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A computer recycling option for the city of San Jose, CA

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A COMPUTER RECYCLING OPTION FOR THE CITY OF SAN JOSE, CA

A Thesis

Presented to

The Faculty of the Department of Civil and Environmental Engineering

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Lavanya Ranganath

August 2002

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ABSTRACT

A Computer Recycling Option for the City of San Jose

By Lavanya Ranganath

Disposal End-of-Life (E-O-L) electronic products, especially desktop computers, pose problems such as large volumes produced, toxicity related issues, and loss of natural resources. A large quantity of obsolete computers is generated from the household sector. This study found that in 2001, approximately 149,051 obsolete computers were stockpiled in residential homes in San Jose, CA. Currently, there does not exist a comprehensive program for collection, reuse/recycle, and disposal of obsolete computers. The local government ultimately bears the responsibility for its disposal. However, the existing regulations do not allow the collection of an advance disposal fee, which is required to support such a program. While the issue is still being debated at local, state, and national levels, so far no solution has been offered. This report identifies important elements needed and proposes a model for handling obsolete computers in San Jose, CA.

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EXECUTIVE SUMMARY

According to the Global Future Foundation (2001), more than 6000 computers are discarded everyday in California. Disposal of obsolete computers poses many problems such as large volumes produced, toxicity related issues and loss of natural resources. The household sector generates a significant portion of obsolete computers. According to Jung and Bartel (1998), 30 percent of desktop computers are purchased for home use.

In this thesis, the number of computers in-use, number of obsolete computers generated, and future computer purchase trends in San Jose, CA are assessed. It was found that personal computer (PC) ownership in San Jose in 2001 was 86 percent. According to The Washington Post (2001), home computer ownership in the United States is 59.4 percent. This indicates that the computer ownership in San Jose is almost 1.5 times higher than the national average. The data obtained from a research survey of 385 residents in San Jose in 2001 was extrapolated to show that there was at least one computer in use per household, and one obsolete computer generated for every two households; one new computer will be purchased for every five households within 6 to 12 months. As of January 1, 2000, there were 281,298 households in San Jose (DoF, 2002). In 2001, approximately 392,356 computers were in-use, 149,051 obsolete computers were stockpiled in residential homes in San Jose, and an additional 56,260 new computers were planned to be purchased in the near future.

Computer monitors contain cathode ray tubes (CRTs), which are categorized as Universal Waste under the new emergency regulation passed by the Department of Toxic Substances Control. A Universal Waste is actually a hazardous waste, but it is regulated under a different section of state hazardous waste regulations that deals with high volume, low-risk wastes such as batteries, fluorescent lamps etc. The new regulation requires proper management of CRTs to prevent any CRT glass release to the environment.

In order to comply with the new CRT regulation, the City of San Jose has made provision for collection of CRTs under the “Recycle Plus” and “Neighborhood Clean-up Program.” These programs do not cover computers or other E-O-L electronic products. The City of San Jose has a contract with NxtCycle for recycling CRTs collected from San Jose households. Management of existing stockpiled CRTs would cost the City an additional \$1,132,778 (based on Nxtcycle’s rate of \$7.6/unit cost for transportation from a Northern California facility and for recycling of the CRTs). Since the existing regulatory system does not impose a disposal fee, the City will have to face this financial burden.

The major challenges related to obsolete computer management are:

- Improve product design for longer life span and easy upgradability and recyclability
- Implement a uniform funding mechanism at state and national levels
- Implement an efficient collection and recycling system to prevent stockpiling
- Educate the public about their role in E-O-L product management

- Develop new markets for recycled components to encourage recycling and to reuse valuable resources

Some of the above challenges, mainly implementing a funding mechanism and developing new markets, need to be addressed by the state agencies. The original equipment manufacturers (OEMs) are responsible for product design. However, the City of San Jose is ultimately responsible for meeting regulatory requirements to manage obsolete computers generated from the household sector and perhaps even small businesses. As in the case of other waste models, *e.g.*, waste tire and used oil models, no single solution, but rather a multitude of solutions are required to address the problem. To this end, in this thesis a model for the collection, reuse and recycle of obsolete computers is proposed.

The proposed model for the collection, reuse, and recycle of obsolete computers offers a solution to the growing problem. The City can play a lead role by developing and implementing a program for managing obsolete computers. The recommendations for a suitable model are summarized below.

- The model, consisting of important elements such as collection, reuse/recycle, disposal, regulatory oversight, and a funding mechanism, needs to be implemented.
- The City has to broaden the existing collection mechanism by organizing/ implementing/funding drop-off events and curbside collection programs. The collection mechanism should be further expanded to include electronic retail stores as collection centers; an increase in store participation should be promoted by offering incentives.

- The City has to inform residents regarding opportunities for collection and disposal of obsolete computers.
- The City can utilize the local companies identified in this report for refurbishing and recycling activities. This would help reduce costs associated with transportation to distant facilities.
- The CIWMB should focus on finding new markets for recycled computers and other electronic product components.
- The original equipment manufacturers should be encouraged to design products for longer life span, easy upgradability, and recyclability.

In order to support all the above activities, a suitable funding mechanism should exist. An advance disposal fee on the sale of every computer is required. Currently, discussions on advance disposal fee collection are in progress at both state and national levels. A resolution for uniform fee collection that includes out-of-state and internet sales is required. This would facilitate uniformity in the funding mechanism and enable the state and local agencies to develop and implement programs for managing obsolete computers.

Since problems related to obsolete computers are growing, it is essential to have a regulatory system in place to address the problem. Even though this report identifies key elements and recommends a suitable model for handling obsolete computers in San Jose, the model may be extended to include other types of waste electrical and electronic products. Implementation of a model similar to the European model, with modifications to suit the local conditions, may also be appropriate. As identified in this report, there are

many key players involved in the lifecycle of a product. Active participation by a multitude of agencies, organizations, and the public in waste management is required for the system to work effectively.

CHAPTER I - INTRODUCTION

In recent years, there has been increased concern about the environmental effects related to the disposal of obsolete electronic products. The disposal of old computers has gained significant importance mainly due to the large volume generated and the presence of toxic constituents. Rapid advancements in technology have resulted in a reduction of the average lifespan of computers. On average, the useful life of computers has been reduced to three to four years (NSC, 1999). While the number of obsolete computers has been rapidly increasing, the level of recycling activities has been comparatively low. In 1998, only 2.3 million desktop central processing units (CPU) (out of 20.6 million obsolete CPUs) were recycled (NSC, 1999). During the same year, only 1.5 million out of 15.8 million obsolete computer monitors in the United States (U.S.) were recycled (NSC, 1999). Compared to the recycling rate of other key household solid wastes *e.g.*, beverage cans, bottles and newsprint, which have maintained an average recycling capacity of more than 50 percent, the computer recycling rate (<15 percent) is very low (USEPA, 1999b). There are many reasons for a lower recycling rate. These include:

- Lack of attractive market for recycled computer components *e.g.*, leaded glass
- Difficulty in sorting and recycling certain computer components such as plastics due to inconsistency in the type of plastics used
- Lack of public awareness regarding recycling opportunities
- Lack of financial assurance to ensure adequate funds for recycling opportunities

According to Mathews *et al.*, (1997), approximately 45 percent of old computers are stockpiled and 5 percent are sent to landfills. Currently, some discarded electronic products are disposed in the landfills (Doyle, S., Personal Communication, November 2001). The major problems associated with landfill disposal of obsolete computers are:

- Requirement of large area
- Release of toxic constituents into the environment
- Loss of valuable components such as precious and base metals

Electronics waste accounts for 2 to 5 percent of the total municipal solid waste generated in the United States and is expected to grow dramatically in the next few years (GFF, 2001). By the year 2005, an estimated 63.4 million obsolete CPUs will be generated in the United States alone (NSC, 1999).

To address the problem related to computer disposal, especially computer monitors, many regulatory agencies, original equipment manufacturers (OEM), and non-profit organizations have conducted studies and made recommendations. The Department of Toxic Substances Control (DTSC), which is the state agency that oversees hazardous waste handling in California, passed emergency regulations in August 2001 categorizing computer monitors as "Universal Waste." The California Integrated Waste Management Board (CIWMB), which regulates solid waste management in the state, has conducted a survey to determine statewide obsolete computer generation and to assess the existing recycling capacity. According to this study, there exists a gap in the generation and recycling capacities in the state (CIWMB, 2001b). The Santa Clara County Department of Environmental Services has made a decision not to cover computer monitors under the

household hazardous waste program (Doyle, S., Personal Communication, November 2001). The Department of Environmental Services, San Jose has now developed a program for handling Cathode Ray Tubes (CRTs) in the City. A Request for Proposal (RFP) was issued by the City last fall seeking contractors for collecting CRTs (Ciprian, J., Personal Comm., 2001). Currently, the City is collecting computer monitors and television sets from residential homes through “Neighborhood Clean-up Program” and “Recycle Plus,” which are prepared for shipment at contracted solid waste facilities, and shipped to NxtCycle for recycling (Dunn, C., Personal Communication, May 2002).

This study focused on gathering information on obsolete computer generation and computer usage pattern in San Jose, California, determining the effectiveness of existing household waste models, and reviewing the applicable regulations and policies on electronic waste. In this study, significant elements of a model are identified and a model to address obsolete computer handling in San Jose is proposed.

