Chapter 17
Closed-Loop Supply Chains: A Strategic Overview

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Managers who consider a closed-loop supply chain just another environmental initiative need to update their thinking. Modern firms that use closed-loop supply chains as a competitive strategy receive many benefits—particularly higher profitability and control over a product's entire lifecycle. In fact, the market for multiple lifecycle products continues to grow, with current estimates holding that remanufactured product sales exceed $100 billion per year.[1] As a result of analyzing the ever-growing remanufacturing sector through years of working with managers in numerous industries, various levers and themes surrounding effective closed-loop supply chain strategies became apparent. This chapter presents these findings and shows how firms in multiple industries experienced both successes and failures of their closed-loop supply chain strategies.

[1] Current estimates of the remanufactured products market in the US come from the United States International Trade Commission (USITC) report on remanufactured goods. See USITC. 2012. Remanufactured goods: an overview of the US and global industries, markets, and trade. Public report, U.S. International Trade Commission accessible at http://www.usitc.gov/publications/332/pub4356.pdf.

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17.1 Understanding a Closed-Loop Supply Chain

Over the past few decades, environmental initiatives moved from tertiary goals to integral parts of corporate strategy. The environmental transformation manifested for multiple reasons, ranging from corporate social responsibility initiatives (see also Chap. 20 by Lee and Rammohan, in this volume) to increasing levels of legislative mandates (see also Chap. 10 by Huang and Atasu, in this volume).[2] Whatever the reason for the shift toward environmental initiatives, the outcome is clear: managers need innovative ways to reduce environmental impact while simultaneously improving profitability. Though common wisdom holds that environmental constraints will inevitably reduce profits, numerous counterpoints exist as manifested in firms that successfully implemented closed-loop supply chain (CLSC) strategies.[3] This chapter provides a current look at the ever-evolving body of CLSC knowledge. Through looking at the body of knowledge, the chapter provides strategies to help managers understand the challenges and opportunities of CLSCs in various types of industries under differing strategic forces.

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[2] Corporate social responsibility continues to generate much debate about the role of a corporation as a good citizen. For an excellent discussion of such issues, see Carroll, A. B. 1999. Corporate social responsibility evolution of a definitional construct. Business & Society 38(3): 268–295.

Additionally, for firms less interested in internally promoting environmental initiatives, legislative mandates regarding environmental performance and impact are particularly prevalent in the European Union with the waste electrical and electronic equipment (WEEE: http://ec.europa.eu/environment/waste/weee/legis_en.htm) and reduction of hazardous substances (RoHS: http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm). Both laws seek to control environmental impact. Though the E.U. was among the first to enact such laws, Japan (http://www.env.go.jp/en/policy/) and Australia (http://www.environment.gov.au/about-us/legislation) have followed with similar legislation aimed at curbing environmental impact.

Though much of the strict recycling mandates legislation has not occurred within the US, multinational firms already maintain product portfolios that meet the ambitious requirements. Should the legislative programs continue to expand throughout the world, firms holding such product portfolios may hold a competitive advantage over competitors who currently do not meet the requirements of such legislation. Various recent works address the issue of environmental legislation and product take-back. For two such works, see Atasu, A. and L.N. Van Wassenhove. 2010. “Environmental Legislation Regarding Product Take-Back and Recovery” in ‘Closed-Loop Supply Chains,’ Eds. M. Ferguson, G. Souza. Taylor and Francis. and a work tailored to the extended producer responsibility for electronics waste Atasu, A., R. Subramanian. 2012. Extended Producer Responsibility for E-Waste: Individual or Collective Responsibility? *Production and Operations Management* 21(6): 1042–1059.

[3] If the concept of a closed-loop supply chain is unfamiliar, multiple resources can provide guidance and insights. For example, see Guide, V.D.R. Jr., and Van Wassenhove, L.N. 2003. “Business Aspects of Closed-Loop Supply Chains” in Guide, V.D.R. Jr., and Van Wassenhove, L.N. (eds.), Business Aspects of Closed-Loop Supply Chains Exploring the Issues. Pittsburgh: Carnegie Mellon University Press. Also, see Ferguson, M.E. and Souza, G.C. 2010. “Closed-Loop Supply Chains New Developments to Improve the Sustainability of Business Practices. Boca Raton: CRC Press.”

17.2 The Core of a Closed-Loop Supply Chain

At the core, a closed-loop supply chain represents a series of processes and flows aimed at some form of reuse or reclamation of products and materials. Specifically, a closed-loop supply chain incorporates design, control, and operation of a system to maximize value creation over the entire lifecycle of a product with dynamic recovery of value from different types and volumes of returns over time.[4] As the definition states, a CLSC must be dynamic and evolve over time to handle changing market conditions. Such evolution makes managing a closed-loop supply chain an ever-evolving set of processes, which can take on many different forms depending on the product and industry in which a firm operates. Though a CLSC requires decisions at every macro decision level—operation, tactical, and strategic—this chapter focuses heavily on the broad strategic issues facing a manager considering a CLSC. As will become clear, the decision to operate a CLSC should be based on seeking increased profit—not just reducing costs—and improving corporate social responsibility through improved environmental performance.

Of course, before a CLSC can start a second lifecycle for a product, a first lifecycle must occur followed by the accompanying return of the product into a reuse market. On one extreme, the return of the product into a reuse market can be in the form of an end-of-use product that received considerable use by a prior owner, which is typical in the business-to-business markets for large industrial equipment (e.g., Caterpillar earth moving equipment and Xerox high-speed imaging equipment). On the other extreme, unlike the end-of-use returns that have often experienced extensive use, consumer product returns are often convenience returns—returns due to the customer simply deciding that the product does not suit their needs.[5] These convenience returns, also called false failures, usually require minimal processing before returning to the market. Staggeringly, consumer product returns in the United States now exceed $260 billion in 2013 alone.[6] In either extreme case, a CLSC using remanufacturing provides a direct form of reuse that converts returned products into like new condition for resale. Remanufacturing entails disassembling the returned product, replacing any worn or broken components, repairing any remaining defects, and repackaging the product for sale as a remanufactured item.[7]

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[4] For a recent discussion of the continuing challenges in closed-loop supply chains, see Guide, V. D. R. and L.N. Van Wassenhove. 2009. The evolution of closed-loop supply chain research. Operations Research 57(1): 10–18.

