Thinking Outside 'the Box':
Designing a Packaging Take-Back System

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The electronics industry is characterized by highly optimized global supply chains, outsourced manufacturing, and critical time-to-market pressures. Despite these high-priority concerns, many firms and industry groups are finding time to manage the environmental impact of their products. Product-specific environmental improvements are difficult due to rapidly changing technology and production methods. Thus firms have been looking for ways to reduce the overall environmental burden of their products by looking at packaging, purchasing, facilities management, and their supplier networks. In this industry, transportation and packaging of electronic components and subassemblies is often accomplished in single-use packages via airfreight. Since packaging waste and the effects of transportation are amongst the most significant sources of the environmental burdens of electronics, there are big opportunities for improvements.

We worked with one of these companies, Quantum Corporation, a computer storage products company, to design and assess a new packaging system for their bulk hard disk drives shipped to Original Equipment Manufacturers (OEMs) worldwide. The system involved a packaging design with a smaller environmental footprint and, more significantly, collection and reuse of the used packaging from OEM sites worldwide. As of the year 2000, Quantum Corporation was the highest volume global supplier of hard disk drives (HDD) for personal computers, and sold a broad range of storage products to OEMs and distribution customers worldwide.[1]

As part of ongoing improvement processes by firms in the electronics industry, many questionnaires were sent between companies in the industry from the OEMs all the way down to component suppliers. The goal of these questionnaires was to help identify areas where environmental improvements

TABLE 1. Key Objectives and Associated Challenges of Packaging Reuse Program (PRP)

Objectives	Challenges
Reuse packaging worldwide with key customers and manufacturing partner	Coordination/approval of internal and external teams and stakeholders
Improve customer satisfaction by reducing waste burden	Showing value to customer in terms of overall system costs and environmental quality
Exhibit industry leadership in environmental management and prepare for compliance with international regulations	Communicating importance of these standards and regulations to internal and external groups
Demonstrate financial savings	Increased use of logistics will offset gains from packaging reduction, uncertainties in modeled versus actual system
Demonstrate local and global environmental benefits	Differences in grasp and appreciation of environmental issues

were possible. However, they also led to the identification of industry best practices in all functional areas.

Through such investigations, Quantum was able to learn that its customers were interested in—and its key competitors had plans to institute—internal supply chain packaging reuse programs as of mid-1999. The hard drive industry was showing signs of moving towards a commodity market, and thus any cost or marketing advantage had large potential benefits.[2] The internal stakeholders decided to pursue the design and implementation of a packaging reuse program between Quantum, its Asian manufacturing partner, and its OEM customers. However, many obstacles and barriers were identified that would need to be overcome to make this initiative a success. In addition, this initiative would need approval and oversight from nearly every business group in the organization. Thus the internal sales pitch would need to be compelling. Table 1 summarizes the key objectives and challenges.

The economic motivation behind this packaging reuse initiative was well founded. Approximately 95% of Quantum's HDD products were shipped in bulk packaging on pallets to OEM customers around the world (e.g., PC assembly lines in Singapore, Europe, and Japan). Because of the high volume of bulk shipments to a small number of globally distinct locations, and the near perfect condition of packaging components after shipment, there was an excellent opportunity to reduce Quantum's financial and environmental burden by redesigning the packaging and logistics system for take back and reuse. The paradigm of product take-back or reverse logistics is well founded.[3] It involves planning, managing, and optimizing both a delivery network of new product as well as a reverse stream of obsolete or unusable items.

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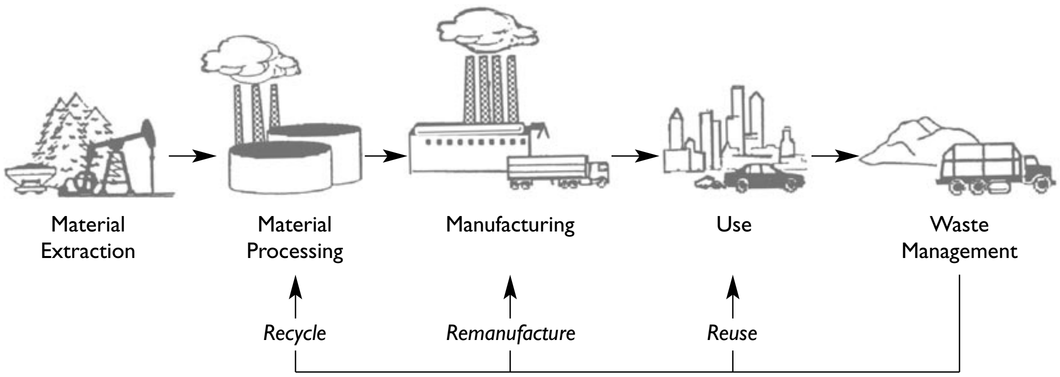
FIGURE 1. Typical Product Life Cycle



