BH056

From Garbage to Goods: Successful Remanufacturing Systems and Skills

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Concern over resource consumption and other environmental issues has led to the creation of an international objective. Known as the "sustainable growth" initiative, it aims to achieve economic growth for the current generation without diminishing the alternatives for future generations. One aspect of achieving sustainable growth is increasing the amount of product materials recovered from the world's waste stream. There are three major recovery approaches: recycling, recovery, and remanufacturing.

The least attractive of these is *recycling*. Examples include sending metal back to a foundry or cartons back to a paper plant. Recycling does reduce the need for raw materials and disposal space, but it involves the use of energy, transportation, and processing resources. *Recovery* involves removing parts and components for reuse, with the rest of the product being dismantled for recycling. It requires the use of logistics, disassembly, and sorting skills.

We focus on *remanufacturing* here, which involves recovering usable parts from discarded or retired products, recycling the unusable parts, and reassembling the recovered parts into usable components and/or products. Remanufacturing requires reverse logistics, disassembly, and sorting skills, plus reassembly capability. Early remanufacturing activity was limited to just a handful of capital goods. Now, a large number and variety of products are being remanufactured. Successful remanufacturing reduces product cost, provides environmental benefits, and enhances profitability simultaneously.

Remanufacturing is not simply a matter of announcing a program, however. To be successful at it, a firm must have a number of corporate capabilities, organizational skills, and areas of market awareness in place. The specifics may vary depending on the industry and/or the company, but there are several common issues. We will consider some of the drivers of increased remanufacturing, then turn to the issues involved in developing the logistics, disassembly, reassembly, and marketing skills necessary to succeed.

Mastering the art of recovering and rebuilding products and parts from the world's waste stream is a big step toward achieving sustainable development.

THE DRIVERS OF REMANUFACTURING

The decision to engage in remanufacturing is driven by several different factors. Legislation is a factor when there are environmental or safety concerns. Rebuilding products to extend their useful economic life has been around for some time. And a growing number of firms find strategic reasons to engage in remanufacturing. **Figure 1** shows examples of remanufactured products for various companies subject to each of these three broad factors. The final decision must satisfy an economic rationale, even if prompted by legislation.

Legislation as a Remanufacturing Driver

Despite what Figure 1 implies, it is important to discuss legislation as a remanufacturing driver

Figure 1
Motivations Behind Product Remanufacturing Programs

Driver	*Organization / Issue*	*Product Example*
Legislation	Municipality / air pollution control Manufacturer / waste water quality Service organization / radiation exposure	Waste incinerator smoke cleaner Water treatment equipment X-ray equipment
Prolonging economic life	Municipality / capital equipment maintenance Manufacturer / capital cost control Service organization / product damage control	Garbage trucks, subway cars Machine tools, conveyers Rail cars, warehouse equipment
Strategic opportunity	Municipality / image enhancement Manufacturer / profit enhancement Service organization / variety enhancement	Buses, official vehicles Photocopiers, ready-to-use cameras Engraving tools, commercial stoves

more because of what is likely to occur in the future than because of the concerns of today. We already know, for example, that German companies are responsible for all their packaging, from cradle to grave. In the future, many companies will likely have to become responsible for all aspects of their products in the same way. Automobiles, many home appliances, computers, and other such products have already been the subject of such discussions. The implications are clear: Companies that have never thought about it will need to develop the same remanufacturing skills as those that are driven by economic or strategic initiatives.

Remanufacturing to Prolong Economic Life

Maintenance and rebuilding are closely related to remanufacturing and are two aspects of prolonging the economic life of equipment. A typical example is an airplane maintenance schedule, which renews the useful life of the airframe and turbines several times before the equipment is retired. Public transportation companies adopt similar policies for their locomotives, subway cars, and buses. Rebuilding is used to extend the useful life of earth-moving equipment, cranes, machine tools, rail cars, and the like. It avoids the need to replace the old equipment, often at considerable savings over new purchases. This form of remanufacturing is frequently contracted out to qualified third parties, thereby providing an economic opportunity for the companies that develop the capabilities needed to do it well.

