Strategic Management of Product Recovery

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A growing concern to durable product manufacturers is how to manage the products they manufacture once they have reached their EOL (end of life). In part, this attention is motivated by legislation enacted by a growing number of countries across Europe and East Asia that imposes greater responsibilities on manufacturers for managing their EOL products and by related bills that have been introduced in nearly half of the 50 state legislatures in the United States.[1] These "product take-back" laws are intended to give manufacturers incentives to implement design changes that reduce the environmental burden of their products at EOL, while also removing a growing waste management cost from municipal governments. Take-back regulations have targeted waste packaging, batteries, automobiles, and a variety of electrical and electronic equipment (including appliances, computers, lighting, and medical equipment).[2] Instead of simply banning these products from landfills and incinerators, take-back laws encourage manufacturers to refurbish, remanufacture, and recycle products. For example, product designers can select assembly mechanisms that can be easily disassembled, that use fewer and less hazardous materials, and are more readily recyclable. Designers can also reduce the cost of assessing the quality of components harvested from EOL products by implanting data logs that reveal how intensively they have been used,[3] and they can facilitate material identification during product recovery by requiring the material composition of all components to be clearly labeled.

EOL product recovery consists of several sequential activities: collecting EOL products (reverse logistics); determining the potential for the product's reuse, disassembling the product, and segregating valuable components from

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scrap (collectively referred to as primary recycling);[4] remanufacturing components; recycling materials; and disposing the residual as municipal solid waste or hazardous waste.[5] In many industries, independent firms have long recovered EOL products to refurbish or remanufacture to supply aftermarkets. Many industries are highly fragmented, and most firms engaged in remanufacturing are small, independent, and privately owned.[6] However, in industries where original equipment manufacturers (OEMs) are also remanufacturers, they are often the largest both in terms of sales and employment.[7]

While acknowledging that non-OEMs dominate remanufacturing markets in many industries, this article focuses on OEM decisions of whether and how to engage in the first five stages of EOL product recovery (the latter two are seldom performed by OEMs). A growing number of OEMs are facing this decision due to legislative mandates as well as a host of market and non-market factors. Voluntary take-back programs have been initiated by manufacturers of carpets,[8] batteries,[9] automotive parts,[10] packaging,[11] tires,[12] and various electronic products (including wired and cellular telephones, power tools, photocopiers, and computers).[13] A recent remanufacturing industry report noted that OEMs "are becoming increasingly aware of the profit opportunities afforded by remanufacturing. In addition to the profit potential, remanufacturing provides feedback on product failure modes and durability, and it permits the firms to maintain brand reputation."[14]

Motives for Voluntary Product Recovery

Even before the emergence of take-back laws, some firms were already engaging in voluntary product recovery. Their motives have included: reducing their production costs, enhancing their brand image, meeting changing customer expectations, and protecting their aftermarkets. Since the arrival of take-back legislation, firms are also motivated to prevent their scope from broadening and to preempt additional legislation.

Reducing Production Costs

Some companies have discovered that components and materials from EOL durable products can often be refurbished to substitute for virgin parts to be used as spares or in remanufacturing. For example, Xerox Corporation saves hundreds of million of dollars a year by disassembling its EOL photocopiers and then cleaning, sorting, and repairing components and recycling residual materials. Mercedes-Benz accepts and disassembles EOL Mercedes vehicles to harvest and sell spare parts to both consumers and commercial customers at a significant discount compared to virgin spare parts.[15] In 1999, Ford Motor Company began buying salvage yards in the U.S., Canada, the United Kingdom, and Germany to dismantle EOL vehicles to provide a source of spare parts that were cheaper than virgin parts.[16]

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Promoting an Image of Environmentally Responsibility

Companies have also enacted product recovery programs to enhance the environmental image of their brand. A recent survey evaluated how various management practices related to labor, philanthropy, local communities, and the environment influenced consumers' intention to invest in, work for, or use a company's products and services.[17] Increasing the use of recyclable materials and becoming an industry leader in developing environmentally sustainable business practices were perceived as having the greatest positive influence. Implementing a take-back program encompasses both of these activities.