[5] The rate of false failure returns can vary widely by the nature of the product and industry. As a prime example in the consumer electronics industry, Hewlett-Packard experienced false failure returns rates as high as 80 % of all inkjet printer returns. On the other hand, Bosch false failure return rates at a vastly lower 2 % of all power drill returns. For more information, see Ferguson, M., V.D.R. Guide, Jr., G.C. Souza. 2006. Supply chain coordination for false failure returns. Manufacturing & Service Operations Management 8(4): 376–393.

[6] The National Retail Federation offers free, detailed reports on returns. For recent reports, such as the 2013 report noted, see http://www.theretailequation.com/retailers/IndustryReports.

[7] The Remanufacturing Institute's (http://www.reman.org) gives an in-depth look at remanufacturing from various industry perspectives. In particular, the website provides details about remanufacturing processes and the resulting environmental benefits.

17.2.1 Overview of Closed-Loop Supply Chain Activities

Before moving into a detailed discussion of the process flows of a CLSC, a high level view at the three major CLSC activities provides context for readers who are not yet familiar with the nature of closed-loop supply chain. Figure 17.1 provides a high level view of the front-end, engine, and back-end of a closed-loop supply chain.

The front-end activities entail collecting returned products through product acquisition management. As noted previously, some products will be heavily used, while others may have seen minimal if any use. Such diversity in the nature of returns makes product acquisition management a critical activity for any manager considering a CLSC strategy. If acquisition of returned product cores is relatively simple, engaging in CLSC operations can be a fairly straightforward endeavor. Conversely, if acquiring returned product cores is difficult or widely dispersed, even the first step of collecting returned products can prove to be a challenge. After returns are collected, the engine activities allow remanufacturing of the returned product to a like new condition.[8] Though this chapter does not delve into the operational details, the topic of the engineering feasibility and technical constraints in a CLSC has

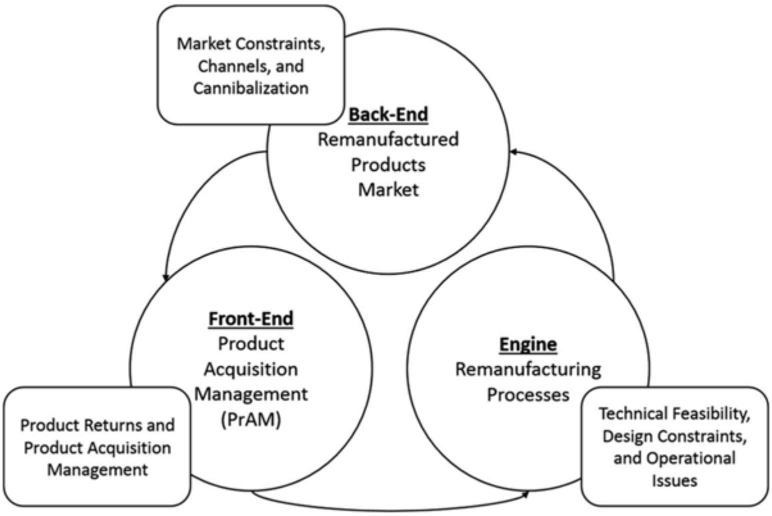

Fig. 17.1 Closed-loop supply chain activities

[8] For an examination of issues in production planning and control in the engine portion of remanufacturing, see Guide, V.D.R., Jr. 2000. Production planning and control for remanufacturing: industry practice and research needs. *Journal of Operations Management* 18(4): 467–483. For detailed information about the issues related to grading the quality of cores acquired through the front-end processes of product acquisition management, see Ferguson, M., V.D.R. Guide, Jr., E. Koca, and G.S. Souza. 2009. The value of quality grading in remanufacturing. *Production and Operations Management* 18(3): 300–314.

received much attention over the past decades (see Footnote 3). After the product has been brought back to a marketable condition, the back-end activities entail putting the product back into the market for another lifecycle. Until recently, the nature of the market for reused products has received little attention. Fortunately, recent research has started to define the similarities and contrasts with the typical new product market.[9] As will be discussed at length later in this chapter, the three major CLSC activities all work in unison and can be done in-house or as outsourced operations.

17.2.2 Examining Closed-Loop Supply Chain Flows

The primary function of a CLSC is to employ some form of reuse at the product, component, or materials level. Each of these choices comes with differing degrees of constraints, both in terms of recovery strategy and remarketing of the multiple lifecycle product. Understanding how these constraints vary by the nature of the industry is critical for managers investigating means to implement or improve their firm's CLSC strategy. Figure 17.2 displays various flows at the product, component, and materials levels.[10] (Chap. 5 by Blass et al., in this volume provides more detail on analyzing and managing material flows.) Each of these flows offers firms differ-

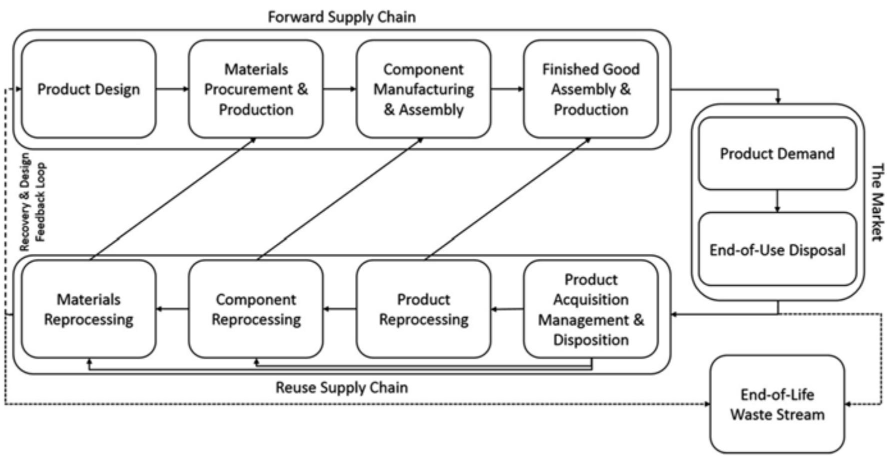

Fig. 17.2 Closed-loop supply chain flows and functions

[9] For an overview of the current state of market based literature for remanufactured products and pricing structures, and market segments, see, Abbey, J.D., M.G. Meloy, V.D.R. Guide, Jr., and J.D. Blackburn. 2015. Barriers and Strategies for Product Reuse in Consumer Markets. Under review at *California Management Review*.

