ELDA and EVCA: Tools for Building Product End-of-Life Strategy

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ABSTRACT

Classification of end-of-life strategies early in design leads to improved eco-efficient product and processes. This paper describes the development of an internet-based tool, End-of-Life Design Advisor (ELDA), that guides product developers to specify appropriate end-of-life strategies. The results identify suitable product end-of-life strategies early in the design cycle of a broad range of products. This paper also describes the application of Environmental Value Chain Analysis (EVCA) to product end-of-life systems. The analysis examines the information, money and product flows between the players. The players of concern are the producers, government, consumers and recyclers. By analyzing the value chains of existing product end-of-life systems, valuable lessons can be learned how to improve take-back and recycling systems. ELDA and EVCA, in combination, identify the appropriate end-of-life strategy, examine the existing end-of-life system and provide roadmaps for future work. Knowing the possible end-of-life strategy is necessary to work effectively on the product design. The value chains of the end-of-life systems must be structured to provide incentives for participation and innovation.

KEY WORDS:

End-of-life, take back systems, product end-of-life strategy, ecodesign

1 INTRODUCTION

Improving product environmental impact at all life cycles is an important topic for manufacturers of electronic and electrical products. The end-of-life is one stage of the life cycle stages gaining attention in the market. Companies must understand how to improve their products so that the environmental impact will be lower at the end-of-life, while still being economically feasible.

The end-of-life stage of the product life cycle has two challenges – technical and non-technical. The technical challenges include items such as type of products received in the end-of-life collection, treatment procedure, and product characteristics. The non-technical challenges include concerns about the consumer relationship at end-of-life, making the end-of-life treatment system economically feasible, developing business goals and metrics to quantify the success of the program, and appropriately organizing the value chain.

New product end-of-life systems should aim to be transparent, reap the maximum end-of-life value and resources and provide incentives to improve design further. Increasing transparency of interactions can enhance performance through better designs and better organization reducing confusion and complexity. As will be shown in this paper, current product end-of-life systems sometimes have vague goals, weak lines of communication, and little room for improving the system in the future. In some cases, there are redundant mechanisms for collecting products, leading to confusion from consumers and increasing end-of-life costs unnecessarily.

All these challenges must be addressed to have an end-of-life treatment system that maximizes environmental gain while minimizing cost. Previous approaches have focused excessively on technical items that the company can control, overlooking wider ranging non-technical items. Some end-of-life treatment systems are starting to shift attention towards business aspect, as the planners run into challenges in non-technical areas. In others, opportunities and impossibilities, set by product characteristics and technology, have not been taken sufficiently into account.

Using both the End-of-Life Design Advisor and Environmental Value Chain helps companies support these needs. Stanford University's End-of-Life Design Advisor uses technical product characteristics to determine the appropriate end-of-life strategy. The Environmental Value Chain Analysis, developed in conjunction with Delft University of Technology, addresses the non-technical aspects to end-of-life product management.

The paper describes the development of the End-of-Life Design Advisor and Environmental Value Chain Analysis. Section 2 provides the background to the two methods. Section 3 is devoted to the development and application of ELDA. Section 4 presents results of the application of EVCA to existing product end-of-life systems. Section 5 demonstrates the link between ELDA and EVCA. Section 6 describes the implications to product designers, recyclers and policy makers. Section 7 summarizes the major findings and conclusions of this paper.

2 BACKGROUND

Previous work in ecodesign focused on detailed design phase and is therefore relying on engineers and designers to solve all challenges associated with environmental product design. Stanford University's End-of-Life Design Advisor (ELDA), available on the website http://dfe.stanford.edu, focuses on the designer perspective, but seeks primarily to recommend the best end-of-life strategy for the product, allowing for improved product design tailored for the end-of-life strategy. Since 1997, ELDA has been under development to determine product end-of-life strategies early in design as well as provide technical basis for decisions made by product planners and end-of-life treatment technology developers and communicate with third parties (e.g. authorities, NGOs) [1, 2]. There appears to be a strong link between the product's technical characteristics and the appropriate end-of-life strategy. Where some of the previous tools concentrate on certain product sectors, ELDA has proven successful for a wide variety of products and focuses solely on the early stages of design where it is possible to have the greatest impact.

