self Replenishing Loop' [1]

Repairing a product is the process of rectifying a number of given faults with a product and returning it to useful service. King and Burgess [2] describe it as the most logical approach to closing the loop on product use. Stahl [1] describes it as elimination of secondary damage such as worn components, or cosmetic damage (i.e. dents). Repairing a product minimises the energy and material needed to keep it in use at the expense of not offering an updated or improved functionality.
Reconditioning, meanwhile, is described by Stahl [1] as the process of putting a product back into prime condition. Examples are overhauls of machinery, and restoring old seals in damp operating environments. King and Burgess [2] describe it as 'rebuilding of major components to a working condition rather than as-new'. However, components which have either failed or are on the verge of doing so are replaced or rebuilt.
The third method of reuse, remanufacturing, is "an industrial process whereby products referred to as cores are restored to useful life. During this process, the core passes through a number of manufacturing steps, e.g. inspection, disassembly, cleaning, part replacement/refurbishment, reassembly and testing to ensure it meets the desired product standards" [3, 4].
Finally, recycling "involves the separation and collection of materials for processing and remanufacturing into new products, and the use of the products to complete the cycle" [5]. This is the method of reuse most clearly established within the public consciousness, where it is inextricably linked with the concept of waste reduction.
Each of these methods has advantages and disadvantages, as outlined in table 1:

Option	Advantages	Disadvantages
Repair	1. It minimises the amount of energy needed to keep product in use	1. Very little infrastructure is in place to provide this service
	2. It minimises the amount of material needed to keep product in use	2. Customers do not receive updated models
Recondition	1. It allows new low-skilled labour markets to establish new jobs	1. Customers do not receive updated models
	2. Relatively low cost of reconditioning means product is ideal for low income families	2. Few products can be economically reconditioned and then resold at a profit
Remanufacture	1. As-new product has the potential to be upgraded	1. Difficult to reclaim products efficiently
	2. This may provide sufficient added value to render product economically viable	2. Products tend not to be designed for ease of disassembly
Recycle	1. Relatively easy to collect waste material through existing disposal routes	1. Existing energy within product is lost during recycling process
	2. Existing wide public understanding	2. Quality and supply of recycled materials is difficult to guarantee

Table 1: Methods of materials reuse: advantages and disadvantages [2]

Remanufacturing, however, is the only method in which the performance of a used product is returned to at least the Original Equipment Manufacturer's (OEM) performance specification [6]. In addition, remanufactured items possess a warranty

which is equal to that of equivalent new products [2]. There are many such generic sets of steps throughout the literature [7]: Stahl [8] describes remanufacturing as “service-life extension of goods and components” and the creation of “new products from waste”; Nasr [9] states that remanufacturing is “the process of disassembling, cleaning, inspecting, repairing, replacing, and reassembling the components of a part or product in order to return it to like-new condition”; It is a process that is particularly relevant to the reuse of complex electronic equipment, which tends to have a core, which, when recovered will possess an added value that is high in comparison to their actual market value, and to their original value [2].
This paper describes some of the findings of the EPSRC funded “Remanufacturing Design Platform (RDPM)” research project. The research has studied the barriers that face the successful identification of remanufacturing; technical barriers have been well documented [2, 6], but business and economic barriers are less well defined. The following sections therefore briefly describe the most common technical barriers, before concentrating on business and economic issues. Finally conclusions are drawn.

Technical Barriers to Remanufacturing

Lindahl et al [10] state that product recovery has traditionally been viewed as an economically beneficial alternative to the ordering of new products. However, there are four principle barriers to the implementation of remanufacturing [2]. These are reverse logistics, disassembly, component inspection, and customer demand. In addition, Sundin [3] lists the following factors, drawn from earlier research by Hammond et al [11]:

- The availability and cost of replacement parts
- Product Diversity
- Cleaning/Corrosion
- Design Related Issues (complexity, fastening methods, means of assembly and disassembly, increased part fragility)
- Employee skills

Parlikad et al [12], meanwhile, suggest that amongst the problems faced by ‘demanufacturers’ are a high variety of products, and uncertain product condition after usage. As such, a large quantity of information is required about a product before it can enter the remanufacturing process, which is a major obstacle to the efficient recovery of value from returned products [12]. The following look at barriers to remanufacturing uses the headings proposed by King and Burgess [2], as headings suggested by other authors tend to fit within the broader four heading classification.

