California Management Review:

Reverse Supply Chains for Commercial Returns

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Introduction

Once lightly regarded, the flow of product returns is becoming a significant concern for many manufacturers. The total value of products returned by consumers in the U.S. is enormous – estimated at $100 billion annually[1]. For commercial product returns—products returned by customers for any reason within up to 90 days of sale—the manufacturer must typically credit the retailer (or reseller) and then decide how to most profitably dispose of the product: reuse as–is, refurbish, salvage, or recycle. Managers struggle to design, plan and control the processes required for reverse supply chains that process returned products from the customer, recover their value and use/sell them again.

To most companies, commercial product returns have been viewed as a nuisance; consequently their legacy today is a reverse supply chain process that was designed to minimize costs. Cost efficient supply chains are not necessarily fast, and as a result returns undergo a lengthy delay until they are re–used, either as–is, or remanufactured. The longer it takes to retrieve a returned product, the lower the likelihood of economically viable reuse options. The advantages of time-based competition and faster response are well known and documented (see Blackburn 1991 for a complete discussion[2]), and our experiences and research suggest that significant monetary values can be gained by redesigning the reverse supply chain to be faster[3] and reduce costly time delays. These monetary values are higher in fast clockspeed industries, such as consumer electronics, where the average life cycle of a personal computer (PC) is expressed in months, as opposed to a slow clockspeed industry such as power tools, with life cycles around six years.

Unlike forward supply chains, design strategies for reverse supply chains are relatively unexplored and underdeveloped. Key concepts of forward supply chain design—such as coordination, postponement, and the bullwhip effect—may be useful for the development of reverse supply chain design strategies, but these concepts have not been examined for their relevance in this context. For forward chains, Fisher (1997)[4] proposes a useful dichotomous structure: *responsive* supply chains are appropriate for high demand uncertainty products; *efficient* supply chains are appropriate for low demand uncertainty products. For reverse supply chains, our research indicates that the most influential product characteristic for supply chain design is marginal value of time (MVT), which can be viewed as a measure of clockspeed. As we argue later, we posit that responsive reverse supply chains are appropriate for products with high MVT (clockspeed), whereas efficient reverse supply chains are appropriate for products with low MVT (clockspeed). In practice, however, we have found that the reverse supply chains of both slow and fast clockspeed industries are remarkably similar. Both are typically focused on local efficiencies where all product returns flow to a central facility. Managers have designed processes focused on providing low-cost solutions, despite the fact that much of the value for their products eroded away because of the lengthy delays.

In forward supply chains, Lee and Tang[5] and others have introduced the concept of product postponement and have shown that it has substantial financial benefits. We show that a modification of this concept can be very useful in a reverse supply chain: managers should make a disposition as *early* as possible to avoid processing returns with no recoverable value. We call this concept preponement and posit that it can greatly benefit the profitability of a firm by avoiding unnecessary processing expenses, while providing faster recovery of products with significant value.

In this article, we build upon principles of design strategy developed for forward supply chains and use the time value of product returns to outline a set of fundamental design principles for reverse supply chains to maximize the net asset value recovered. We provide numerous examples from our work with a number of global companies. In our view, product returns and their reverse supply chains represent an opportunity to create a value stream, not an automatic financial loss. Reverse supply chains deserve as much attention at the corporate level as forward supply chains and should be managed as business processes that can create value for the company.

Product Returns and Reverse Supply Chains

Not all reverse supply chains are identical, nor should they be[6]. However, most return supply chains are organized to carry out five key processes:

- Product acquisition – obtaining the used product from the user,
- Reverse logistics – transporting the products to a facility for inspecting, sorting, and disposition,
- Inspection and disposition – assessing the condition of the return and making the most profitable decision for reuse,
- Remanufacturing (or refurbishing)[*] – returning the product to original specifications,
- Marketing – creating secondary markets for the recovered products.

A simplified schematic of a generic reverse supply chain for commercial product returns is shown in Figure 1. Customers return products to the reseller (product acquisition), who ships the product to the manufacturer's returns evaluation location (reverse logistics) for credit issuance

[*] We use the terms remanufacturing and refurbishment interchangeably.

and product disposition (inspection and disposition). The manufacturer performs diagnostic tests to determine what disposal action recovers the most value from the returned product. These products are tested and are remanufactured if deemed cost effective; some firms may simply treat all product returns as defective[7]. Some returned products may be new and never used; these products are returned to the forward distribution channel. Products not reused or remanufactured are sold for scrap or recycling, usually after physically destroying the product. Remanufactured products are sold in secondary markets for additional revenue, often to a marketing segment unwilling or unable to purchase a new product. Returns may also be used as spare parts for warranty claims to reduce the cost of providing these services for customers.

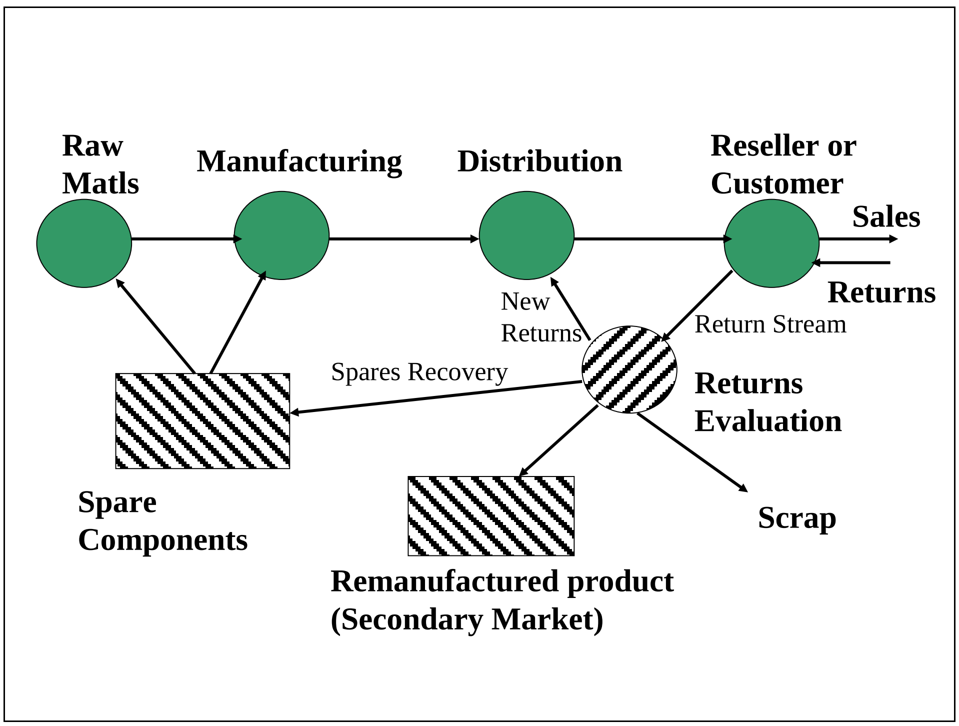

Figure 1- A reverse supply chain for product returns

Product Returns at ABC Company[8]