In developing ELDA, it was realized that some companies were making different strategy decisions regarding the end-of-life strategy although the technical characteristics of the product were the same. The difference in corporate strategy pointed towards issues can not be addressed through technical solutions. These differences are exacerbated by differences in economies of scale, end-of-life treatment systems and disassembly processes. In some cases, the internal organization and the mindset of the company inhibited the end-of-life strategy attainable. Such an example is a company traditionally producing new products with little experience in remanufacturing the product although the opportunity exists but are still not interested.

Environmental Value Chain Analysis addresses these non-technical issues and is based on the concepts of Customer Value Chain Analysis and Supply Chain Management. Customer Value Chain Analysis seeks to identify pertinent customer and other stakeholders' interests, their value perceptions and the relationship between these parties in green product or process development projects [3]. Environmental Value Chain Analysis (EVCA) illustrates the value relationships between the groups implementing environmental improvement programs [4].

3 END-OF-LIFE DESIGN ADVISOR (ELDA)

3.1 Definition of End-of-Life Strategies

Before discussing the ELDA method, some background is given to the end-of-life strategies and the hierarchy chosen in the recommendations of ELDA. The definition of end-of-life used throughout this work is the point in time when the product no longer satisfies the initial purchaser or first owner. The end-of-life strategy hierarchy, given in Table 1, is based on decreasing environmental impact as calculated using LCA data from Philips Consumer Electronics [5].

Table 1. Hierarchy of End-of-Life Strategies

End-of-Life Strategy	**Definition**
Reuse	Reuse is the second hand trading of product for use as originally designed.
Service	Servicing the product is another way of extending the life of a durable product or component parts by repairing or rebuilding the product using service parts at the location where the product is being used.
Remanufacture	Remanufacturing is a process in which reasonably large quantities of similar products are brought into a central facility and disassembled. Parts from a specific product are not kept with the product but instead they are collected by part type, cleaned,

	inspected for possible repair and reuse. Remanufactured products are then reassembled on an assembly line using those recovered parts and new parts where necessary.
Recycling with disassembly	Recycling reclaims material streams useful for application in products. Disassembly into material fractions increases the value of the materials recycled by removing material contaminants, hazardous materials, or high value components. The components are separated mostly by manual disassembly methods.
Recycling without disassembly	The purpose of shredding is to reduce material size to facilitate sorting. The shredded material is separated using methods based on magnetic, density or other properties of the materials.
Disposal	This end-of-life strategy is to landfill or incinerate the product with or without energy recovery

3.2 Product characteristics

Through the collection of extensive case studies on product end-of-life strategies, the following technical product characteristics have been identified as influencing most strongly the end-of-life strategy [6]. These final product characteristics are used because they provide general information, describe the physical properties, technology changes and design changes of the product. These product characteristics are generic and definable over a wide range of products, from cell phones to aircraft engines.

Table 2. Technical Product Characteristics

Product Characteristics	**Input Ranges**
Wear-out life	0-20 years
Technology cycle	0-10 years
Level of integration	High, medium, low
Number of parts	0-1000
Design cycle	0-7 years
Reason for redesign	Original, Minor / major and function / aesthetic

3.3 Differences Observed

The resulting classification, using the technical product characteristics, was validated using the existing industry practice. The procedure for collecting the current end-of-life strategies practiced in industry included observing and questioning recycling organizations, producers and consumers. As well, the legislation requiring particular end-of-life treatment and internet sales were monitored to have a better view of the end-of-life treatment situation. Literature describing end-of-life treatment was also very helpful in collecting the end-of-life strategy data.

In the present paper, the current industry average is defined as the end-of-life treatment of the product most often found in industry. The current industry best practice is the end-of-life treatment for the product that has highest ranking on the hierarchy of end-of-life strategies, according to the hierarchy given in Table 1. The following picture shows the different end-of-life strategies with the ELDA classification, current best practice and current average practice. ELDA classifies twenty products to be remanufactured. Currently, sixteen products have remanufacturing as industry best practice. Seven products experience remanufacturing, as average practice. There are eight products, out of the thirty-seven products examined, that have disposal either incineration or landfill as the end-of-life strategy as average practice. ELDA does not recommend disposal as an end-of-life strategy for electronic products.