[10] This figure is adapted from, Abbey, J.D., V.D.R. Guide Jr. 2012. "Closed-Loop Supply Chains" in T. Bansal, A. Hoffman, (eds.), Oxford Handbook on Business and the Natural Environment. New York: Oxford University Press, 290–309.

ent opportunities for recovery and reuse strategies, which are directly influenced by the original product design. In particular, materials reprocessing would typically fall in the realm of recycling. For example, recycled plastics may be used as either like-to-like (e.g., water bottles) or down-cycling (e.g., tires to rubber mulch) materials. The component and product reprocessing, typically called refurbishing or remanufacturing, generally require far less energy intensity than materials recycling. As such, product and component reuse are generally preferable over the more energy-intensive recycling, which is the least preferred of the options from an environmental standpoint.[11]

As shown in Fig. 17.2, some form of a waste stream is inevitable. Simply put, some products, components, and materials have a limited number of lifecycles or only a single use. The goal of a manager trying to implement environmental initiatives through a CLSC is to convert what was previously a stream of waste into profitable reuse. Though this sounds like an ideal win–win scenario—environmental benefits and higher profits—many pitfalls prevent firms from committing to a CLSC strategy. In the consumer products arena, one of the highest hurdles is the challenge of cannibalization of new product sales with the sale of lower-priced remanufactured offerings. As discussed just a few years ago, managers should handle this challenge from a total profitability, portfolio perspective.[12] For most firms considering a CLSC, the problem of reacquiring previously sold products, product acquisition management (PrAM), can be daunting as the reverse supply chain flows may not be a current competence.[13] In particular, for firms in the technology sector that face a high marginal value of time—a rapid decline in a product's value during a lifecycle—acquiring, testing, inspecting, and returning the product to market quickly are imperative. On the flip side, for firms facing lesser marginal value of time pressures—minimal decline in the product's value during a lifecycle—the acquisition and resulting remanufacturing activities are not as time-sensitive or asset-intensive.[14]

Other related research has shown that there is no one-size-fits-all strategy for a closed-loop supply chain. For some firms, such as the Xerox Corporation, product

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[11] For further information on the reduce, reuse, and recycle (3R) hierarchy, see the Environmental Protection Agency's website at http://www2.epa.gov/recycle.

[12] See Atasu, A., V.D.R. Guide, Jr., L.N. Van Wassenhove. 2009. So what if remanufacturing cannibalizes new product sales? *California Management Review* 52: 56-76.

[13] For additional insights into how to operate in a competitive core acquisition market, see Guide, V. D. R., R.H. Teunter, and L.N. Van Wassenhove. 2003. Matching demand and supply to maximize profits from remanufacturing. *Manufacturing & Service Operations Management* 5: 303–316.

[14] For a detailed look at the nature of such challenges related to marginal value of time in fast moving industries such as consumer electronics, see Guide, V. D. R., G.C. Souza, L.N. Van Wassenhove, and J.D. Blackburn. 2006. Time value of commercial product returns. *Management Science* 52: 1200–1214. For potential solutions to maximize profits based on the nature of the industry's marginal value of time, see Blackburn, J.D., V.D.R. Guide, G.C. Souza, and L.N. Van Wassenhove. 2004. Reverse Supply Chains for Commercial Returns. *California Management Review* 46: 6–22.

acquisition is quite simple as customers often lease large printing equipment, but lifecycle management and design issues represent major challenges.[15] Conversely, many consumer product firms have had great difficulty managing the core acquisition process and reverse supply chain as the consumer products typically have a short, single lifecycle.[16] To shed light on the differences in strategy by the nature of the industry, this chapter delves into two major dimensions that help a firm match their CLSC strategy with the nature of their market—product design and core competencies.

17.3 A Framework for Matching Product Design and Core Competencies

Product design is a highly complex topic in its own right. Thus, adding yet another layer of complexity in the form of designing for more than one lifecycle may seem daunting. Fortunately, designing for multiple lifecycles tends to have many positive effects, such as reduced return rates, easier reparability, and faster turnaround for warranty claims and returns.[17] Of course, when market pressures are high to get an innovative product to the market, speed and efficiency of production often take predominant roles as is often the case in the consumer technology industry. Due to such market-based pressures, many firms have naturally evolved core competencies based on the nature of their industries' competitive layout. However, as a product line matures and technological innovation slows, the move toward CLSC operations

[15] The Xerox Corporation has been a world leader in remanufacturing systems at their Webster, New York manufacturing/remanufacturing hybrid facilities. In both popular press and academic research, Xerox stands out as an exemplar of environmentally friendly closed-loop supply chain systems. Xerox works diligently from the design phase forward to recycle and remanufacture their equipment with great success in energy, materials, and waste reduction. For instance, in 2011, Xerox's remanufacturing operations diverted over 13 million pounds of waste from landfills. See a recent corporate sustainability report at http://www.xerox.com/corporate-citizenship/2012/sustainability/product-design/enus.html.

[16] Reverse supply chain design for consumer products remains a persistent issue for many firms. For a detailed discussion of viable solutions in consumer product industries, see the *California Management Review* article, Blackburn, J.D., V.D.R. Guide, G.C. Souza, and L.N. Van Wassenhove. 2004. Reverse Supply Chains for Commercial Returns. *California Management Review* 46: 6–22.

