Assessing the Technical and Economic Feasibility of Remanufacturing

Environmental Issues

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Current political and environmental trends are leading to mandatory take-back programs in which the producer of the product is responsible for remanufacturing or recycling its products. This emerging trend represents an opportunity for companies to lessen their impact on the environment in an attempt to gain or retain their competitive advantage. Remanufacturing is especially critical for electronic products where end-of-life issues emerge quickly due to short life spans. We present a framework that identifies the critical conditions under which remanufacturing is technically and economically feasible. We will also test our framework by applying it to the remanufacturing of an office copier.

Introduction

An opportunity for companies to reduce some of their negative impacts on the environment and gain or retain their competitive advantage has emerged. Recovering products at their end-of-life (EOL) from customers diverts waste disposed in landfills and results in recaptured asset value from the recovered products. Common processes of recovery are repair, refurbish, recycle, reuse, and remanufacture. Numerous factors determine which of these methods is best for a given company. This study proposes to elucidate what factors allow remanufacturing to be feasible.

There are three main reasons why companies choose to recover their EOL products: market restrictions, recapturing hidden economic value, and government regulations [Gungor, Gupta 1999]. Market restrictions refer to after-market sales. The original equipment manufacturer (OEM) may want to inhibit other firms from reclaiming its products and reselling them under the OEM's name. To accomplish this, the OEM must reclaim the products, thus restricting the after market for third party firms. Recovery due to market restrictions currently occurs only on a small scale. Recapturing hidden economic value fails to provide adequate profit motivation at current landfill disposal rates. Firms that recover EOL products for this purpose in an attempt to resell the materials or parts a second time rarely see enough profit to justify the costs of the recovery process. Therefore, the third reason for recovery, government regulations, typically acts as the driving force behind product recovery by companies.

Government regulations for recovery are already proposed or enacted in several European countries. For example, the European Commission published the Waste from Electrical and Electronic Equipment (WEEE) Directive obligating manufacturers to take-back and recycle significant percentages of their EOL products [Goggin and Browne 2000]. A German legislation mandated manufacturers and retailers to take back and salvage EOL products and design new ones with recycling in mind as of January 1,1994 [Gungor and Gupta 1999]. European take-back legislation has also been enacted in Sweden, Switzerland, the Netherlands, and Norway, and draft take-back legislation has been produced in Austria and Denmark [Nagel and Meyer 1999]. As of 1998, Austria was handling disagreements between the government and industry on which electronic scrap should be considered hazardous, thus delaying take back legislation on office equipment, computers, TVs, VCRs, and other products [Product Stewardship Advisor 2000]. The legislation, if passed, would be funded through a surcharge on new products. Denmark's law will require municipalities to operate recovery schemes and allow producer take back for those who demonstrate environmental compliance. The plan, expected to have taken effect in early 1998, covers audio/video equipment, IT equipment, telecommunications equipment, and equipment for monitoring, medical use and laboratory use [Product Stewardship Advisor 2000]. This law will be funded through municipal waste removal fees and additional fees for business. In addition, pollution taxes have been introduced in countries such as Denmark, Norway, and the Netherlands [Gungor and Gupta 1999]. By 1998, Italy had an enforced comprehensive waste management decree that called for industries to develop take-back schemes for refrigerators, washing machines, TVs, and computers. The take back is free of charge to consumers upon purchase of a new product.

As these regulations continue to be established in Europe, the United States must prepare for take-back schemes of its own. The impending government regulations will force companies to determine the best alternative for removing products at their EOL from the waste stream. Thierry, Salomon, Nunen, and Wassenhove (1995) discuss five options of recovery: repair, refurbish, remanufacturing, cannibalization, and recycling. Gungor and Gupta (1999) classify these options into two categories: material recovery (i.e., recycling) and product recovery (i.e., remanufacturing).

Recycling is currently the most common form of recovery [Remich 1993]. It consists of disassembling a product to material level, sorting the materials, and transforming them into a reusable form. However, recycling does not retrieve the highest economic value for the used product. Robert Lund, a manufacturing and engineering professor at Boston University indicated, "Most people are unaware that remanufacturing is really a higher and more profitable form of recycling that retains most of the material, energy, capital, labor and other value-added services that went into making the product in the first place. Recycling, on the other hand, spends a lot of energy and expense tearing apart a product to gain a few elemental components. I've yet to see anyone make a profit off recycling…" [Baker 1995].

Remanufacturing is the reuse of components and assemblies of returned products to produce new or similar products of equal or superior quality and reliability. It encompasses collection, sorting, disassembly, cleaning, replacing and/or repairing defective components, testing, reassembling, and inspecting [Gungor and Gupta 1999]. The main goal of remanufacturing is to extend the product life of equipment, thus diverting it from a landfill [McConocha and Speh 1991]. Only those components that are technologically obsolete or worn-out are replaced.