Source: U.S. Office of Technology Assessment, "Green Products by Design: Choices for a Cleaner Environment," OTA-E-541, 1992.

Companies involved in European operations had already begun to experiment with reverse logistics, but relatively few concentrated strictly on packaging take-back. These systems have demonstrated cost-effectiveness if designed appropriately.[4] However, Quantum sought to demonstrate social benefit of the program above and beyond the financial benefits, and it would also need to quantify estimated energy and environmental effects from the various packaging systems.

Life Cycle Assessment of Packaging Take-Back

Estimating the environmental effects across a large range of categories was a task outside the competency of the internal stakeholders. Quantum's Environmental Stewardship group needed to estimate and quantify the environmental aspects of the program to verify that the additional logistics costs (i.e., financial, air emissions from transportation) would be more than offset by reduced consumption of raw materials for packaging. The method chosen to consider these various issues was Life Cycle Assessment (LCA). LCA is used as a framework within the ISO 14001 environmental management standard for considering the various aspects of a product or process from the design process through raw materials extraction, materials processing, component manufacturing, final assembly, delivery, and disposition. Figure 1 shows an overview of a typical product life cycle.

To estimate and quantify the environmental gains from the reuse program, Quantum used a quick, no-cost method of Economic Input Output-Life Cycle Assessment (EIO-LCA) developed by Carnegie Mellon University's Green Design Institute (and available freely on the Internet at <www.eiolca.net/>). The EIO-LCA model traces out the various economic transactions, resource requirements, and environmental emissions required for a particular product or service using the United States 1997 input-output table.[5]

Our general analysis of the new packaging system follows that of a traditional investment problem, with up front costs and streams of yearly benefits and costs. For this project, the initial costs arise from the time and effort spent designing the new packaging system, testing it, and so on. The yearly costs are from increased logistics. The yearly benefits are from reduced packaging costs.

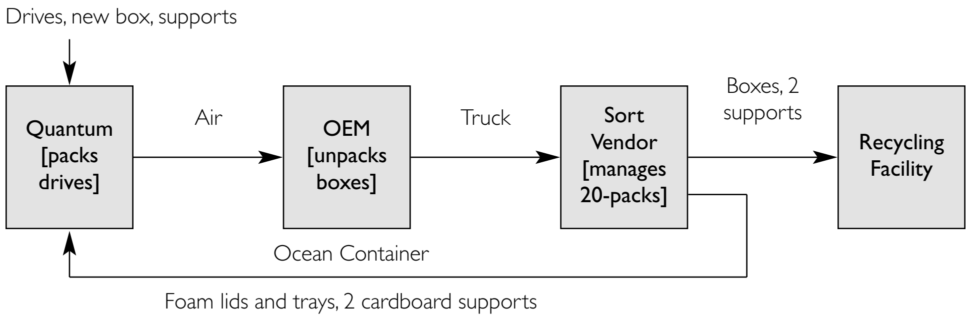
Details of the Packaging Systems

The OEM bulk-packaging container in use as of late 1999 consisted of 13 discrete parts, including a corrugated paperboard box and corner support pieces as well as polyurethane foam plastic for every 12 drives shipped. As noted above, safely getting products to customers was of primary importance, and these boxes were generally over-designed for a single shipment. The belief within the packaging engineering department (and inspiration for the project) was that they could have lasted many more times if allowing for reuse. Because packaging could potentially experience rough handling during shipment, the inner cushioning and outer corrugated box were specially designed to withstand specified shock and vibration requirements set by the company. Thus the packaging was extremely durable and generally arrived at customer facilities in pristine condition because the majority of boxes were shipped together on shrink-wrapped pallets. The logistics process in place included air transportation to the OEM, followed by on-site disposal or recycling of the packaging. These on-site costs were of course the responsibility of the customer. Thus, a reusable packaging system would potentially reduce overall costs from the customer's perspective.

