# REVERSE LOGISTICS IN THE COMPUTER INDUSTRY

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## ABSTRACT

The computer industry has witnessed an unprecedented growth in the last few decades. It is one of the fastest growing manufacturing industries and, due to high rate of obsolescence, one of the industries with the highest rate of e-waste. This paper applies a reverse logistics hierarchy to determine what steps are being taken in the industry and presents some suggested solutions to the problem from the systems theory perspective.

**Keywords**: Reverse logistics, computer industry, e-waste, systems theory solutions

## 1. INTRODUCTION

The past couple of decades have witnessed a technological revolution. There has been a rapid growth in the dependence on electronics and most of the consumers in the developed economies own a computer and upgrade these systems every few years.

Indeed, electronics are a fast growing portion of waste in the US with 250 million computers becoming obsolete by 2005. In 2001, only eleven percent of the retired computers were recycled (Environmental Protection Agency, Resource Conservation Challenge, 2004). The average life span of a computer has shrunk from four or five years to about two years (National Safety Council, Electronic Product Recovery Report, 1999). Americans are buying more computers than people in any other nation and, at present, more than half of American households own computers (United States Department of Labor, Issues in Labor Statistics, 1999). More than 50% of the computers turned in for recycling are in good working order but are turned in to make way for latest technology and one computer will become obsolete for every new one put on the market by the year 2005 (Silicon Valley Toxics Coalition, Poison PCs and Toxic TVs, 2001). In 2002, 63.3 million computer desktops will be taken out of service and 85% of these will end up in landfills (TechSoup, Ten Tips for Donating a Computer, 2003).

Moore's law states that new microprocessors double in power every 18 months. One fortunate corollary is that old computers get better and better and since these are technically obsolete, they are cheap as well. However, the negative aspect of this law is that due to the pace of innovation, there is a glut of old machines that affluent societies do not know what to do with (Manjoo, 2002). Obsolete computers and televisions generate millions of pounds of e-waste in the US and about 50% to 80% of the e-waste collected for recycling, is being exported.

The purpose of this paper is to explore the opportunities for returns within the computer industry and to analyze the solutions to the problem of managing e-returns from the systems perspective. Since systems theory focuses on the inter-linkages between sub-systems, we posit that this theory is well-suited to address the issue of computer, and related, e-waste.

### 1.1 E-Waste

E-waste or electronic waste consists of materials that are no longer usable or computer scrap. E-waste comes from a range of electronics, from computers to household appliances to cell-phones. Large amounts of e-wastes end up in landfills in US or are sent to developing countries. The main toxic is lead that can leach into groundwater. The US federal government has not enacted any laws banning e-waste from landfills though a few of the states have imposed bans on CRT monitors and TVs. There is 4-6 lbs of lead in CRT monitors on average. Circuit boards contain lead and other heavy metals such as arsenic. Also, half of the computer is plastic and a large portion of this is treated with toxic brominated flame retardant chemicals in a process called doping (CompuMentor, Computer Recycling and Reuse Program, 2003).

### 1.2 Amount of E-waste

20 million computers became obsolete in the US in 1998 and the overall e-waste volume was estimated to be 5 to 7 million tons (National Safety Council, Electronic Product Recovery and Recycling Base Report, 1999). These figures are projected to be higher today and rapidly growing. A study in Europe indicates that the volume of e-waste is increasing by 3-5 % annually (Arensman, 2000). A projection stated was that by 2001, about 41 million computers would become obsolete in the US (National Safety Council, Electronic Product Recovery and Recycling Base Report, 1999). Between 1997 and 2007, experts state that we will have more than 500 million obsolete computers in the US (Silicon Valley Toxics Coalition, Poison PCs and Toxic TVs, 2001).