Reverse Logistics

Traditionally, the supply chain is seen as a one-way structure with a well-defined hierarchy, where goods are used for a certain period, and then discarded. However, remanufacturing inverts this process, reversing the usual logistical approach. The main aim of reverse logistics is to add economic, ecological and legal value to the product returned [13]. However, there are several problems in achieving this [2]. The end of life (EOL) product needs to be transported to the remanufacturing centre, and this can incur substantial costs. The cost can vary significantly between customer and location, which means that costs are difficult to define and predict. There is also the space aspect, as large quantities of products awaiting remanufacture can take up a considerable area. This area may be unavailable, and may incur further costs. The difficulties mentioned earlier in reclaiming parts for remanufacture also cause a problem, as variability of supply can lead to an unpredictable output, and affect availability to the secondary market. This can affect profit and the economic viability of the remanufacturing process. Finally, the identification and handling of returned goods can present issues, due to the potentially large variety of returned products and components, which could be in a damaged condition. This can render part identification extremely difficult, and cause problems because make and model details are crucial to the successful remanufacture of the product.

Disassembly

Disassembly is a particular problem within the remanufacturing process. Many authors address disassembly issues from the point of view of disassembling for material recycling. From a remanufacturing perspective, this is not necessarily a good idea, as it encompasses material reuse rather than whole component or product reuse. For example, it has been proposed that heating EOL components can release materials which can then be recycled [14]. Whilst this reduces time for disassembly, and associated labour time and costs, it is likely to prove unsuitable for remanufacturing as the heating process could damage the extracted componentry. Weiss and Karwasz [15] note that designers should consider disassembly issues in the very early stages of the product design process, thus reducing waste and energy loss from the product at end-of-life (EOL). However, they suggest that over 90% of waste from products cannot be utilised because it contains different compounds of materials and compounds. This would suggest that little thought is currently being given to designing products with EOL recycling or remanufacturing in mind. This point is also made by other authors, who suggest that further reasons why disassembly can prove a significant issue for remanufacturers are: the poor condition of products and components when they reach EOL, and the fact that many products are manufactured overseas, meaning that assembly logic and sequence information has frequently been misplaced [2].

Component Inspection

Components parts need to be inspected either visually or mechanically in order to confirm their suitable for remanufacturing. These inspections focus particularly on the condition of the component [16], but also the dimensions of the part to ensure that it is suitable for reuse. Certain components which are in good condition can be included in the remanufacturing process, whilst others, which may be either damaged or in generally poor condition, can be recycled [2]. Further checks must also be undertaken to ensure the quality of the remanufactured parts before they can be reintroduced to the market [17]. This can be a large cost issue for the remanufacturers for the following reasons [2]:

1. Components which will be unsuitable for remanufacturing can often block access to those that have the potential to be remanufactured. Inspection is therefore not always a quick or simple practice

2. It is difficult to identify the degree to which a component has worn or distorted unless there is access to an original as-new component. This can create problems in judging suitability for remanufacturing
3. The effort needed to inspect physically complex assemblies may be disproportionate to the value of remanufacturing. Therefore a method of inspection proxies to ensure fundamental issues can be established quickly

Customer Demand

“By far the greatest policy barrier to initiate new remanufacturing schemes is having a credible and stable demand for the remanufactured products” [2]. It has already been stated earlier that products created from reused materials can experience significant market acceptance problems [18, 19]. There are three key reasons for this [2]:

1. A remanufactured product that represents the previous generation of technology, styling, and functionality cannot compete with new products. Cheaper new products may lead to remanufactured products being uncompetitive within the market environment
2. Long standing customer perceptions of remanufactured goods as second hand can be extremely difficult to change. Manufacturers are also reluctant to offer guarantees that are fully extensive in case of high product recall costs.
3. It is possible that the introduction of a remanufactured product may damage an existing brand in terms of both image and sales. This can make remanufacturers reluctant to introduce remanufactured products.