CHAPTER II - DESKTOP COMPUTERS

In the late 1970's, personal computers (PCs) began to appear on the market; their usage slowly started to increase. The first and the most popular computer, Apple II, was introduced in 1977; it was followed by the IBM PC in 1981. Since then, many new models have been developed with the recent and the popular ones being the PC-286, PC-386, PC-486, Macintosh and the Intel Pentium series. Projections based on the National Safety Council survey indicate that in the year 2005 approximately 63.4 million PC, CPU's will become obsolete (NSC, 1999). Figure 1 summarizes the past, current and

Figure 1: Forecast of US PC, CPU Shipments and Recycling, 1997-2005 (NSC, 1999)

projected shipment, obsolete computer generation, and the recycle rates for the period 1997-2005 (NSC, 1999).

Material Composition

In general, computers consist of three main parts: a central processing unit (CPU), a monitor (also referred to as cathode ray tube (CRT)), and a keyboard. Each of these parts consists of various components such as a housing unit, switches, sockets, printed wiring boards, capacitors, resistors, batteries etc. Computers are mostly made of plastics, metals, and silica, with metals being the major material of construction (MCC, 1996). Appendix A provides detailed information on the composition of a typical desktop computer system. Figure 2 indicates the approximate percent composition of major materials that make-up a desktop computer.

Figure 2: Percent Composition of Major Materials in Computers (MCC, 1996)

A typical desktop computer is composed of 23 percent plastics, 25 percent silica (glass), and more than 45 percent metals and other elements such as antimony, bismuth, selenium, resin material, etc (MCC, 1996). The precious metals mainly, silver, gold, platinum, and palladium accounts for approximately 0.02 percent of the total mass of the computer. Table 1 presents the location of precious metals in electronic scrap in general (Setchfield, 1987). Precious metals are used in electronic components mainly for their properties such as ductility, hardness, and resistance against frictional wear, temperature, and corrosion (Hack, 1987).

Table 1: Location of Precious Metals in Electronic Scrap (Setchfield, 1987)

Location	Physical Form
Edge Connectors	Plated gold (or platinum) on copper pins or copper laminate
Integrated Circuits	Fine gold bonding wires. Plating (gold on nickel/iron)
Transistors	Plated gold on nickel/ iron
Ceramics	Fired pastes, mixed metals
Relays	Solid metal, plate or alloy
M.L.C.'s	Fired multilayers normally silver/ palladium

Computer Recycling

Recycling is an important component in the End-of-Life (E-O-L) management of a product. Recycling is important because it facilitates the recovery of materials that could be used as raw materials for making similar new products or other secondary

products. Recycling also helps in conserving valuable natural resources. Closed loop recycling is the preferable recycling option, where all the components or materials in the waste product are recycled back into a new product. Unfortunately, it is not possible to recycle computers in a closed loop manner, because it is either practically impossible or economically unattractive. For instance, the leaded glass in CRTs can be reused in the manufacture of new CRT glass only up to a certain percentage because of the quality issues (Monchamp *et. al.*, 2001). In such cases, new markets or new uses for a component will have to be explored. Approximately, 40 percent by weight of a personal computer (mainly single-material components) is readily recyclable (Selvaduray, 2000). Computers consist of a variety of materials and the recyclability of each of these materials varies. Figure 3 shows the recyclability of some of the major materials found in computers.

Figure 3: Details of the Recyclable Materials in Computers (MCC, 1996)

The recyclability of some of the major materials used in a desktop computer is discussed below.

Plastics

The common types of plastics used in computer casings are polyvinyl chloride (PVC), polycarbonate (PC), and acrylonitrile butadiene styreneplastic (ABS) blend (Gutowski *et al.*, 2001). Some plastic is also used in other components, such as printed wiring boards (PWB), keyboards, and CRTs. Currently, only 20 to 25 percent of the computer plastics is recycled (MCC, 1996). In the past, the disposal option for computer plastics was limited to landfill disposal, but efforts of OEMs, plastics and resin manufacturers, and other organizations has resulted in the development of limited open and closed loop plastic recycling (Ching *et al.*, 1996). Some of the challenges in plastic recycling include difficulty in the material identification and disassembly process, identification of new end uses for mixed and contaminated plastics, and development of more efficient recovery processes. There has been some success related to plastic recycling. IBM recycled 500,000 pounds of PVC in a closed loop system over two years period (Ching *et al.*, 1996). In yet another study conducted by IBM, use of magnesium housing as a substitute for plastic housing was studied. This study found that the cost of using recycled materials was much lower than the use of virgin material (Higuchi and Nakajima, 1996).

Printed Wiring Boards (PWB) or Printed Circuit Boards (PCB)

PWBs are used in the CPUs, monitors, and keyboards. The PWBs are fabricated to have multilayers, usually four or more, and are commonly constructed with epoxy-

glass and copper, with connectivity between layers (Gutowski *et al.*, 2001). The board-level assembled PWB will have integrated circuit (IC) chips, resistors, capacitors, and batteries composed of tin, copper, ceramic, stainless steel, plastics etc. These materials, except batteries which have to be separated, can be shredded and melted in smelters to recover base and precious metals.

Brominated flame retardants (BFRs) are incorporated into PWBs and housing components mainly to prevent fire hazard (Gutowski *et al.*, 2001). Figure 4 shows the existing recycling options and current situation of waste plastics containing BFR in Europe.

Figure 4: Current Situation of Waste BFR Plastic in Europe (BSEF, 2000)

Cathode Ray Tubes

Monitors are electronic devices that provide a visual display via the CRT. Significant amounts of lead are used in computer monitors. Figure 5 shows the important parts of a CRT. The total CRT contains about 8 percent lead by weight from the funnel,

neck and frit (Smith *et al.*, 1996). Lead is used mainly to protect the user from the adverse effects of radiation, mainly x-rays. CRTs including televisions and computer monitors, do not contain pure lead, but one fourth of the funnel glass contains 22-25 percent of lead oxide (MOEA, 2001). The most significant lead in CRTs is in the glue, or frit, that holds together the funnel and the face panel of color monitors (MOEA, 2001). Furthermore, the concentration of lead is found to vary based on the type of CRT

(monochrome or color) and on the location (frit, panel or funnel). Appendix B lists the lead concentrations found in some of the leading computers and televisions on the market along with corresponding tube makers.

Figure 5: Cathode Ray Tube (MOEA, 2001)

The lead content in color CRTs is higher than in monochrome CRTs (MCC, 1996). Table 2 indicates the breakdown of lead concentration in CRTs.

Table 2: Lead Content in CRT Glass Components (MCC, 1996)

Glass	Color CRT	Monochrome CRT
Panel	0-3%	0-3%
Funnel	24%	4%
Neck	30%	30%
Frit	70%	N/A

Currently, few options exist for recycling CRTs. The EPA, under its Common Sense Initiative Program, has proposed glass-to-glass recycling rule to facilitate a closed loop recycling system (Monchamp *et al.*, 2001). At present, there are three major companies in the U.S. that have a glass to glass recycling process; these are NxtCycle in Arizona and Utah, Envirocycle in Pennsylvania, and Dlubak Glass Company in Ohio (MFF, 2001). The glass to glass recycling process includes disassembly, material segregation, release of vacuum from the CRT, X-ray analysis and removal of phosphorescent coating, and preparation of uniform cullet (Menad, 1999). A detailed flowchart of this process is provided in Appendix C. Other alternatives include use of CRT glass as a raw material (flux) in smelters and lead recovery in lead smelters.

Even though various opportunities exist for recycling obsolete computers, no effective model has been developed for managing computers generated from the residential sector. Some models have been developed and implemented by the CIWMB and local agencies for managing household wastes such as used oil and waste tire. Because of the similarities in the waste generation, used oil and waste tire models have been selected for review and potential application to this study. The details of these two models and the regulatory structure for managing solid waste in general, used oil, and waste tires are discussed in the next chapter.

CHAPTER III - EXISTING REGULATIONS AND PROGRAMS ON SOLID WASTE MANAGEMENT IN CALIFORNIA

The California Integrated Waste Management Board (CIWMB), which is one of the six agencies of the California Environment Protection Agency (Cal EPA), is responsible for safeguarding public health and safety through management of solid waste generated in the state. Two important acts of legislation, Assembly Bill 939 (AB 939), sponsored by then assemblyman Byron Sher, and Senate Bill 1322 (SB 1322) were passed into law in 1989. These bills brought significant changes to the management of solid waste in the state. The above two pieces of legislation were the main reason for the enactment of the “California Integrated Waste Management Act of 1989”. This law acts as a guiding document for CIWMB (also referred to as the Board) and local agencies (cities and counties) which implement programs on waste reduction, recycling and environmentally safe transformation, and land disposal of solid waste. The CIWMB plays a lead role in promoting activities for achieving waste diversion goals and developing markets for recycled products. The local agencies enforce the California Integrated Waste Management Act by means of permitting and inspections.

With the passing of AB 939 into law, significant changes took place in the history of solid waste management in California (CIWMB, 2001a). The following list presents some of the significant changes:

- Replaced Solid Waste Management Board with the CIWMB at the state level and the Integrated Waste Management Plan with the County Solid Waste Management Plan at the county level.

- Established waste diversion goals of 25 percent by January 1, 1995 and 50 percent by January 1, 2000.
- Established a comprehensive statewide system on permitting, inspections, and enforcement of solid waste facilities.
- Authorized local agencies to generate revenue for implementing solid waste management plans by imposing fees on the generation of solid waste.

SB 1322 made several legislative declarations. According to these legislative declarations, the Board was directed to implement state programs to:

- Increase procurement of recycled products,
- Change manufacturing and consumption habits,
- Conduct research and development to improve the manufacturing process,
- Improve the market for recycled products, and
- Create public awareness.

Management of Solid Waste Generation from the Household Sector

Various types of wastes, both hazardous and non-hazardous, are generated from the household sector. Approximately 66 million tons of solid waste are generated in California annually, of which 42 percent is recycled (CIWMB, 1999b). The household sector contributes 38.1 percent of the total waste generation, while the commercial and self haul sectors contribute 48.8 percent and 13.1 percent, respectively (CIWMB, 1999b). Information on material distribution in the residential waste stream is provided in Table 3.