Most of the e-waste comes from three major sectors: Individuals and small businesses; large corporations, institutions, governments; and original equipment manufacturers (OEMs) (Basel Action Network, Exporting Harm, 2002). A majority of this e-waste goes into storage. Three quarters of all the computers sold in the US remain stockpiled and await disposal (National Safety Council, Electronic Product Recovery and Recycling Base Report, 1999). Some other studies indicate that numbers of unused, stored computers is 315-680 million units (Silicon Valley Toxics Coalition, Poison PCs and Toxic TVs, 2001). On average, a consumer has 2-3 obsolete computers in storage spaces. The value of these units drops down to 1-5% of the original cost of the equipment (Matthews, et. al., 1997). The net worth of old computers is very little. The 5 lbs of steel is worth $0.25, the CPU with gold tips and wiring is worth about $1.00, the motherboard with metal (gold, silver and copper) connectors is worth about $ 2.00, the cable is approximately $0.09, the hard drive (15% aluminum) may fetch $0.10, and the monitor yoke (60% copper) is approximately $0.80 (Hamilton-Endicott, 2001). Hence, computers are worth very little if not for the precious metals used. Recycling computers often entails subsidizing the recycler. For individuals, this cost might run into $10 to $30. Hence many consumers would rather throw away their old computers rather than pay this cost.

## 2. REVERSE LOGISTICS

What are the steps being taken to alleviate this amount of e-waste? In the area of supply chain management, reverse logistics is used to manage the return flow of products. Reverse Logistics is a process whereby a manufacturer accepts products from consumers for possible remanufacturing, recycling, reuse or disposal (Dowlatshahi, 2000). Other manufacturers also attempt to reduce the amount of materials used in the input process. It is much more than simple recycling since there is an emphasis on actual reduction of materials used, or on remanufacture or reuse of materials. In the traditional supply chain, the logistician managed the flow of products from the producer to the consumer. In reverse logistics, the reverse flow of the products from the consumer to the producer is managed. Reverse logistics can extend the life cycle of a product and promote alternate use of resources that can be both cost-effective and ecologically-friendly (Melbin, 1995). Reverse logistics may be able to increase profitability and productivity by lowering inputs. There exist numerous studies that indicate the cost savings potential of implemented reverse logistics programs (c.f. (Carter and Ellram, 1998), Rogers and Tibben-Lembke (2001), Caldwell (1999), Tibben-Lembke (1998), etc.)) The companies that have used reverse logistics in their operations include BMW, DuPont, General Motors, Hewlett Packard, among others (Dowlatshahi, 2000).

There are three primary intra-organizational activities that impact reverse logistics. These are: a sincere commitment to environmental issues; a successfully implemented set of ethical standards; and the existence of policy entrepreneurs who are responsible for organization adoption of an environmentally friendly philosophy (Carter and Ellram, 1998). In addition, the reverse logistics activities of an organization are also directly impacted by four environmental forces which are customers, suppliers, competitors, and government agencies.

The reverse logistics hierarchy proposed by Stock (cf. 1992) and (Kopicki, et. al., 1993) states that resource reduction ought to be the ultimate goal. This resource reduction would include both the minimization of materials used in the product along with the minimization of waste and energy achieved through the design of more environmentally efficient products. Once the option of resource reduction has been exhausted, the next aim is to reuse materials followed by recycling of as much waste as possible. Disposal typically is the last option employed and, even in this case, incineration is preferable since some form of energy recovery is likely (Carter and Ellram, 1998). -

We will modify this hierarchy as shown in Figure 1 and apply each of the steps in this hierarchy to the computer industry. In this modification, we include another step entitled Refurbishing that fits between Reuse and Recycling and we collapse the two disposal stages into one. The reason for this is that Refurbishing is an important step that is rather unique to the computer industry. A large portion of computers are refurbished by both commercial and non-commercial enterprises and a thriving market exists for these refurbished pieces. For the disposal changes, we collapse the two stages into one stage since disposal with incineration might be more harmful in the case of computers due to the presence of some hazardous materials used.

## 2. 1 Resource Reduction

The major question is does the computer industry attempt to minimize materials used in the product? Alternatively, are there any attempts made to minimize waste? Does the computer industry design for disassembly or design for environment? The answer in all cases is in the negative.