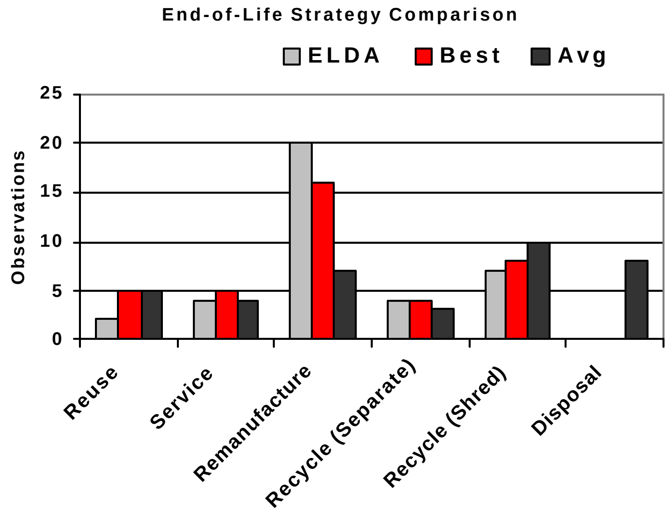

Figure 1. End-of-Life Strategy Comparison

ELDA succeeds in classification of product end-of-life strategies in agreement with current best practices in end-of-life treatment. The classification method yields 89% agreement with current best practices. This ability to classify strategies enables companies to design future products that attain highest levels of eco-efficiency by planning for the highest hierarchy level attainable. The ELDA classification matches the current average industry practice in 41% of the products. This indicates that there is still much room for improvement at many companies. Apparently, for products with similar technical characteristics, companies may choose different end-of-life strategies based on business or non-technical concerns rather than on technical items. Therefore, examining only the technical issues is not good enough for business practice and only through close examination of the non-technical items can the end-of-life treatment systems become more successful.

4 EVCA

The differences between the end-of-life strategies implemented by companies reveals that other factors beyond technical issues are affecting the decisions. In most cases, these decisions relate to the corporate culture, image considerations and financial perspective of a company, traditionally considered business issues. Environmental Value Chain Analysis can help address these cultural and financial issues methodically through close examination of the flows between the players. The most important flows are information, money and product.

4.1 Players

The following figure demonstrates an external EVCA (see [7] for internal EVCA) applied generally to the relationships among producers, consumers, recyclers and government. The entire life of the product is examined -- from the producers, to the consumers and lastly to the recycling companies. The information flows are separated into complaints, information exchange, top-down information and feedback. Below the roles of the stakeholders are explained in more detail.

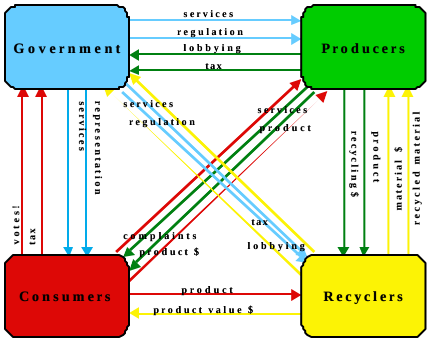

Figure 2. Example of External Environmental Value Chain Analysis

Government: Many levels within the government establish laws about environmental issues. In the European Union, the Directorate General for Environment is responsible for take back and recycling regulation. However, in order to propose to the EU Council and the European Parliament, other Directorates General have to be consulted. In the Member States, similar relationships exist. As one can imagine, having numerous organizations responsible for environmental legislation can be very complicated and at least will be time consuming.

Consumers: In the end-of-life stage, consumers possess a product that no longer satisfies their needs, which they desire to dispose. This process can cause discomfort to the consumer if they are unable to get rid of the product in an easy way or have to pay for its disposal. Van Nes [8] identifies nine reasons for consumers discarding products in her work; however, it can be simplified into three main categories: breakdown, functionality changes, or design aesthetics.

Producers: The group of producers includes suppliers, manufacturers and assemblers of products. Increasing legal and consumer pressure pushes producers to develop take back systems. Sometimes, however, it is profitable to take products back. Such systems are already in place. Before the external issues are addressed associated with implementing take back systems, producers must work on their internal value chain, the relationships internal to the organization, for instance, to provide appropriate incentives for further innovation. Only through such internal support and systems will designers have incentives to improve designs specifically with end-of-life in mind. Apart from the design incentives, other items such as economies of scale, must be organized to optimize end-of-life costs.