The new packaging was envisioned to be able to hold 20 drives, and consist of only 1 corrugated paperboard box, 4 corrugated corner box supports (2 attached to the box), 1 expanded polypropylene (EPP) foam tray, and 1 EPP foam lid. Of these pieces, all would be taken back from the OEM, but only 2 of the 4 corrugated supports and the EPP trays and lids would be reused—the box and 2 of the supports would be recycled. As stated above, boxes would likely survive several reuses, but there were concerns that boxes showing significant discoloration or multiple shipping labels might be perceived as lower quality and lead to increased customer service issues. Thus each box shipped (as well as 2 of the 4 supports) would be from new cardboard stock.

Handling for reverse shipment from customers was done by a sort vendor. The logistics included air transportation to the OEM, handling by a local sort vendor to manage cardboard and plastic parts for reuse and recycling, and reverse logistics via ocean container and truck (not air freight). Figure 2 below presents a flow diagram of the proposed Packaging Reuse Program (PRP) bulk-packaging system logistics. The new reusable packaging design replaced the older and heavier polyurethane foam and corrugated paperboard with the new packaging (EPP and less corrugated cardboard material). While lighter than the old package, the weight of the drives shipped was the driving factor in freight cost,

FIGURE 2. Flow Diagram of Packaging



thus no savings were expected from the lighter box. Due to the design changes, less physical space was required per box, and shipping weights were reduced. As a result of the weight reduction, worker ergonomic performance was improved. Quantum also redesigned this bulk packaging to take advantage of increased pallet and box density.

The new design reduced the number of discrete packaging components from 13 to 5, and in-house testing indicated that the reusable packaging components could easily withstand 10 uses. This in-house testing involved subjecting boxes loaded with product to a severe battery of shipping and handling tests that were designed to simulate 10 trips in a rough and uncertain shipping environment. The degree of the test was well beyond Quantum's and the HDD industry's stringent requirements, yet the packaging and product were still intact.

Next, Quantum sought bids from third parties to handle the reverse logistics, sorting, and delivery of the packaging material. While there were several companies qualified to perform these tasks, ultimately it was most efficient to use the new packaging provider for several reasons, not the least of which was integration with new packaging deliveries and consistency in packaging quality between used and new packaging. Reaching a bid price (on a per-box, per-region basis) was an iterative project between the vendor and the packaging, legal, purchasing, and accounts management departments. Many departments had to be involved because distribution and return of product is complicated and quantities (and locations) would constantly fluctuate. A wide range of scenarios had to be considered in the bidding on both sides to ensure that capacity and price constraints were not expected. Quantum developed criteria for qualifying OEM locations to be targeted for collection of used material based on location and volume, with the goal of pursuing the sites with fastest payback periods first.

To receive approval from upper management for PRP, Quantum developed a cost model to justify that the estimate of increased costs for transportation, sorting and quality control, and customer management would be offset by the reduction in cost for new packaging. Additionally, Quantum approved the

TABLE 2. Steady-State Cost Comparisons of Old and New Packaging Systems

"Old" Packaging System		PRP System	
1 cardboard box	$3.46	1 box	$3.46
4 cardboard supports	$2.39	2 new, 2 reused supports	$1.31
1 foam insert	$8.54	1 reused foam insert	$0.85
1 lid	$5.15	1 reused lid	$0.52
Subtotal	**$19.54**	**Subtotal**	**$6.14**
Shipping (air)	$62.82	Shipping (air)	$62.82
		Return ship	$5.47
		Sort cost	$4.71
		Return truck	$2.36
		Warehouse storage	$0.63
Total	**$82.36**	**Total**	**$82.12**
Total (per drive)	**$6.86**	**Total (per drive)**	**$4.11**

Note: All costs assumed for filling one shipping package with drives. PRP costs are at "steady state unit cost" reflecting some components as reused 10 times.

program on its customer service merits (customer satisfaction in waste reduction and, for some, helping OEMs meet ISO 14001 environmental targets) and environmental benefits.