Table 3: Details of Material Distribution in the Residential Waste Stream
(CIWMB, 1999b)

Material Class	Percent Distribution
Construction & Demolition	4.48
Glass	4.04
Household Hazardous Waste	0.32
Metal	4.63
Mixed Residue	4.00
Other Organic	45.00
Paper	27.45
Plastics	8.85
Special	1.24

The CIWMB, in partnership with the Local Enforcing Agencies (LEA), industries, and the general public, implements several programs for managing solid waste. Two comprehensive programs developed and implemented by the Board and the LEAs include models on used oil and waste tires. These models have been chosen for the following reasons:

- Similarity in the rate of waste generation, which ranges from 1 to 5 years.
- Similarity in the quantity (large quantity) and weight (waste tire and obsolete computer qualify as bulky items).
- Understanding the regulatory structure, funding sources etc, which could be

applied to obsolete computers.

A detailed discussion of these models is provided in the following sections.

Used Oil Model

The used oil model deals with industrial and lubricating oils. A detailed description of industrial and lubricating oil consumption and recycling patterns, regulatory highlights, economics involved, and important features of the used oil model is provided in this section.

Industrial and Lubricating Oil Sales, Used Oil Generation and Recycling

During the year 2000, approximately 304.8 million gallons of industrial and lubricating oil were sold and 88.5 million gallons of the used oil were recycled in California (CIWMB, 2000). Figure 6 shows the oil sales and recycling rate for the year 2000. According to the CIWMB (2000), approximately 149.2 million gallons of

Figure 6: Details on 2000 Oil Sales and Recycle Rate in California (CIWMB, 2000)

lubricating oil were sold in the year 2000, of which 75 percent was used in automobiles by the private and public sectors. Assuming a 35 percent loss during driving, the Board estimated that approximately 73 million gallons/yr of used lubricating oil were generated in the state (CIWMB, 2000). In the above mentioned report, the Board states that 22 million gallons of lubricating oil were generated by the public through self-oil change system, of which 8 million gallons were recycled during the same year.

Regulations

The California Oil Recycling Enhancement Act of 1991 applies to uncontaminated used oil. This law is codified under Title 14 of the California Code of Regulations (CCR). A brief description of the important provisions and requirements of this regulation is provided below:

- Oil manufacturers have to pay \$0.16 oil fee for every gallon of lubricating oil sold or transferred in the state. The oil manufacturers have to maintain records and submit reports to the Board on both lubricating and industrial oil sales.
- Used oil transporters are required to register with the Department of Toxic Substances Control as hazardous waste haulers and submit reports regularly to the Board on the total quantity of industrial and lubricating oil collected and transported.
- Certified collection centers are required to obtain certification from the Board once every two years and comply with other regulatory requirements such as acceptance of used oil only in regulated quantities (20 gal/person/day maximum), storage of used oil in approved quantities, and advertising in local media to educate the public.
- Used oil recycling facilities are required to obtain certification/recertification from the

Board and operate the facility in compliance with the stipulated standards.

Under the used oil program, certified collection centers are not required to accept contaminated used oil. They may direct the person to the nearest county's hazardous waste collection center or to a facility that accepts contaminated waste. Contaminated used oil is categorized as a hazardous waste and is subject to the regulations under Title 22 of California Code of Regulations. The Department of Toxic Substances Control is the agency that oversees contaminated used oil management.

Economics

The California Oil Recycling Enhancement Act allows the collection of \$0.16/gallon oil fee only on the lubricating oil sold in the state. Based on the CIWMB's used oil sales data discussed in the previous section, the revenue generated for the year 2000 amounts to approximately 23.87 million dollars. The revenue generated through the collection of the oil fee is used for various purposes. Incentive at a rate of \$0.16/ gallon is granted to the industries, curbside collection programs, certified oil collection centers, and electric utilities for recycling used lubricating oil. The local agencies are awarded block grants at a rate of 43 cents per capita (CIWMB, 2002a). A block grant is awarded on a non-competition basis to primarily assist local agencies in their enforcement efforts. The Board refers to the census data maintained by Department of Finances for awarding this grant. For example, the population of San Jose as of January 1, 2000 is 923, 600 (DoF, 2001). Based on the above data, the City of San Jose is eligible for a grant of \$397,148. The Board also provides an opportunity grant up to \$300,000 to local agencies that submit a proposal for expanding the existing collection programs and/or educating

the public, especially of the underserved population (CIWMB, 2002b). The Board also sets aside a substantial amount of funding for non-profit grants and awards to non-profit organizations that conduct studies, collection programs etc. Approximately three million dollars is awarded once every two years to non-profit organizations (CIWMB, 2002c).

Features of Used Oil Model

The used oil model implemented under the California Oil Recycling Enhancement Act, is summarized in Figure 7. The important features of the used oil model are summarized below.

- Board certified 2,700 convenient collection centers facilitate easy collection of used oil from the residential sector.
- Incentive offered at a rate of \$0.16/ gallon encourages residents to recycle used oil.
- Re-refined oil used in the automobiles facilitate closing the recycling loop.
- Markets, such as use of lubricating oil as fuel oil and in asphalt, further promote the recycling activities.
- Good regulatory system to oversee used oil management practices in the state is established.
- Grants provided for local governments, non-profit organizations, and for research and demonstration projects help support and improve used oil management activities.

Figure 7: Used Oil Model

Another model that has been implemented and that may be applicable in part, to a computer recycle model is the waste tire model. This model is discussed in detail in the following section.

Waste Tire Model

A waste tire is categorized by the Board as a special type of waste (CIWMB, 1999b). A description of the sales, waste tire generation and recycling rate; features of the waste tire model; applicable regulations; and economics involved in implementing the model is provided below.

Waste Tire Generation and Recycling Rate

California deals with approximately 31 million waste tires that are generated annually (CIWMB, 2001c). Waste tire generation has been increasing steadily and so has the recycling rate. During 1999-2000, the waste generation increased by 48 percent and the waste tire recycling rate jumped from 34.1 to 72.5 percent (CIWMB, 2001c). Various uses of recycled waste tires have been identified. These include crumb rubber production; alternate fuel source in cement kiln; and applications in civil engineering projects such as rubberized asphalt concrete, play ground cover etc. Figure 8 provides a break down of the various alternative uses of waste tires.

Figure 8: Alternative Uses of Reused Waste Tires (CIWMB, 2001c)

Figure 9 shows the details of the current waste tire model.

Figure 9: Waste Tire Model

Regulations

Waste tire management is overseen by the Board under the California Waste Tire Recycling Act of 1989. The Act was introduced through Assembly Bill 1843 (AB 1843) with an aim to find an alternative for land disposal of waste tires. The Act requires any person who stores, stockpiles, accumulates, or discards waste tires to obtain a permit from the Board. The Act provides permit exclusions to facilities that carry out the following types of activities:

- Facilities that do not handle more than 500 waste tires
- Solid waste facilities and transfer stations handling fewer than 150 tires/day
- Auto dismantlers with fewer than 1,500 waste tires on their property and tire retreaders with fewer than 3,000 waste tires
- Cement kilns that store up to one month supply of tires

Current regulation requires any person transporting 10 or more tires to possess a tire hauler registration, which has to be renewed on an annual basis. When registering for the first time, waste tire haulers are required to submit a surety bond for \$10,000.

Economics

To support the implementation of a waste tire program, a disposal fee of \$1.00 is charged on the sale of each new tire. The Board allocates various types of grants for enforcement, tire recycling, and market development projects. Since its inception, the waste tire enforcement grant has awarded funds up to \$1.3 million dollars to local agencies for enforcement of regulations to avoid illegal stockpiling (CIWMB, 2001c).

The Board has estimated that \$40 million dollars annual revenue is required to meet the goals of the waste tire program (CIWMB, 1999a).

Features of Waste Tire Model

Under the waste tire program, the Board has so far identified 626 active waste tire facilities; has registered approximately 800 waste tire haulers and has cleaned up approximately 5.8 million waste tires since 1994 (CIWMB 2001c).

The main features of this model are:

- Various alternatives for recycled waste tires are identified.
- Fewer regulatory requirements are imposed on minor waste tire handling facilities to increase the recycle rate.
- Grants are awarded for tire enforcement, technology commercialization, public education etc.
- Stricter regulatory control over major tire handling facilities is emphasized.

Even though no model similar to either used oil or waste tire exists for computers, many regulations and policies have been developed by various agencies. These regulations and policies are discussed in the next chapter.

CHAPTER IV - REGULATIONS AND POLICIES

Many laws, regulations, and policies have been developed to address the global problem of a growing waste stream of electronic products. Some of the European countries already have administrative provision, policy, or regulation on the management of waste electrical and electronic equipment (WEEE). For example, the government of Switzerland adopted an ordinance which came into effect in July 1998 that requires retailers, manufacturers, and importers to take back waste equipment free of charge and treat it in an environmentally tolerable manner (South, 2000). Similarly, in 1998 the government of Denmark passed a regulation requiring municipalities to start a separate collection system for WEEE (South, 2000). The European Commission has recently adopted a proposal for a directive on WEEE and on the restriction of certain hazardous substances in electrical and electronic equipment (EC, 2000). In the United States, several policies and programs have been adopted by the Environmental Protection Agency (EPA) to address E-O-L electronic products related matters. Some of these programs are: the Common Sense Initiative (CSI), Extended Product Responsibility (EPR), Design for the Environment (DfE), Environmentally Preferable Purchasing (EPP), and Waste Wise Program (USEPA, 2001). These programs are briefly discussed below.