Business/Economic Barriers to Remanufacturing

The Remanufacturing Design Platform Model (RDPM) research has revealed a number of non-technical barriers to the introduction of remanufacturing. These range from economic reasons, such as financial unviability and lack of incentive, to skill shortages, corporate identity, and environmental legislation. In addition to these barriers, the very size and structure of organisations can influence the ability to remanufacture successfully. Sundin [3] identified three distinct sets of actors within the remanufacturing process:

- the Original Equipment Remanufacturer (OER), which is in fact an Original Equipment Manufacturer (OEM) that undertakes to remanufacture its own products from service centres, trade-in agreements, or end-of-lease contracts
- Contracted Remanufacturers, which are organisations that are contracted to remanufacture certain products on behalf of other companies. This usually means that the OEM retains ownership of the product, but chooses to out source remanufacturing rather than undertake the process internally. The OEM is then able to sell the product back to the consumer for a slightly lower price.
- Third Party Remanufacturers. These are organisations who remanufacture usually independently of the OEM. Their business relies upon sourcing sufficient cores to make the business profitable. Sourcing may be achieved through the collection of redundant products cores from the consumer, and the process is likely to require the purchase of new or replacement components, probably from the OEM.

Our research has shown that non-OEM remanufacturers can face significant difficulties, and feel squeezed out of the market, if they do not receive the support of OEMs [20, 21]. Amongst the suggestions made have been that OEMs deliberately design components so that they cannot be remanufactured, restrict the availability of parts and components to hinder third-party remanufacture of whole products, and withhold schematics and other design documents from non-OEM supported remanufacturers [21, 22]. Conversely, OEMS can, and do, foster non-centralised remanufacturing by forging partnerships with 'contracted remanufacturers'. This leads to an OEM dominated market, where the OEM exerts a large degree of control over the remanufacturing operation [22]. These partnerships, which turn independents into semi-independent remanufacturers, are structured by the agreement of joint ventures with long-term Service Level Agreements (SLAs) and contracts [20].

The research has identified the following ranking of non-technical barriers to remanufacturing [20]:

		Barrier to Remanufacturing
1.		Risk to Reputation (Corporate Identity)
2.		Uneconomic to Remanufacture
3.		Low Arising (low number of instances)
4.		Lack of Skills
5.		Environmental
6.		Lack of Incentive
7.		Technology

Table 2: Non-technical Barriers to Remanufacturing

The following sub-sections deal with each of the barriers listed above, describing them in greater detail:

Risk to Reputation (Corporate Identity)

OEMs tend to be extremely protective of their 'brand', which in many cases is their biggest asset, to which consumer perception is inextricably linked. This can have twin effects upon the decision to remanufacture. On the once hand, organisations may never lose interest in the remanufacture of a product, however old it is and however few remain in the market place, because to do so would be to risk the perception of quality associated with the brand [20]. Conversely, to some, the brand is so precious that it would render remanufacture too big a risk to undertake at all [23], as potential loss of control of branded products (i.e. through third-party manufacture) and associated risk of product failure could cause incalculable damage to the product/brand image.

Uneconomic to Remanufacture

There are instances where a remanufacturing operation can simply be too uneconomic to undertake. Although these are rare due to reasons outlined in preceding and succeeding sub-sections, possible reasons for this are [20, 21, 23]:

1. OEM non-cooperation with third-party remanufacturers/OEM restrictive practices
2. Too few examples of the product remaining in the market place
3. Cost of remanufacture
4. Brand Awareness
5. Unavailability of specialist equipment/machinery

Generally, however, if the organisation is large enough, and is the OEM, remanufacturing can be made to economically viable by offsetting the economic outlay against future business, potential market growth, and enhanced brand awareness.