Strategic Opportunities for Remanufacturing

Firms that develop the capability to succeed in the rebuilding business can apply those skills in other markets. Several automobile component remanufacturers gained their experience rebuilding race cars and now serve a broad automotive component market. Some photocopier dealers gained remanufacturing experience by maintaining their machines. The remade photocopiers are often sold with a maintenance contract and a warranty comparable to that of a new product. In another example, several companies have begun to remanufacture personal computers for schools and small businesses, where cost is an important factor.

Some firms have adopted remanufacturing as a major component of their manufacturing strategy. Successfully incorporating it into corporate strategy, however, may require significant changes in the product design, as was the case with Kodak and its ready-to-use cameras. It may also require process changes to ensure cost-effectiveness and product quality, as was the case with Xerox and its remanufactured copiers. Other capabilities must also be developed if firms are to succeed at remanufacturing. One of these is the ability to collect and transport discarded or retired products.

REVERSE LOGISTICS IN REMANUFACTURING

Retrieving used products and components from customers and returning them to a processing facility is called *reverse logistics.* Once the user has decided to trade in or retire a durable good, the existence of an efficient reverse logistics system is necessary if any remanufacturing is intended. The system can involve intermediate collection points, and the processing facility can be the original plant or some other location. In fact, the process for transporting and handling used goods can require an organizational infrastructure even more complex than that for new products.

Management must make a number of important decisions in designing and operating the reverse logistics system. Such decisions seem very similar to those in distribution logistics, but they are often more complex. Management must provide an efficient means for collecting, transporting, and storing a large number of products and components in different states of wear, and delivering them to the appropriate remanufacturing facilities. Several major logistics decision issues affect product remanufacturing. The development of the transportation and storage network that feeds the remanufacturing operation, the handling and packaging required to accommodate a variety of product models and states of wear, and the selection of disassembly facility locations are those discussed below.

Transportation and Storage

Researchers have tackled many of the scheduling and inventory management problems appearing in forward logistics for a given distribution network. One very difficult problem, however, is to identify the most efficient network of central and regional warehouses with all the related transportation links. Remanufacturers face the same issues in designing the system to collect the used items needed for their operations.

Since the company has already developed a distribution system, why not just use the return trip as the backbone of the collection system? Combining the forward and reverse logistics system may seem appealing, but forward distribution rarely fits reverse logistics needs. Usually, forward distribution is designed to handle large volumes of the same product from the manufacturer to a few customer locations. In reverse logistics, the product mix can vary substantially, with the volume for some of them being quite low. Moreover, there can be many more locations for retrieving used products than for delivering new ones, and the final destination for the used products might not be the original manufacturing site. Some idea of this complexity is illustrated in **Figure 2.**

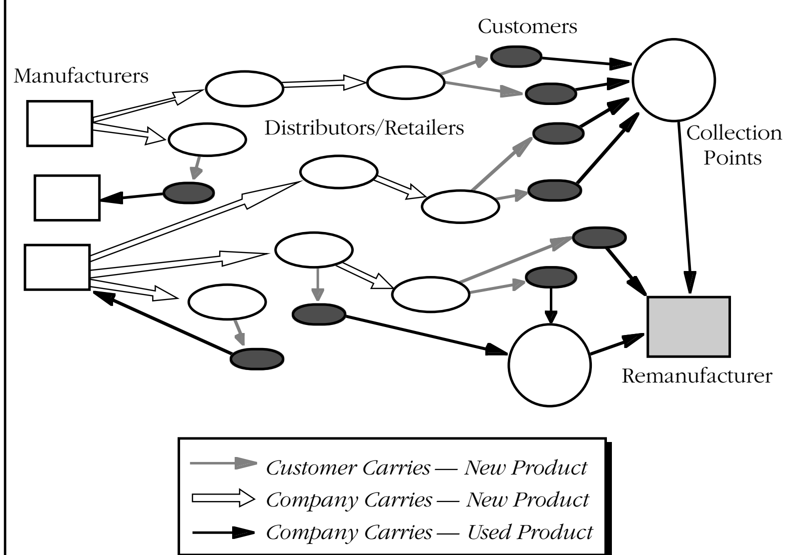
The transportation and storage network must match the availability and location of used products—"cores," as they are called in the industry—to the requirements at the remanufacturing facilities. It may be necessary to develop the collection network separately from the distribution system to accomplish this. Moreover, the reverse logistics system must reflect the remanufacturing strategy of the firm. One company's strategy may require a centralized stocking point of cores for a remanufacturer to serve a single large customer, while another company may have highly decentralized activities because of low economies of scale and scattered demand.