Estimating Economic Efficiency of PRP

Since the cost of the basic material components for new boxes were not significantly different, no consideration was given to the cost difference of the old package and the new (reusable) system. The primary cost comparison instead was made between using the new packaging once (as an analogue to the old system) and reusing the same packaging multiple times. Table 2 shows estimates of the cost category items for these comparative models given packaging re-uses and associated reverse logistics.[6] This example is for the "worst case" reverse logistics scenario—i.e., the case with the longest return shipping distance, handling costs, and so on. Other sites would have smaller distances and costs and thus would be even more economically attractive.

With the components described above, the materials cost of a completely new 20-drive package was approximately $20. Delivery via airfreight was about $60. The take-back costs (including water transport, sort vendor, trucking, and warehousing) were approximately $13 per package. At these costs, and with the specified packaging components to be reused, the breakeven for the PRP system was estimated as 6 uses on a per-drive cost basis, assuming the old packaging could support 20 drives. This would be achievable since the packaging was tested

TABLE 3. Summary of Costs between Old and New Packaging Systems

Cost of Shipping 2.5 Million 12-packs		Cost of Shipping 1.5 Million 20-packs	
2.5 million boxes	$8,637,750	1.5 million boxes	$5,182,650
10 million supports	$5,967,900	New and reused supports	$2,088,765
2.5 million inserts	$21,358,800	Reused inserts	$2,135,880
2.5 million lids	$12,878,100	Reused lids	$1,287,810
Total Packaging	**$48,842,550**	**Total Packaging**	**$10,695,105**
Air transport	$157,050,000	Air transport	$94,230,000
		Return sea shipping	$8,198,010
		Sort vendor	$7,067,250
		Trucking	$3,533,625
		Storage	$942,300
Total All	**$205,892,550**	**Total All**	**$124,666,290**
Total Cardboard	**$14,605,650**	**Total Cardboard**	**$7,271,415**
Total Foam Plastic	**$34,236,900**	**Total Foam Plastic**	**$3,423,690**

for at least 10 uses. When considering the difference of 12 and 20 drives between the two systems, and 10 reuses, the cost would be 40% lower overall on a per-drive basis.

Given roughly 30 million drives shipped per year to OEMs in 1999, roughly 1.5 million 20-drive packages would be sent. Packaging costs in a single-use system would be about $29 million or about $10 million with 6 uses. Table 3 shows that as compared with the old packaging system, PRP would cost 40% less, with 80% less packaging material cost and 25% less logistics/handling. Assuming these cost savings could be achieved, the financial implications were compelling, especially in a time when the industry had razor-thin profit margins. Overall, costs were increased for ground transportation, warehousing, labor, and management. Costs were reduced for air transportation, waste disposal, and material. In the long term, the labor and management costs would become negligible.

Implementation Issues

PRP was developed and implemented primarily by Quantum's Package Engineering Department; however, many other functional groups within Quantum were involved in the design, negotiation, and rollout of the program. The Environmental Stewardship group was responsible for assessing the environmental impacts of the program, including the effects from waste reduction and increased logistics. Transportation was involved in specifying the types and methods of delivery currently used and available in delivering product and taking back the boxes. Customer Service was involved in developing metrics for how the OEMs responded to the program. Account Management helped to identify which OEMs might be most receptive. As the program moved from development to implementation, Sales/Marketing was included as a critical component for gaining customer approval and in developing and presenting materials that could be shared with OEMs to increase sales volumes, with the environmental and financial aspects as a value-added part of doing business with the company.

Implementation of the program required two steps. PRP was proposed to customers as having mutual cost savings over the existing packaging system (as OEMs would incur less on-site waste handling costs). While the environmental goal was accepted by customers, test data had to be shared (and in some cases, repeated cooperatively) to convince them of the feasibility of the plan. The apparent caution of the OEMs was well founded. Drives damaged from packaging loss would be replaced; however, the spillover potential of a defective shipment was a shutdown of the assembly line due to the just-in-time inventory method practiced by most firms.

Quantum received approval from all major customers to receive reusable packaging, although final implementation with each required several months longer than expected. This was largely due to the critical importance of packaging performance for HDD products and the additional time required by customers to evaluate the test data and approve the program. In one case, a customer conducted their own durability testing, which subjected the bulk-packaging system to experiences far beyond the expected shipping environment. The packaging passed even this more rigorous testing.