For example, after consumers began referring to Kodak's single-use cameras as "disposables" or "throwaways" and the media reported environmental groups' concerns of their wastefulness, Kodak and FujiFilm launched a take-back program that recycles more than 90% of these cameras and reversed the product's poor environmental image.[18] Hewlett-Packard has received positive media coverage for investing in a recycling infrastructure for EOL computing equipment.[19] IBM Europe and Xerox have reported that their product recovery activities have strengthened their brand image.[20] Such gains are based on legitimate improvements in environmental performance. For example, on a life cycle basis, remanufacturing photocopiers consumes 20-70% less materials, water, and energy and generates 35-50% less waste than conventional manufacturing.[21]

Meeting Customer Demands

Customer expectations are driving some OEMs to become increasingly involved in product recovery in some industries. In the computer industry, the growing trend of OEMs to lease rather than sell equipment to business customers has created the need to retrieve equipment when leases expire.[22] In addition, customers are increasingly expecting OEMs who supply "fleets" of computers to business customers to remove the outdated computers as they install the new ones.[23] Dell collects EOL PCs from their commercial customers in the U.S. as a service associated with the sale of new equipment. Furthermore, some companies are recovering EOL products to meet growing customer demand for products with recycled-content. For example, "Some auto manufacturers are setting ambitious recycled-content goals for auto parts. The large nylon producers are important suppliers (automotive products account for about one-third of nylon's end uses) and can provide nylon made from recycled carpet for use in auto parts."[24] In addition, some local governments are considering mandating their agencies to purchase only from firms that recycle or remanufacture their own products.[25]

Protecting Aftermarkets

Aftermarkets refer to the market for parts and accessories to maintain or enhance a previous purchase, and they are often quite lucrative for OEMs.[26] While independent remanufacturers can attract new buyers into a market by providing "like-new products at prices that typically range from 45% to 65%

of comparable new products"[27] they can also pose a threat to this market that many OEMs highly value. OEMs may recover their EOL products to deter independent firms from remanufacturing and selling them, thus preventing potential losses of both market share and brand image. Hewlett-Packard asks its customers to return their used laser toner cartridges using the replacement cartridge box that is marked to provide free shipping. Ford's and Mercedes's recent interest in their EOL vehicles can also be viewed as a strategy to preclude independent competitors from accessing their branded spare parts. Lexmark offers a "prebate" discount to customers who agree to return their Lexmark printer cartridges to Lexmark for remanufacturing.[28] The terms of sale prohibit customers of prebate cartridges from selling them to other companies who would refill, reuse, or remanufacture them. Lexmark says this program is designed to protect its brand image, claiming its brand is sullied when customers blame its printers for providing poor print quality when they use cartridges refilled by other companies. According to Lexmark, this program has boosted their cartridge return rates.[29] Lexmark has installed security chips in its prebate cartridges and printers that disable printing if these cartridges were refilled by other firms, though this and similar programs are being challenged in court and in legislatures.[30]

Preempting Regulation

Some firms have sought to reduce the pressure for new or expanded legislation by improving their own performance or by attempting to have their trade association impose more stringent requirements on its entire membership. In the environmental arena, perhaps the most successful example is the Responsible Care program developed by the chemical industry to reduce pressure for additional environmental regulation following several major chemical plant accidents in the mid-1980s.[31] Several voluntary take-back programs have followed this approach. For example, facing draft take-back regulations, major manufacturers of power tools that are sold in Germany agreed to voluntarily take back their EOL products from customers at no charge.[32] Similarly, seeking to deter take-back regulations on large appliances, Frigidaire began working with independent appliance recyclers to determine what design changes it could make to reduce recyclers' disassembly costs and bolster recycling rates.[33] More recently, the U.S. rechargeable battery industry responded to a growing number of landfill bans by states and municipalities, take-back laws by several states, and the threat of more legislation by establishing the Rechargeable Battery Recycling Corporation (RBRC).[34] This industry-funded organization takes back and recycles rechargeable batteries at no cost to consumers. RBRC notes that over 95% of the portable rechargeable battery power industry across North America is involved in its battery-recycling program.

Product Manufacturers' Strategic Choice

Regardless of whether manufacturers choose to engage in product recovery to reduce production costs, meet customer demands, protect aftermarkets, enhance brand image, or preempt regulation, they face a strategic choice. Should they contract with recyclers, establish joint ventures with recyclers, form consortia with competitors, vertically integrate into product recovery, or simply promote the recycling market?[35]

Guide and Van Wassenhove describe several advantages of employing advance deposit fees (ADFs), credits toward future purchases, cash payments, and leasing.[36] Recovery firms that specify a sliding scale of prices they pay for products with different residual quality levels facilitates product sorting and may even increase the average quality of recovered products. In addition, they argue that these mechanisms can decrease recovery firms' product inventories, reduce disposal costs, and increase equipment utilization. Where product manufacturers are better positioned than other recovery companies to employ these tools (e.g., ADFs, discounts on future purchases, and leasing), they can gain competitive advantages in conducting product recovery.