Recyclers: Recyclers consists of the collectors, processors, and distributors of discarded products, either disposing of waste or retrieving value from products and materials. Collection may be through retail or municipal infrastructure, through charitable donations, or through individual curbside pick-up. End-of-life processing include repair, servicing, remanufacturing, recycling through shredding with or without disassembly and disposal through incineration or landfill. Recyclers seek to minimize the costs and maximize the profits mostly by focusing on specific material or product streams. This should be aligned with characteristics of products to be treated.

Others: Other players of relevance in end-of-life systems are distributors, retailers and pre-processors of secondary materials and waste. The first two members provide direct links between the customers and producers. These groups may have little motivation to participate in product end-of-life treatment as such because they make money by keeping new products on their shelves or in storage, not for storing old products that have been returned from the customer. To remove the barrier, an incentive is provided in the Netherlands, retailers are paid 2 NLG ($0.75) for handling old televisions.

Due to differences in product characteristics, the end-of-life costs can be substantially different. For products with end-of-life costs, including end-of-life collection and processing, that yield a monetary surplus, end-of-life systems are best developed through voluntary means, according to the market forces. In cases where the product processing and collection costs yield a deficit, the end-of-life system is best managed and developed through regulatory means. This is summarized in the following table.

Table 3. Need for Mandatory and Voluntary end-of-life systems.

Product characteristics	EOL Processing and Collection Costs Yields:	Customer	
		OEM	Private
	Surplus	End-of-life System best developed through voluntary means	
	Deficit	End-of-Life System best developed through mandatory or regulatory influences	

In voluntary product take-back systems, there are large differences between private and institutional consumers. Private consumers typically make purchases in small volumes and small monetary amounts. For private consumers, collection is difficult to organize effectively since private customers are anonymous, may be emotionally attached to products and discard products for different reasons. The differences between institutional (OEM) and private consumers are exacerbated at the end-of-life phase, requiring additional effort placed in the development of private consumer end-of-life systems.

4.2 Examples of Mandatory End-of-Life Treatment Systems

Television take back in the Netherlands

As a consequence of the new Dutch legislation on producer responsibility and product take-back, the branch organizations initiated a collection system for discarded white and brown goods. Figure 3 depicts the situation for a consumer electronics company and the collection of televisions from consumers.

Product: The collection system is based on several waste collection streams, stemming from municipalities as well as from retail outlets. The products are collected through the retailers and municipalities, then processed by existing recyclers. A new organization, NVMP, coordinates the recycling efforts.

Money: NVMP pays for the processing, from the funds collected by the retailers. NVMP is therefore responsible for a fund that pays recyclers to treat end-of-life products mostly through material recycling. Retailers collect money from consumers, on the order of \$2-\$10 per product, to help defray the cost of processing the product. Since companies do not have to pay the fees themselves, there is no incentive in this system to improve designs. Due to its economy of scale, it is operating effectively.

Information: The information flow to develop and update the program is complicated. Different government organizations, industry branch organizations and consumer groups were involved in the discussions to establish and to operate the take-back system.

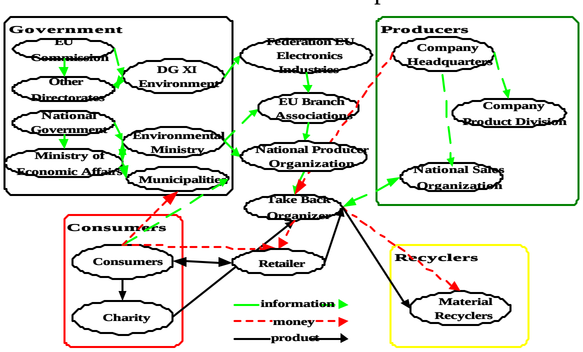

Figure 3. Television take-back in the Netherlands

IT equipment take back in Germany (Proposed)

In Germany, the proposed product take-back system is not as complicated because less governmental intervention exists. Excluding the collection costs, the system is more or less cost neutral for participants. The financial and information flows are more direct as compared to the Dutch take-back system. The goal of this system was to encourage recycling of electronic products.