Because the forward and reverse logistics systems are often different and the cores widely distributed, transportation economies can be hard to achieve. Some clever approaches have been devised. A firm might aggregate the reverse flow of used products from several companies. One example of a multi-company network is the one developed for the collection of used "ready-to-use" cameras in Europe. In each country or geographic region in Europe, a different manufacturer coordinates the collection and transportation of used cameras from photo development laboratories where they are stored. The cameras are taken to an independent separation warehouse where they are sorted and sent to the appropriate remanufacturer. In a variation of the theme, the separation of used cameras is performed under the auspices of a philanthropic organization in France.

Another means of gaining transportation economies is to aggregate products. An example of a multi-product network is the system developed by IBM for collecting used computers in Europe. Recovery subsidiaries in different countries collect all types of used IBM products in their region. They perform a first-level disassembly of all products containing reusable components and deliver the components to the corresponding product subsidiary for storage and remanufacturing. The parts of the product that cannot be remanufactured are recycled locally. With this procedure, IBM gains economies by transporting only the remanufacturable components to the subsidiaries.

These examples of transportation and storage were developed to suit the companies' used

Figure 2
Product Flows



product logistics needs, remanufacturing strategies, and available resources. The used product has little or no value before the recovery process occurs. Hence, it is crucial to ensure that the volume and quality of the used material is worth the transportation and storage cost. By aggregating the collection of ready-to-use cameras from different manufacturers at the processor, it is possible to achieve economies of scale. By separating the valuable components of used computers early in the reverse logistics system, IBM saves transportation costs.

Handling and Packaging

Several details about the collection and return of used products complicate the design of the system. There can be many more models of the product in the reverse logistics flow than in forward distribution. Paradoxically, used products may be more "fragile" than new ones. The state of the products as they enter the reverse logistics system can vary enormously in terms of cleanliness, condition, location, and ease of access. Each of these factors imposes an added dimension of complexity in handling, which places extra demands on the design of the system to be able to accommodate the variability.

Even if the reverse logistics system is only concerned with collecting one product family from a single manufacturer, product variety for collection can be greater than that for distribution. This occurs because of product life cycles, if for no other reason. Consider a manufacturer that releases a new product design about every two years. This implies that a new product is handled by the forward logistics function every two years. Now if some customers dispose of the product four years after introduction, the reverse logistics system must start to handle the used product and continue until disposal stops—say, five years later. On average, if this process repeats itself for several product generations (and all used units are returned), the reverse logistics system deals with two and a half times as many models as the forward logistics system. Of course, adding more products or other manufacturers will increase this variety.

The implication of this process is that, surprisingly, the collection of used products may require more skill than the distribution of new ones. Other factors also require more talent than might be assumed for "used" products. The product is unlikely to be packaged protectively; some companies, like Sonoco, take back the original packaging as a part of their own environmental programs. Some cores may even need to be disconnected before being removed from the facility. Different tools or skills may be required to handle the different generations of product that may be encountered. Moreover, used products may be inherently more fragile than new ones because structural integrity may have been compromised during use. If the product is handled roughly, some of the remaining value may be destroyed. Again, this may require more care in handling than with new products.

When the forward logistics provider receives the merchandise, it is appropriately packaged, ready for distribution. The situation is quite different when collecting used products at the customer's site. Transporting unprotected used products to the collection warehouse and stocking them with other unprotected goods may damage them. Hence, packaging systems may be needed to avoid further deterioration of the used product and to protect the remaining value. This may be as simple as providing packing material for use at the collection point to package the used product. In other instances, a standardized, reusable container may have to be designed for protecting, transporting, and storing.