Majumder and Groenevelt describe several advantages manufacturers possess in retrieving their products from customers, including their ability to provide trade-in rebates on new equipment and offering prebates.[37] In fact, Dell, Xerox, Hewlett-Packard, Compaq, and several large appliance and automobile manufacturers provide trade-in rebates.[38] Lexmark, as mentioned earlier, offers prebates on its toner cartridges. Dell offers to recycle a customer's old printer for free upon their purchase of a new one. Fleischmann describes several ways the efficiency of reverse logistics systems can be influenced by whether the OEM or another party manages the process.[39] For example, he argues that OEMs possess several advantages in predicting the quality and timing of EOL product flows because they can monitor equipment usage by using real-time electronic sensors and can forecast return flows through end-of-lease returns.

Guide et al. describe several reasons why manufacturers may choose to acquire EOL products from third parties, including buffering themselves against supply fluctuations to facilitate production planning and improve asset utilization.[40] On the other hand, they note that obtaining EOL products directly from customers can provide manufacturers with better control over EOL product condition and quality. Collecting directly from customers avoids intermediaries who may cherry pick the most valuable items and supply only the lower quality ones. Savaskan et al. compare alternative collection methods for manufacturers who incorporate components from their EOL products into their new products. Their model shows that, compared to establishing their own reverse logistics network or engaging other third-parties, manufacturers that provide incentives to retailers to collect their EOL products will achieve higher collection rates and will encourage retailers to reduce their prices, thereby increasing sales.[41] As such, higher profitability is predicted for manufacturers who collect EOL products through their retailer networks instead of collecting them themselves or contracting with other companies to do so. Ferrer and Whybark describe several tradeoffs between a manufacturer's choice between conducting remanufacturing within its manufacturing plants (or in its stand-alone facilities) or whether to outsource remanufacturing to third parties.[42] They focus on economies of scale, transportation costs, and coordination needs.

The Role of Recovery Technologies and Supply Uncertainty

Transaction Cost Economics (TCE) theory predicts the circumstances when firms govern a particular transaction using the market, a "hierarchical" form (vertical integration), or a "hybrid" form (joint venture, partnership, or alliance). According to TCE, this decision depends upon transaction costs—including the costs associated with identifying transaction partners, negotiating and drafting agreements, monitoring the exchange, and enforcing its terms—and transaction hazards.[43] The key hazard of transacting via markets (characterized as spot exchanges between two unaffiliated organizations) emerges when one party must invest in transaction-specific assets to conduct the transaction efficiently. Because such investments lose value when applied to other transactions, whoever makes this investment becomes dependent upon the other party.[44] TCE anticipates the latter would seek to leverage its position by renegotiating or threatening to "hold-up" the party who made the investment.

According to TCE, as the need to employ transaction specific assets increases, "Simple market exchange thus gives way to credible contracting (to include penalties for premature termination, information disclosure and verification mechanisms, specialized dispute settlement mechanisms, and the like). Unified ownership (vertical integration) is predicted as bilateral dependency hazards successively build up."[45] To mitigate hold-up risks, hybrids and vertical integration are preferred because they are better able to "ensure the continued supply of…inputs necessary to keep the specialized asset fully employed."[46] Hundreds of studies have provided empirical validation of TCE's predicting the circumstances under which transactions are most efficiently governed using vertical integration, markets, or hybrids.[47] As such, TCE can shed insight on the circumstances where product recovery transactions are more efficient by having OEMs vertically integrate, rely on third-parties, or develop hybrids such as consortia, alliances, or joint ventures.

Product Recovery Investments

Various types of equipment and training can bolster the productivity of EOL product recovery by reducing the cost of assessing, disassembling, or identifying valuable components in EOL products. When a technology improves the productivity of recovering only one particular product, its value may decline significantly should it no longer be applied to that product. For example, consider a specialized machine designed to disassemble a particular EOL product, where the machine's value would depreciate if applied to any other transaction. According to TCE, when productive EOL product recovery requires transaction-specific investments, hold-up risks are better mitigated by joint ventures or vertical integration than by relying on markets. An example of a large investment that features high transaction specificity is Signature Analysis technology, which facilitates the comparison of noise, heat, or vibration produced by a remanufactured Xerox machine to the company's new product quality standards.[48] The unified governance by Xerox Corporation in this case is aligned with TCE predictions.

On the other hand, some EOL product recovery investments are not transaction specific, such as those that improve disassembly productivity across a range of products. For example, SpectraCode's Polymer Identification System technology improves disassembly productivity by quickly identifying plastic polymers used in electronic products.[49] Because it can be applied to a wide variety of EOL products, investing in this technology is not transaction-specific and thus neither the developer nor any invidivual buyer is subject to hold-up risk. Indeed, it was developed to facilitate the recycling of both EOL electronics and automotive products.[50] In accordance with TCE predictions, a wide variety of independent primary recyclers and OEMs are purchasing this technology from an independent developer.[51]