The ABC Company is an example of a consumer electronics firm for which product returns have become a significant management concern. They handle enormous product return volumes in the U.S.—over 100,000 units of products such as PCs and computer peripherals are returned every month. ABC estimates the annual total cost of product returns to be between 2 and 4 percent of total outbound sales, where the cost of product returns is defined as the value of the return plus all reverse logistics costs minus revenue recovered from the product.

Product returns are transported to a central returns depot for initial processing. At ABC the first transaction is credit issuance: a third party physically verifies the return and issues credit to the retailer. Products are then sorted by type and model, palletized, labeled, and moved to shipping. Products are shipped to specialized testing and refurbishment (T&R) facilities scattered around the U.S.

In each facility, all units sent from credit issuance undergo the refurbishment processes although some will be scrapped during processing or fail to meet ABC quality standards after refurbishing. Refurbished products such as PCs are first used to fill the warranty pool; all remaining units are sold in secondary markets in the U.S.

According to our experience, ABC's centralized reverse supply chain design is remarkably similar to that used by others firms in Europe and in the U.S. When we first began studying ABC's reverse supply chain in the late 1990s, they had an efficient supply chain that was designed to minimize the cost of processing returns, not to recover value. In the intervening years, ABC has been committed to developing a more responsive supply chain.

The Time Value of Product Returns

The flow of returned products represents a sizeable asset stream for many companies, but much of that asset value is lost in the reverse supply chain. Managers, focused predominantly on the forward supply chain for new products, are often unaware of the magnitude of these losses and of how they occur. A visual model that illustrates how assets are lost in the return stream is shown in Figure 2: the returns process is modeled as a shrinking, leaky pipeline. The percentage losses we show in Figure 2 are representative averages from our research base of companies. In Figure 2, for $1000 of product returns nearly half the asset value (> 45%) is lost in the return stream. Most of the loss in asset value falls into two categories: (1) the returned product must be downgraded to a lower-valued product—a product once valued as new must be remanufactured, salvaged for parts, or simply scrapped as not reparable or obsolete; (2) the value of the product decreases with time as it moves through the pipeline to its ultimate disposition. Of these two loss categories, much of the first is unavoidable because only a fraction of returns can be restocked as new items (20% in our example). However, the losses due to time delays represent a significant opportunity for asset recovery. These losses include not only the deterioration in value of a returned product with time, but also the forced downgrading of product due to obsolescence.

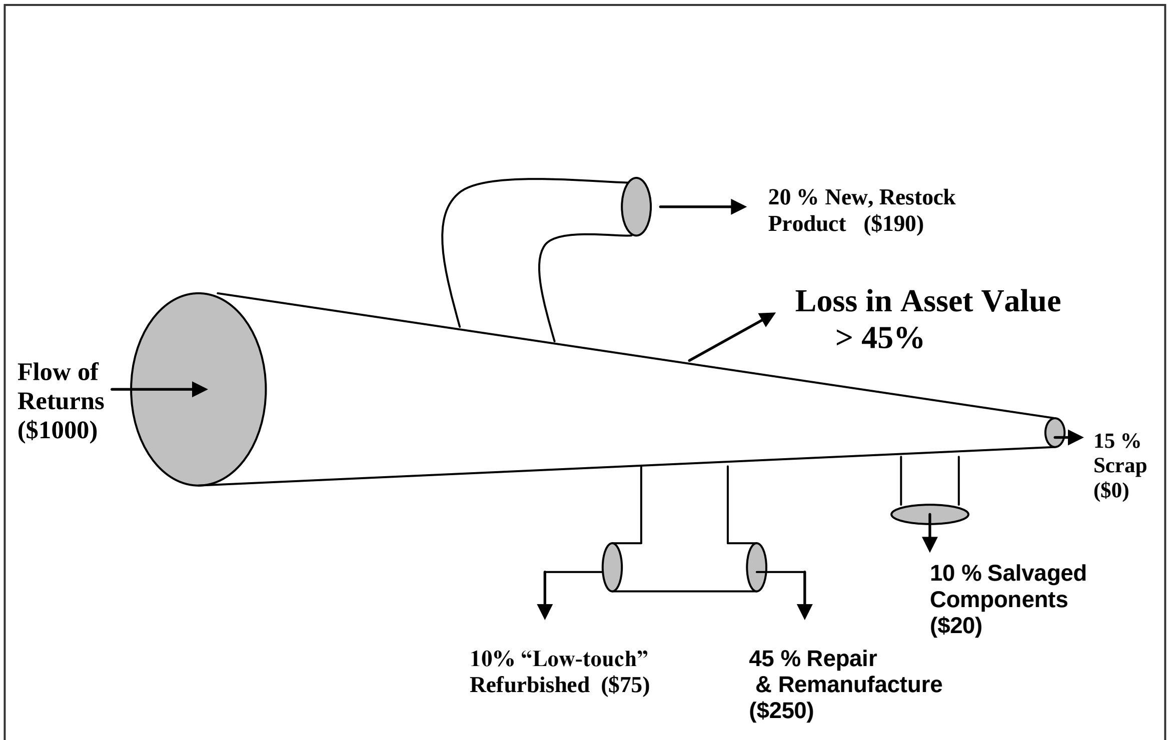

Figure 2—The Shrinking Pipeline for Product Returns

Figure 3 illustrates the effects of time delays and product downgrading on asset loss in a return stream. The upper line in Figure 3 represents the declining value over time for a new product. The lower line indicates the declining value over time for a remanufactured version of the same product. In our example, only 20% of product returns would remain on the upper curve, losing value due to time delays; 80% of the returns would drop to lower values and the product that is ultimately scrapped would fall to zero. Products near the end of their life cycle will show sharp increases in the rate of value deterioration.