Why is this so? Computers are not designed for ease of recycling and, hence, the dismantling is highly labor-intensive. The existence of toxic components is an added risk to recyclers. In addition, retrieving the valuable materials in e-waste is difficult since it is bound with plastics and mixed with other contaminants. Another issue is that the price of a computer does not include its end-of-life costs. The pricing war of electronics seriously impedes the capability for manufacturers to include the cost of recycling into the purchasing cost of their products, respectively deterring the incentive to design products with recycling and disassembly in mind. The only economically viable recycling that can take place is in a poor developing country, far from where this product was consumed and utilized. With the competition the US recyclers face with their Asian counterparts, it is highly unlikely organizations can invest in effective recycling infrastructures such as computer shredders and material separators for recycling of e-wastes (Basel Action Network, Exporting Harm, 2002).

## 2.2 Computer Reuse

This step refers to the efforts aimed at keeping computers in operation by extending their life beyond three years. This is direct second-hand use and it makes up a small percentage, about 3% in 1998, of the computers that have been discarded (Basel Action Network, Exporting Harm, 2002).

In noncommercial reuse programs, computers are distributed to a particular population by non-profit and school-based programs. Approximately 70 percent of this reuse serves schools and about 400-500 such programs exist in the US with average capacity of 200 computers per year. The largest program supplies about 10000 computers. Some examples are StRUT (Students Recycling Used Technology) in Portland, Phoenix, Silicon Valley, Georgia, Computers for Schools in Chicago, The Computer Recycling Center (CRC) in the Bay Area, Per Scholas in New York, Computers for Schools Canada (CompuMentor, Computer Recycling and Reuse Program, 2003).

In commercial reuse programs, individuals or businesses can sell computers in auctions (eBay) or local classifieds. The larger portion is the secondary wholesale market wherein ‘asset management’ companies receive computers from large corporations or recyclers. These computers are then resold in developing countries. The most profitable part of electronics recycling comes from reselling usable parts rather than crushing equipment to salvage metals, plastics, or glass (CompuMentor, Computer Recycling and Reuse Program, 2003).

Foreign markets have very cheap labor and computers are bought, repaired for very low cost and resold for a profit. However, these older units also have a limited life-span and will end up as e-waste sooner or later (Basel Action Network, Exporting Harm, 2002). Some of the large corporations have divisions for this work such as HP Financial Services or IBM Global Asset Recovery Services. Other large secondary market companies are Asset Recovery Center, Sysix, Micro Metallics, United Computer Exchange, Waste Management Asset Management, etc (CompuMentor, Computer Recycling and Reuse Program, 2003).

Similar to how Moore's Law applies to the increase of processing power, there seems to be a similar trend in software development. Faster processors allow for more advanced and complex computer software. This eventually limits the reuse of computers to a relative small audience, and will probably continue to be a very small viable solution for computing recycling.

### 2.3 Computer Refurbishing

This step refers to the reconditioning of discarded computers in order to get them back in working order. This is different from reuse since the computers are tested, repaired and, in some cases, reinstalled with new software. Some examples of commercial refurbishers are IBM Refurbished, Dell Refurbished, Nxtcycle, etc. The non-commercial refurbishers are usually non-profit or school-based companies. The refurbishers receive discarded computers that are then tested and repaired. In case a computer cannot be repaired, its useable parts are extracted. The non-working equipment is sent to the recyclers for disposal. In general terms, it takes 2 to 3 computer donations to get a yield of 1 usable computer. A critical task is to clean out all the hard drives and install clean operating systems and software to make the computer functional. The cost of refurbishing is approximated to be $105 per computer and this cost includes labor, parts, and disposal of e-wastes (CompuMentor, Computer Recycling and Reuse Program, 2003).

Some of the refurbishing is done in prison facilities. Herein, the prisoners dismantle computer monitors, televisions, and other e-waste. Since the prisoners are paid low wages, some domestic recyclers think that they will not be able to compete. Others point out that the federally prescribed health and safety regulations of OSHA (Occupational Safety and Health Administration) will not be applicable (Geiselman, 2002).