Common Sense Initiative

The United States Environmental Protection Agency (USEPA) established the Common Sense Initiative (CSI), a formal advisory council, in 1984 to bring together

government, industry, and non-profit organizations. The purpose of this program is to examine the impact of government environment regulations on six industrial sectors, including the computer and electronics sector. Under this program, the USEPA has proposed a nationwide rule on CRTs and has also supported pilot studies on residential waste electronic products collection program.

Extended Product Responsibility

This concept is also known as 'Product Stewardship' and calls for a shared responsibility approach to pollution prevention. In this approach, key players in the chain of commerce take responsibility, within their sphere of influence and capabilities, for reducing environmental impacts throughout the product life cycle *i.e.*, from product design and manufacturing to use and disposal.

Design for the Environment (DfE)

This program was initiated by the USEPA to help businesses incorporate environmental considerations into the design and redesign of products and processes through voluntary partnerships with industry. This step is taken voluntarily by environmentally conscious industries in an effort to produce products that have less environmental impact. DfE goals are achieved through continuous research and development activities.

Environmentally Preferable Purchasing (EPP)

The EPP is a set of guidelines used by federal government agencies to help determine the implication of their purchases on the environment. The USEPA provides the guidelines to federal agencies on how to minimize adverse environmental impacts of

its purchases.

Waste Wise Program

EPA's Waste Wise Program is a voluntary program aimed at reducing the generation of non-hazardous solid waste. Electronic products are targeted under this program, which promotes waste reduction activities such as donating used equipment to schools, which corporations can claim as a tax deduction; purchasing refurbished equipment instead of new equipment; and leasing equipment rather than buying etc., all of which qualify as waste reduction activities.

Currently, federal statutory authority to control environmental impacts of product systems is limited. Hence, the USEPA encourages voluntary initiatives and partnership among the industry, states, local governments, and non-profit organizations to address the problem related to life-cycle impacts of several product groups, including electronic products (USEPA, 2001).

The two most popular concepts developed to address the waste electronic equipment problem are electronic product takeback and advance disposal fee. A description of these two concepts is provided below.

Electronic Takeback

This concept, which is popular and is mandatory in some countries, requires the producers to takeback certain types of waste electronic equipment when it has reached the end of its product life. For example, Norway's takeback regulation, which came into effect in 1999, makes producers responsible for collection, transport and environmentally safe treatment of wide range of products (South, 2000).

Advance Disposal Fee

An advance disposal fee is the fee collected at the time of sale of a product. The fee is used to cover the cost of management of products that have reached the end of life. In California, a fee on lubricating oil and tires is collected to cover the cost of handling and treatment when the product becomes a waste.

Major Federal and State Regulations

The Resource Conservation and Recovery Act (RCRA), an amendment to the Solid Waste Disposal Act, was passed into law in 1976. The RCRA regulates the management of solid waste and hazardous waste in the United States. The two major related provisions are:

- Subtitle C: Hazardous Waste Program
- Subtitle D: Solid Waste Program

The USEPA has been authorized by the Congress to develop regulations to implement the RCRA statute. The USEPA, while reserving some authority, has delegated the power to oversee waste management to those states that have a program equivalent to or more stringent than the federal program. In California, the Department of Toxic Substances Control regulates the management of hazardous waste and the California Integrated Waste Management Board (CIWMB) oversees the management of solid waste. The federal regulations on “Protection of Environment” are codified in Title 40 Code of Federal Regulations (40 CFR) and the California State regulations on solid waste and hazardous wastes are codified in Title 14 and Title 22 of the California Code of

Regulations (CCR) respectively (H&SC § 25245 and 25246 and PSC §40502, 40002, 43020 and 43021).

In order to determine if a material is regulated and what regulations apply, sequential classification of a material as a waste, then as a solid waste and finally as a hazardous waste is required. In general, a waste is any discarded material in any form (solid, semi-solid, liquid or gaseous) except those excluded under special provisions of the law. The definition of solid waste under the RCRA serves as a first step in waste material identification. The regulatory definition of solid waste encompasses (1) materials that are abandoned; (2) materials that are recycled; (3) materials that are inherently waste like; and (4) waste military munitions (Section 261.2(a) of 40 CFR).

Old or discarded computers that are of no further use are a waste and would have to be managed according to the regulations. To determine the applicable regulations for handling a waste computer, a more detailed review of the regulations is required. The following determinations are made based on review of federal regulations and state regulations. A different set of regulations applies to various components of a computer as discussed in the following sections.

Scrap Metal and Scrap Plastics:

The disassembled solid plastic and metal computer components such as metal casing or plastic housing, keyboards casings etc. can be categorized as scrap metal and solid waste respectively, unless they are contaminated with substances that meet the legal definition of hazardous waste as specified in Title 22 CCR section 66260.10.

Computer Monitors or Cathode Ray Tubes (CRTs):

Cathode Ray Tube materials are categorized as Universal Waste (22 CCR §66273.1); computer monitors fall under this legal definition due to lead content. Under federal and state regulations, the regulated level for lead is 5 mg/L and any waste that has a concentration of 5 mg/L or more is categorized as a toxic hazardous waste as determined by the Toxicity Concentration Leaching Procedure (TCLP). California uses two other criteria for toxicity identification of wastes. These are the Total Threshold Limit Concentration (TTLC) and the Soluble Threshold Limit Concentration (STLC) as determined by Waste Extraction Treatment (WET) method. The TTLC and STLC standards for lead are 1000 mg/kg and 5 mg/l respectively. A study conducted by the Florida Center for Solid and Hazardous Waste Management on the lead leachability of CRTs indicated that out of 26 computer monitors analyzed, 17 of them failed the TCLP test (Townsend, 1999). This study also concluded that an average lead concentration of 19.3 mg/L could be found in leachate from CRT glass.

Even though CRTs meet the definition of hazardous waste, they fall under a separate waste category called Universal Waste. The reason is that some hazardous wastes are more frequently generated in a wide variety of settings such as household, commercial, and industrial settings. The huge volume and size of the waste stream poses difficulties in regulatory program implementation. In order to streamline the system and to increase the efficiency of collection and recycling mechanisms, regulations are relaxed for such wastes. The important features of the emergency regulation on CRTs are provided below:

- Generators handling more than five CRTs are required to submit notification to the DTSC and respective local agency.
- Electronic product generators who generate a total of five or less CRTs per year are exempt from this regulation.
- CRT material handlers exporting CRTs need to obtain prior approval from the USEPA.
- CRT material handlers importing CRTs are subject to transporter, handler and destination facility requirements in the United States.
- CRT material handlers are allowed to ship materials only to a lead smelter or a glass-to-glass recycling facility.
- CRT material handlers who treat or recycle CRTs have to submit notification to DTSC, are required to prepare and maintain facility closure cost estimate and demonstrate financial assurance for closure in the form of insurance or bonds.

Batteries

Batteries, which include consumer type batteries such as metal hydride, nickel-cadmium, lithium, small sealed lead acid etc., fall under the Universal Waste category, similar to CRTs. Under 22 CCR Chapter 23, a separate set of regulations is laid out for battery management.

Printed Circuit Boards (PCBs)

The federal regulations specifically exempt printed circuit boards from the solid waste classification under 40 CFR Part 261.4 if they are managed properly and are free of batteries, mercury relays and mercury switches. The state regulation under section 25143.2 of H&S Code exempts materials from the hazardous waste category and categorizes them as recyclable materials if they are:

- Used or reused as an ingredient to make a product,
- Used or reused as an effective substitute to commercial products, or
- Returned to original process as a substitute for raw material without first being reclaimed.

To be classified as an excluded recyclable material, certain restrictions apply based on the method of processing, as detailed in the regulations.

California Senate Bills on CRT Regulation

Currently, two senate bills are proposed on CRTs and electronic waste. These are SB1526 proposed by Senator Byron Sher and SB1526 proposed by Senator Gloria Romero. According to the daily legislative updates posted on Office of Legislative Counsel web site, as of June 19, 2002, SB1526 has been placed on inactive file (OLC, 2002). The status of SB 1522, as of June 18, 2002, posted on the same web site indicate that the hearing was cancelled at the request of the author.

Local Agencies Response to CRT Regulation

As a result of the passing of emergency regulations related to CRTs, local agencies are faced with the challenge of having to develop a special program for managing CRTs generated from the household sector and small businesses. In order to obtain information on the current status of such programs in San Jose, two local agencies (Santa Clara County Department of Environmental Health and City of San Jose's Department of Environmental Services) were contacted. In addition to obtaining information on CRTs, the functioning and effectiveness of the existing models on certain types of household waste were also discussed. The details of the interview with the personnel of these two agencies are summarized below.

Interview # 1

Interview with: Ms. Sharon Dowell, Hazardous Materials Program Manager
Santa Clara County Department of Environmental Health

Date and Time: November 26, 2001 from 10.00 a.m. to 11.30 a.m.

Interview # 2

Interview with: Mr. Jordan Ciprian, Associate Environmental Services Specialist
Dept. of Environmental Services, City of San Jose

Date and Time: November 27, 2001 from 10.30 a.m. to 11.30 a.m.

The following information was obtained based on the above two interviews.

- The Santa Clara County Department of Environmental Health has made a decision

not to take CRTs under the household hazardous waste program.

- The County views lack of space for collection as one of the major hindrances to CRT collection. In addition, manpower and finances for development and implementation of a separate program for electronic waste are also considered as limitations.
- The City of San Jose is currently collecting CRTs under the existing Recycle Plus program to prevent illegal dumping. The Recycle Plus program is meant to collect large items from single family homes. A fee of \$19 is charged for collecting up to three items. An extra fee will be charged for more than 3 items.
- In order to comply with the recent regulation on CRTs passed by the DTSC, a Request for Proposal (RFP) has been called from contractors for alternative methods of managing CRTs other than landfill.
- The Extended Product Responsibility approach for managing waste electronic product from civic amenities in San Jose is under consideration.
- The City is planning to develop a more comprehensive collection program for electronic waste.