Product: The collection of products is intended to be mostly through the municipalities and some retailers. The take-back organizer will not handle any of the products. The products are sent to recyclers for reprocessing, failing to take the maximum advantage of the possible reuse of the product.

Money: The difference between this system and the Dutch system is that the take-back organizer does not handle the fees paid to the recyclers as they are paid directly by the company. The processing costs are paid by the member company's national sales organization, which makes it basically a company specific system. As the end-of-life system stands now, the consumer pays the collection cost to the municipalities through taxes.

Information: The information flow to develop and update the program is less complicated than the Dutch system, mostly due to the lack of involvement of the collectivity of industry groups.

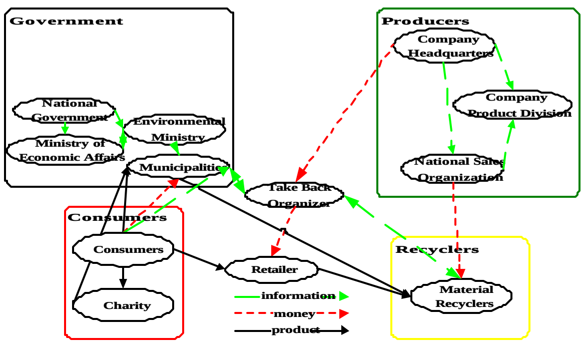

Figure 4. IT equipment take back in Germany

4.3 Examples of Voluntary End-of-Life Treatment Systems

Voluntary program at Siemens Nixdorf

In contrast to the previous product end-of-life systems, the following example shows a voluntary program established by Siemens Nixdorf, in anticipation of the proposed legislation in Germany.

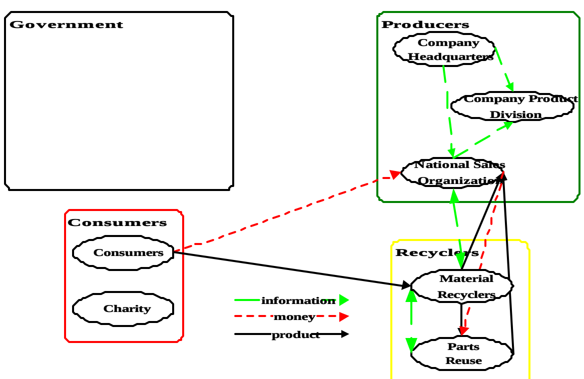

Figure 5. Voluntary program at Siemens Nixdorf

Product: The end-of-life products from Siemens Nixdorf, mostly electronic equipment, flow directly from the consumer to the recycler. This in-house recycling company works with other component refurbishers to remanufacture parts to be returned to Siemens Nixdorf for reapplication. This system of harvesting service parts and reusing them in the repair of existing equipment has been quite successful from a financial perspective.

Money: Since the company is it's own take-back organizer in this system, the external money generated from customers flows directly from the national sales organization. Depending on if recycling of the product category produce a yield or a deficit, the in-house recycling company either credits or debits to the appropriate unit. In this system, there are direct incentives – national sales organization has incentive to generate money from the customer and the business unit has incentive to improve design.

Information: Of the examples included in this paper, this system represents the most effective communication, providing direct links between the producing departments and the recyclers. There was no involvement from the government, as this is an industry initiated product end-of-life system.

Kodak Single Use Cameras

Kodak has developed an extensive remanufacturing organization for their single use cameras, remanufacturing over 60% of the product worldwide [9]. The company reported that more than 80 million one-time-use cameras had been recycled and / or reused, representing a 77 percent recycling rate, exceeding recycling rates for both aluminum cans and soft drink bottles.

Product: Consumers return the cameras in order to have the film developed. After removing the film for processing, photofinishers are encouraged to return the cameras to Kodak for recycling and reuse, after which Kodak reimburses the photofinishers for each camera returned.

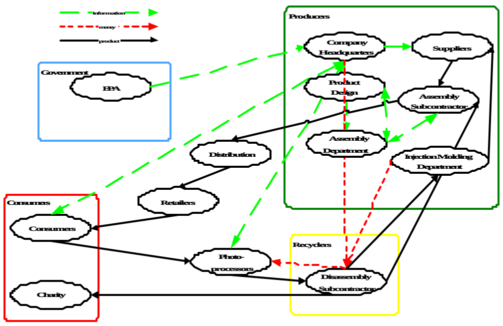

Figure 6. Kodak single use cameras

Money: Kodak pays the photo-processors approximately $0.25 for each camera returned to Kodak's disassembly facility. Kodak also pays shipping costs for the cameras.