### 2.4 Computer Recycling

The breakdown of computer equipment for the purposes of recovering metals, plastic and glass is termed as computer recycling. It is a complex process since there are over thousand different materials in a computer. In addition, diminishing amounts of precious metals like gold, silver, platinum, palladium, have been used in computers in recent years. This fact, combined with low commodity prices, makes computer recycling not very profitable. For this reason, most of the computer recyclers are large commercial companies or government programs. The working parts and whole computers are also resold and this area termed as "asset management/recovery" yields higher profits than smelting and shredding to recover materials. The largest recycling companies in this area are Noranda / Micrometallics Corporation, Waste Management, IBM Credit Corporation, MeTech International, Envirocycle, and UNICOR Federal Prison Industries (CompuMentor, Computer Recycling and Reuse Program, 2003).

Large corporations and OEMs have a much higher rate of recycling than individuals due to the application of EPA regulations. These companies need to protect, and hence, destroy proprietary information and some recyclers will offer to clean the hard drive (Basel Action Network, Exporting Harm, 2002).

### 2.5 Disposal

Landfill and Incineration: According to EPA, more than 3.2 million tons of e-waste landed in US landfills in 1997. About 70% of the heavy metals found in landfills come from electronic discards and these can contaminate groundwater (Computers, E-Waste, and Product Stewardship, 2001). A common assumption is that recycling is better than disposal in a landfill. However, if the recycling results in toxic waste exposures, open dumping or burning of toxic residues, then this assumption does not hold true.

## 3. EXPORT AS A SOLUTION

As noted in the section above, a large portion of computers are exported. The Basel convention was created in 1989 to counter the unjust and unsustainable effects of free trade in toxic wastes. In 1994, the Basel convention adopted a total ban on the exports of all hazardous wastes from rich to poor countries for any reason, including recycling. Instead the convention calls for all countries to reduce their exports of hazardous wastes to a minimum and contend with their waste problems within national borders. However, the United States is the only developed country that has not ratified the Basel convention.

Why are these e-wastes exported to Asia? There are three primary reasons for this phenomenon. First of all, the labor costs are very low. In China, the costs are $1.50 per day versus the minimum wage of $5.50 per hour in the United States. Another reason is that the environmental regulations are lax. Even in the presence of legislation, the actual monitoring and enforcement does not always follow through. Yet another reason is that it is legal in the United States to export hazardous e-waste (Basel Action Network, Exporting Harm, 2002).

Market forces state that toxic waste will run downhill on an economic path of least resistance. The toxic effluents of affluent societies will flood towards the world's poorest countries where labor is cheap, environmental regulations are non-existent. Free trade in hazardous waste leaves people in these countries with very few choices – poverty or exposure to toxins. In view of these facts, the Basel convention was created in 1989 and the convention agreed to adopt a total ban on the export of hazardous wastes from rich to poor countries for any reason in 1994. There are two compelling reasons to ban trade in hazardous wastes:

- downstream impacts: this trade is environmentally damaging and fundamentally unjust since it victimized the poor and burdens them with toxic exposure and environmental degradation. These are the same victims that did not benefit from industrialization in the first place
- upstream impacts: allows waste generators to externalize their costs, thus creating a major disincentive to finding true solutions to the problem. As long as waste can cheaply dumped elsewhere, there will never be any incentives to minimize hazardous waste at the source. Thus, necessary innovation to design for the environmental is forestalled (Basel Action Network, Exporting Harm, 2002).