The second step was to initiate the collection of used boxes in one area to test assumptions about logistics, warehousing issues, customer implementation rates, and quality sorting of the boxes. Because customers had to allocate some small storage space to separate packaging from other waste, ramp-up of collection sites was slower than expected. The slower ramp-up schedule increased management costs of the program. Regardless, the program accelerated from 20% of all shipments using reusable packaging to 80% in less than one and a half years. PRP target sites were generally done serially rather than in parallel, to better track potential problems and to ensure they were solved before moving on to the next site. This strategy left lower-volume, low-payback sites until the end of the program rollout. This overall implementation time could have been reduced by grouping OEM sites with similar challenges together.

As mentioned above, cardboard boxes were not initially slated for reuse because inventory and shipment data were printed or glued onto the outer box and could not be efficiently removed for the next shipment. Multiple sets of shipping information on a box could lead to misdelivery and timing problems. Additionally, the pristine appearance of the outer box was deemed critical for customer confidence in product quality. It is hoped that, as packaging reuse programs proliferate, this aesthetic expectation of perfect appearance can be managed with education and experience to allow for reuse of outer cartons as well. If cardboard boxes could also be reused, approximately $5 million more per year could be saved on packaging costs (but reverse logistics and sorting costs would again increase).

Overall, customers were pleased that their waste loads to landfills or incinerators decreased. The program was expanded to include collection at additional sites in Europe, Asia, and North America. As such programs mature and the market for third-party reverse logistics continues to develop, it is assumed that the threshold criteria for entry into a collection system will lower to allow increased participation.

Estimating Environmental Efficiency

While the PRP initiative sought financial benefits, the other primary motivation for implementing the system was to reduce excess packaging waste in the logistics system. As mentioned above, this packaging waste was a cost driver for the OEM customers, not Quantum. By taking back packaging through the sort vendor, Quantum was increasing logistics costs (and associated energy/environmental effects). As noted, to analyze this tradeoff Quantum used the EIO-LCA model developed by the Green Design Institute at Carnegie Mellon University. EIO-LCA is an implementation of a Leontief economic input-output (I-O) model.

Leontief developed input-output models to relate the production of goods and services in an economy to the production outputs of the other sectors (as well as the provision of labor and other inputs).[7] The most basic of these I-O models describes an economy only by inter-sectoral transactions. The input-output framework shows the total supply chain effects of producing all goods and services in an economy. We can, however, separate these effects between the "direct" economic effects—e.g., the effects from production of the final goods (such as a computer assembly line)—and the "indirect" effects—the effects related to producing all goods and services needed to produce the final demand (i.e., the supply chain of computer components). In all, we call the sum of the direct and indirect effects the "total" economic supply chain effect of production. When we consider the environmental effects of this production, it is common that the indirect effects are larger than the direct effects. This concept is crucial to the creation of a framework for analyzing relative environmental effects of production.

As noted above, EIO-LCA estimates all of the various supply chain manufacturing, transportation, mining, and related requirements to produce a product or service. The tool returns all resource requirements and environmental emissions across the supply chain. For example, the user may wish to trace out the implications of using $3,000 of water transportation or $10,000 of air transportation to deliver a product to a customer. The model would include not only impacts of using the transport vehicles, but also of producing them, their components, and the fuel to needed to use them. The model is based upon the U.S. Department of Commerce's 500 x 500 input-output model of the U.S. economy. The EIO-LCA model currently uses the 1997 input-output model of the U.S.

Economy.[8] This data is in the form of a 500-sector model. This model is augmented with a variety of environmental impact data on emissions of conventional pollutants, greenhouse gases, and toxic releases from each of the 500 sectors.

EIO-LCA data are developed from a variety of public data sets and assembled for the economy's 500 sectors. For the most part, the data are self-reported and are subject to measurement error and reporting requirement gaps. For example, very small businesses, like automotive repair shops, do not have to report emissions.