If a new container is required, it has to satisfy some basic constraints such as content protection, high reusability, and low cost. In addition to these, some constraints are specific to the collection needs. The container has to be simple to use in the field and compatible with many product models. Flexible packaging can be created in several ways. Multi-compartment containers with packing material and/or quick clamp tie-downs, for example, work for a variety of small units. Larger equipment can be placed on pallets to be wrapped with plastic film. The transport vehicles themselves can have multiple racks or cubicles for products.

An alternative to developing specialized packaging or vehicles is to contract with the customer for the return of the product in good condition at a specified collection point. Leasing contracts can also be used to control the "return" of particular models to realize the benefits of reduced variety. Xerox manages the return of its large photocopiers by means of leasing contracts. This ensures that returning machines are about the same age, thereby creating volume economies in transportation, storage, and remanufacturing. Regardless of the approach, the reverse logistics system must accommodate the special handling and packaging demands of used products, requiring more sophistication than might appear necessary on the surface.

Sorting and Disassembly

One aspect of the collection system that again illustrates the need for skill in the reverse logistics system is that of sorting the used products. For many product types, a judgment as to remanufacturability should be made early in the collection process. If, for instance, the wear state of a product indicates that there is little likelihood of recovering any value, it is not economical to add extra transportation and handling costs to the product. In many instances, the trade-off between the potential recoverable value and the added costs is not easy to make. It requires skill and experience. Skill in making this decision may mean the difference between profitability and no profitability for some firms. This makes the development of sorting capabilities a priority for some reverse logistics systems.

Figure 3
Some Alternative Remanufacturing Choices

Location of Facility	*Advantages*	*Disadvantages*
Manufacturing plant	Experience of work force Product knowledge infrastructure	Decreases the focus of the plant Increases part variety and inventory
Few specialized facilities	Volume—economies of scale Few specialized work forces	Increased transportation of cores
Many specialized facilities	Decreased transportation of cores	Increases coordination needs Need many specialized work forces
Third party	Transport volumes can reduce costs Economies of scale reduce costs	Loss of control of process Loss of priority control

Once the products are sorted, those deemed worthwhile must be disassembled before any remanufacturing can take place. An important question is where the disassembly should be done. An obvious possible location is the facility to which the material is first brought after collection. For widely distributed products, however, this could mean a large number of disassembly facilities, all of which would require skilled labor. Staffing a large number of small facilities may not be warranted. On the other hand, transporting the used products back to a central facility or to the original manufacturing site means transporting potentially useless items. Also, if the disassembly activities are added to the original manufacturing site, it could so complicate the work environment that all efficiencies would be lost.

The question of where to disassemble is similar to the question of plant or warehouse location, involving trade-offs between transportation, storage, facility, and processing costs that vary with the number of facilities and their locations. Observations of empirical decisions provide mixed results. Because it may be difficult for any single company to achieve economies for disassembly, third-party providers may contract with a number of firms to perform the disassembly operation, providing economies for everyone. Pitney Bowes contracts with a third-party provider for disassembly, having determined that the costs for transportation, labor, and processing inside Pitney Bowes are greater than paying for what the third party can do. Of course, this implies careful monitoring of the contractor's performance. Some advantages and disadvantages of the choices are provided in **Figure 3.**

Certainly the location and organization of the disassembly process is a critical component of success in remanufacturing. As with ready-to-use cameras in Europe, creative ways of collaborating with similar companies, competitors, and third-party providers can help in obtaining economies in disassembly and in developing an efficient reverse logistics system. But disassembly itself takes special skills, as we shall see.

UNDERSTANDING DISASSEMBLY

Once the disassembly location is determined, a series of capabilities must be developed if remanufacturing is to be successful. First, if the cores were not inspected and sorted prior to collection, that must be done prior to disassembly. Next there is the issue of what to disassemble. This is driven partly by the need for parts and partly by the nature of the incoming products. Finally, remanufacturers must be able to obtain the best feedback and information available for advising on future product improvements.