[17] Much recent research focuses on the need for better understanding of design for remanufacturing and reuse. Many resources exist for those interested in the engineering side of design such as the Rochester Institute of Technology's Center for Remanufacturing (http://www.rit.edu/gis/remanufacturing/). For an excellent summary of recent research on the topic of product design in a CLSC, see Bras, B. 2010. "Product Design Issues" in Ferguson, M.E. and Souza, G.C. (eds.), Closed-Loop Supply Chains New Developments to Improve the Sustainability of Business Practices. Boca Raton: CRC Press. Finally, for general resources on remanufacturing, see The Remanufacturing Institute website at http://www.reman.org/ and the Remanufacturing Industries Council website at http://remancouncil.org/.

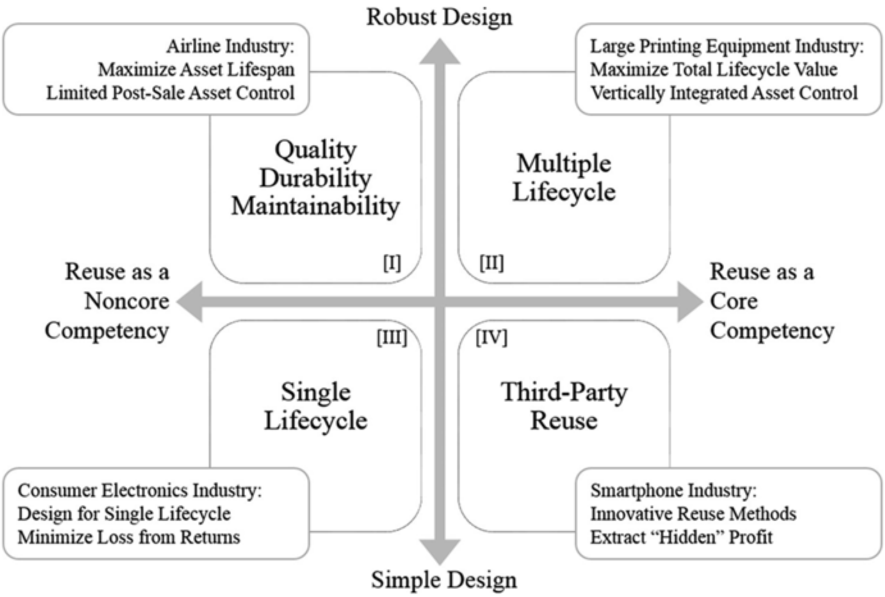

Fig. 17.3 Design and core competence for product reuse in a CLSC

as a core competency may offer increased profit opportunities. Figure 17.3 shows how design and core competencies interact with four resulting strategies.[18]

Breaking down each quadrant in the manager's matrix of Fig. 17.3 provides insights into the influence that product design has on product acquisition management, reverse logistics, reuse processes, and the nature of the reused product market. First, as shown in Fig. 17.3, product design plays a key role in dictating recoverable value, particularly at the product and component levels. Even at the materials level, product design plays a significant role. For example, recovering heavy metals from smartphones and many other small electronic devices is no easy task as the devices are integral by design.[19] Second, reverse logistics both entails product acquisition management—the means to reacquire end-of-use returned products—and requires either ownership or outsourcing the transportation network for moving the end-of-use products. Third, the core operational reuse processes,

[18] The major impetus for this chapter and framework for understanding strategies for reuse through remanufacturing comes from ongoing research found in the manuscript, Abbey, J.D. and V.D.R. Guide. 2016. A typology of remanufacturing in a closed-loop supply chain. *Working Paper*, Texas A&M University and The Pennsylvania State University. Relatedly, see Abbey, J.D. and V.D.R. Guide. 2016. Remanufacturing Strategies in a Circular Economy. *Working Paper*, Texas A&M University and The Pennsylvania State University.

[19] Reclaiming rare earth and other precious metals from electronics products has been an issue for decades. For a review of issues related to such reclamation, see Cui, J., and E. Forssberg. 2003. Mechanical recycling of waste electric and electronic equipment: a review. *Journal of Hazardous Materials* 99: 243–263.

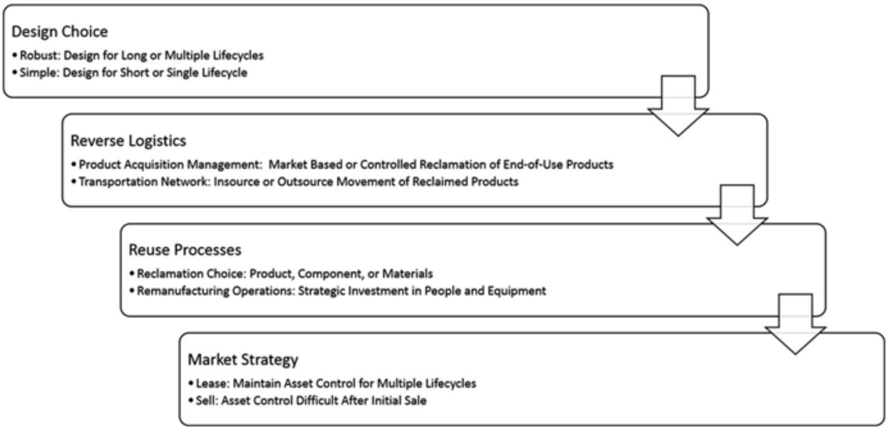

Fig. 17.4 Strategic levers in a closed-loop supply chain

such as the choice of the recovery level (i.e., product, component, or materials), require decisions regarding investment in remanufacturing capabilities in both capital equipment and people. Finally, the fourth lever describes the means of remarketing products going through more than one lifecycle. If a market for such products does exist, then deciding whether to lease or sell the products has major implications on the CLSC strategy. As will become clear throughout this chapter, a decision in any one of the levers can have significant impacts on all other decisions. Figure 17.4 summarizes the four key levers that either derive from or drive a closed-loop supply chain strategy (see Footnote 18).