### 3.1 Recycling or Trading

As stated earlier, most companies that claim that they are recyclers of waste actually engage in waste trading, rather than waste recycling. Approximately 80% of what they collect will be sent to Asia and 90% of this goes to China and the rest goes to India and Pakistan. In most cases, the recycler will take out the most valuable components of the product and this will be sold to brokers. The rest of the material may be broken down and sorted by waste (circuit boards, cables, CRTs) and thrown into large cardboard boxes called gaylords. These are further sold to brokers who arrange the shipment to Asia. The warehouses in Asia (there are 4 of these in port of Nanhai, near Hong Kong) will again sell the most valuable parts in Asia. Alternatively, the e-waste broker might simply take the material in bulk and ship it to Asia without separation. This is an aggressive and competitive business and the largest market for non-working equipment is for circuit boards rich in precious metals such as gold, silver, palladium and platinum (Basel Action Network, Exporting Harm, 2002).

It is estimated that it is ten times cheaper to ship monitors to China than it was to recycle them in the US (US EPA Report, Analysis of residential collections, 1998).

### 3.2 How is this Export Rationalized?

Initially, it seems surprising that all this waste actually gets shipped over to other nations, However, as this topic is explored further, it comes to light that numerous reasons are given to justify or rationalize this export. These reasons are stated as follows.

Global Standards: The stand of the US regulatory body is that they need to improve the standards and operating procedures in developing countries and this would justify the e-waste export to these countries. However, the reality is that these countries lack the infrastructure to monitor and maintain technology. Furthermore, the protection of worker and community rights is not guaranteed. Technology, by itself, is not enough to guarantee environmental and health protection (Basel Action Network, Exporting Harm, 2002).

Take Back to Asia: There exists an argument that if electronics are manufactured in Asia then the waste from these electronics needs to be exported back to Asia. The most toxic stages of the life cycle of electronics – manufacturing and disposal – have been sent to developing countries. The fact that cheap labor is first exploited in production of the product cannot be used as a justification for yet another instance of exploitation for the disposal of the product waste, especially when the consumption of the product has taken place in a developed country. Take-back programs do not imply a physical transportation of the product to where it was manufactured. Rather, take back must occur in the country of consumption and where the product ends its useful life (Basel Action Network, Exporting Harm, 2002).

Export for Re-Use: Another argument is that obsolete computers need to be sent for re-use or refurbishing to Asia since this would add extra life to the product and would provide technology to the most needy. The reality is that when these computers are sent to Asia, they will end their life in Asia as well. The environmental and justice impacts will be the same though the problem of moving the toxic e-waste from US to Asia will be delayed somewhat (Basel Action Network, Exporting Harm, 2002).

## 4. SYSTEMS THEORY

Systems theory is a system that focuses on complexity and interdependence. A system is composed of regularly interacting or interdependent groups of activities/parts as a whole. Systems dynamics is concerned with the structure of any system – the many circular, inter-locking, time delayed relationships, among components – and states that the structure is just as important as individual components in determination of behavior (Wikipedia, Systems Theory, 2005). Since systems theory focuses on arrangement of and relations between parts which connect them into a whole (holism), this thinking has been developed to provide techniques for studying systems in holistic ways (Principa Cybernetica Web, What is Systems Theory, 2005). Systems analysis applies systems principles to aid a decision maker with problems of identifying, reconstructing, optimizing and controlling a system while taking into account multiple objectives, constraints and resources (Principa Cybernetica Web, What are Cybernetics and Systems Science, 2005).

Systems thinking can be applied at every stage of products life cycle - from concept development to raw material extraction, manufacturing, distribution end-use, recovery, and disposal. In the case of disposal, many other opportunities exist and conserve resources and energy by recycling the waste of one or more products within a system (Ottman, 2000). Furthermore, Hoffman (2003) states that, as a methodology, systems dynamics can be used for understanding how complex systems change over time. This methodology can be used to understand how all the objects in a system interact with one another in presence of accumulation and delays (Forrester, 1961, 1969). Previously, systems dynamics have been used to link subsystems based on population growth, pollution, nonrenewable resource use, food production, land fertility, land development and land loss, industrial output, service outputs, and jobs when analyzing environmental problems within a global system (Meadows, Meadows, and Randers, 1972). In this context, systems dynamics can be used to link subsystems based on consumption, industrial output, waste generation, and waste export.