One of the big advantages of the EIO-LCA method compared to other LCA tools is the inclusion of supply chain effects in the results. Most alternatives can only consider (at most) the "first round" effects of producing a product, e.g., the major components used in building a hard drive or the electricity needed to run the assembly line. They do not have the capacity to consider the higher-order effects in the supply chain, e.g., the metals, silicon chips, and wires used inside the drive. EIO-LCA thus presents a more realistic picture of the economic and environmental effects resulting from product design. The large share of results comes at a price—input-output models are inherently aggregate, and even the 500-sector model used here will distort the effects of producing particular products since the results calculated are for the average product in a sector. For example, production of a large class of paperboard products is included in a single sector—the effects of producing corrugated cardboard may be more or less than the "average" production in the sector. Similarly, there could be significant differences in producing polyurethane or EPP plastics, which cannot be distinguished in EIO-LCA.

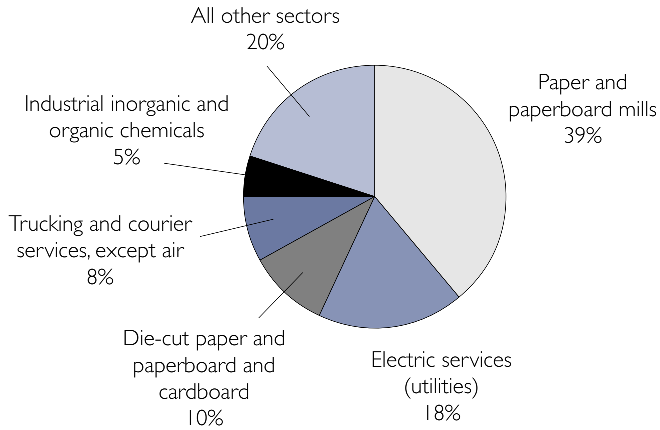
A visualization of sample output from EIO-LCA is presented in Figure 3 below. This summarizes the supply-chain-wide energy use from producing cardboard in the United States. EIO-LCA estimates the supply chain purchases from all 500 sectors, but details are shown for only the top five inputs of cardboard production in Figure 3. Note that the top 5 sectors (paper mills, electricity generation, die-cut paper, trucking, and chemicals) consume 80% of the energy in the supply chain of cardboard.

Via a similar estimation procedure, the implications of transportation were also completed. One interesting and relevant discovery during this process was that, of all activities within the firm, transportation—rather than manufacturing—was the primary contributor to carbon dioxide emissions. This further motivated the need to look at the net environmental benefits of PRP.

The EIO-LCA model was used to estimate the differential impacts associated with the reduction in paperboard and plastic material demand against the increase in demand for logistics and transportation between worldwide sites. We analyze a particular take-back instance—the "worst case scenario" between a central shipping facility and the most remote global location for a single use of the PRP package versus 10 uses.

Inputs into EIO-LCA included the relative total packaging costs of plastic and paperboard parts, delivery, and the reverse logistics steps of water

FIGURE 3. Supply Chain Energy Use of Cardboard



Note: Total energy use is 13.3 Terajoules.

Source: EIO-LCA, 2003.

transportation, warehousing, and trucking. Table 2 summarizes the inputs that were used in EIO-LCA analysis. For each cost (e.g., cardboard), the appropriate economic sector (e.g., paperboard container manufacturing) in EIO-LCA was identified and used.

EIO-LCA estimated that the 40% reduction in cost of raw materials from reduced cardboard and plastic when considered against the overall increase in logistics resulted in 57% reduced electricity, 39% less overall energy use, and 42% less carbon dioxide (as summarized in Table 4). Recall that the above example was the "worst case" reverse logistics scenario amongst the various customer sites affected. Other sites had smaller shipping distances, which reduce the impacts of the transportation and logistics, showing further cost, energy, and environmental benefits.

As noted earlier, the PRP was an overall cost savings to the corporation. Across all bulk shipments to customers around the globe, per-drive packaging costs reduced by 80% (including logistics). While outside the scope of this study, customer site packaging waste management costs were also significantly reduced.