In order to obtain information on the current status of the RFP, the Department of Environmental Services, San Jose was again contacted. An excerpt of the telephone conversation is provided below.

Interview # 3

Interview with: Ms. Cynthia Dunn, Environmental Services Specialist.
Dept. of Environmental Services, City of San Jose

Date and Time: May 24, 2002 from 1.30 p.m. to 1.45 p.m.

Ms. Dunn stated that the RFP has been finalized and the City currently has two programs on CRT material handling. A description of these two programs is provided below.

1. Neighborhood Clean-up Program

The City implements this program in coordination with Department of Planning, Building and Code Enforcement. The City residential solid waste haulers will collect large items including CRTs. The CRTs are taken to waste haulers facility where they will be prepared for shipment to NxtCycle, a glass-to-glass recycling facility. The City has a contract with Philip Services Corp. for transportation of CRTs from San Jose to NxtCycle. The Department of Planning, Building and Code Enforcement will be responsible for a public outreach program including economics related to CRT management. No fee will be charged to the residents dropping-off CRTs.

2. Recycle Plus Program

This is an existing program as mentioned in the previous section. The City has set aside approximately \$130,000 for transportation and treatment of CRTs under this program for the period Nov. 2001- Nov 2002.

International Policy on Electronic Waste

In the following section, policies adopted by the European Commission, Japan and Taiwan are discussed.

Management of WEEE in European Countries

The European Commission, which is comprised of 15 nations, is the first entity to develop stricter regulations of Waste Electrical and Electronic Equipment (WEEE). The European Commission has estimated that WEEE make up 2 to 3 percent of the municipal solid waste (MSW) stream. Generation of WEEE is expected to increase by 16-28 percent every five years (EC, 2000). As mentioned earlier, the European Commission recently adopted a proposal for a directive on WEEE (EC, 2000). The European Commission requires that all its member states enforce necessary laws, regulations and administrative provisions to comply with the directive by June 30, 2004. The important features of this proposal are summarized below:

- Producers should take responsibility for certain phases of waste management to achieve the highest level of collection.
- Producers should ensure that the users of WEEE are informed about their role in the system.
- For equipment that contains cathode ray tubes, producers shall achieve a minimum rate of recovery of 75 percent by weight of the appliance and component by 12/31/05.
- The hazardous constituents, mainly lead, cadmium, hexavalent chromium, mercury and two important brominated flame retardants ((polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE)) should be substituted with other materials by January 1, 2008. (Exemptions from this requirement are extended to some substances such as lead used for radiation protection etc.).
- A minimum collection rate of 4 kgs/person/year shall be achieved by 31 Dec 2005.

- The costs for collection, treatment and recovery, and environmentally sound disposal from users other than households should be covered by agreements between the producer and the user of the equipment at the time of purchase.
- Necessary systems should be set up so that final holders and distributors can return WEEE from private households free of charge.
- Distributors, when supplying a new product, should offer to takeback free of charge from private households, provided the equipment is free of contamination.
- Producers should take steps to achieve the highest level of collection rate by appropriately marking WEEE with a crossed out mark on the wheeled bin as shown in Figure 10.

Figure 10: Crossed Out Wheel Bin (South, 2000)

Management of WEEE in Taiwan

Taiwan's Waste Disposal Act of 1974 addresses the proper management of certain types of general wastes, industrial wastes, and hazardous industrial wastes. An amendment to this Act in March 1997, required producers to takeback end-of-life

computers, refrigerators, air conditioners, television sets and washing machines. The Taiwan Environmental Protection Agency has estimated that between June 1998 and July 1999, the number of computer related products recycled increased from 5,060 to 21,013 units (South, 2000). Currently, the producers have agreed to bear the fee burden instead of passing it along to the buyers of new equipment. The system is managed by a foundation of manufacturers, importers, retailers and recyclers; it is overseen by the Taiwan Environmental Protection Agency. Although a target recycle rate is not specified under the law, all collected waste units are required to be sent to a recycling facility.

Management of WEEE in Japan

Under Japan's Electrical Appliances Recycling Law, manufacturers and importers are required to take back television sets, refrigerators, air conditioners and washing machines (South, 2000). This law took effect in April 2001. Unlike the Taiwanese legislation, a targeted recycle rate is set for certain types of electronic appliances and a fee is charged to the end users returning waste units for recycling. A target of 50 percent for refrigerator and washing machines, 55 percent for television sets, and 60 percent for air conditioners is set under the Electrical Appliances Recycling Law (South 2000).

All of the above policies and regulations have been developed with an intention to minimize environmental impacts of the WEEE and to conserve valuable natural resources. The environmental concerns associated with the manufacturing processes and disposal of computers are discussed in the next chapter.

CHAPTER V - ENVIRONMENTAL CONCERNS

Historically, the electronics manufacturing industry and its products were considered to be clean, meaning having lesser impact on the environment compared to other type of industries. The computer and electronics industry contribute only 1.6 percent of the total hazardous waste generated in the U.S. (MCC, 1995). Nonetheless, computer manufacturing involves a whole spectrum of processes carried out at various levels and by various industries. Some of these processes such as wafer fabrication, chip level assembly, plating operations etc. generate gaseous, liquid and solid hazardous wastes that have significant impact on the environment. A wide variety of toxic chemicals are used during the manufacturing process. California has 34 percent of the total computer and electronic industry in the United States (USEPA, 1995). The USEPA under the Emergency Planning and Community Right to Know Act (EPCRA) requires certain types of industries to report their toxic releases to the environment and the transfer of chemicals to offsite facilities for treatment, disposal, recycling etc. The toxic releases from three important manufacturing processes: printed wiring boards, cathode ray tubes, and semiconductors, which are widely used in the computer and electronics industry are provided in Appendix D. Figure 11 shows that the toxic releases from the electronic industry are fairly low.

The average pollution load per facility is provided below (USEPA, 1995).

- Printed wiring boards: 289,929 lbs/yr

Figure 11: Summary of the Toxics Release Inventory (USEPA, 1995)

- Cathode ray tubes: 460,834 lbs/yr
- Semiconductor and other related devices: 186,923 lbs/yr

In obsolete computers, a variety of toxic constituents, both minor and major, can be found. Some of these toxic constituents have significant health effects. The U.S. Occupational Health and Safety Administration (OSHA), which is the agency responsible for the protection of health and safety of the workers, has set exposure limits for certain compounds that can cause health effects. The OSHA mainly uses the terminology Permissible Exposure Level (PEL) and Immediately Dangerous to Life and Health (IDLH) in setting the standards for employee exposures at workplaces. These terms are defined below:

Permissible Exposure Level (PEL)

The PEL is the standard to which a worker can be exposed for a period of 8hrs/day or 40hrs/week without any adverse health effects. If the worker's exposure is higher than the PEL, then the employer is required to install pollution control systems as a first line of defense. If pollution control system is either inadequate or not feasible to provide, then personal protective equipment, such as respirators should be provided to the workers.

Immediately Dangerous to Life and Property (IDLH)

The IDLH concentration is the airborne concentration of a substance that, upon exposure is likely to result in immediate death or have a permanent adverse health effects.

The recycling of obsolete computers involves processes such as shredding,

grinding, etc. These processes causes fine dust containing toxic constituents to become airborne, which when inhaled can cause many health effects as indicated in Table 4.

Fate of Toxic Constituents in Computers

Even though computers are made up of many metals and elements, it is possible to recover only a few metals in a practical and economical manner. Metals such as iron, used in large amounts in casings can be more easily recovered compared to other metals such as barium, indium, cobalt etc. that are present in very low quantities. The elements that are used in lesser concentrations may be released into the environment during the recovery process. Plastics, BFRs and lead are considered to be a concern because of the environmental impacts as well as low recyclability. The issues related to recycling these substances are discussed in the following section.

Waste plastics

Plastics in computers are a concern because currently no efficient system exists for waste plastic sorting and recycle/reuse. A large amount of computer plastic is either destroyed during the recovery process or disposed of in landfills. Many chemical additives that give plastic products desirable performance properties, such as flame retardants, heat stabilizers, and barrier resins, have negative environmental and human health effects. Trace amounts of some of the monomers, additives, and stabilizers which are toxic may migrate into the environment (Ecology Center, 1996).