Inspection and Sorting

Core inspection and sorting are an important prelude to the disassembly process. If uninspected cores arrive at the disassembly facility, a judgment must be made as to whether an investment in disassembly is warranted. In some cases, the condition of the core will be a clear indication. In cases where it is not so clear, the capability of correctly making the determination is a key factor in success. Processing bad cores means that the disassembly investment is not offset by the recovery of enough good parts, while discarding potentially valuable cores is a waste. This is an area in which considerable skill is required and experience useful.

The development of products that can "self-monitor" their condition can facilitate inspection.

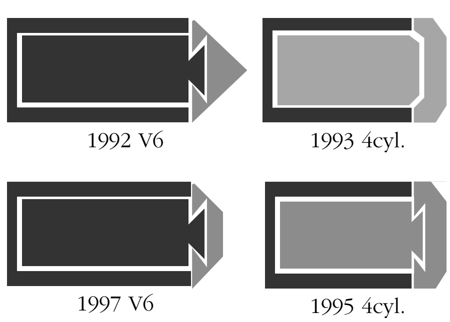
Just as the imbedded nubs in the tread of a tire show when it is time to replace the tire, other types of markers can be used to indicate that there is still life in certain items. Just as automobiles with on-board computers can remind the owner that it is time for a maintenance check, electronic indicators can also be used to indicate the wear state of components. Large electronic equipment such as medical devices may warrant the installation of such monitoring equipment. Other cores might contain physical markers that would indicate the expiration of their physically useful life. An information feedback loop from the remanufacturing facility to the manufacturer's design engineers would facilitate the development of these techniques.

What to Disassemble

There are at least three considerations in determining what to disassemble. The first is to provide the parts or components needed to remanufacture units that are currently scheduled for completion. It is not worthwhile to invest in the disassembly of cores when the parts or components recovered must sit around waiting for the units they are slotted for to be remanufactured. Second is the condition of the unit to be disassembled. Of course, inspection and sorting should have removed any units for which disassembly did not seem warranted. Still, it is worthwhile to use those cores first that are likely to have the highest yield of good parts. Third, part commonality can mean that several alternative cores could provide the parts necessary to meet remanufacturing needs. Choosing which of these cores to disassemble means taking into account the cost, the residual parts inventory, and other criteria.

Figure 4 shows a hypothetical example of four automobile starters from different years and different engines. There are some common and some unique parts in the product family. Nothing is common among all four starters, but the outer cases for the 1992 and 1997 V6 starters are common, as are the outer cases for the 1993 and 1995 4-cylinder starters. The inside assembly for the 1992 and 1997 V6 starters and the tops for the 1997 V6 and 1995 4-cylinder starters are also common. All other parts in these four starters are unique.

Figure 4
A Simple Commonality Example



To produce starters for the 1997 V6 engine, the remanufacturer faces a rather complex set of alternatives, even for this example. The preference would seem to be to use parts coming exclusively from the 1997 V6 model—a solution that would be ideal if the yield of each part from the core and the initial part inventories were the same. If other cores are used, the 1992 V6 starter leaves tops that are not common to any other starter shown here. The 1995 4-cylinder starter has a common outer case, but the inner assembly is different. The choice is therefore dependent upon what is available, the cost of disassembly, what parts will be left over in inventory, and whether they will be needed in the future.

The inspection of parts in the disassembly process is somewhat like the inspection of cores. The decision to be made has to do with the remaining life in the part or component that is recovered. Again, this decision can be facilitated with condition indicators, but much still depends on training and experience. The judgment necessary for making these inspection decisions is an important element in the set of skills required for successful remanufacturing.

Feedback to Designers

There is no question that many firms have the management talent to operate a disassembly facility. Such tasks as scheduling and managing the physical disassembly process itself require skills that already exist. More skill is needed, however, for sorting and inspection. More awareness in the industry and engineering talent devoted to providing assistance will help. To facilitate the development of wear indicators, quick-release disassembly and other aids to remanufacturing call for feedback on the products and processes from the disassembly site.