Low Arising (low number of remanufacturing instances)

Where the number of older or outmoded products remaining in the market place is small, and consequently the need for remanufactured examples is rare, a remanufacturing operation can be rendered uneconomic and infeasible due to skill shortages (i.e. where the process would require antiquated machinery and old-fashioned skills/methods that have long since been replaced) [20]. However, brand/quality awareness, and the potential to secure further business ensures that OEMs can often still wish to remanufacture, even if the operation appears to be a loss-leader. This can be offset by packaging the remanufacture of older products with the sale of newer versions, or even by organising a trade of old for new(er) products [20].

Lack of Skills

This barrier has already been mentioned in preceding sub-sections. It usually affects ‘legacy’ products. This can be especially prevalent in the aerospace sector [20], where products can have been in market place for decades, and have been sold on from primary- to secondary- and possibly, tertiary-user. Often this can result in OEM concern over losing control of the product and potential damage to brand. However, it can also suit small-scale remanufacturers that have geared themselves to an increasingly niche market [20], where product information has become available due to the passage of time, and where the organisation has acquired the specialised tooling and skills required for the particular product(s).

Environmental

Increasingly, fears over the environment are leading to legislation to promote reuse. In Europe, for example, the Waste Electronic and Electrical (WEEE), Removal of Hazardous Substances (RoHS) legislation has recently been enacted [24, 25]. This will shortly be joined by the Energy using Product (EuP) directive [26]. As a result of these legislative efforts, manufacturing organisations are mandated to put aside funds to cover the costs of end of life (EOL) product disposal. One view is that as the disposal costs are already accounted for, so reuse becomes an unnecessary expense, and so environmental legislation becomes a barrier to remanufacturing. A further reason is that the required methods and practices to strip and renew parts may be so environmentally unfriendly (i.e. the use of acids for cleansing purposes etc) as to deter remanufacturers.

Lack of Incentive

Smaller or independent organisations are more likely to forego potential remanufacturing operations where there is a lack of incentive to remanufacture certain products. Amongst the potential reasons for this are [20, 21]:

1. OEM non-cooperation with third-party remanufacturers/OEM restrictive practices
2. Insufficient profitability potential
3. Set-up costs and affects on revenue (short- and medium-term)
4. Lack of tax breaks

These effects are less common where OEM-remanufacturers or OEM-supported remanufacturers are concerned [21, 22].

Technology

Technology can prove a barrier to remanufacturing where advances in practices, construction methods and materials occur rapidly, leading to short-lived or unstable technological environments [23]. This can make the remanufacture of products such as white goods and domestic appliances difficult to justify both in terms of initial outlay and medium-term profitability. This can also be the case where the technology of the product in question is long outmoded or obsolete.

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Conclusions

This paper has described the nature of remanufacturing, and the principle barriers that affect its successful implementation. These barriers are mainly technical, business and economic in nature. However, the type of organisation has a significant impact upon the ability to remanufacture. Original Equipment Manufacturers (OEMs) are in a position to dominate the remanufacturing market, and to dictate terms to smaller independent and semi-independent remanufacturers. Where OEM support is withheld or not sought, the operation of remanufacturing can be badly compromised. The most important business-related factor outside of this has been found to be brand awareness/risk to reputation – with this providing both an incentive and a disincentive to remanufacture. Other factors, such as economic viability and skill base, provide obstacles to remanufacturers, but can be overcome in the appropriate business environment. This paper highlights some of the most visible business- and economic-related barriers to affect remanufacturing. Further research needs to be carried out in to how they affect remanufacturers, and how they can be mitigated. Other research could also be conducted to discover how social trends such as fashion and perception could be addressed.

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