TABLE 4. Environmental Improvements Achieved with New Packaging Systems

Category	Net Change	Percent Change
Electricity	–12 million kilowatt-hr	–57%
Energy	–541 Terajoule	–39%
SO_2	–50 metric tons	–38%
CO	–130 metric tons	–35%
NO_2	–50 metric tons	–27%
VOC	–40 metric tons	–39%
PM10	–20 metric tons	–40%
CO_2	–40,000 metric tons	–42%

Potential for Electronics Industry

Electronic products are incredibly complex, with average products having 100-1000 components. In general, each of these components is manufactured by one supplier and sent to another higher up the supply chain. The amount of bulk packaging used to transport components through the supply chain varies considerably. A 1995 study done by member companies of the American Electronics Association suggested that nearly 40% of all operational waste came from packaging (both initiated and received).[9] Thus reverse logistics methods, if fully integrated in the supply chain, could lead to significant cost and environmental savings. Using EIO-LCA, it can be seen that for the total amount of output in the electronic computers sector for 1997 ($60.5 billion), there would be approximately $250 million in cardboard purchases across the supply chain. The vast majority of this amount (70%) is indirect—i.e., it is the packaging used in the supply chain before it is used in the final product. Assuming an average price of $50 per ton, this would amount to 5 million tons (10 billion pounds) of cardboard packaging per year used in the industry. Thus practices like this that reduced packaging use by 40% could save $150 million across the supply chain and save 2 million tons (4 billion pounds) of cardboard production (and its energy/environmental effects).

Aside from supply chain effects, electronic products are pervasive in the retail sector, and packaging use is significant. This has become more important as products have become very small, and as packaging has remained relatively large to prevent retail theft (e.g., printer cartridges). While taking back packaging from end-use customers is not an ideal solution, there are still opportunities for packaging take-back from retail outlets.

The economic and environmental benefits here can potentially be gained by industry in general. If cardboard is taken as an indicator of packaging use, the total amount of cardboard packaging produced in the U.S. is approximately $40 billion per year (or 800 million tons at $50 per ton). There is growing movement around the world to reduce the amount of waste from packaging of products and intermediate goods. While pure reductions in package size are optimal, packaging reuse via reverse logistics is an effective strategy as well.

A Manager's Pocket Guide to Take-Back System Design

Implementing a reverse logistics system is not for the faint of heart. However, it is a process that has been done in many different types of businesses around the world and there is a fair amount of expertise available. The project described above involved an internal effort across a large, global organization by approximately 20 people. There were 10 people external to the firm involved as well.

As mentioned above, the project was inspired by the anecdotal evidence of packaging being durable beyond single use, as well as information gathered through supply chain management suggesting that it would be well received. In the electronics industry, where changes are always fast, implementing a reuse program is not considered overly disruptive. In other industries, it could be viewed as highly disruptive. Regardless, there are certain steps that can be used to help get a packaging reuse project off the ground at any company.

The first step is to get a preliminary indication about how important packaging waste is within the firm and its primary customers. If it is not viewed as significant, the time spent in designing a new system may not be seen as contributing significant benefit.

The next step is to broadly consider how to both redesign the packaging as well as the logistics system. Quantum not only made reusable packaging, but they increased the product density by more than 50% in the boxes being shipped. This is important because it allowed the number of containers being shipped to decrease. Since more handling will be done after use, limiting the number of containers will help to lower costs. If container density cannot be increased, it will be more difficult (although not impossible) to show cost-effectiveness. A first cut must then be made through a net present value (NPV) analysis that considers industry-average shipping costs for transportation modes, as well as any per-product-unit benefits from increasing the container density.

The next step is to start contacting internal and external stakeholders to discuss the business implications of such a system. By lining up internal support behind the program (hopefully on both economic and environmental grounds), a stronger and broader business case can be developed and presented to management. The cross-functional unit pitch is likely to be more compelling. It will also likely have identified areas of concern and cost that may not be appreciated if only initiated by the packaging group. An estimate of how much internal staff time will be devoted to the project can be included as an initial cost. The primary efforts will be in the packaging group, followed by the bid and accounts department.

Once internal stakeholders are in agreement on a system, the next step is to determine which customers would be most receptive to such a system. The company's environmental management may have leads on who they are. The sales team might also have received feedback or inquiries during the last bid process. It is important to talk to these customers to see if they have any additional expectations. For example, they might need to allocate temporary storage space to the packaging that will not be reused. However, they can then be shown that their waste disposal costs will be reduced by more than the cost of the space. Customers may even suggest better ways of designing the system—such as for reuse of even the external containers (e.g., boxes).