Information: Since Kodak manages the disassembly facility closely, it has had the opportunity to learn from the disassembly of the products. As designers have learned more in this way about the recycling and recovery of the cameras. They have incorporated the new ideas into the products, resulting that now in 26 of the 27 (96.3%) parts that are either recycled or reused in a new camera (some components are reused up to 8 times).

Philips Medical Systems

Philips Medical Systems refurbishes and resells their medical equipment, from ultrasound equipment to MRI equipment. The options for warranties provided for the refurbished equipment are equivalent to the new products.

Product: Customers have the choice of purchasing new and refurbished medical equipment from the national sales organization. The customers, typically hospitals or research institutions, return the products after approximately seven years to Philips Medical Systems or sell the used product to brokers. The competition with brokers for sales and even returns is a large challenge to increasing Philips' market position in medical systems.

Money: The financial transaction associated with the used equipment is handled by the National Sales Organization. They pay the refurbishing organization, called Metracom, when a refurbished product is sold.

Information: Information flows freely from new product design to the National Sales Organizations, but the link between Metracom and the National Sales Organizations is weaker. This affects the available market that the refurbished products have. The role of brokers is not transparent.

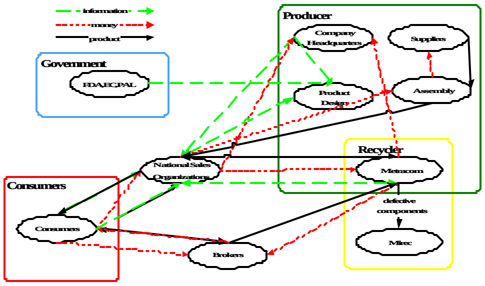

Figure 7. Philips Medical Systems

5 BRIDGING THE GAP WITH ELDA AND EVCA

As discussed in section 3, product characteristics determine the product end-of-life strategies. ELDA accurately classifies products end-of-life strategies by the technical product characteristics with an accuracy of 89%. Companies decide end-of-life treatment based on financial concerns and external circumstances and pressures (consumers, government, recyclers) as shown through the Environmental Value Chain case studies in section 4. Business decisions rather than the technical characteristics of the product, in some cases, control the actual end-of-life treatment. The simple diagram below demonstrates the link between these two variables.

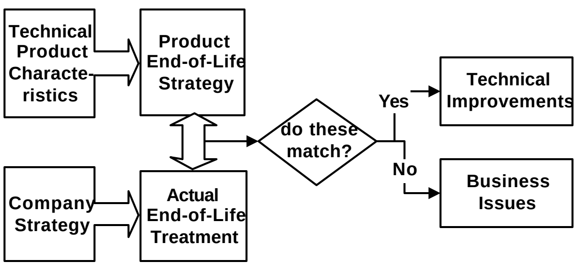

Figure 8. Relationship between ELDA and EVCA.

If there is a mismatch between recommended end-of-life strategy and the actual end-of-life treatment, it is due to inefficiencies in the organization of the end-of-life systems and culture not providing incentives for participation and innovation towards higher levels of reuse. These bottlenecks can be eliminated through work on the value chain, both internal and external.

This mismatch between the recommended end-of-life strategy and actual end-of-life treatment pursued by industry is relevant to defining steps for improvement. In table 4, selected cases are listed for which the strategy recommended by ELDA does or does not agree with the current end-of-life treatment practiced in industry. For televisions, single use cameras and medical systems, the end-of-life strategy and treatment indeed agree. The audio systems and monitors are actually recycled but their recommended end-of-life strategy according to their product characteristics is remanufacture. It is also important to notice for three of these example products (televisions, monitors and audio), legislation mandates the end-of-life treatment, recycling.