Brominated Flame Retardant (BFR)

Approximately 2.5 percent of all electrical and electronic equipment uses

Table 4: Health Effects of Various Constituents used in Desktop Computers (NIOSH, 1997)

Constituent	Concentration Lbs./computer	IDLH mg/m ³	PEL mg/m ³	Use in Computer	Health Effects, Symptoms and Comments
Antimony	< 0.1	50	0.5	Diodes/ housing, CRT	Irritation of skin, eyes & throat; Nausea; Diarrhea; Anorexia.
Arsenic	< 0.1	5	0.01	Doping agents in transistor.	Potential carcinogen; Dermatitis; Respiratory Irritation
Barium	< 0.1	---	---	Vacuum tube, CRT.	Affects upper respiratory system; Gastroenteritis; Hypokalemia. (BaCl ₂ , BaNO ₃ have very low PEL's of 0.5 mg/m ³ & IDLH of 50 mg/m ³).
Beryllium	< 0.1	4	0.002	Thermal conductivity, Connectors.	Causes lung cancer and skin diseases etc.
Cadmium	< 0.1	9	1.0	Battery, blue-green phosphor emitter.	Causes pulmonary edema and mild anemia.
Chromium	< 0.1	250	0.005	Decorative, hardening.	Causes skin & eyes irritation; Lung fibrosis
Cobalt	< 0.1	20	0.1	Structural, magnetivity, CRT	Results in decreased pulmonary function. Symptoms include cough, wheezing etc.
Indium	< 0.1	---	0.1	Transistor, Rectifiers.	Pulmonary edema; Possible liver, kidney, heart, blood effects.
Lead	3.8	100	50*	Radiation shield in cathode ray tubes, soldering.	Known carcinogen; Affects central nervous system, kidney, blood etc.
Mercury	< 0.1	10	0.025	Batteries, switches, housing.	Affects central nervous system, kidney, liver etc.
Selenium	< 0.1	100	0.2	Rectifiers.	Acute toxicity observed in animals
Silver	< 0.1	10	0.01	Conductivity, connectors.	Gastrointestinal disturbance; Nasal septum

* - Unit in ug/m³

brominated flame retardants and accounts for 56 percent of the BFR market worldwide (BSEF, 2001). The major environmental risk associated with BFR plastics is the formation of dioxins and furans during combustion at lower temperatures (Gutowski *et al.*, 2000). Two types of brominated flame retardants (BFR) are commonly used in the electronics industries; these include polybrominated diphenyl oxides (PBDPO) and pentabromodiphenyl oxide (PeBDPO) (Gutowski *et al.*, 2000). Since the current practice of PWB recycling includes shredding and recovery of metals in smelters at a high temperature sufficient to destroy organic toxins, release of these compounds are not believed to occur. In a recent study, trace amounts of PDBE were found in a recycling workers' blood (BSEF, 2001).

Lead

Approximately 3 to 8 lbs of lead are used in CRTs and PWBs. During recovery of precious and base metals in smelters, lead may be lost due to low melting point. As reported in MCC (1996), approximately 5 percent of total lead used in the computer can be recycled. One of the reasons could be that lead is being lost as fumes or dust during smelting operation or as slag material, which is a waste product, generated in smelters.

The points that are researched and noted so far in the previous chapters serve as a foundation for assessing and evaluating the problems related to computer disposal in San Jose. To quantify the magnitude of the problem and to make further recommendations, a survey was conducted from August through November 2001. The results are discussed in chapter 6.

CHAPTER VI - METHODOLOGY AND ANALYSIS

Data on computer usage patterns, recycling capacity, and electronics store policies on computer takeback programs in San Jose, CA were gathered by means of phone survey and personal interviews. An attempt was also made to contact major software companies in San Jose to assess the level of obsolete computer generation. Since the software companies were not willing to participate in the survey, and as it was difficult to reach the concerned personnel at these companies, no information on computer usage could be gathered. A list of software companies in San Jose that were contacted is provided in Appendix E. The approach used to gather information on each of the above items is discussed in the following sections.

Population Size of San Jose

In this study, the data on the number of computers in use, obsolete computers, and future computer purchase were obtained by means of survey research. Since it is not practically feasible to interview all the residents of San Jose, a sample size was calculated to represent the whole of the San Jose population. The sample size for the survey was determined according to the guidelines given by Rea and Parker (1997). According to Rea and Parker (1997), a population size of 100,000 or greater may be considered as large and a population of less than 100,000 could be considered as small. Data available from the Department of Finances Census indicates that the population of San Jose is

923,600 (DoF, 2001). Therefore, the population of San Jose can be considered as large.

Sample Size Determination

Prior to determining the sample size required for the survey, two parameters were needed to be established. These were the Confidence Interval and the Level of Confidence. According to Rea and Parker (1997), these two statistics terms are defined as follows:

Confidence Interval: is a probabilistic estimate of the true population mean. It represents the margin of error, which indicates the level of sampling accuracy obtained. The confidence interval is typically set in the range of 3 to 5 percent, but never to exceed 10 percent.

Level of Confidence: is the degree of confidence associated with the accuracy of the measurements derived from sample data. In most cases, either a 95 percent or 99 percent level of confidence is chosen.

The following formula is generally used to calculate sample size for a large population:

$$\text{Sample Size 'n' = } \left(\frac{Z_{\alpha} (p)}{C_p} \right)^2 \dots\dots\dots(1)$$

Where,

Z_{α} = Z scores of various levels of confidence. For a 95 percent confidence level, this value is set at 1.96.

p = True proportion, which is an unknown factor, can be handled by setting a most conservative value that would result in the highest sample size. This occurs when the value is 0.5.

C_p = Confidence interval, the margin of error, in percent determines the level of sampling accuracy. For this study, ± 5 percent confidence interval was used.

According to Rea, researchers generally use 3 to 5 percent confidence interval for obtaining satisfactory results.

Substituting the above values in equation (1),

$$\begin{aligned} \text{Sample Size 'n'} &= \left(\frac{1.96 (0.5)}{0.05} \right)^2 \\ &= 384.16 \sim 385 \end{aligned}$$

Hence, a survey of 385 residents in San Jose would yield a result which is representative of the entire population.

Method of Sampling

A random sampling was conducted by choosing the residents arbitrarily. The survey was conducted by the following methods:

- Telephone survey
- In-person Survey
- E-mail Survey

The telephone survey was extensively used in this study, as the data collection was quicker and more economical. The questionnaire in Appendix F was used in the interview. The intention of the survey was to determine the computer usage trend among the residents of San Jose; hence simple and straightforward questions were asked. The following points were made clear to the residents who were being interviewed:

- Only desktop computer needs to be reported
- A desktop computer includes a monitor, a CPU and a keyboard
- A computer that is obsolete may be either in working or non-working condition, but is of no further use to the user

Approximately 500 residents had to be contacted to obtain 385 responses, since not all the residents contacted were willing to participate in the survey. Out of 385 contacts, 333 responses were obtained by phone interviews, 40 by personal interviews and the remaining 12 by e-mail. The survey results are enclosed in Appendix G.

Analysis of Survey Results

A research survey of 385 residents of San Jose revealed that in 2001, 537 desktop computers were in-use, 204 obsolete desktop computers were stockpiled, and 77 new desktop computers were planned to be purchased in the next 6 to 12 months. These values indicate that there are at least 1-2 computers being used per household, one obsolete computer per two households and purchase of one new computer per every five households. Table 5 shows the total number of computers that are currently being used.

Table 5: Data on Residential In-use Computers in the San Jose Survey

Description	Total Number
Number of households with no computers	55
Number of households with one computer	191
Number of households with two computers	93
Number of households with three computers	35
Number of households with four or more computers	11

Figure 12 shows the above data in terms of percentage in-use computers/household.

Figure 12: Percentage of In-use Computers/ Household

Table 6 shows the details of obsolete computers that are stored in residential homes in San Jose.

Table 6: Data on Residential Obsolete Computers in the San Jose Survey

Description	Total Number
Number of households with no obsolete computers	258
Number of households with one obsolete computers	84
Number of households with two obsolete computers	30
Number of households with three or more obsolete computers	13

Figure 13 shows the percentage of obsolete computers stored per household.

Figure 13: Percentage of Obsolete Computers/ Household

The total number of households in San Jose, as of January 2000 is 281,298 (DoF, 2002).

By extrapolating the data, the total number of computers in-use in San Jose is approximately 392,356 units. Similarly, the total number of obsolete computers in San Jose that are currently stored in residential homes is approximately 149,051 units.

According to the National Safety Council's forecast, the total number of obsolete

computer generation in the U.S. is expected to increase from 41.9 million units in 2001 to 63.4 million units in 2005 (NSC, 1999). This indicates that the obsolete computer generation will increase approximately 1.513 times nationwide. Using this forecast, an estimate of obsolete computer generation in San Jose can be made. By 2005, the total number of obsolete computers would then be 225,514. In addition, 77 residents expressed their intention to buy new desktop computers, while 12 residents were unsure about a purchase in the next 6-12 months. By extending these data, approximately 56,260 new computers will be purchased in the next 6-12 months.

According to The Washington Post (2001), home computer ownership in the United States is 59.4 percent. In this study, it was found that in 2001, the personal computer ownership in San Jose was 86 percent. Hence, the actual figures for San Jose will be much higher than the projected numbers.

Under the new program, the City of San Jose would collect CRTs from the household sector and ship them to NxtCycle for recycling. Based on NxtCycle's pricing structure, approximate cost for transportation and disposal of CRTs (monitors under 36") is \$7.6/unit (MFF, 2001). In order to dispose only the existing stockpiled computer monitors, the City would need approximately 1.132 million dollars.

A desktop computer comprising of desktop CPU, CRT computer monitor and computer peripherals weighs approximately 85 pounds (NSC, 1999). The total weight of obsolete units that will be generated by the end of 2005 would be approximately 19.2 million pounds. Therefore, some means of disposal of these obsolete units will be required.

Estimation of Recycling Capacity

A list of major electronics recycling companies identified by the Santa Clara County Department of Environmental Services and listed by other sources such as internet, yellow pages etc. was compiled. The companies were contacted by telephone to assess the nature of recycling activities, volume of computers handled, and service area covered. The details are provided in Appendix H. Due to confidentiality, individual capacities or volume processed is not provided in this report. The total volume of computers recycled was found to be approximately 10,000 units/month including 500-600 obsolete computers/month that were shipped to China. A further extensive survey of other small electronic repair shops and non-profit organizations that donate computers is required to establish the recycling capacity more accurately.

Major electronics stores were contacted to determine if a computer takeback program was offered as a part of the customer service. Out of twelve electronic stores identified in San Jose area, ten were contacted. The results indicate that only three stores accept old computers. A list of electronics stores contacted is provided in Appendix I.