### 4.1 Solutions from the Systems Perspective

We shall discuss the various solutions from the systems perspective. In the materials recycling context, materials such as paper and plastic are extracted and processed, manufactured into a consumable product, and then disposed off. Clearly, this process is highly linear and does not offer any potential material gains through options such as recycling, remanufacture, or reuse (Hoffman, 2003). This is an issue that needs to be addressed at numerous levels – consumer, industry, and regulatory. In addition, if we consider the whole as a system, or take a holistic approach, we shall realize that this issue can be addressed from numerous different levels. Systems theory suggests that a problem cannot be addressed on one singular level, since there might be a potential implication on another level. In each of the solutions presented, we shall identify the different players or levels and discuss how each of these can have an impact.

**Ban of Hazardous Waste** – The Basel Convention calls for the ban on the exports of hazardous e-wastes that are found in computer monitors, computers and circuit boards. Systems dynamics is concerned with the structure, the time circular time delayed relationships. In this case, the industrial world is linked with the developing world. The former needs to manage its own hazardous wastes and the latter needs to be given tools and training to develop waste management strategies. In case of China that has already ratified the Basel convention, the grass-root organizations in China and other international organizations need to put pressure on China to abide by the convention and to stop accepting these e-wastes even though these imports of e-wastes might bring in jobs for their citizens. This ban is a necessary first step and one that needs to be adhered by all the nations irrespective of their level of development. Overall, this ban can serve as system constraint to ensure that hazardous wastes are not being moved around among nations.

**Extended Producer Responsibility**- Looking from the systems perspective, the producer is an active player who ought to be held responsible to manage the entire life cycle of the product. In other words, the producer needs to take back the product and recycle or dispose of it in a responsible manner. In the absence of this responsibility, manufacturers are all too willing to externalize the environmental costs on to the consumers and, in case of transnational pollution, to poorer, developing nations. Producers need to be encouraged to prevent pollution and reduce energy and resource in the product life cycle by changes in the design of the product and the process technology used. If the producers are financially responsible for end-of-life waste management, it will serve as an incentive to design products with more recycled materials and less hazardous materials (Basel Action Network, Exporting Harm, 2002). The reasoning of EPR is based on the "polluter-pays" principle, first articulated in the German Ordinance on the Avoidance of Packaging Waste passed by the German government in 1993 (Goldfine, 1994). EPR implies shared responsibilities in the product chain, although often the producer is in the best position, both technically and economically, to influence the rest of the product chain in reducing life-cycle environmental impacts (Davis et. al., 1997). In the United States, there is a substantial amount of opposition to new take-back legislation among industry constituents. Rather, U.S. policy tends to prefer voluntary measures. However, these measures can be insufficient and unattainable when economic incentives are not present. Government intervention can provide for these economic incentives. Another approach would be to enact the "Take It Back" laws, wherein the producer is required to take back the product at the end of its life cycle. This is the ideal solution that would aim to close the loop of the product life cycle and would coerce the manufacturers of the product to work with the designers of the product to devise and implement sound recycling and re-use solutions. This solution reflects upon the holistic, circular approach provided by the systems thinking wherein the actions of a subset of players, in this case, the designers and the manufacturers, would have a positive impact upon the overall system.

**Marketable Permits** – Another approach that would promote a positive linkage between the industrialized world and the developing world with a view of protecting the environment is the one of marketable permits (Dhanda, 1997). For example, developed countries could issue permits free-of-charge to existing e-waste polluters at some predetermined level of ecological degradation. Accordingly, if the U.S. generates 1 million tons of e-waste per year, then companies responsible for e-waste could receive permits that allow up to 1 million tons of pollution annually. Countries that are victims of this biohazard, such as China and India, would be allowed to participate and buy these permits in order to retire them. However, this approach violates international forums such as the UN Stockholm Conference, which requires polluting nations to take responsibility for their actions and avoid damaging areas beyond their national borders.