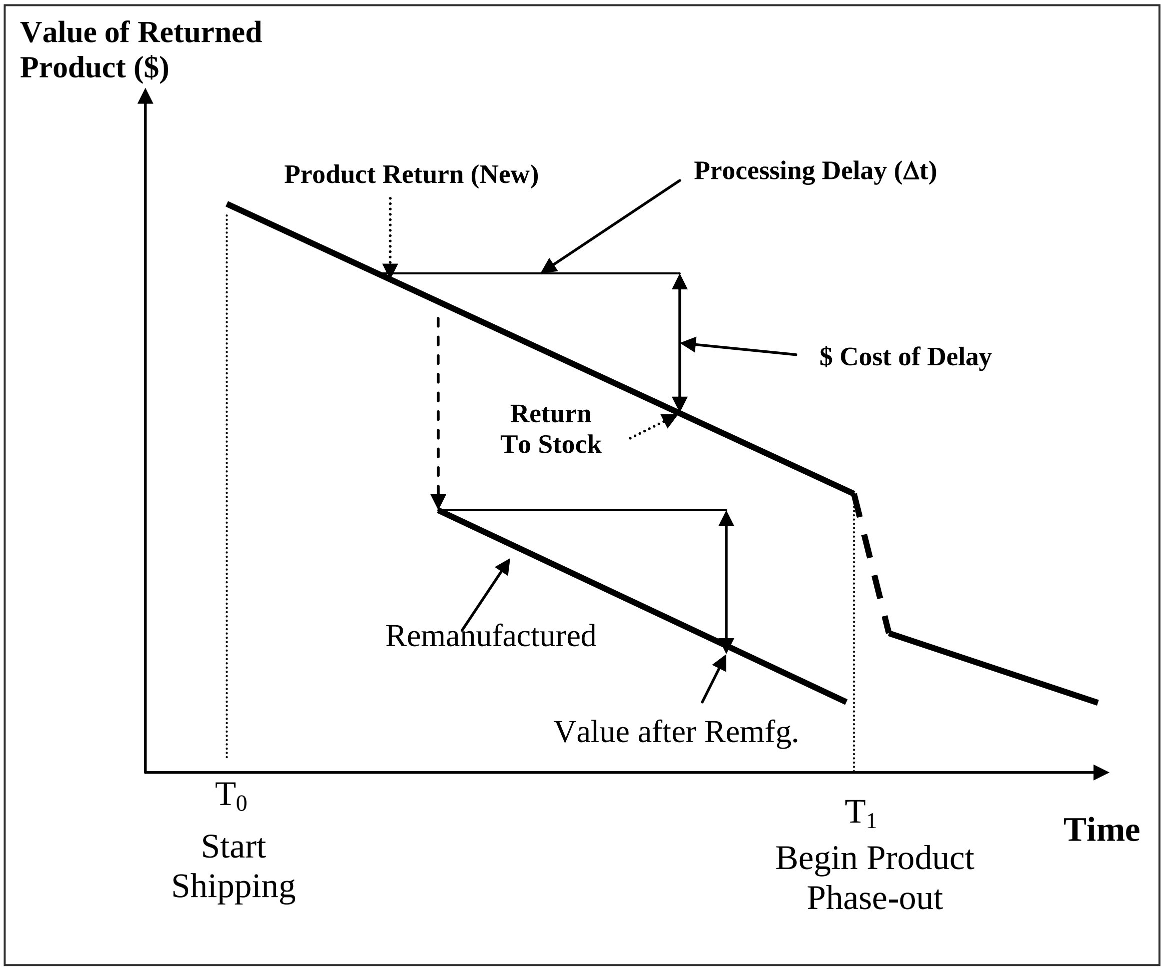

Figure 3—Time Value of Product Returns

Because much of the recoverable asset loss in the return stream is due to time delays in processing, managers must be sensitive to the value of time for product returns and use it as a tool to (re)design the reverse supply chain for asset recovery. A simple, but effective, metric to measure the cost of delay is the product's marginal value of time: the loss in value per unit of time spent awaiting completion of the recovery process. For our example, the marginal value of time is represented by the slopes of the lines in Figure 3.

The time value of returns is best represented in percentage terms to facilitate comparisons across products and product categories with different unit costs. Our research studies show that the time value of returned products varies widely across industries and product categories. Time-sensitive, consumer electronics products such as PCs can lose value at rates in excess of 1% per week, and the rate increases as the product nears the end of its product's life-cycle. At these rates, returned products can lose up to 10-20% of their value simply due to time delays in the evaluation and disposition process. When we first documented ABC's processes we found that a returned consumer product could wait in excess of 3.5 months before it was sent to disposition and during this time period much of the value of the product simply eroded, making it very difficult for any value to be recovered. On the other hand, a returned disposable camera body or a power tool has a lower marginal value of time; the cost of delay is usually closer to 1% per month. These differences in the marginal value of time are illustrated in Figure 4.