Even though the City of San Jose has made provision to collect and recycle CRTs, a more comprehensive method needs to be established to address all issues related to obsolete computer handling. The next chapter discusses a model for obsolete computer management in the City.

CHAPTER VII - PROPOSED MODEL

Keeping the existing options in mind, a model for collection, transportation, reuse and recycling of obsolete computers is proposed. Figure 14 is a schematic of the proposed model, which shows the flow of materials from the original equipment manufacturers to the final reuse/disposal of the materials. A description of the terms used in the model is provided below:

Original Equipment Manufacturers (OEMs)

OEM refers to a person or entity that first sells a computer in the state. The equipment could be manufactured in the state or transferred from a neighboring state for sale.

Distributors/ Retailers

The term distributors or retailers refer to electronic hardware stores, either wholesale or retail stores, which sell equipment to consumers.

Consumer

Consumer is the person who purchases computer equipment.

Primary Processors

Companies that carry out the repair and refurbish work on obsolete computers for resale or perform limited demanufacturing are referred to as primary processors.

Secondary Processors

Companies that demanufacture and pre-process computers, for e.g., sorting, size reduction etc. for further recovery of materials are referred to as secondary processors.

The secondary processors may also function as primary processors.

Figure 14: Proposed Model for Collection, Reuse and Recycling Obsolete Computer

Roles and Responsibilities of Key Players

The roles of key players are summarized in Figure 15 and discussed below.

Figure 15: Role and Responsibilities of Key Players in E-O-L Product Management

Original Equipment Manufacturers

The product life cycle begins with the OEMs carrying out manufacturing process to produce a computer. The OEMs have greater control over product design and hence can improve its design. The key roles of OEMs are to:

- Assess and reduce environmental impacts during manufacturing process
- Design computers for longer lifespan and easy upgradability
- Design computers for maximum recyclability
- Substitute toxic compounds with less toxic materials
- Provide information to the consumers on their role in E-O-L product management

Distributors

Distributors act as a link between the producers and consumers and also between consumers and recyclers. Distributors can play an important role in the collection mechanism of E-O-L products. Maintenance of logs on computer sales and generation of obsolete computers can assist in better waste management. Distributors can also act as primary processors and increase the product life span by refurbishing and reselling old computers.

Recyclers:

Recyclers, both primary processors and secondary processors, play a key role in the E-O-L management of computers. Current practice has been to charge customers for recycling old computers. By charging an advance disposal fee at point of sale, funds can be generated and utilized for the purpose of recycling obsolete computers generated from the household sector.

Government Agencies

New policies/ regulations on E-O-L electronic product management should allow the collection of an advance disposal fee. While keeping a good oversight on the larger waste electronic product managing facilities, reasonable flexibility should be offered to small operations and collection centers. This is necessary, as increased regulatory burden will increase the cost of recycling. Since the present market for recycled electronic products is not very encouraging, programs should be developed to increase the market demand and at the same time encourage research and development activities by funding scientific projects. The government agencies can use motivators such as incentives to recyclers, awards to manufacturers for their effort in producing greener products etc. to boost such activities.

Collection Programs

The collection program is an important component of waste management. An elaborate discussion on options that exist for the collection of obsolete computers is provided below. The efficiency of a collection program depends on many factors and includes, but not limited to, local infrastructure, public perspective and motivation, computer usage and obsolete computer generation pattern etc. The existing waste collection programs show that no single collection program is considered to be the ideal method. Instead, a combination of collection programs, when implemented with proper planning will result in the increase of collection efficiency. The Department of Environmental Services, San Jose may consider the following options, in addition to

recycle plus and the proposed neighborhood clean-up program, for collecting obsolete computers from the household sector.

- **Curbside Collection Program:** The Santa Clara County Department of Environmental Health has a countywide program for curbside collection of garbage and recyclable materials. The curbside collection program is expensive compared to other types of collection programs (USEPA, 1999b). The City can reduce expenditure by 'piggy backing' on to an existing program. This type of collection program should be implemented in areas that are underserved and lack proper infrastructure.
- **Drop-off Events:** Drop-off events can be organized in partnership with recyclers. The local agencies can obtain an opportunity grant, if made available by CIWMB, to organize drop-off events to increase the collection efficiency. The location of the event can be planned based on the existing collection and recycling rate and by targeting specific areas. The drop-off events can be made more successful by,
 - Sorting for reusable and non-reusable equipment prior to waste consolidation
 - Diverting pre-sorted equipment to appropriate locations

The above two activities performed at the point of collection can considerably reduce cost and the man-hour requirement.

- **Point-of-Purchase:** Utilizing retail stores for WEEE collection and refurbishing used equipment will help reduce extra few steps in the E-O-L product management chain. Retailer's willingness and availability of space are the two important issues that need to be resolved prior to implementation of this program. The City can increase store participation by providing incentives to retailers.

Best Buy has taken a pro-active approach by offering consumers to recycle electronic products during recycle days at specific stores. A fee is charged for customer drop-offs. In addition, Best Buy plans to expand electronic recycling program in the next several years (Best Buy, 2001). The City can develop plans to partner with Best Buy and participate in the collection programs.

Existing Opportunities for Recycling

Since reuse is an important component of waste management, efforts on refurbishing and reusing computers should be the primary focus. Approximately 14 percent of the San Jose households do not own a computer. There may be many non-profit organizations and schools that are in need of computers. The computers that are in workable and easily upgradeable condition may be refurbished and reused. The City will need to develop a plan to divert reusable computers to primary processors.

Many primary and secondary processors are located within San Jose. By shipping obsolete computers directly to these facilities, the total transportation cost can be reduced considerably. Figure 16 represents some of the existing recycling options that City could use for addressing the problem related to computer disposal.

Economic Issues

While various options exist for recycling obsolete computers, the cost issue still remains unresolved. Some of the primary processors contacted during the survey indicated that they take old computers free of cost if the computer is in a reusable

Figure 16: Opportunities for Recycling Obsolete Computers

condition; others said they would charge a fee. Since obsolete computers need to be reused/ recycled and the City has expressed lack of funds (Foster, M. Personal Communication, May 28, 2002), a disposal fee should be collected at the point-of-sale.

Many pilot studies have been conducted to determine the cost of recycling. There is no uniformity in the data generated from these pilot studies; the estimates provided in them do not include all types of costs. For this reason, the costs associated with transportation and recycling are estimated in Table 7 using data available from Micro Metallica and NxtCycle. Micro Metallica, which has a facility in Roseville, California, processes waste electronic equipment; NxtCycle, located in Utah, recycles CRTs.

Table 7: Cost Associated with Transportation and Recycling of Obsolete Computers*
(Micro Metallica Corp**, 1998 and MFF, 2001)

Description		Cost/lb	Cost/unit
<u>CRTs</u>	Transportation to NxtCycle	\$0.053	\$1.6
	Recycling at NxtCycle	\$0.20	\$6.0
Other Components***	Transportation to Micro Metallica	\$0.009	\$0.5
	Recycling at Micro Metallica	\$0.28	\$15.4

Note: * Estimated cost does not include cost associated with collection, storage and preparation of obsolete computers for shipment

** Pricing information obtained directly from Micro Metallica Corp.

*** Other components include CPUs and keyboards

Various pilot studies have been conducted to analyze the municipal collection programs. Appendix J shows details of some of these programs. There were a lot of variations in the implementation of drop-off events and curbside collection programs. Since utilizing these data would not yield accurate numbers, an estimate of cost for the above mentioned programs was not made. Appendix K summarizes the pilot study conducted in San Francisco, Hayward and Oakland. The information in appendices J and K and with additional research and analysis, the total cost for implementing curbside and drop-off event models could be estimated.

Future Research Needs

In this study, an attempt was made to develop a working solution for handling obsolete computers in San Jose, CA. It may be more efficient to further evaluate and include all types of waste electronics under one program. Further research in identifying different types of electronic products, their usage patterns and waste generation, and opportunities for recycling is recommended. The basic structure of waste collection models may be applied to other types of electronic wastes. The CIWMB has a program for appliance recycling and is currently working on a separate model for CRTs. Instead of identifying each type of waste and developing a separate model for each waste, it would be appropriate to cover all types of electronic wastes under one program. The EC's WEEE directive covers different types of electronic products such as large and small home appliances, information technology equipment, medical equipment etc. It may be reasonable to adopt a program that is similar to the European model.

CHAPTER VIII - RECOMMENDATIONS

Obsolete computers are a growing problem. The City of San Jose needs to address this issue as soon as possible. Similar to waste tire and used oil models, a separate model for managing obsolete computers generated from the household sector is required. The recommendations for implementation of a model, which could also be extended to include other End-of-Life products, are summarized below.

- A model, consisting of important elements such as collection, reuse/recycle, disposal, regulatory oversight, and a funding mechanism, needs to be implemented.
- In addition to the existing provision for collection of CRTs under the Recycle Plus and Neighborhood Clean-up program, the City needs to expand the collection mechanism by funding, organizing, and implementing drop-off events and curbside collection programs in underserved areas. Electronic stores can be used as collection centers for customer drop-offs. Encouragement in the form of incentives is required to obtain a positive response to the City's collection programs.
- The local facilities identified in this report can be utilized for refurbishing or recycling obsolete computers. By utilizing local companies, transportation costs can be reduced.

- Since the City has to bear the financial burden for managing household wastes, recommendations to state agencies can be made for supporting a regulation on the collection of advance disposal fee on every computer that is sold in the state.
- In order to increase public participation, the City needs to create awareness among the public by distributing brochures to residents or advertising in the local newspaper about the program.
- The CIWMB is the appropriate agency to implement programs on waste electronic products. This agency needs to fund or develop programs for identifying new markets for recycled computer components.
- The manufacturers have greater control over product design and hence should focus their effort in developing products that have a longer life span and that can be easily recycled or upgraded.