17.3.1 Quadrant I: Quality, Durability, and Maintainability

In this quadrant of Fig. 17.3, the original manufacturer of the assets tends to focus on selling with limited post-sale support. As a prime example, consider the airline industry. In many cases, airlines prefer to buy the multi-billion dollar fleets of airplanes from the aircraft manufacturers. As such, the aircraft manufacturers accommodate by going through intensive new product design processes focused on quality, reliability, and maintainability in the field. These traits actually mesh with the multiple lifecycle design traits of other industries that do maintain asset control (e.g., Xerox) and lend themselves well to product reuse in a CLSC. However, the loss of asset control post-sale has significant downsides. The most obvious downside is that reacquiring a used product may be difficult if not infeasible. The airplane manufacturers simply have no interest in reacquiring the assets after a sale occurs. Such lack of asset control opened up an entire third-party industry centered on overhauling and remanufacturing products ranging from full airliners to engines to small components of airplanes.[20] In other words, the airplane manufacturers have ceded profits to third-party remanufacturers due to their robust designs combined with a lack of access to the assets after the initial sale.

Another downside is that investing in a reverse logistics network for components/parts is often prohibitive when third-party entrants, such as Delta and Lufthansa, already have a strong presence in the market. Additionally, the airplane manufacturers (e.g., Boeing and Airbus) generally lack both tacit and explicit knowledge of the testing, inspecting, and disposition processes as well as the appropriate asset base for intensive remanufacturing of the assets. Finally, without a strong market presence as a remanufacturing original equipment manufacturer, the airplane manufacturers lack the market cache from which to capitalize. Overall, in this quadrant, firms maintain minimal control over product reacquisition, reverse logistics, and little to no market presence in the multiple lifecycle product market. However, the firms do not need to invest heavily in capital-intensive remanufacturing systems.

17.3.2 Quadrant II: Multiple Lifecycle

In this quadrant, the original equipment manufacturer focuses on designing the product for multiple lifecycles from the inception of a product's design. The intention for such products is to extract as many lifecycles as possible to maximize total lifecycle profits. Such designs require strong vertical integration of both the initial sales and end-of-use product reacquisition channels. If such integration of the initial sale and reacquisition are not present, then third-party remanufacturers will gladly enter the market to extract the additional lifecycle value missed by the original equipment manufacturer as seen in the airline industry. Firms playing in this vertically integrated multiple lifecycle design quadrant also need to invest heavily in the reverse logistics systems to maintain appropriate transportation to the asset-intensive remanufacturing facilities. At the remanufacturing facilities, the product design naturally leads to rapid testing, inspecting, and disposition of the products for reentry into the market. As exemplified by the Xerox Corporation, markets for such multiple lifecycle products are highly segmented based on the dimensions of product performance and price. The Xerox sales force actively markets the right package of "newly manufactured" (i.e., blended new and remanufactured products) and completely new products to suit any customer type. In fact, at the time of end-of-use for a product at a

[20] Delta Airlines and Lufthansa continue to generate significant cost savings and profits through repair and refurbishment of both their own equipment and equipment for other airlines. For details on Delta Airlines' continued strategy of extending lifecycles of aircraft, see Carry, Susan. 2012. "Delta Flies New Route to Profits: Older Jets," The Wall Street Journal November 16, 2012. Lufthansa Technik AG actively markets their commercial airline refurbishment services for all levels of maintenance, overhaul, engines, components, aircraft systems, and more. For details, see Lufthansa website at http://www.lufthansagroup.com/en/company/business-segments/maintenance-repair-overhaul.html.

customer site, Xerox uses their sales expertise to provide higher performing, remanufactured machines as a means to maintain a strong competitive foothold against their non-remanufacturing competitors who cannot compete at the same price-performance thresholds. In sum, this quadrant represents the pinnacle in maximizing both environmental benefits and profitability through tight control over asset reacquisition, reverse logistics networks, heavy investment in remanufacturing capabilities, and a deep understanding of market segments for the multiple lifecycle products.

17.3.3 Quadrant III: Single Lifecycle

The astute reader might have noticed that the prior two quadrants largely focus on high value, business-to-business products. Though some firms still design such high-value equipment for a single lifecycle, the most common examples of such single lifecycle products come from the consumer products industries. Consumer tastes and preferences often change rapidly, particularly in fast moving product segments such as consumer electronics. Such fast moving industries can make extracting value from returned products extraordinarily difficult (see Footnote 14). In response, many firms have abandoned the idea of designing products for anything beyond a single lifecycle. Instead, such firms focus on extracting maximum profit through efficient design and manufacturing systems with an accompanying focus on preventing returns. Such a strategy has been successful for many companies with the side effect of a massive resulting waste stream. Such a copious waste stream represents a continuing force for increasing legislative mandates to prevent electronics waste even in the United States.[21] In effect, though companies found the strategy sustainable for making profits and meeting consumer needs, legislative forces view the strategy as unsustainable from a societal and environmental standpoint. Though little has changed on the design front, the single lifecycle product design may diminish in the coming years.

In sum, firms operating with the single lifecycle design strategy may soon find themselves seeking ways to improve reacquisition of the products through reverse logistics networks at least at the materials level. Without a move away from the single lifecycle philosophy, investment in testing, inspection, and disposition technologies and related remanufacturing systems will be a moot point. Interestingly, there is recent evidence that select product types should be designed for a single lifecycle or easy materials reclamation, as a sizeable portion of the consumer market holds no interest in purchasing a multiple lifecycle product.[22]

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[21] As noted before, the E.U., Japan, and Australia have all moved toward increasing legislative mandates for recycling and waste stream reduction. This increasing legislative pressure has also come to the US in the form of California's recycling laws aimed to curbing electronics and other waste (http://www.calrecycle.ca.gov/recycle/).