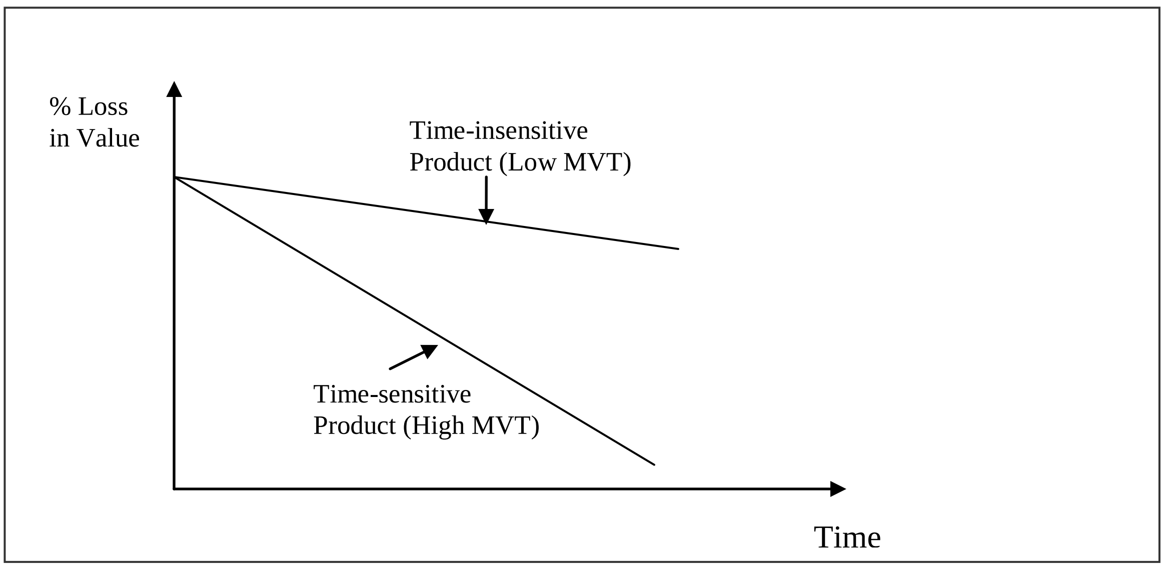

Figure 4: Differences in Marginal Value of Time for Returns

Reverse Supply Chain Design

Reverse supply chain design decisions should reflect, and be driven by, differences in the marginal value of time among products. In Fisher's [1997][9] taxonomy of strategic design choices for the forward supply chain, products are characterized as either *functional* (predictable demand, long life cycle) or *innovative* (variable demand, short life cycle). He then proposes two fundamental supply chain structures:

efficient—a supply chain designed to deliver product at low cost;

responsive—a supply chain designed for speed of response.

Within this framework, there is an appropriate matching of product to supply chain: efficient supply chains are best for functional products, and responsive chains are best for innovative products.

The relevance of Fisher's strategic model for reverse supply chains is clearly seen by recasting it in time-based terms because asset recovery depends so strongly on reducing time delays. To make the translation, observe that the product classifications—functional and innovative— roughly correspond to products with *low* and *high* marginal values of time respectively. Innovative, short life-cycle products, such as laptop computers, have a high marginal value of time, whereas products such as power tools or disposable cameras are less time-sensitive and have low marginal values of time.

Having classified products by time value, we can develop an analog of Fisher's supply chain structure to maximize the value of recovered assets in the return stream. If our objective is to maximize the net value of recovered assets, then the cost of managing the reverse supply chain must also be considered. To use Fisher's terminology, efficient supply chains sacrifice speed for cost efficiencies, and in a responsive chain speed is usually achieved at higher cost.

Viewed in this way, reverse supply chain design is a tradeoff between speed and cost efficiency. For products with high marginal time values (such as laptop computers), the high cost of time delays tips the tradeoff toward a responsive chain. For products with low marginal time values, delays are less costly, and cost efficiency is a more appropriate objective. This suggests a supply chain design structure similar to the one Fisher proposes for forward supply chains; it is displayed as a two-dimensional matrix in Table 1. The right reverse supply chain matches responsiveness with high time value products and cost efficiency with low time value.

	Efficient Chain	Responsive Chain
Low MVT Product	Match	No Match
High MVT Product	No Match	Match

Table 1: Time-Based Reverse Supply Chain Design Strategy

The major structural difference between efficient and responsive reverse supply chains is the positioning of the evaluation activity in the supply chain—that is, where in the chain is testing and evaluation conducted to determine the condition of the product? If cost efficiency is the objective, then the returns supply chain should be designed to *centralize* the evaluation activity. On the other hand, if responsiveness is the goal, then a *decentralized* evaluation activity is needed to minimize time delays in processing returns.

Efficient Supply Chains: The Centralized Model

A schematic of a returns supply chain with centralized testing and evaluation of returns is shown in Figure 5. The returns supply chain is designed for economies of scale—both in processing and transport of product. Every returned product is sent to a central location for testing and evaluation to determine its condition and issue credit. No attempt is made to judge the condition or quality of the product at the retailer or reseller. To minimize shipping costs, product returns are usually shipped in bulk. Once the condition of the product has been determined, it is channeled to the appropriate area (or facility) for disposition: restocking, refurbishment or repair, parts salvaging, or scrap recycling. Repair and refurbishment facilities also tend to be centralized, often outsourced.

The supply chain is designed to minimize processing costs, often at the expense of long delays. Our research on reverse supply chains indicates that these delays can be excessive. Figure 6 shows the delay times for a typical product in ABC's product returns system.