Remanufacturing reduces virgin raw material costs and utilizes less energy than recycling, thereby increasing its profit potential as a recovery process. Another benefit of remanufacturing is it enables manufacturers to discover weaknesses in the product structure and materials thus identifying areas needing improvement [Hormozi 1996]. An obvious obstacle in this scenario is that not all products are remanufacturable. Indeed, numerous factors such as cost, labor availability, returning flow volume, and optimal disassembly level, determine which recovery process is feasible.

Due to the possibility of profitability in asset recovery by remanufacturing, it is important for firms to investigate this option. Extensive research has been conducted on asset recovery options. Models to determine optimal recovery and disposal strategies for OEMs have been proposed [Remich 1993, Krikke et al.1998, Goggin and Browne 2000]. Comparisons between recovery options in reference to disassembly levels and quality are offered [Thierry *et al.* 1995, Zussman and Zhou 1999]. There have also been software tools designed to aid in the planning of recovery systems [Remich 1993]. The existence of such literature symbolizes the increasing effort to determine an optimized recovery strategy. With the possibility of regulations reaching the United States to mandate product take-back, researchers are focusing their efforts at finding the most effective strategies for firms faced with having to retrieve their EOL products. Efforts to optimize disassembly, recycling efforts and even the decision as to which recovery option is most effective are evident. However, there is yet to be a framework to assess the technical and economic feasibility of remanufacturing.

The objective of this research is to determine the factors that contribute to making remanufacturing a viable option. Firms need to be aware of potential opportunities and obstacles to asset recovery through remanufacturing. By reviewing recent literature on the subject of asset recovery, we develop a framework to assess the technical and economical feasibility of remanufacturing. The framework will then be validated through a case study involving an office copier machine. As such, the framework will focus on the remanufacturing of electronic products and all aspects relevant to the electronic and electrical equipment industry. In addition, the framework will be developed from the viewpoint of the original equipment manufacturer, not an outside third party.

Proposed Framework

The framework will examine all factors critical to the success of a remanufacturing operation, extrapolate those that are most influential and determine the ultimate feasibility of remanufacturing, based on an economic analysis. This framework is developed to aid those companies expected to participate in a government mandated take-back scheme. Remanufacturing is often thought of as a highly complex recovery system, giving rise to the popularity of recycling. The outcome of an analysis on the remanufacturing process hopes to uncover a simple method by which to determine the feasibility of remanufacturing thus maximizing profit for those companies involved. There are numerous variables contributing to the feasibility of remanufacturing; return flow, collection costs, inventory costs, disassembly cost, technological feasibility, labor cost, and cost of testing. Each of these costs plays a role in determining the profitability of remanufacturing.

Return Flow and Collection Costs

The assumption of forthcoming government take-back regulations on certain electronic products has two major impacts on the proposed framework. First, the issue of the expected quantity of returned products is factored out. This parameter represents the certainty manufacturers have in the amount of products returned over a predetermined time. The expected return flow, if too low, results in the termination of any attempted recovery process. For example, companies that lease their products are in a more favorable position than those that only sell their products because leasing companies have more information on the quality and timing of returned products [Thierry *et al.* 1995]. However, this framework is developed for those companies facing the unimpeded return of a product who merely need to determine the appropriate process by which to recover them. Rolf Winkler (1996) offers suggestions to improve forecasting techniques for companies attempting to remanufacture in a non-enforced environment.

Secondly, all costs of collection, shipment and storage of used products are factored out from the framework due to their presence in all forms of product recovery. For example, whether the product is being recycled or remanufactured similar transportation and collection costs exist. The only difference may occur in handling of the product. If the product is bound for recycling it may not be handled as safely as one intended for remanufacture. Any cost difference experienced for this reason could be recuperated in reduced liability for the workers.

Inventory Costs

Inventory costs vary between recovery options. Recycling requires the OEM to retain the material either in a collection bin until a vendor is found, or if a vendor exists, until the bin becomes full enough to transport. There are two approaches to executing a remanufacturing process. First, returned products are disassembled to part level, the parts tested, necessary upgrades performed, and reassembled into a “new” product with the same parts as before. If this process is utilized, inventory could be minimal assuming there is a customer order to purchase the product or assuming the remanufactured product takes the place of a newly manufactured one in inventory. The second approach is to disassemble the machine to part level, test all parts, and place those that pass the test in inventory as parts alongside new, unused parts. Again, in this scenario no increase in inventory cost occurs because the remanufactured parts replace inventory space previously inhabited by new parts. The second approach whereby remanufactured parts are stored as inventory and eventually reassembled into a product is the one assumed in this framework.