[22] Two recent studies shed light on the nature of consumer perceptions of multiple lifecycle products. The first study delves into the various factors that influence how consumers perceive multiple

17.3.4 Quadrant IV: Third-Party Reuse

The final quadrant represents a simple fact: lost profit opportunities on the part of the original equipment manufacturer. As a case in point, ReCellular started their business by refurbishing Motorola cellular phones when Motorola proclaimed that no one could make money off such a venture. Of course, if the third-party reuse occurs at the materials reclamation (i.e., recycling of plastics) level, the original equipment manufacturer may simply cede such markets for a lack of interest in entering a non-core competence market. However, when the third-party reuse occurs at the component or particularly product level, the original equipment manufacturer has inadvertently created a competitor in their own market space—a competitor using the original equipment manufacturer's own product. The common excuse for allowing such third-party entry comes straight from Fig. 17.3: the original equipment manufacturer views the product or component reuse as a non-core competence region. As such, the original equipment manufacturers argue that reacquisition is simply too expensive or difficult, that reverse logistics systems are too hard to manage, and that investment in remanufacturing equipment as well as the related testing, inspection, and disposition processes is simply too risky. Finally, such original equipment manufacturers may also view internal remanufacturing as a source of new sales cannibalization—a fear shown to be questionable at best.[23] Yet, all these arguments seem to be mythical from the third-party remanufacturer's perspective as thousands of third-party remanufacturers make billions in profits every year.

17.3.5 Contrasting the Quadrants

Table 17.1 provides an accessible summary of the criticality of each major CLSC function available to a manager deciding which quadrant best fits with their design-competence status (see Footnote 18).

Table 17.1 shows that each quadrant has varying functional dimensions for the closed-loop supply chain. In particular, the Quality, Durability, and Maintainability

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lifecycle (e.g., remanufactured) products (see Abbey, J. D., et al. 2015. Remanufactured Products in Closed-Loop Supply Chains for Consumer Goods. *Production and Operations Management* 24(3): 488–503.). An even more recent work examines how various consumer segments emerge with a sizeable portion—upwards of 35 %—of consumers refusing to consider a remanufactured product of any kind (see Abbey, J.D., J.D. Blackburn, V.D.R. Guide Jr. 2015. "Optimal Pricing for New and Remanufactured Products." *Journal of Operations Management* 36: 130–146.). For a managerially-oriented discussion of these and expanded topics, see Abbey, J.D., M.G. Meloy, J.D. Blackburn, and V.D.R. Guide. 2015. Consumer Markets for Remanufactured and Refurbished Products. *California Management Review* 57(4): 26–4.

[23] Fear of new product sales cannibalization when offering a remanufactured product has been a long-standing source of opposition for remanufacturing at many firms. For a nice discussion of such opposition and strategies to handle common issues with potential cannibalization, see Atasu, A., V.D.R. Guide, Jr., L.N. Van Wassenhove. 2009. So what if remanufacturing cannibalizes new product sales? *California Management Review* 52: 56–76.

Table 17.1 Summary of CLSC process intensity by quadrant

Quadrant	Product design	Reverse logistics	Reuse processes	Marketability
Quality and durability (I)	Maximal lifespan	Minimal	Minimal	Minimal
Multiple lifecycle (II)	Intentional reuse	Simple	Intensive	Simple
Single lifecycle (III)	Maximal efficiency	Minimal (outsourced)	Simple to intensive	Challenging
Third-party (IV)	Profit extraction	Intensive	Intensive	Challenging

quadrant has little to no CLSC functions as a result of the sales of products and little if any direct interaction with the product post-sale. Conversely, the multiple lifecycle quadrant has relatively simple reverse logistics and marketability by the very nature of the typically vertically integrated system. Nonetheless, the multiple lifecycle quadrant also requires intensive resource investment to remanufacture and extract value from the returned end-of-use products. The single lifecycle (i.e., consumer products) quadrant usually focuses on minimizing costs related to returned or end-of-use products. As such, third parties provide most logistics needs to minimize cost, though such a strategy can be a severe mistake for firms that face a high marginal value of time market (see Footnote 14). Additionally, the single lifecycle products typically have highly varied reusability due to both the initial design intentions and lack of investment in remanufacturing technologies by the original manufacturer. Further, the marketability of remanufactured single lifecycle products can be questionable due to varying forces from rapid depreciation, quality concerns, and more.

In general, the third party's core business is finding innovative ways to extract profit that the original equipment manufacturers either ignored or missed completely. The third parties typically lack easy access to the returned or end-of-use products, which makes reacquiring the products an intensive endeavor. The remanufacturing and reuse processes must be retrofitted to the decision made by the external entity—the original manufacturer. Finally, as the third party rarely has the same market power or existing forward supply chain channels as the original manufacturer, remarketing the products can also be an intensive challenge. Yet, in spite of all these challenges, third-party remanufacturers are plentiful, and more importantly, profitable.

17.4 Design and Core Competence: One Size Does Not Fit All

The above discussion demonstrates that implementing a true, fully closed-loop supply chain requires the vertically integrated, multiple lifecycle design strategy. However, many firms may find that complete vertical integration combined with a multiple lifecycle design is both technically infeasible due to the nature of the product and financially infeasible due to requisite investment in reverse logistics and remanufacturing facilities. Moreover, a sizeable reuse market may not even exist for products that have a short market lifecycle. As such, to maximize profitability and environmental benefits under the various constraints, the original equipment manufacturer should take an active role in establishing the appropriate level of third party involvement. Recent research describes just such trade-offs with three major strategies that sit on a continuum from pure outsourcing to pure insourcing. Between these two extreme points sit various levels of hybrid strategies, which are often the best choice for a remanufacturing original equipment manufacturer. Even Xerox, which represents one of the best remanufacturing firms in the world, only maintains a limited reverse logistics fleet with a preference for using third-party logistics carriers to haul end-of-use products back to the centralized remanufacturing facilities. Figure 17.5, adapted from work by Pinar Martin, provides the basic process flow decisions for the vertically integrated remanufacturing, hybrid remanufacturing, and outsourced remanufacturing strategies.[24]