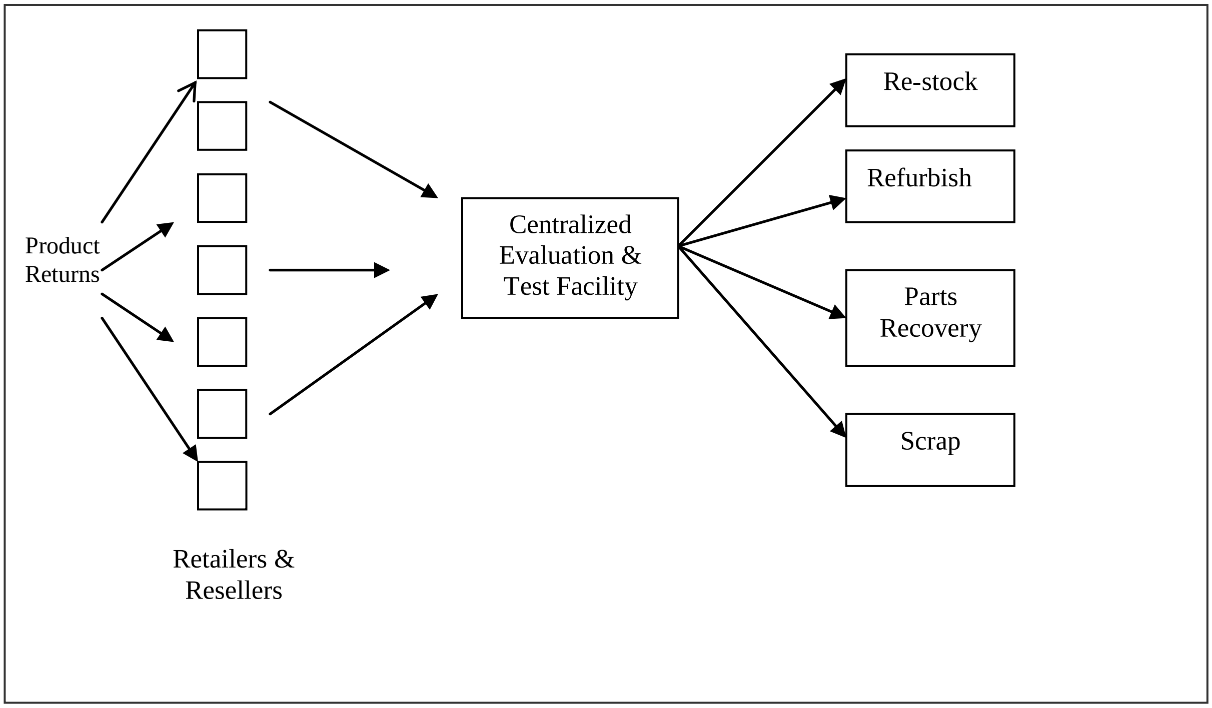

Figure 5: Centralized, Efficient Reverse Supply Chain

The centralized, efficient supply chain structure achieves processing economies by delaying credit issuance and testing, sorting and grading until it has been collected at a central location. This approach has been widely adopted by managers of reverse supply chains, perhaps because it embodies a fundamental design principle of forward supply chains: *postponement*. Postponement—or delayed product differentiation—has been used as an effective strategy for dealing with the cost of variety in forward supply chains[10] Manufacturing and stocking a basic product in generic form and delaying the addition of features, or options, until the product is closer to the customer has been used by firms such as ABC to avoid the cost of carrying separate inventories of all varieties of final product. The centralized, efficient supply chain structure is also easier from the perspectives of the third party provider offering credit issuances and the retailer who can send all the products back to a central location and do not have to sort returns and ship products to multiple locations. Figure 7 shows how early and delayed product differentiation work in a reverse supply chain for product returns; we fully discuss this in the next section.

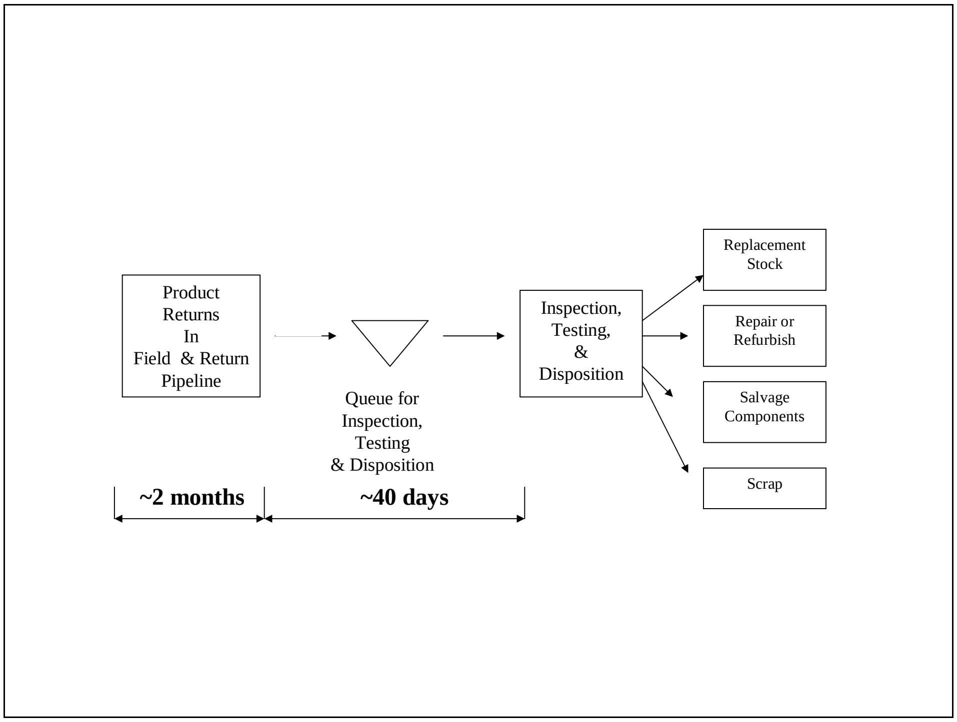

Figure 6 – Delays in the Disposition Process for a Product at ABC *

Postponement has less appeal as a strategy for reverse supply chains. With returns, product variety is already determined upon receipt, as is the condition of the product, even though it may not be observable without examination and testing. With a returned PC, for example, the same model may take different forms, each requiring a different action: some PCs are new "factory seals" in which the box has never been opened; some may have only operated a few times; some may need repair; some may only be salvageable for parts; and some can only be

* ABC has worked aggressively to significantly reduce these times.

scrapped (or recycled). The key return decision is to first evaluate the product to determine its condition in order to make a disposition decision. There is little to be gained from postponing product differentiation.