Uncertainty

TCE posits that hold-up risks accompanying transactions featuring asset specificity are exacerbated as transaction uncertainties increase.[52] Thus, exchanges that feature both transaction-specific assets and high uncertainty are especially likely to be governed by hybrid mechanisms or by single firms via vertical integration.[53] Reverse supply chains associated with product recovery are subject to much more uncertainty than forward supply chains for at least seven reasons: "(1) the uncertain timing and quantity of returns, (2) the need to balance demands with returns, (3) the need to disassemble the returned products, (4) the uncertainty in materials recovered from returned items, (5) the requirement for a reverse logistics network, (6) the complication of material matching restrictions, and (7) the problems of stochastic [random] routings for materials for repair and remanufacturing operations and highly variable processing times."[54] Managers are significantly challenged to accurately predict and control the supply of many EOL products—a key success factor for profitable product recovery.[55] A survey of production-planning-and-control practices in remanufacturing indicated that a primary cause of late deliveries of customer orders was a lack of available components from EOL products.[56]

Remanufacturers may be able to reduce the high variation in the quality of EOL products they receive by offering financial incentives to those who return products at a specified quality level.[57] Companies that provide a schedule of prices across various quantities and qualities of end-of-use or EOL goods include ReCellular (cell phones) and Dell (computer equipment).[58] To facilitate identifying the residual quality of components in EOL products, Robert Bosch GmbH has installed electronic data logs in their power tools to record their usage history, and similar data logs are being developed for other products such as large household appliances (white goods).[59]

Even if these tactics achieve their objective of reducing quality variation or the cost of detecting the residual quality of EOL components, firms seeking to rely on recovered products as a key ingredient to manufacturing still face greater uncertainty surrounding the timing and number of recovered products than those relying on virgin materials and components. Indeed, remanufacturing firms report maintaining high inventories of EOL products to buffer against uncontrollable fluctuations in their supply.[60] As Guide recently noted, "Forecasting models designed to predict the availability of returns are needed to reduce some of the uncertainty."[61] Indeed, a recent survey of executives of remanufacturing firms indicated that they believe one of the greatest threats to their industry is a lack of EOL products.[62]

Consequently, OEMs that rely upon components or materials harvested, remanufactured, or recycled from recovered EOL products often face many new sources of uncertainty. In addition, as independent product recovery companies have little control over the EOL product return rate, they would be hard pressed to supply exact numbers of recovered components at precise times with high penalties for late deliveries, as typically required by manufacturers employing just-in-time (JIT) systems or lean manufacturing principles. Such concerns are exacerbated when OEMs face difficulties determining whether a supplier's claim that it cannot meet a scheduled delivery of recovered components is a hold-up attempt or the result of legitimate fluctuations in the availability of EOL products. In such cases, manufacturers may have to accumulate stocks or engage with additional suppliers to buffer against shortfalls from the supplier, adding costs to the transaction. The additional costs and risks associated with buying EOL product components from independent firms may convince OEMs to govern the transaction by developing joint ventures or vertically integrating to gain better access to information and thus mitigate hold-up risks. This would be consistent with TCE predictions empirically validated in other domains.

Leveraging Manufacturing-Associated Capabilities to Product Recovery

While the TCE analysis provides insight at the transaction level, it is less useful in explaining why manufacturers in the same industry choose different strategies. The Resource-Based View of the firm, Dynamic Capabilities, and Core Competencies are related management theories that provide insight on this question (for simplicity, these theories will collectively be referred to as the RBV). These theories assert that firms possess unique sets of resources, capabilities, and competencies—similar terminology for related concepts—and that these form the foundation of competitive advantage.[63] Resources have been defined as "inputs into the production process" including "items of capital equipment, skills of individual employees, patents, brand names, [and] finance,"[64] as well as customer loyalty and production experience acquired from learning-by-doing.[65] Resources that lead to competitive advantage are those that are rare, valuable, difficult to imitate, non-substitutable,[66] and costly to transfer across firms.[67] Capabilities, which refer to "the capacity for a team of resources to perform some task or activity," can also provide competitive advantage when firms leverage them into new opportunities.[68] Core competencies, defined as "the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies" to significantly enhance a product's value, are often difficult for competitors to imitate.[69] Similarly, "the set of activities that a firm can organize and coordinate better than other firms" have been termed "distinctive competencies."[70]

According to these theories, transferring tacit knowledge and leveraging related competencies are easier within firms than between them. Firms create organizing principles such as coding schemes, values, and common languages that enable them to outperform markets at sharing and transferring the information and know-how possessed by individuals and groups within their organization.[71] As such, firms internalize activities when tacit knowledge or related competencies are important drivers of competitive advantage.[72] For example, vertical integration occurs when competitive advantage requires "inputs that cannot be purchased, such as learning-by-doing and organizational culture" because these are "on average, likely to be more specific to the firm than purchasable inputs and hence have the potential to be the more significant rent-generators."[73] Because companies achieve competitive advantage by leveraging their core competencies into new activities,[74] vertical integration is more likely when their required competencies are "something about which the firm already has some degree of relevant knowledge."[75] Vertical integration may depend upon "how good a firm is currently at doing something, how good it is at learning specific capabilities, and the value of these capabilities as platforms into new markets."[76] On the other hand, a lack of relatedness reduces the likelihood of integration.[77] Empirical studies have validated these claims, finding that vertical integration is much more likely when the integrated activities require similar technological knowledge, particularly when this knowledge is "partly tacit and team-based and therefore takes significant time to acquire."[78]