Table 4. Comparison of current end-of-life treatment and strategy recommended

Products	**Current end-of-life treatment implemented in industry**	**End-of-life strategy recommended by ELDA**	**Action Needed**
TV	Recycle (with disassembly) [1]	Recycle (with disassembly)	Match
Audio	Recycle (without disassembly)[1]	Remanufacture	Mismatch
Monitors	Recycle (with disassembly)[1]	Remanufacture	Mismatch
Single Use Camera	Remanufacture	Remanufacture	Match
Medical Systems	Remanufacture	Recycle without disassembly	Match

[1]In the Netherlands, mandated by end-of-life treatment legislation.

Examining the difference between the industry practice and ELDA recommendation determines the focus for future efforts for product designers and managers, recyclers and policy makers. Table 5 shows the recommended actions if the ELDA classification corresponds to the best practice and in the cases that it does not correspond to best practice. If the two strategies match, then the focus should be placed on technical aspects of the particular end-of-life strategy, understanding items such as reason for discarding, functionality changes over time and recycling technology development. For the cases that the ELDA classification and industry best practice do not match, then the focus should be on the business issues including value chain concerns.

Table 5. Efforts needed from Product Management, Recyclers, and Policy Makers

Match or Mismatch?	Product Management	Recyclers	Policy Makers
ELDA classification corresponds to best practice	• reason for discarding • functionality over time • Work on recycling technology, infrastructure	• Lower costs, improve yields	• Improve efficiency of system
ELDA classification does not correspond to best practice	• Internal value chain • Consumer, political issues	• Find new outlets • Talk to producers • Talk to organizers of take back systems	• Redefine system so that it can handle higher levels of reuse

Section 5.1 describes the issues and recommendations for action for product management within producing organizations. Section 5.2 summarizes the recommendations for recyclers and policy makers.

5.1 Product Management

5.1.1 Technical Improvements

For products where the current treatment and strategy coincide, the future activity should emphasize design improvements. For products that have end-of-life strategies of reuse, service and remanufacture, the focus should be to understand the reason consumers discard products and the functionality changes over time. By focusing on these two issues, higher percentages of products to which the best strategy can be applied will be attained. For products with end-of-life strategy of recycling, product designers and mangers must look into the recycling technology and the materials used in the products in order to harvest maximum conservation of resources and value.

By focusing on the end-of-life strategy appropriate for the product, designers and managers must identify avenues and design options for achieving the same results with higher eco-efficiency. Eco-efficiency means not only ecological efficiency, but also economic efficiency, making a direct connection between environmental targets and market opportunities [10]. Using generic tools such as Environmental Benchmarking and Ecodesign matrix can help brainstorm opportunities for product improvement. Environmental Benchmarking has been successful for many companies for comparing products of similar functions or in similar market segments, rating products on energy usage, environmentally relevant materials, end-of-life performance, material composition, and packaging [11]. The Ecodesign matrix can organize the options for improvement by outlining the benefits to the environment, business, customer and society before assessing the technical and financial feasibility [11]. Other tools, which can be helpful for a specific end-of-life strategy, examples are included in table 6.

Table 6. Example Tools for Design Improvements

End-of-Life Strategy	Example Tools
Reuse	Functionality-time diagram [12] Optimizing product life time [8]
Service	Best levels of disassembly and recovery of subassemblies, components, or materials for reuse or recycle [13] Life Cycle Serviceability [14] Transforming services business [15]
Remanufacture	Linking qualitative measures of remanufacturability to CAD systems [16] Remanufacturing operations at Electrolux [17]

Recycle with disassembly	Planning disassembly using Petri Nets [18] Understanding disassembly layout planning [19] Integrating disassembly analysis tools in their software [20] Experiences from demanufacturing operations [21]
Recycle without disassembly	Estimating product recycling costs [22] Shredding or disassembly of electronic products [23]
Disposal	Understanding environmental impact of hazardous materials [24]

Designers have a challenging task to improve products for end-of-life treatment and must proceed with creativity and should take the life cycle perspective into account. The possible improvements must be balanced with gains and losses in eco-efficiency in other life cycle phases.

5.1.2 Focus on business issues

For products where end-of-life treatment and recommended end-of-life strategy differ, the business issues dominate. The organization must first tackle these value chain items, using Environmental Value Chain Analysis. Mapping the ideal product end-of-life system, necessary information and appropriate analysis of financial flows can identify the bottlenecks or inefficiencies of the current practice. Comparing the ideal with the current product end-of-life systems will help identify the bottlenecks or sources for inefficiencies. Benchmarking the end-of-life strategy with other existing systems is another helpful activity. Making sure that responsibility for a particular issue is assigned or attributed to the actor who can manage the item concerned the best is a helpful tactic for eliminating inefficiencies.