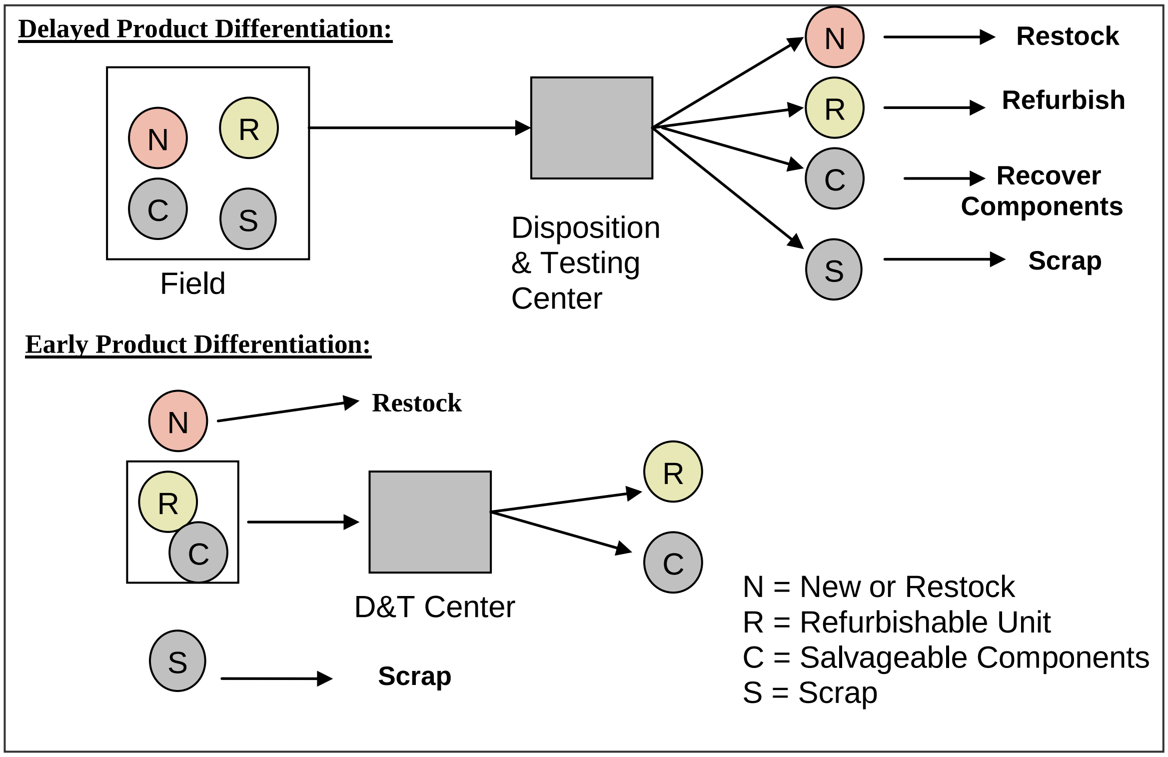

Figure 7: Early vs. Delayed Product Differentiation in Return Stream

Responsive Supply Chains: The Decentralized "Preponement" Model

In the reverse supply chain, there are significant time advantages to early, rather than late, process differentiation, and we call this design principle to accomplish early differentiation: *preponement*. Early diagnosis of product condition maximizes asset recovery by fast-tracking returns on to their ultimate disposition and minimizing the delay cost.

The reverse supply chain for PCs at ABC illustrates the advantages of a preponement strategy. Figure 7 illustrates two alternative reverse supply chain configurations for PC returns. To simplify the example, we focus on a single PC model in four possible return conditions—new, refurbishable, salvageable for components, or scrap. In appearance these PCs can look identical, and they must be tested and evaluated to determine their true condition. With delayed (or postponed) product differentiation, all PCs are shipped from retailers and resellers to a central facility for evaluation and then diverted to the appropriate processing center. Alternatively, if a field test is carried out to screen product into three categories— new, reparable, and scrap—then the new, unused product can be restocked *without delay*, scrap units can be filtered out and sent for recycling, and the remainder can be shipped to a central facility for further evaluation and repair.

To achieve preponement and make the reverse supply chain responsive, the testing and evaluation of product must be *decentralized*. The reverse supply chain for one such responsive supply chain in displayed in Figure 8. Instead of a single point of collection and evaluation, product is initially evaluated at multiple locations, when possible at the point of return from the customer.

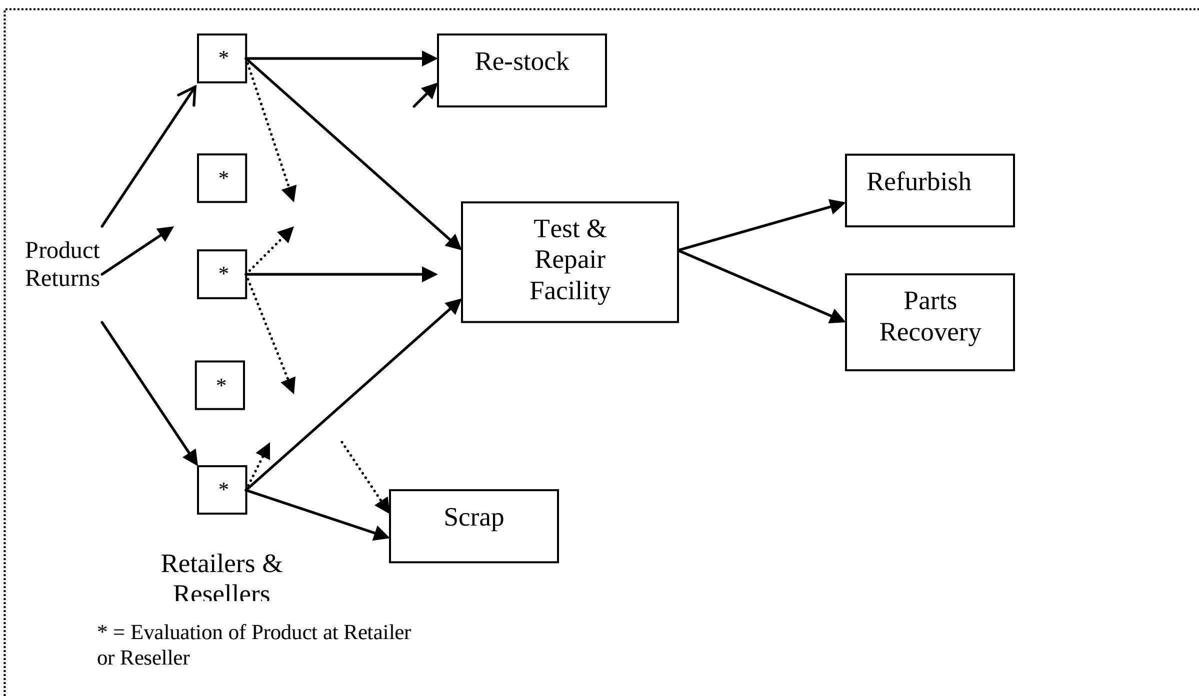

Figure 8: Decentralized Returns Supply chain with Preponement

Decentralizing the returns process with preponement improves asset recovery by reducing time delays in two important ways. First, it reduces the time delays for disposition of new and scrap products; new, unused products tend to have the highest marginal time value and the most to lose from delays in processing. Second, and not so obvious, preponement also tends to speed up the processing of the remaining products—the units that need further testing and repair. By diverting the extremes of product condition (new and scrap) from the main returns flow, the flow of product requiring further evaluation, perhaps by remanufacturing specialists, is reduced. Reducing congestion for the flow of repairable product reduces the time delays in queuing and further diagnosis, thereby reducing the asset loss for these items as well. Referring back to the example in Figure 2, observe that preponement to screen out new and scrap would reduce the flow of units needing further evaluation by about 35%, which would make diagnosis easier and faster.

For products with a high marginal value of time, preponement can dramatically increase asset recovery. In the case of ABC, reducing the losses in value of new product alone can be significant. If a returned product is unused, then sending it to a centralized test and evaluation facility could keep the product off the shelves for a month or more. During this time, the product could easily lose more than 5 % of its value. Preponement can eliminate much of the loss in that product segment, as well as reduce the return flow to only those units needing the attention of technicians.

There are two significant issues that must be addressed to achieve responsive, decentralized reverse supply chains. First is the question of technical feasibility; that is, being able to determine the condition of the product return in the field quickly and inexpensively[11]. Second is the question of how to induce the reseller to do these activities at the point of return. Incentive alignment via shared savings contracts may be the best way to induce cooperation and coordination between the manufacturer and resellers, but firms must first know the value of such activities. As an alternative, ABC could use a vendor-managed inventory (VMI) approach at large retailers. This would entail ABC using their own technicians, or a contractor, to do disposition at the resellers' sites or distribution centers.