One negative aspect of this approach is that the victims end up paying for the cleanup. This is a matter of ethical concern. In the case of transnational pollution issues, it is stated that

> "*less-developed countries that choose uncontrolled domestic pollution as means to improve their economic position will voluntarily become the repository of world's dirty industries* (Baumol and Oates, 1993)"

The authors analyze the case of unidirectional transnational pollution theoretically in order to find a pareto-optimal solution. Interestingly, theory suggests that simply requiring the developed country to reduce e-waste would not be pareto-improving since there would be no benefits to this country. A mutual gain to both the countries requires that the victim nation make some payments to the developed country. In order to have a pareto improvement implies a victim-pays principle.

Within the systems context, the solution of marketable permits would also be feasible. If all the players trade permits with an overarching goal of reducing e-waste, the overall goal of protection of the environment would be met. This solution is also dynamic in nature as volume of permits can be changed over time, leading to a relaxation or tightening of the limits over a long term period.

**Design Changes –** This approach calls for analyzing the product itself since the product is at the crux of the matter. In this approach the product could be designed using the following two principles:

*Design for Longevity, Upgradability, Repair and Re-use* **–** This approach states that the rapid obsolescence of the computer industry needs to be halted. The rapid advancement of technology has played a key role in the obsolescence of computers. A case could be made for the software and engineers to make more flexible software and hardware systems that are upgradeable over time. For example, in case of faster processors, a modular design could be incorporated to insert the newer, faster processor, rather than throwing out the entire computer or motherboard (Basel Action Network, Exporting Harm, 2002).

*Design for Recycling/Design for Disassembly* **–** When the product needs to be retired, it needs to be designed to ensure clear, safe, and efficient mechanisms for recovering the raw materials. In case of input materials, there needs to be a pre-identifiable recycling market. It would be useful to have a mechanism whereby the input material could be reconstituted and recycled. All the equipment components ought to be labeled as plastic or metal types. The product ought to be designed for rapid and easy dismantling or reduction to a useable form. Lastly, warnings ought to be placed for any possible hazard in disassembly or recycling (Basel Action Network, Exporting Harm, 2002).

Systems thinking can be applied at every stage of the product life cycle and its application in the design stage can tremendously impact and improve the design of the overall product.

## 5. CONCLUSIONS

In this paper, we attempt to analyze reverse logistics activities or the lack thereof in the computer industry. There exist numerous barriers in the recycling, reuse, refurbishing, or appropriate disposal of computers. The primary roadblock is that reverse logistics programs are at their infancy in the computer industry. Though initial studies indicate that such programs, once implemented, yield cost-savings, these examples are far and few between. Another challenge is the consumer mindset. Though there exist pockets in the United States where consumers are involved in grass root efforts to recycle or reuse computers, this phenomenon does not occur nation-wide. Furthermore, there is a reluctance to pay for recycling and most consumers state a preference for virgin products versus products made from recycled parts. Yet another obstacle is the pro-business backing that is politically motivated. EPA, the regulatory agency in the US, has started some initiatives to promote recycling but all these are in the pilot stages. Most of the initiatives are voluntary in nature and companies take these up to be viewed as being ‘green’ in nature. Even though there is an absence of mandatory standards such as the directive on Waste from Electrical and Electronic Equipment proposed in the EU, there might be some leadership coming from the industry initiatives. If IBM or Dell or any major player can employ their reverse logistics practices as a market leadership strategy, then the company could pave the way for other companies to follow. Herein lies an opportunity for US manufacturers to lead the way towards environmentally responsible practices in the disposal and disassembly of computers.

From a systems paradigm, this is an issue that needs to be addressed at numerous levels – consumer, industry, and regulatory. The consumers need to be more pro-active in recycling responsibly and purchasing recycled products. Within the industry, manufacturers need to adhere to take-back laws and be responsible for managing the returns of their products. The designers of the products can play an active role by designing products for longevity, repair, re-use, recycling and disassembly. The regulatory agency can play a large role by ratifying the Basel convention and by setting up systems such as marketable permits or extended producer responsibility that would work to protect the environment. However, all these stakeholders need to work together with a similar aim or purpose in mind for the initiatives to be implemented successfully.