Some large firms in the computer and automotive industries—Hewlett-Packard, Siemens, IBM, BMW, and Daimler-Chrysler, among others—have installed pilot disassembly facilities providing the opportunity to learn the recovery limitations of their products. This is one way they can learn for themselves the disassembly difficulties and gain insights into how to improve the remanufacturability of their products. Even for captive facilities, however, there is sometimes a problem in getting this information to the designers. It is even more difficult to get designers to listen to feedback and advice from independent remanufacturing companies, despite the valuable experience they have.

It is not just information on wear indication that is important for the design of the products. Disassembly operations are a good source of information for several design concerns: reliability, serviceability, disassembly, and so on. This point of view needs to be heard because direct clashes often occur between design for assembly and design for disassembly. Snap fits that are quick to assemble and provide secure closure, for instance, are often very difficult to take apart. Collaboration between the design engineers and the disassembly experts is more difficult with third-party providers, but mechanisms can and should be developed. Doing so, of course, will contribute to successful remanufacturing in the long run.

DEVELOPING REASSEMBLY CAPABILITY

The task of reassembling recovered parts and components requires special capabilities, even though this is the area in which companies have the greatest amount of experience. Companies also have considerable experience in outbound logistics, but there are differences in integrating remanufactured products into the consumer channels. Several management skills, highlighted here, are critical to remanufacturing success. They include inventory control and scheduling, reassembly, and forward logistics.

Inventory Control and Scheduling

Remanufacturers need to manage inventories of returned cores, parts that have been recovered from cores, and remanufactured products that are ready to be distributed to customers. In each of these inventories there is uncertainty in the supply, yield, or market demand, thus illustrating the management dictum of "buffer or suffer." However, deciding where and how much to buffer is a difficult management choice, compounded by the interdependence between the different types of inventory (as seen in **Figure 5**).

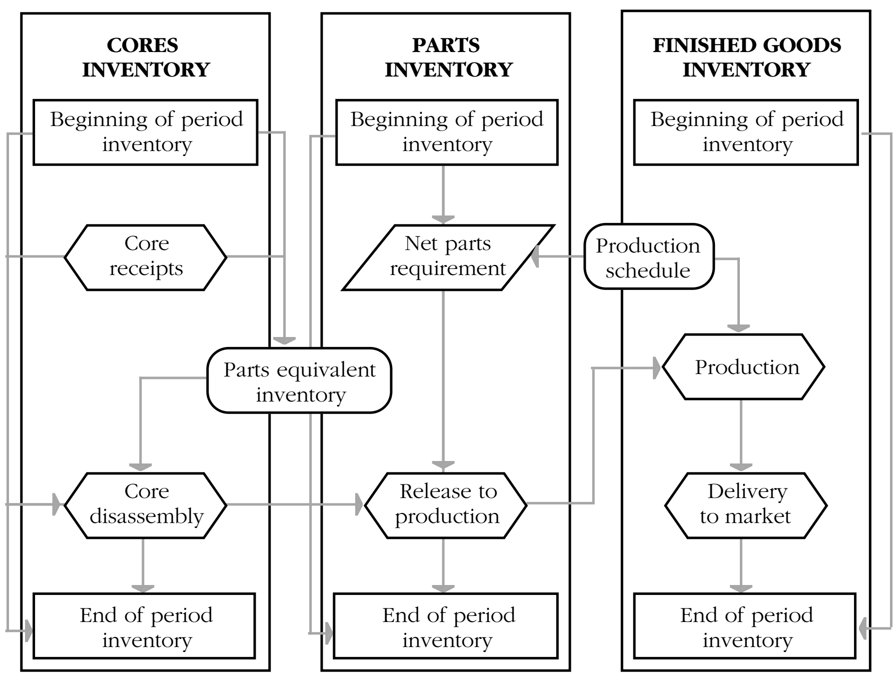
The inventory of cores is constantly but uncertainly supplied by the reverse logistics system. Its content can be thought of as a "parts equivalent inventory." Upon disassembly, the cores supply the parts inventory, subject to uncertain yields. The production schedule converts the parts into finished goods inventory to meet uncertain market demand. The control of these inventories is complicated by the opportunities to purchase or sell any item, by the uncertainties in yield, demand, and supply, and by the commonality of parts in the cores and reassembled products. Considerable sophistication is required to manage all this well. Profitability may depend on being able to avoid accumulating too much of any inventory. Developing systems for managing these inventories is important, and much remains to be done.