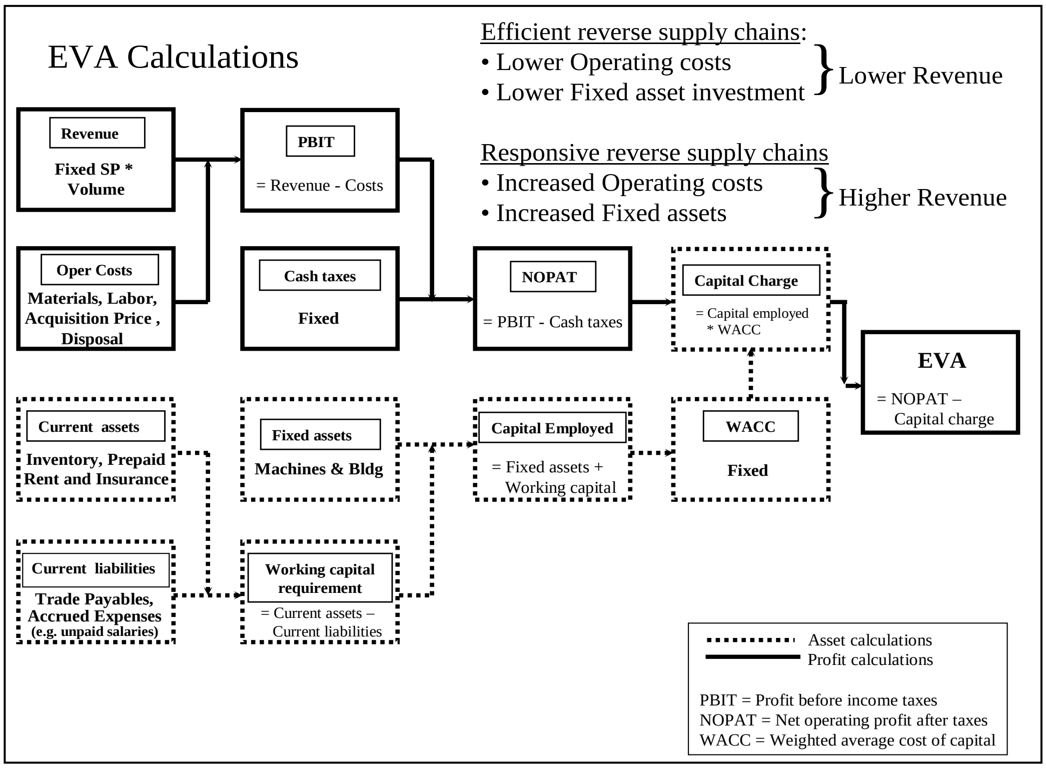

Figure 9: The Impact of Effective and Responsive Reverse Supply Chain Design on EVA

The Efficient-Responsive Tradeoff

To maximize the net value received from a reverse supply chain, the choice between efficient and responsive designs involves a tradeoff between the value of assets recovered and the cost of processing returns. The desired design maximizes the sum of product value recovered minus the processing cost. This may be best illustrated via an economic value added model

(EVA®*). EVA measures the difference between the return on a firm's capital and the cost of that capital[12]. In Figure 9, the efficient/effective tradeoff influences the different categories (revenue, costs, fixed and variable assets) differently. At one end of the scale, efficient chains minimize processing costs, but the accompanying time delays may reduce the value of assets recovered. This is accomplished by lowering operating costs via economies of scale at a centralized facility and the lower fixed asset expense of a single facility. However, the time to return a product to the market for an efficient reverse supply chain will be longer and this may reduce the selling price and, as a result, the revenue generated by the system. Managers will need to examine the final impact of the changes to determine whether an efficient system is the best one from an EVA perspective.

At the other extreme, responsive chains maximize recovery by reducing time delays usually at the expense of higher processing costs. The higher processing costs are a result of increases in the operating costs and fixed assets required when there are multiple facilities used. Since the time to return a product to market is significantly faster, the selling price and revenues are higher. Managers will again need to assess the net impact on the EVA. In either case (efficient or responsive), managers should act to maximize profits by examining the impact of decisions on total economic profit.

In a responsive chain, preponement typically increases processing cost due to the expense of performing diagnostics in the field near the point of return. It is often necessary to send out technicians or distribute test equipment, and in some cases to provide monetary incentives and training to retailers to enlist their cooperation. Processing costs are generally lower when the product is brought to a centralized facility than when the testing is moved out to the point of collection.

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This tradeoff between efficiency and responsiveness depends primarily on the marginal time value of the product. For PCs, printers and other products with high marginal values of time, preponement is a potent weapon for maximizing asset recovery. The reverse supply chain should be decentralized and responsive. For products with lower marginal values of time, such as power handtools, the tradeoff tips toward centralized processing for cost efficiency because the cost of field testing can easily exceed the benefits of reduced time delays.

Technology: Making Preponement More Efficient

Technology now included in some products can sharply reduce the cost of field evaluation to make preponement economically attractive even for products with low marginal costs of time. To be effective, the technology must provide a simple, inexpensive way to determine (1) if the product is new and has never been used; (2) if the product needs repair; (3) if the product has exceeded its useful life. In recent years manufacturers have begun to include such technology in their products, not for the purpose of preponement, but to facilitate problem diagnosis and repair. For example, automobiles have always had odometers, and many automobiles are now equipped with on-board computers that can provide a time profile of engine use and even early warning of potential problems.

Technology, designed and built in for early product differentiation, also exists now in simpler products such as printers and power tools. In power tools sold in Germany, Bosch has introduced a "data logger" into their products—an inexpensive chip is built-in to the electric motor of each tool to record the number of hours of use and the speed at which the tool has been operated[13]. By connecting a returned tool to a test machine Bosch (or a retailer) can quickly determine if the product is better used for remanufacturing or recycling (operated above a certain number of hours) and if the product has been run at high speed. The data logger makes preponement possible, quickly and inexpensively. Tools that have been run under extreme conditions can be identified and sent immediately to a recycling center; the remainder can be returned directly to dedicated remanufacturing facilities.