The RBV can offer insight to explain some of the diversity of product recovery strategies among product manufacturers. The RBV assumes that companies possess heterogeneous bundles of capabilities and predicts that firms pursue opportunities where they can leverage their capabilities to secure competitive advantage. Specifically, the RBV suggests that an OEM's decision to engage in voluntarily product recovery depends upon the extent to which it can leverage its existing capabilities. Analysis based on the RBV thus requires understanding the capabilities involved in product recovery and how closely these align with capabilities OEMs already possess.

Manufacturing, Service, and Repair Capabilities

To efficiently disassemble EOL products and accurately distinguish reusable, repairable, recyclable, and non-recyclable components and materials, specialized skills are often required. As Ferrer and Whybark note, "A judgment must be made as to whether an investment in disassembly is warranted. . . . The capability of correctly making the determination is a key factor in success. Processing bad cores [EOL products] 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."[79] Required skills include careful disassembly to prevent damaging potentially valuable components, quality inspection to estimate the intensity of prior usage, and sufficient familiarity with materials to accurately identify often unlabeled materials such as plastic polymers.

Through manufacturing and repair experience, product manufacturers may acquire material selection, assembly, and quality inspection skills that can be leveraged to perform disassembly tasks. Since firms are more likely to vertically integrate into activities that require knowledge similar to that which they already possess, companies with extensive manufacturing, service, and repair experience may be more likely to vertically integrate into EOL product recovery. This may explain why IBM and Hewlett-Packard—companies with world-class capabilities in these areas—have become deeply involved in product recovery, while companies such as Gateway that possess limited manufacturing capabilities have not.

Acquiring Tacit Disassembly Know-How

Disassembly requires tacit knowledge that is seldom communicated by codified OEM specifications. Indeed, even among independent recyclers who possessed OEM specifications, two-thirds still have to reverse engineer the product to understand how to disassemble it efficiently.[80] Reverse engineering is expensive and time consuming, averaging $37,000 and 23 days per product.[81] Since firms that design, engineer, and manufacture products acquire tacit knowledge of how their products are assembled, they—unlike independent firms conducting product recovery—have the opportunity to leverage this knowledge into tacit disassembly knowledge. For example, "Ford maintains its Experimental Dismantling Center in Germany [which] dismantles vehicles to benchmark design practices and materials use against materials recovery capability."[82] This suggests that firms that design, engineer, and manufacture products are apt to possess a cost advantage over other firms in disassembling EOL products, and this gap widens when economies of scale enable more EOL product models to be processed in the same facility. In addition, after studying the product recovery operations of Océ, a Dutch photocopier firm, Krikke et al. suggest that dismantling, preparation, and reassembly processes situated in the same location can facilitate the dissemination of tacit knowledge that can boost productivity.[83] In addition, locating remanufacturing within manufacturing facilities may facilitate the transfer of tacit knowledge between manufacturing and remanufacturing operations.[84]

Feeding Back Recovery Know-How to Designers

Engaging in product recovery often generates knowledge about EOL products such as the relative durability of their components and the ease of unfastening assemblies. In the hands of product designers, this knowledge can lead to design modifications that facilitate EOL product disassembly, assessment, and recycling and reduce the amount of non-recyclable residual. Products designed to facilitate disassembly have more predictable material recovery rates, faster disassembly times, and generate less waste.[85] For example, IBM has used its Asset Recovery Center to evaluate the effectiveness of its design initiatives meant to facilitate its EOL products' disassembly and plastic resin identification.[86] While even disassembly facilities owned by equipment manufacturers face difficulties "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."[87] This factor alone suggests manufacturers possess advantages over other firms in reducing the overall cost of recovering their EOL products. BMW operates a Recycling and Disassembly Center in Germany to conduct "detailed disassembly analyses [to] take a close look at the amount of time and the tools required for disassembling end-of-life vehicles. This information is then used as a basis for determining whether the vehicle construction and materials are suitable for recycling. Recommendations are made regarding recycling-optimized design and the eco-efficient, i.e., ecological and economical recovery of end-of-life vehicles . . . [The Center] consistently exchanges information with the BMW research and innovation center."[88] In Japan, electronics manufacturers have formed two consortia to collect, recover, and recycle their EOL products pursuant to legislative requirements. However, "each manufacturer holds at least one treatment plant so that it can compile and communicate information from the downstream to the upstream, accumulate knowledge and recycling technology, and grasp the actual cost for recovery and environmentally sound treatment. Exchange of information between recycling plants and product design department has been taking place by way of periodical meetings among the personnel involved, seminars, via intranet and designers' visits to recovery plants."[89]