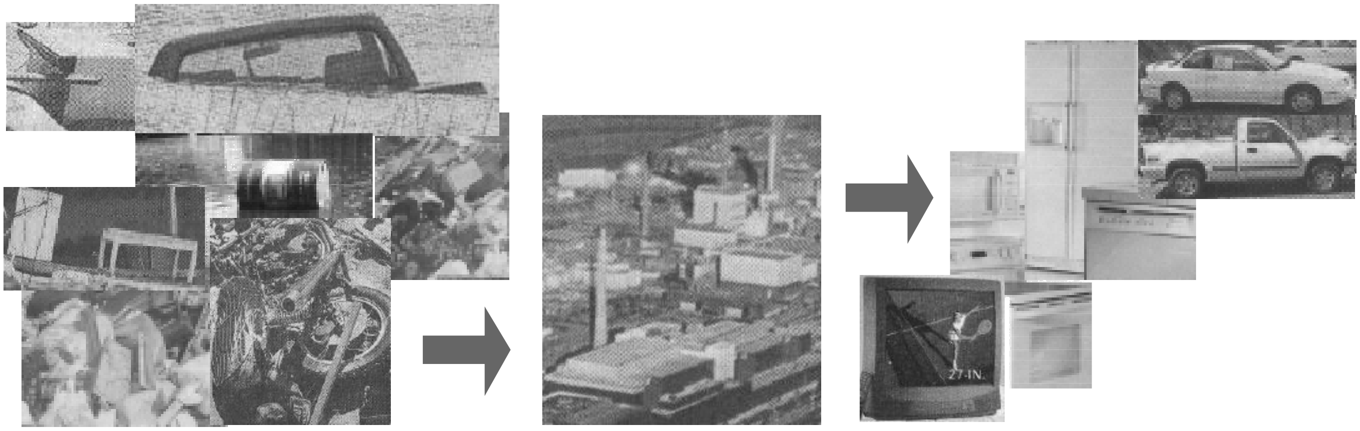
Scheduling a remanufacturing facility appears similar to scheduling a parts fabrication and assembly operation, but it is not. As with parts fabrication, the disassembly process produces parts that will be used for reassembly, but scheduling the disassembly of a core produces multiple parts with uncertain yields. Thus, in developing the disassembly schedule, managers must account for the possible accumulation of unwanted parts as well as those needed for reassembly. Moreover, the core inventory may provide limits on what the managers might want to do. The choices are complicated and, despite decades of scheduling research, scheduling core disassembly is still an area in which much skill and care is required.

The Reassembly Task

The reassembly task is similar to assembly in a regular manufacturing facility. Subtle differences, however, require the development of special

Figure 5
Relationship Between the Inventories of Used Products (Cores), Recovered Parts, and Remanufactured Products





"From garbage to goods…"

skills. One difference is that used parts and components are being combined to make a final product. If several badly worn parts are combined in a single component, the life of the entire component could be shortened. Some assembly worker judgment may be required in determining how far to go in assembling heavily used parts together, compared to a combination of newer and older parts. Again, this is an area in which feedback to product designers could be valuable. If, say, the product could be designed for adjustment, anticipating wear on the parts, the amount of judgment required in assembly could be reduced.

Forward Logistics

When the remanufactured products are completed, they must be introduced back into consumer channels. This means the remanufacturer must have the capability for distribution logistics, even if it is just to the original manufacturer. Complicating forward logistics are some of the same issues considered in locating facilities. If the remanufacturing facilities are widely dispersed, then forward logistics may involve only local distribution and/or drop shipments on behalf of the original manufacturer. On the other hand, centralized remanufacturing requires the full development of a distribution logistics capability. This involves not only transporting but also warehousing the finished goods to provide customer access.