Some printers have similar usage technology to measure the total number of pages that have been printed. It is feasible, then, with a small investment to equip resellers or field collection centers with a handheld device (preliminary costs offered by a printer manufacturer are estimated to be between $250-$350 per handheld device) to determine if the product has never been used, lightly used, or heavily used. Given this information, the printer can be more effectively channeled to the desired processing facility, saving time, and boosting asset recovery.

Metering the usage of a product is one simple way that manufacturers can facilitate preponement. What next? As management grows more cognizant of the importance of the value in the return stream, increased emphasis should be placed on designing new products to facilitate returns processing; for example, building in software that enables more extensive diagnosis of product condition at the point of collection (or even before the product is returned by the customer). Including technology to facilitate preponement can reduce some of the cost of in-field diagnosis and give organizations the tools to be *both* responsive and efficient in their return supply chains.

Conclusions and Recommendations for managers

In our research we have observed a small, but growing, number of forward-looking companies that extract value from product returns. By their actions, these successful firms provide a template for managers in other firms. The principles that managers can follow to improve their asset recovery are summarized below.

Treat Returns as Perishable Assets

Fundamentally, managers in organizations such as ABC and Bosch take a different view of commercial returns: returns are viewed as perishable assets, not simply a waste stream. Recognizing the perishability of returns and their loss of value over time, they emphasize quickly extracting value from the returns flow rather than simply disposing of product.

Elevate the Priority of the Returns Process: Close the Loop on the Supply Chain

At most firms, returns flow below top management's radar screen. To change this, management must, by its stated objectives and actions, establish high priority for the returns process and make it a supply chain responsibility. In this way, returns become an integral part of the supply chain management process.

Make Time the Essential Performance Metric

Surprisingly, many firms do not track or record time metrics in their returns process; they are unaware of the magnitude of losses in product value simply due to time delays at different stages in the process. For example, only when ABC began recording time metrics did they realize that it was taking several months for returned products to reach the remanufacturing facility. Because returns are perishable assets, the percentage of asset value recovered is directly proportional to the speed of recovery and disposition of returned product.

Use time value to design the right reverse supply chain

Like forward supply chains, the reverse supply chain can be designed for cost efficiency or quick response, and the decision pivots on the product's time value. If the product has a low marginal value of time (that is, its value decays slowly), then the returns supply chain should be designed for cost efficiency. A centralized reverse supply chain is cost efficient because it brings economies of scale in transportation and returns evaluation.

If the product has a high marginal value of time, speed is critical, and a decentralized reverse supply chain is appropriate. Product is evaluated as close as possible to the returns point and moved rapidly, often in small quantities, to its ultimate disposition. Although the costs of operating the returns process increase with decentralization, these costs can easily be offset by the gains from speedier recovery of perishable assets.

Use Technology to Achieve Speed at Lower Cost

To reduce the cost of evaluating a returned product's condition, evaluation is often conducted at a centralized location, but centralization usually means longer delays. If the product evaluation can be simplified sufficiently to be carried out at the point of customer return, then the need for a centralized evaluation process is reduced, and a decentralized supply chain can become attractive even for a low time-value product.

Bosch provides an illustrative example. Bosch's products lose value at a rate considerably lower than ABC's, suggesting that the appropriate returns supply chain for Bosch would be centralized. However, technology built into the product made early product differentiation, or preponement, easy to carry out in the field, reducing the need for centralized evaluation.

To conclude, managers should give reverse supply chains as much attention as forward supply chains. Recognizing the significant value remaining in product returns and their time sensitivity are keys to designing their reverse supply chains. This is especially true for maturing markets such as consumer electronics, where there are declining margins. Poorly handled return streams and increasing returns volumes can quickly erode asset values significantly. At ABC, returns average 6% of outbound sales and many of their products erode quickly in value. For ABC and companies under similar circumstances it becomes a crucial issue to handle returns as well as forward sales.

Notes

[1] J. Stock, T. Speh and H. Shear, "Many Happy (product) Returns," *Harvard Business Review*, 80/7 (2002): 16-17.

[2] J. Blackburn, *Time Based Competition: The Next Battleground in American Manufacturing* (Homewood, IL: Business One Irwin, 1991).

[3] G. Souza, V. Daniel R. Guide Jr., L.N. Van Wassenhove and J. Blackburn, "Time Value of Commercial Product Returns," Working Paper 2003/48/TM INSEAD R&D Fontainebleau France.

[4] M. Fisher, "What is the Right Supply Chain for Your Product," *Harvard Business Review*, 75/2 (1997): 83-93.

[5] H. Lee and C.S. Tang, "Modeling the Costs and Benefits of Delayed Product Differentiation," Management Science, 43/1 (1997): 40-53.

[6] See V. Daniel R. Guide Jr. and L.N. Van Wassenhove, "The Reverse Supply Chain," *Harvard Business Review*, 80/2 (2002): 25-26. and V. Daniel R. Guide Jr. and L.N. Van Wassenhove "Business Aspects of Closed-Loop Supply Chains," in *Business Aspects of Closed-Loop Supply Chains,* edited by V. Daniel R. Guide, Jr. and L.N. Van Wassenhove, (Pittsburgh: Carnegie Mellon University Press, 2003).

[7] Some firms, including Robert Bosch Tools, treat all returned products as defective for several reasons. First and foremost, is brand name protection; companies are unwilling to risk damaging their reputation for quality. Second, from a legal standpoint a product that has been used must be clearly labeled as such.

[8] The information in this section is from our work with an international firm in the computer and computer peripherals industry. We have disguised the company name and use representative data provided by the firm. We would also like to recognize that ABC has been working over the last few years to build a more responsive returns supply chain and that the system we discuss in this article is undergoing significant changes.

[9] Fisher, op. cit.

[10] E. Feitzinger and H. Lee, "Mass Customization at HP: The Power of Postponement," *Harvard Business Review*, 75/1 (1997): 116-121.

[11] For a complete discussion on the problem and some possible solutions, see M. Klausner, W. Grim and C. Hendrickson, "Reuse of Electric Motors in Consumer Products: Design and Analysis of an Electronic Data Log," *Journal of Industrial Ecology* 2/2 (1998): 89-102 and M. Klausner, W. Grim, C. Hendrickson and A. Horvath, "Sensor-based Data Recording of Use Conditions for Product Takeback," *Proceedings of the 1998 IEEE International Symposium on Electronics and the Environment* (Piscataway, NJ: IEEE, 1998): 138-143.

[12] D. Young "Economic Value Added: A Primer for European Managers," *European Management Journal* 15/4 (1997): 335-343.

[13] Klausner et. al op. cit.