Cross-functional management and continuous improvement capabilities can enable organizations to leverage EOL product knowledge into design improvements. This suggests that manufacturers with these capabilities may be better than others at facilitating this internal knowledge transfer. Total quality management (TQM) programs typically require "collecting relevant information from all phases of an organization's operations" and "quality assurance and improvement efforts [that] include manufacturing [and] supporting functions which impact operations."[90] Firms with TQM programs often possess capabilities that enable them to implement improvement activities based on recommendations from a wide variety of sources and to manage cross-functional activities,[91] both of which can increase the likelihood that knowledge accumulated while conducting product recovery activities is transferred quickly and accurately to product designers. In addition, firms with more comprehensive environmental management programs often possess capabilities in cross-functional management, stakeholder integration and higher-order learning processes.[92] Many companies with deeply engrained quality cultures, such as Shell Chemicals and DuPont, are expanding their TQM programs and quality management systems to include environmental issues.[93] As such, manufacturers with well embedded quality and environmental programs may be more likely to possess capabilities that enable them to leverage the knowledge accumulated during product recovery into design improvements. This can lead to lower costs of managing products throughout all of their life cycle stages.

Environmental Reputation Capabilities

Proactive environmental management can also foster a strong reputation among customers for environmental leadership. This can provide competitive advantage when selling to customers who value their suppliers' environmental performance. The same drivers that encourage a company to pursue an environmental leadership stance may also encourage it to actively engage in product recovery. For example, the corporate environmental sustainability strategy of Hewlett-Packard, a company with a reputation for environmental leadership, includes "Developing product end-of-life solutions, such as recycling technologies and infrastructures, across high tech industries to create reliable streams of recycled materials."[94] Interface, the largest commercial carpet manufacturer in the world, has adopted the ambitious goal of becoming "the world's first environmentally restorative company" and views its voluntary product take-back program as instrumental to its success.[95]

Launching a voluntary product take-back program can also enhance a firm's environmental reputation. Kodak, as mentioned earlier, initiated its take-back program to overcome the wasteful image associated with its single-use cameras and has largely removed their environmental stigma.

Unique Assets and Avoiding Supplier and Buyer Dependence

Resource Dependence theory provides a third lens to examine product manufacturers' decisions of how to manage their EOL products. According to this theory, firms manage transactions and define their organizational boundaries to avoid depending upon other organizations for critical resources.[96] This is a particularly important perspective for OEMs considering whether to vertically integrate into product recovery. As discussed earlier, EOL products may also become critical resources to product manufacturers' business models if other firms can refurbish or remanufacture their products and threaten their customer base. Not only could this erode the OEM's market share, but its brand reputation could be sullied if its products, when refurbished or remanufactured by another firm, do not deliver the performance expected of its brand—since its brand label typically remains affixed to the product.

The extent to which a buyer is dependent upon a supplier depends upon three factors: the importance of the resource to the buyer, the extent to which the buyer can access alternative sources, and the degree to which the supplier has discretionary control over the resource.[97] Therefore, a buyer is most dependent upon a supplier when an individual supplier has complete discretion over resources the buyer views as crucial to its cost or differentiation advantage and for which the buyer has no ready substitute.[98] On the other hand, a supplier is most dependent upon a buyer when "a buyer represents a large share of a seller's revenues and if this buyer cannot be easily replaced."[99] From this perspective, organizational strategies are designed to enable organizations "to minimize their dependence and increase the dependence of others on them"[100] and to increase the predictability and stability of relationships with organizations upon which they depend.[101]

One strategic option for dependent organizations is to expand their boundaries through vertical or horizontal integration to absorb the resources upon which they depend.[102] Alternatively, organizations can establish cooperative relations using "cooptive ties" with organizations that control their critical resources by developing cartels, alliances, joint ventures, or common members of their boards of directors.[103] To mitigate their dependence on suppliers, buyers can develop buffering strategies such as investing in reserve inventories that provide some protection against temporary supplier instabilities.[104] Suppliers can mitigate resource dependence by diversifying their customer base.