The primary difference among the strategies is the intensity of remanufacturing operations. Even in the vertically integrated CLSC, both initial manufacturing and remanufacturing still source some components from an external entity (e.g., microprocessors or memory cells). Such components are not part of the core-competence

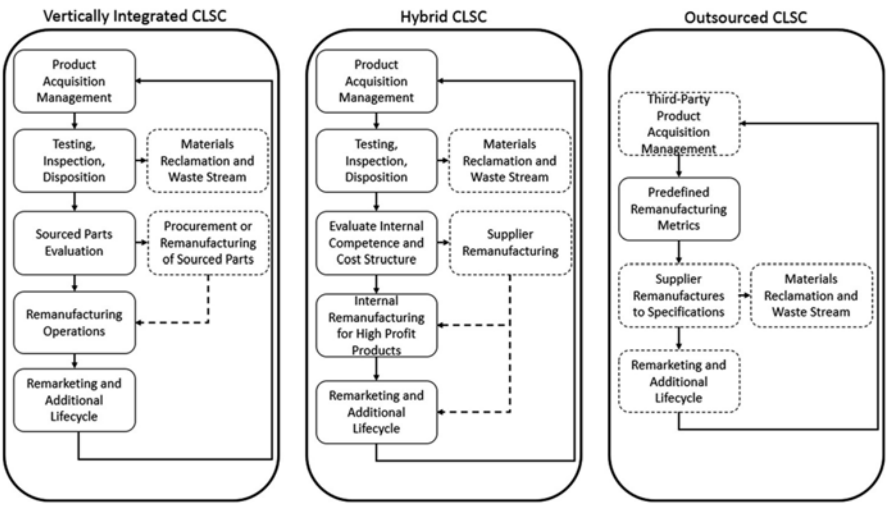

Fig. 17.5 Vertical, Hybrid, and outsourced CLSC strategies

[24] Pinar Martin has recently released a book on the various levels of remanufacturing strategy as well as a scholarly paper on the topic. For those interested in the more managerially oriented materials, see Martin, P. 2010. Remanufacturing as a Supply Chain Strategy: Business Models and Case Studies. Dusseldorf, Germany: VDM Verlag. For those interested in the technical details, see Martin, P., V.D.R. Guide, and C.W. Craighead. 2010. Supply chain sourcing in remanufacturing operations: an empirical investigation of remake versus buy. *Decision Sciences* 41: 301–324.

of the manufacturer and are often either replaced with new components or tested for viability in the remanufactured product. In the hybrid strategy, firms handle some products internally, while third parties handle less complex or less profitable products. Finally, in the outsourced CLSC, the original manufacturer exerts only minimal control in the form of performance specifications or other inputs. Note that in all cases, the original manufacturer plays some role to prevent an unauthorized third party from entering the market. Obviously, each of the various choices holds significant tradeoffs. Thus, a quick breakdown of the implications for each choice follows starting with the endpoints of vertical integration and outsourcing.

17.4.1 Vertically Integrated CLSC Strategy

Control represents a major impetus for the vertically integrated strategy. Under vertical integration, a firm retains control over the brand name, customer service, intellectual property, product acquisition, and even the forward and reverse supply chains. However, control creates challenges. For instance, forward supply chain procurement can represent a major hurdle for the remanufacturing operations. If the procurement division has to acquire additional new parts to support the production of new machines but remanufacturing decreases order quantities for new parts, the bulk rate economies of scale in both purchasing and transportation may disappear. Other issues stemming from metrics decisions can also play a significant role. For example, labor and equipment utilization may actually look better with remanufacturing, but variability in production times may increase. Additionally, overhead allocation to both new and remanufactured product production can be a tricky balancing act. Too much or too little allocation to either new or remanufactured products can create major problems for the manufacturing division profitability.

17.4.2 Outsourcing CLSC Strategy

If the forward supply chain is largely outsourced, then the reverse supply chain and reuse operations will be outsourced as well. Simply put, if a firm does not manufacture, they cannot easily remanufacture. This issue became manifest for Dell. As Dell outsourced more of their forward supply chain production, reuse operations became increasingly more difficult. In the end, Dell eventually outsourced of the previously profitable remanufacturing operations.[25] Many other problems emerge when trying to manage a closed-loop supply chain in an outsourced system. Visibility of design flaws and improvements all but vanish as returned products are

[25] For a detailed look at Dell's outsourced remanufacturing/refurbishing strategy, see Vitasek, K., Ledyard, M., & Manrodt, K. 2013. *Vested outsourcing: five rules that will transform outsourcing*. Palgrave Macmillan. pp. 185–198.

not highly accessible for designers to garner feedback. Contractual obligations become vastly more complex as contracting parties must consider both the forward and reverse supply chain contingencies. Moving products that lose value rapidly (i.e., high marginal value of time products) represents a major challenge as the contracted reverse logistics and reuse partners typically do not possess great competence in moving products back to market. In sum, with only a few exceptions, a fully outsourced CLSC rarely achieves the same profitability and environmental benefits as a vertically integrated or hybrid strategy.

17.4.3 Hybrid CLSC Strategy

In a hybrid strategy, a firm ideally chooses remanufacturing functions that best mesh with core competencies. However, such hedging can be a double-edged sword as firms may dismiss profit opportunities due to lack of a *current* core competence—one that could easily be developed to generate additional profit. Further, if too many functions are outsourced, the firm loses control over design specifications, which all but assures difficulty for remanufacturing. Other issues include intellectual property, pricing contracts, lack of visibility across the supply chain, and loss of control over both the forward and reverse supply chains. Overall, the hybrid strategy is the most common strategy but always represents a balancing act—in many cases, the hybrid strategy can create cross-divisional conflict as different stakeholders fight for shares of profit.

In the end, there is no single solution for deciding the right level of insourcing or outsourcing. The next section provides some basic guidance and a decision tool when considering the various choices involved in implementing a closed-loop supply chain.