The next step is to sketch out the details of the system, starting with the generic case but giving consideration to any regional geographic issues. For example, the Quantum project primarily used ocean transportation for the return of packaging, since air transit would not have been cost-effective. The bidding process will involve a generic bid for services as well as geographically specific or per-mile-shipped bids to help cost out the various logistics sites around the world that will participate. At this point, the NPV analysis is ready to take to senior management for approval to sign the contracts.

Once senior management is on board, the next step is to implement the system. Rollout time expectations need to be extremely generous. While everyone on both sides may sound ready to go, there will inevitably be hitches—from delays in getting the quantities of new packaging up to steady-state levels to customers not being ready to receive it yet. Staying in touch with customers to keep them in the loop is critical.

Companies should not try to do the whole rollout at once. There are many ways to decide the ordering of customers to target first, including experimenting with a lower-volume customer before rolling it out to the largest supplier. Identifying the problems in the field will make all subsequent rollouts less painful. Most important is that the company should not be afraid to pause to solve problems. Keeping to a rollout schedule simply for its own sake can be dangerous. Even minor disruptions due to defective packaging (or even the perception of it being sub-par) could have serious business implications when these customers decide to renew purchases or contracts.

Summary

Quantum's hard disk drive bulk-packaging reuse program was developed to reduce the volume of raw materials consumed in shipping product worldwide to OEM customers. Achieving the goals of the project required significant coordination of internal departmental teams as well as with external OEM customers. Despite these challenges, the project was able to achieve cost savings for both Quantum and its customers. The PRP system reduced the number of discrete packaging components from 13 to 5. In addition, various environmental effects such as packaging waste and emissions from logistics were significantly reduced as a result of the program. The EIO-LCA model estimated 40% reduced supply chain energy use and a 40% reduction in greenhouse gases. Thus, the system succeeded in trading off increased logistics costs against reduction of packaging use. In general, actual cost savings from such a system may take several years to be realized, due to slower than expected project acceptance and higher transportation and warehousing costs.

Notes

1. Quantum's hard disk drive business was sold to Maxtor Corporation in 2001.
2. This movement towards a highly competitive, lower profit margin business began in the late 1990s and continues today. There was a fair amount of market consolidation (including the sale of Quantum to Maxtor) as well as the privatization of another key manufacturer, Seagate.
3. See J.R. Stock, "Reverse Logistics," Council of Logistics Management, Oak Brook, IL, 1992.
4. As one example, see Markus Klausner and Chris T. Hendrickson, "Reverse-Logistics Strategy for Product Take-Back," *Interfaces*, 30/3 (May/June 2000): 156-165.
5. For more information on EIO-LCA, see C.T. Hendrickson, A. Horvath, S. Joshi, and L.B. Lave, "Economic Input-Output Models for Environmental Life Cycle Assessment," *Environmental Science & Technology*, 32/7 (April 1998) pp. 184A-191A; A. Horvath, C.T. Hendrickson,

L. Lave, F.C. McMichael, and T. Wu, "Toxic Emissions Indices for Green Design and Inventory," *Environmental Science & Technology*, 29/2 (February 1995): 86-90; L.B. Lave, E. Cobas, C.T. Hendrickson, and F. McMichael, "Using Input-Output Analysis to Estimate Economy-Wide Discharges," *Environmental Science & Technology*, 29/9 (September 1995): 420A-426A. For more details on I-O, see R. Miller and P. Blair, *Input-Output Analysis* (Englewood Cliffs, NJ Prentice-Hall, 1985), Chapter 7.

6. Note that actual costs have been disguised due to non-disclosure requirements and proprietary data concerns.
7. For information on input-output models and the application of environmental impacts, see W. Leontief, "Quantitative Input-Output Relations in the Economic System of the United States," *Review of Economics and Statistics*, 18/3 (August 1936): 105-25; W. Leontief, "Environmental Repercussions and the Economic Structure: An Input-Output Approach," *Review of Economics and Statistics*, 52/3 (August 1970).
8. Input-output data available from Peter D. Kuhbach and Mark A. Planting, "Annual Input-Output Accounts of the U.S. Economy, 1997," *Survey of Current Business* (January 2001), pp. 9-43.
9. Clean Washington Center, "Waste Characterization Profile of the Electronics Industry," <www.cwc.gov/>, 1995.