Internal challenges should be addressed first. The internal value chain items include but are not limited to the following: financial incentives, design incentives and information flow. After addressing the internal challenges, the external issues including government and consumer and political issues should be examined. External value chain issues include needs for product returns incentives (from consumer), relationship with government, incentives for processors and retailers incentives. Increasing the percentage of consumer returns will increase the economy of scale for the processing of the products. Better relationship with the government gives insights to future requirements and targets to be realized. Incentives for processing can be achieved by using materials with higher potential recycling potential and components that can be reused. Retailer incentives can come as discounts in purchasing, trade-in reimbursements and direct payment for storage and collection of the products returned by consumers. Understanding the relationship through product, information and financial flow from the consumer to the producer or other take-back organization can help improve the organization of the end-of-life system, as well.

5.2 Recyclers and Policy Makers

In the case of products that the recommended end-of-life strategy corresponds to the end-of-life treatment, recyclers and policy makers should primarily seek to assist in improving the efficiency of the end-of-life treatment. The recyclers must focus on specific technical issues associated with particular end-of-life strategy, identifying opportunities to reduce costs and improve yields of the process. Policy makers should work towards improving the overall efficiency of the systems through redefining requirements to support maximizing the eco-efficiency of the strategy. This includes clear goal setting and prioritizing recommended treatment actions and enable their smooth operation and execution.

Recyclers and policy must address a different set of issues when the products' end-of-life strategy does not correspond to industry's current end-of-life treatment. Recyclers must identify new outlets for the material or product stream needed for the higher level strategy, collaborate with producers and organizers of take back systems. Finding such new outlets for materials or the product streams requires creativity and business savvy. On the other hand, policy makers must work to redefine the conditions under which the end-of-life systems need to operate in order to create success.

6 IMPLICATIONS ON DECISION MAKERS

6.1 Product management

Global competition, new markets and rapidly developing technologies are pushing to shorten product development cycles. Product designers and managers face augmented pressures, strategic plans focus on one metric – time to market. As with other aspects, environmental improvement possible in product design stage are frequently delayed or forgotten.

Environment, especially end-of-life, concerns must be addressed early in the design stage, when alterations are still possible. The extra time spent addressing these strategic issues can pay off in resource allocation and amount of product design. Strategy decisions like identifying the product end-of-life strategy and building value chains must be made first. After determining the end-of-life strategy, options for redesign can be prioritized and the efforts can yield outstanding results. Without both the end-of-life strategy and system in place, the efforts expended at detailed design stage are misspent.

6.2 Policy Makers

The effort for policy makers, in legislative bodies throughout the world, needs to focus on end-of-life systems that yield deficits. Product end-of-life systems with efficient collection, incentives for design improvements and have products with high material value are frequently correlated to end-of-life systems that yield surpluses and are operating voluntarily. Hence, legislation should focus on helping provide incentives for collection, processing and design for the product end-of-life systems where product characteristics imply high end-of-life costs.

These end-of-life systems must be set up carefully considering the information, financial and product flows. Concern must be given and thorough investigation of the ramifications of possible end-of-life collection options, end-of-life cost distribution, linkage to actual design departments within companies. The unintentional ramifications can preclude success and even prevent operation.

Product characteristics do control the possible end-of-life strategy; therefore care must be given to develop individualized end-of-life systems. The success of one end-of-life system may not be directly applicable to other products, because of the differences in technical product characteristics. Policies made must not over-specify the details unintended consequences of end-of-life legislation.

7 CONCLUSIONS

The two tools discussed in this paper build product end-of-life strategy. ELDA recommends the best possible product end-of-life strategy; EVCA represents organization of the product end-of-life system and identifies the issues and makes them transparent for all end-of-life systems' players. These two tools combine to yield powerful results – a framework to build a strong product end-of-life strategy and steps for future action.

Organizing end-of-life treatment systems require business savvy. Typical business issues such as organization development, program establishment, consumer-product interaction and financial concerns must be addressed in addition to the technical items. ELDA is creating a solid basis for just that.

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