17.5 Choosing a Closed-Loop Supply Chain Strategy

The one clear message so far is that choosing a CLSC strategy is no easy task. As with most decisions, multiple tradeoffs exist when choosing how to compete for more than just maximum profit. In some industries, such as the earth moving and mining equipment, the decision to remanufacture previously produced machinery is a simple matter of materials availability and obvious profitability.[26] Unfortunately, the lines

[26] Caterpillar is proud of their industry-leading remanufacturing and reuse systems. To say that remanufacturing and reuse is a core competence of Caterpillar would be an understatement. In any given year, Caterpillar reuses more than 120 million pounds of iron alone. For a detailed look at Caterpillar's remanufacturing operations, see their website at http://www.caterpillar.com/en/company/sustainability/remanufacturing.html.

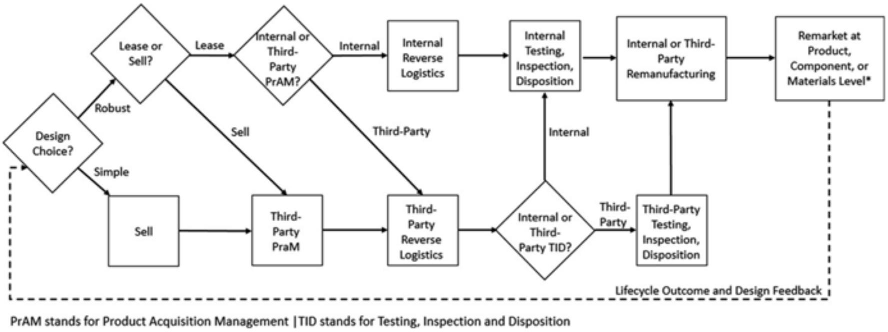

Fig. 17.6 Decision process for major closed-loop supply chain activities

blur as the products become less expensive and more widely distributed. The problems compound when the product has a relatively short lifecycle in the market.

Figure 17.6 puts the pieces, originally outlined in Table 17.1, together with a decision flow process for managers considering particular levels of reuse. In some cases, the decision flow outlined in Fig. 17.5 might have exceptions. However, based on observations from dozens of companies over dozens of years, the decision flow is largely in line with successful CLSC strategies.

Figure 17.6 summarizes the major levers that all managers must consider when contemplating a CLSC strategy: the product design; product (re)acquisition management; reverse logistics; the testing, inspection, and disposition process as well as the remanufacturing processes; and finally the remarketing of the reused product, components, or materials. As the figure displays, third parties typically play a role—often significant—in managing at least some elements of a CLSC. The question managers face is choosing the right level of third-party involvement.

17.5.1 The Role of Third Parties Revisited: When and How to Maintain Control

As noted in the previous section, the choice between internal and third-party activities largely sits on a continuum (see Fig. 17.5). In only a very few cases does a firm do all CLSC activities internally. Xerox and Caterpillar represent uncommon examples of firms that maintained a significant, vertical control over both the forward and reverse supply chains. For both firms, such control has been invaluable in providing improved profitability, design feedback, and environmental benefits. However, such cases of vertically integrated CLSCs are largely the exception.

As outsourcing the forward supply chain gained popularity, insourced remanufacturing became increasingly difficult. Facilities that used to serve for dual new and remanufacturing production were economically unsustainable for only remanufacturing operations. As a case in point, Dell moved nearly all remanufacturing activities to a third party on a contractual basis as the forward supply chain evolved toward outsourced contract manufacturing (see Footnote 25). However, Dell still maintains contractual control over the third party, which is significantly superior to the all too common strategy of simply ignoring the activity of third parties that will enter the market with or without the original manufacturer's consent. In other words, a complete omission of a remanufacturing strategy opens the door for third parties to extract profit that could have been controlled by the original manufacturer, which can have significant implications on the original brand's reputation.[27]

The automotive industry serves as a case in point for ceding control over remanufacturing. The remanufactured automotive parts industry has a long-standing tradition of heavy third-party involvement. Though Ford and other major automotive manufacturers have tried to make inroads into reuse of parts, third-party players (e.g., Cardone Industries) have maintained a strong control on the automotive parts product acquisition market.[28] During a meeting of original equipment automotive manufacturers and their third-party remanufacturing competitors, an interesting argument emerged: the original equipment manufacturer accused the third party of "stealing parts" to which the third party responded "stop me." Though the original manufacturer may felt entitled to "their parts", the original manufacturer had taken no steps to maintain any vertical control after the time of the initial sale. The automotive industry provides a cautionary message: once an industry cedes control over remanufacturing to third parties, regaining control over the remanufacturing market can be a difficult and costly proposition.

17.6 Closing the Loop

This chapter provides high-level guidance on the structure of closed-loop supply chain strategies with an overriding theme: third parties will play a role in nearly all closed-loop supply chain systems. As such, manufacturers in the forward supply chain need to make a conscious decision on their closed-loop supply chain strategy: that decision needs to ask when and how third parties should play a role. If the forward supply chain original manufacturer does not make such conscious decisions, an *unauthorized* third party will make the decision for them by entering the market as a competitor. Even if the prospect of investing in resources—capital equipment, skilled labor, and reverse logistics networks—is beyond the core competencies of an original equipment manufacturer, forethought in developing and contracting with third parties can prove valuable. The value of such contracts comes from

[27] For a fascinating look at the adverse and even beneficial consequences of third-party remanufacturing, see Agrawal, V., A. Atasu, K. van Ittersum. 2015. Remanufacturing, third party competition, and the perceived value of new products. *Management Science* 61(1): 60–72.

[28] For a look at the broad range of products—some of which are only available in remanufactured form—that Cardone Industries remanufacturers, see their website at https://www.cardone.com/.

improved control over all aspects of the reverse supply chain including product design feedback, environmental reuse opportunities, hedging against future legislative pressures, increased opportunity to reach additional markets, and greater control over brand image. In the end, if the forward supply chain manufacturer does not have a closed-loop supply chain strategy, a third-party remanufacturer will.