Remanufactured goods need field maintenance, which requires providing and distributing spare parts. Placing these parts close to the customer may involve the product warehouses or special arrangements with repair shops and parts distributors. Some of the capabilities that must be developed to effectively service remanufactured products are providing a means for servicing products in the field, diagnosing problems that may be different in remanufactured products, and ensuring a quick response to customer problems. These service programs are important in supporting the marketing efforts needed to build a market for remanufactured products.

MARKETING REMANUFACTURED PRODUCTS

Successfully marketing remanufactured products involves at least two major activities. The first is developing market awareness, appreciation, and acceptance. The second is supporting these marketing efforts by delivering on the expectations created. This does not just involve product servicing and maintenance as described above; it also requires other reinforcements of the quality, durability, and reliability of the product.

Market Acceptance

Just as market forces cannot be ignored when introducing a new product, they must also be taken into account when introducing remanufactured products. Because customer perceptions are particularly important with the latter, market reaction may be more difficult to assess than for new products. Uninformed, initial perceptions of products containing used components are generally negative. For many products, this is a serious impediment to developing a viable market. Even if a customer's perception is neutral, there may be concern about the image projected to others. Other potential customers may be concerned about the longevity of the remanufactured product, the cost of maintenance, and the product's durability. These concerns must be addressed before any market penetration can occur, and they may still affect the prices the remanufactured products will be able to command.

Manufacturing companies may face internal resistance to the development of a market for remanufactured products, even under heavy pressure from the drivers mentioned earlier. Managers in some firms are reluctant to offer such products because of real or imaginary added potential liability in case of failure. Others fear the cannibalization of the market for new products. So there may be a need to educate company employees as well as potential customers. Certainly, if any of these internal concerns are communicated to the market, the marketing task becomes much greater.

Developing market acceptance involves an educational campaign directed at the appropriate market segments. There may be some segments for which the perception of remanufactured products makes the task of market development too expensive. For the segments that contain potential customers, however, the remanufactured product must be positioned to deliver positive value to the customer. The customer must understand how the product will provide value so as not to create unreasonable expectations that the product cannot deliver. This could be done through price, warranty, or extra services.

Supporting the Marketing Effort

If the remanufactured product is to be positioned as "good value for the money," marketing must identify the market segment for which the price concession is important. The management task here is to find the price that convinces customers of the product value to them and generates the revenue to support the remanufacturing activity. Even if the key value proposition to the customer is price, image and reputation dictate that the customer cannot perceive the product as simply a cheap substitute for a new one, with no support from the company. The rebuilt components in the automotive sector are examples of products that have found the balance between these competing concerns.

A value proposition that does not rely strictly on price is to provide a warranty consistent with the positioning of the remanufactured product in the market. For Xerox, the warranty is equivalent to that of a new product. Such a warranty could command a higher price, but requires developing the capabilities necessary to support it. For example, to supply diagnoses, parts, repairs, and service for a remanufactured product, complete product records are needed. Other steps, such as developing means for customers to provide feedback, will help ensure that the market is not disappointed with the performance and support of the remanufactured product. If the market is satisfied, the prospects for achieving sustainable growth are improved.

The need for responsible use of the resources provided us is beyond question. Recovery of resources used in the manufacture of products is one element of satisfying this responsibility. Several forces are driving companies to recover and reuse resources in used products, leading to a number of economic opportunities to remanufacture products with the recovered parts.

Successful remanufacturing, however, requires the development of skills that are currently not a major part of the manufacturing portfolio. Locating used products, removing them, and transporting them to a disassembly facility means creating and learning how to use a reverse logistics system. The special skills needed for knowing what to disassemble and what parts to save need development and collaboration with the original equipment manufacturers. Reassembling the products is not as straightforward as it seems and requires the development of new skills. Customer perceptions of remanufactured products in the market place must be overcome through education and the creation of legitimate value for the customers. Once accomplished, the use of remanufactured products can reduce our consumption of natural resources.

The requirements for success in remanufacturing are the same as for successful manufacturing, plus those occasioned by the additional uncertainties in supply, newness of reverse logistics, difficulties in inspection of used parts, and lack of attention to design for remanufacturing. Steps in the direction of improving our capabilities for succeeding will move us closer to the ideal of sustainable development. ❒

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