Disassembly Cost

The cost to disassemble is not the same for all products [Thierry *et al.*, 1995]. In fact, it can be more expensive to disassemble for recycling because products are disassembled to the select part or material level, while remanufacturing requires disassembly to the component or part level. Costs to disassemble are not exclusive to remanufacturing and are not greater than other more familiar forms of recovery (e.g., recycling) that would be adopted if remanufacturing were unfeasible. Therefore, this cost is also not the governing factor in deciding the feasibility of remanufacturing. It is important to note that disassembly cost can be minimized to an economic optimal. The sequence in which a product is disassembled depends on the type of product and desired quality of the disassembled components or parts. A disassembly analysis tool such as the one developed by Johnson and Wang (1998) or Zussman and Zhou (1999) could prove useful in determining this economically optimal sequence.

Technological Feasibility

Technological feasibility refers to the viability and durability of the product under analysis. Viability is the ability of a product to be reclaimed and disassembled into reusable components while durability refers to the quality of the components/parts disassembled. Researchers have accumulated several key factors in assessing the technological feasibility of remanufacturing. First, the product has to have a ‘core’ that can be the basis of the restored product characterized by relatively low technological obsolescence and made up of mechanical and electromechanical components/parts that can be easily disassembled and restored [McConocha 1991, Sarkis 1995, Klausner 1999]. Stable product and process are mandates of a remanufacturable product [Sarkis 1995]. It is more suitable to remanufacture a product that fails functionally rather than one that is discarded due to obsolescence. The proposed framework will focus on an office copier machine. This electronic product is technologically remanufacturable so further assessment on this factor is not necessary. When applying the model to different products technological feasibility will be addressed during the testing stage of remanufacturing.

Labor and Testing Costs

Labor costs vary significantly between recycling, remanufacturing, and manufacturing. Testing and reconditioning the remanufactured components requires considerable amounts of time and manual labor, as well as some material costs for repairs and upgrades. These factors will determine the feasibility of remanufacturing because their economic burden is highest for a remanufacturing process.

Case Study

The proposed framework addresses the remanufacturing of an office copier machine. The focus on one type of electronic product is necessary because of the vast differences among the remanufacturability of different products [Goggin and Browne, 2000]. Developing a useful framework encompassing every type of electronic product would be nearly impossible or so generic it would not be useful.

Another important distinction of this framework is its working definition of remanufacturing. Similar to Goggin and Browne's (2000) reassemble to order scenario, remanufacturing of copiers can include used and new components and parts. The machine is disassembled to component level, tested, and usable components are placed in inventory until a remanufactured machine is made based on a forecast or customer order. Therefore, the EOL machine is not remanufactured using the same components, but rather from an array of remanufactured components from various machines. In addition, if a certain component is no longer technologically viable, or not of highest quality, the component will be replaced with a newly manufactured one.

The labor cost to remanufacture must be less than or equal to the cost of manufacturing in order for remanufacturing to be feasible. The framework will provide an answer to the feasibility of remanufacturing an office copier and will not provide further guidance as to which remaining recovery option is most appropriate. For instance, if the result of an analysis is that remanufacturing will not be profitable for the company's product, the framework will not provide an alternative recovery solution. There is a chance that remanufacturing is infeasible, but that recycling is even more infeasible due to higher costs. It is not the intent of this framework to determine recycling costs and feasibility, however. In addition, the "do nothing" scenario of simply landfilling the product is not considered in the cost analysis because the purpose of recovery is to divert waste from the landfill. This option may not even be viable due to the decreasing number of non-hazardous solid waste landfill sites. Furthermore, current and near future disposal costs are unlikely to reach a point where recycling or remanufacturing is less expensive than landfilling.

Data on an office copier machine will be collected at a well-known copier manufacturer. When gathering information, it may be necessary to estimate values for which data is not available. These estimates will be made on a case-by-case basis and cannot be anticipated at this point.

Conclusions

Manufacturers will be given a process by which to determine if they should continue remanufacturing a product. Data needs include, but are not limited to, a list of the components of the product that could be remanufactured, the expected life-time use of each component, the cost associated with the manufacturing of each component, and labor cost for testing per component or unit. The company utilizing this framework will need to track the time spent testing remanufactured components/machines and the amount of those deemed acceptable for remanufacturing. As such, each time the framework is applied to a product, the input values will vary. Note that a considerable amount of input data is generally required.

In summary, the proposed framework will be a useful tool for those companies faced with the return of their EOL products. Remanufacturing is considered to have a higher profit potential than recycling and as such should be a company's first recovery choice. This framework will determine whether remanufacturing is a profitable process for the company.

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