Suppose a manufacturer that employs a unique polymer for its product casing can produce additional units at less cost by harvesting and recycling this material from its EOL products than by purchasing virgin polymer. Further suppose the manufacturer values the recovered components more than the next highest bidder. Should other companies seek to recover and disassemble these products, they risk becoming dependent upon the manufacturer. If only a few companies recovered this product such that supply is concentrated, the manufacturer risks becoming dependent upon these suppliers. The importance of this dependency rises as the gap increases between the cost of using recovered versus virgin resources.[105]

The circumstances described above predict that resource dependence will emerge when the product manufacturer seeks to recover manufacturer-specific components or materials from its EOL products, especially when precise deliveries are required as in JIT systems that minimize buffer inventories. In such cases, Resource Dependence theory predicts that these manufacturers will seek to increase the relationship's predictability and stability by employing cooptive ties or by integrating into product recovery. The key concern in relying on other organizations is that the OEM may become dependent upon a provider of what may become a key resource. This is a parallel concern of TCE cautioning against the use of markets for transaction-specific assets due to hold-up concerns. Indeed, Resource Dependence advocates boundary-spanning approaches, which may include the use of hybrids or vertical integration as encouraged by TCE.

In fact, many manufacturers that reuse manufacturer-specific components from their EOL products have avoided supplier dependence by developing schemes that encourage EOL products to be returned directly to them. For example, Hewlett-Packard offers postage paid labels to encourage customers to return their toner cartridges. Kodak pays film processors to return their "single use" cameras directly to Kodak. Xerox has long relied on a leasing strategy that ensures that its used photocopiers are returned to the company. Interface has recently begun leasing flooring tiles to commercial customers, with the company reclaiming worn tiles to recycle them into new flooring.

On the other hand, dependence concerns are largely absent in industries where manufacturers do not gain particular advantages by recovering their own EOL products. For example, EOL computers are partially disassembled to harvest components with resale values on secondary markets (e.g., disk drives, memory chips) and are then crushed and recycled to reclaim metals and plastics. In general, few of these components or materials are manufacturer-specific, and thus resource dependence is generally not a concern between computer manufacturers and third-party companies that recover EOL computers. As such, it is not surprising that third-party companies conduct a great deal of EOL computer recovery.

Managerial Implications: Crafting a Strategy

This article has described several factors that motivate manufacturers to engage in voluntary product recovery: reducing production costs, enhancing brand image, meeting customer demands, protecting aftermarkets, and preempting regulations. Managers contemplating product recovery strategies should consider which of these drivers currently apply to their company and industry. This will likely require discussions with managers from a variety of functions, since knowledge about production costs, brand reputations, customer expectations, and legislative agendas is typically diffused across an organization. These discussions should also explore which additional drivers are on the horizon. Understanding existing drivers and anticipating additional ones informs the strategic decision of how to proceed. For example, if the firm is seeking to address legislative pressures, this industry-wide concern might be best addressed through a response coordinated by an industry association, as the rechargeable battery example illustrates. However, if customer expectations are the main driver for exploring product recovery strategies, then attempting to work with competitors might undermine an opportunity to gain competitive advantage by providing product recovery services that best meets customer needs.

The three management theories that provide insight on the potential benefits and drawbacks of various product recovery strategies are summarized in Table 1. The transaction cost analysis suggests that when efficient EOL recovery requires investments specific to a particular product or its material, independent product recovery firms and OEMs face hold-up risks. Consequently, recovery of such products is likely to involve more active engagement of its manufacturer, such as through joint ventures or vertical integration. Similarly, manufacturers must consider whether minimizing product recovery costs entails sharing proprietary information, as this could deter relying on independent third parties or developing a consortium with competitors. In addition, the high environmental uncertainty surrounding some types of product recovery complicates contractual relations among a manufacturer seeking to buy its EOL components from an independent product recovery firm. Though some contractual solutions such as price/quantity schedules have emerged to deal with this issue, manufacturers

TABLE 1.

Theoretical Perspective	OEMs should consider vertical integration or hybrids (e.g., joint ventures, alliances) instead of relying on independent companies when . . .
Transaction Cost Economics Analysis	Product recovery requires investments that are specific to an OEM's products or materials, especially when EOL product recovery rates are highly uncertain.
Capabilities Analysis	OEMs can leverage tacit knowledge and proprietary information acquired during product design, engineering, and production to their product recovery activities (since tacit knowledge cannot be easily transferred between independent organizations). OEMs possess a culture of cross-functional management and continuous improvement that facilitates rapid transfer of tacit knowledge from their product recovery operations to their designers and engineers.
Resource Dependence View Analysis	OEMs risk becoming dependent upon independent product recovery firms for rare or unique components or materials recovered from EOL products. OEMs can develop durable cooperative relations with third-party firms or competitors to exert some control over the recovery of their EOL products.

using JIT delivery face greater hold-up risk are more likely to use hybrids or vertical integration than rely on independent product recovery firms.