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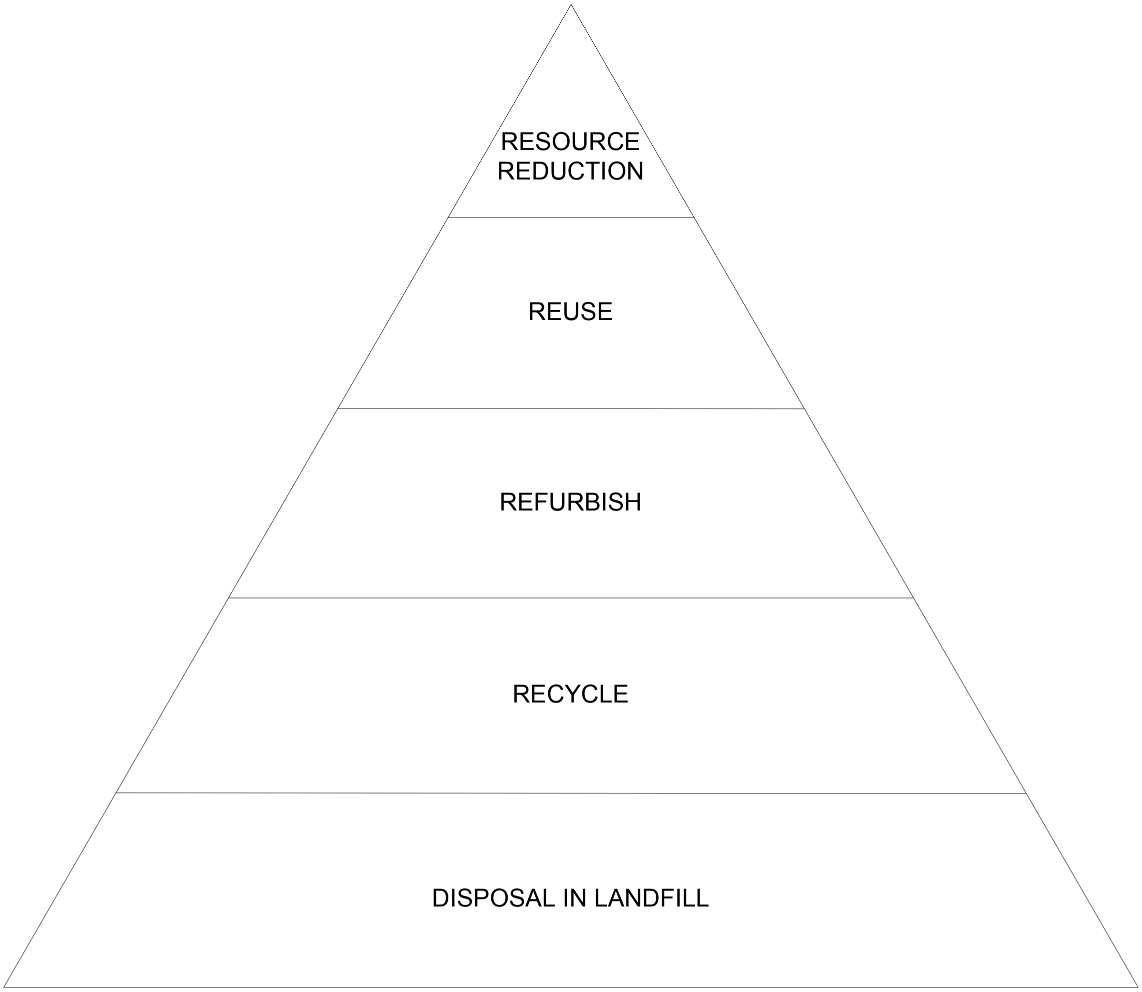
FIGURE 1 THE MODIFIED REVERSE LOGISTICS HIERARCY



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