The capabilities analysis suggests that by leveraging tacit knowledge and proprietary information acquired during product design, engineering, and production, product manufacturers are likely to possess competitive advantages compared to independent product recovery firms in several stages of EOL product recovery. Furthermore, manufacturers with quality cultures may possess key capabilities that enable them to more rapidly and accurately provide feedback to designers and engineers about the knowledge accumulated during EOL product recovery, which can reduce future product recovery costs.

Finally, the resource dependence analysis suggests that manufacturers and independent product recovery firms seek to avoid being dependent on each other for unique resources. One implication is that when a manufacturer seeks to use its particular EOL products or materials as a source of parts for spares and remanufacturing, the manufacturer will attempt to avoid becoming dependent on an independent product recovery firm by developing more direct recovery channels. In addition, some EOL products risk being disposed of inappropriately, such as being exported to developing nations that feature unsafe working conditions and limited pollution controls. Recent reports by activists and the media have demonstrated that OEMs are being held publicly accountable for goods with their brand name,[106] irrespective of the fact that disposal decisions are made by customers (and not the OEM). In these cases, OEMs should seek to develop durable cooperative relations with third-party firms or competitors or else vertically integrate to exert greater control over the recovery of their EOL products

Limitations and Further Research

That some OEMs are more heavily engaged in product recovery than this analysis suggests may be due to the novelty of this activity. The U.S. Environmental Protection Agency recently reported that the "infrastructure for materials recovery is not sufficient in the U.S. to deliver quantity and quality of recovered inputs demanded by progressive implementation of recycled content requirements."[107] This may explain why some OEMs are deeply engaged in product recovery in circumstances other than those described above.

While the focus here has been on the collection and primary recycling stages of product recovery, Fleischmann et al. argue that there are actually several classes of product recovery networks and that each should be evaluated separately because "re-usable item networks, remanufacturing networks, and recycling networks appear each to have their own typical characteristics."[108] As such, each product recovery stage may warrant individualized analysis.

While operations management research on product recovery is clearly a growing field, research on this subject from other perspectives is less common.[109] For example, several antitrust and economic questions arise from the prebate concept that prevents other companies besides the OEM from refurbishing its products. Is this a legitimate business practice or is it designed to monopolize aftermarkets? Are recycling rates likely to be higher or lower if prebates are permitted or outlawed, either by court decisions or legislation? Could manufacturers use prebates to preclude other companies from refurbishing their EOL durable goods, thus artificially curtailing equipment durability to force consumers to purchase newer models?[110]

In addition, product take-back regulations have evoked concerns about international treaty obligations. Little research has investigated the implications of take-back regulations on international treaties, including whether they violate obligations imposed by the General Agreement on Tariffs and Trade (1994) and the World Trade Organization's Agreement on Technical Barriers to Trade (1994)—as alleged by the American Electronics Association[111]—and whether such regulations are consistent with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1992) and the pending Basel Ban (1995).

Finally, only tentative steps have been taken to identify which EOL products make better candidates for remanufacturing or recycling. For example, Klausner and Hendrickson suggest that remanufacturing is particularly well suited for EOL products that include components characterized by long technology cycles and low technological obsolescence, and when *ex ante* uncertainty regarding usage intensity results in "over-engineering for certain user groups in order to meet the needs of other user groups."[112] Rose has developed a model that forecasts whether EOL electronic products should be remanufactured, disassembled and then recycled, recycled whole (without prior disassembly), or disposed of.[113] According to her model, this decision is based on technical product characteristics including product durability, rate of technological obsolescence, extent of product complexity, the duration of a design cycle, and the reason for redesigns.

Notes

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109. Product recovery research is most advanced in the operations management perspective, as indicated by several conferences, special journal issues, and books focusing on reverse logistics and closed-loop supply chains. For example, conferences on closed-loop supply chains were held at Carnegie Mellon University in 2001 and INSEAD in 2002. Six European universities participate in RevLog, a working group focusing on reverse logistics. *Production and Operations Management* published a special issue [10/2, 2001] on environmental management and operations that focused on manufacturing and eco-logistics. An edited book has recently been published on this issue as well: V. Daniel R. Guide, Jr. and Luk N. Van Wassenhove, eds., *Business Aspects of Closed-Loop Supply Chains: Exploring the Issues* (Pittsburgh: Carnegie Mellon University Press, 2003). In addition, *Computers and Operations Research* is planning to publish a special issue on reverse logistics in 2004.
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111. Eric Scigliano, “Europe May Ban Today’s Toxic-Laden Computers, If the U.S. and WTO Don’t Block it,” *Seattle Weekly*, November 18, 1999.
112. Klausner and Hendrickson, op. cit.
113. Catherine Michelle Rose, “Design For Environment: A Method for Formulating Product End-of-Life Strategies,” Ph.D. dissertation, Stanford University, 2000.