Implementation of all or some of these recommendations represents the first step in managing the large volume of obsolete computers currently stockpiled and those that will be generated in the near future. Failure to act soon may result in a larger waste problem.

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List of Acronyms

AB	Assembly Bill
ABS	Acrylonitrile Butadiene Styreneplastic
ADF	Advance Disposal Fee
BFR	Brominated Flame Retardants
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CIWMB	California Integrated Waste Management Board
CPU	Central Processing Unit
CRT	Cathode Ray Tube
DfE	Design for Environment
DTSC	Department of Toxic Substances Control
EOL	End of Life
EPCRA	Emergency Planning and Community Right to Know Act
EC	European Commission
GFF	Global Future Foundation
H&SC	Health and Safety Code
IDLH	Immediately Dangerous to Life and Health
LEA	Local Enforcing Agency
MCC	Microelectronics and Computer Technology Corporation
MSW	Municipal Solid Waste
NSC	National Safety Council

NIOSH	National Institute of Occupational Safety and Health
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PBB	Poly Brominated Biphenyls
PBDE	Poly Brominated Diphenyl Ether
PBDPO	Poly Brominated Diphenyl Oxides
PC	Personal Computers
PC	Polycarbonate
PeBDPO	Penta Bromo-Diphenyl Oxide
PEL	Permissible Exposure Level
PSC	Public Safety Code
PVC	Poly Vinyl Chloride
PWB	Printed Wiring Board
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposal
SB	Senate Bill
STLC	Soluble Threshold Limit Concentration
TCLP	Toxicity Characteristic Leaching Procedure
TTLC	Total Threshold Limit Concentration
USEPA	United States Environment Protection Agency
WEEE	Waste Electrical and Electronics Equipment
WET	Waste Extraction Test

Appendix A

Composition Of A Typical Desktop Computer System (MCC, 1996)

Name	Content (%)	Value (\$/T.O.)	Intrinsic Value	Recycl. Effic.	Value of Recycled	Value of Non-recycled	Use/Location
Plastics	22.9907	0.05	\$11.73	20%	\$2.35	\$9.39	includes organics, oxides other than silica
Lead	6.2988	0.03	\$1.93	5%	\$0.10	\$1.83	metal joining, radiation shield/CRT, PWB
Aluminum	14.1723	0.06	\$9.11	80%	\$7.29	\$1.82	structural, conductivity/housing, CRT, PWB, connectors
Germanium	0.0016	93.00	\$1.49	0%	\$0.00	\$1.49	semiconductor/PWB
Gallium	0.0013	90.00	\$1.15	0%	\$0.00	\$1.16	semiconductor/PWB
Iron	20.4712	0.02	\$4.18	80%	\$3.34	\$0.84	structural, magnetivity/(steel) housing, CRT, PWB
Tin	1.0078	0.20	\$2.06	70%	\$1.44	\$0.62	metal joining/PWB, CRT
Copper	6.9287	0.09	\$6.01	90%	\$5.41	\$0.60	conductivity/CRT, PWB, connectors
Barium	0.0315	1.35	\$0.43	0%	\$0.00	\$0.43	getter in vacuum tube/CRT
Nickel	0.8503	0.25	\$2.17	80%	\$1.74	\$0.43	structural, magnetivity/(steel) housing, CRT, PWB
Zinc	2.2046	0.04	\$0.81	60%	\$0.49	\$0.32	battery, phosphor emitter/PWB, CRT
Tantalum	0.0157	1.71	\$0.27	0%	\$0.00	\$0.27	capacitors/PWB, power supply
Indium	0.0016	30.00	\$0.48	60%	\$0.29	\$0.19	transistor, rectifiers/PWB
Vanadium	0.0002	100.00	\$0.16	0%	\$0.00	\$0.16	red phosphor emitter/CRT
Terbium	0.0000	933.00	\$0.15	0%	\$0.00	\$0.15	green phosphor activator, dopant/CRT, PWB
Beryllium	0.0157	0.40	\$0.06	0%	\$0.00	\$0.06	thermal conductivity/PWB, connectors
Gold	0.0016	390.00	\$6.27	99%	\$6.21	\$0.06	connectivity, conductivity/PWB, connectors
Europium	0.0002	35.00	\$0.06	0%	\$0.00	\$0.06	phosphor activator/CRT
Titanium	0.0157	0.30	\$0.05	0%	\$0.00	\$0.05	pigment, alloying agent/(aluminum) housing
Ruthenium	0.0016	15.00	\$0.24	80%	\$0.19	\$0.05	resistive circuit/PWB
Cobalt	0.0157	1.75	\$0.28	85%	\$0.24	\$0.04	structural, magnetivity/(steel) housing, CRT, PWB
Palladium	0.0003	173.00	\$0.56	95%	\$0.53	\$0.03	connectivity, conductivity/PWB, connectors
Manganese	0.0315	0.07	\$0.02	0%	\$0.00	\$0.02	structural, magnetivity/(steel) housing, CRT, PWB
Silver	0.0189	5.33	\$1.03	98%	\$1.01	\$0.02	conductivity/PWB, connectors
Antimony	0.0094	0.19	\$0.02	0%	\$0.00	\$0.02	diodes/housing, PWB, CRT
Bismuth	0.0063	0.26	\$0.02	0%	\$0.00	\$0.02	wetting agent in thick film/PWB
Chromium	0.0063	0.25	\$0.02	0%	\$0.00	\$0.02	decorative, hardener/(steel) housing
Cadmium	0.0094	0.14	\$0.01	0%	\$0.00	\$0.01	battery, blue-green phosphor emitter/housing, PWB, CRT
Selenium	0.0016	2.00	\$0.03	70%	\$0.02	\$0.01	rectifiers/PWB
Niobium	0.0002	5.14	\$0.01	0%	\$0.00	\$0.01	welding allow/housing
Yttrium	0.0002	5.00	\$0.01	0%	\$0.00	\$0.01	red phosphor emitter/CRT
Rhodium	0.0000	650.00	\$0.01	50%	\$0.01	\$0.01	thick film conductor/PWB
Platinum	0.0000	448.00	\$0.07	95%	\$0.07	\$0.00	thick film conductor/PWB
Mercury	0.0022	0.09	\$0.00	0%	\$0.00	\$0.00	batteries, switches/housing, PWB
Arsenic	0.0013	0.00	\$0.00	0%	\$0.00	\$0.00	doping agent in transistors/PWB
Silica	24.8803	0.00	\$0.00	0%	\$0.00	\$0.00	glass, solid state devices/CRT, PWB
Subtotals			\$50.92		\$30.71	\$20.21	

Appendix B

Lead Concentration In Some Leading Computer Monitors And T.V.'S

Maker	TV/ Mon	Color/ Mono	Year Man.	Tube Maker	Leachable Lead Concentration (mg/l)			
					Neck	Funnel	Face	Weighted Average
Acer	MON	C	93	Panasonic	9.5	347.3	<1.0	57.2
Digital	MON	M	90	Clinton	4.2	<1.0	<1.0	<1.0
Elite	MON	C	92	Chunghwa	9.7	81.2	<1.0	19.3
Emerson	TV	C	84	Goldstar	6.5	6.6	<1.0	1.5
Gateway	MON	C	93	Toshiba	9.0	9.2	<1.0	3.2
Gateway	MON	C	92	Toshiba	12.8	174.5	<1.0	54.1
Hp	MON	M	84	Matsushita	<1.0	<1.0	<1.0	<1.0
Hp	MON	M	85	Matsushita	1.7	<1.0	<1.0	<1.0
IBM	MON	C	87	Matsushita	9.5	38.4	<1.0	9.4
IBM	MON	C	89	Panasonic	9.5	142.9	<1.0	41.5
IBM	MON	M	92	Phillips	1.1	<1.0	<1.0	<1.0
Intec	MON	C	89	Samsung	8.2	200.6	<1.0	60.8
Intec	MON	C	89	Hitachi	13.6	403.6	<1.0	85.6
Memorex	MON	C	97	Toshiba	10.1	103.0	<1.0	21.3
Memorex	MON	C	97	Kch	12.7	49.4	<1.0	15.4
Memorex	MON	C	98	Samsung	7.0	25.7	<1.0	6.1
Memorex	MON	C	98	Chunghwa	10.9	7.8	<1.0	2.3
Memorex	MON	C	97	Toshiba	8.4	34.9	<1.0	9.1
Memorex	MON	C	98	Samsung	7.1	7.1	<1.0	2.2
Memorex	MON	C	97	Chunghwa	8.3	35.3	<1.0	10.6
NEC	MON	C	87	NEC	11.3	50.3	<1.0	10.7
Orion	TV	C	96	Orion	9.1	132.5	<1.0	33.1
Panasonic	TV	C	84	Matsushita	22.4	11.8	<1.0	3.5
Quasar	TV	C	84	Quasar	13.6	182.4	<1.0	43.5
Samsung	MON	M	89	Samsung	<1.0	<1.0	<1.0	<1.0
Seiko	MON	C	87	NEC	9.1	100.0	8.0	26.6
Sharp	TV	C	94	Sharp	8.7	16.4	<1.0	4.4
Sharp	TV	C	84	Sharp	7.9	6.0	<1.0	1.5
Tandy	MON	C	85	Sharp	17.6	116.1	<1.0	35.2
Techmedia	MON	C	95	Samsung	<1.0	20.1	<1.0	6.9
Teknika	TV	M	86	Phillips	1.6	<1.0	<1.0	<1.0
Ttx	MON	C	91	Chunghwa	7.5	10.0	<1.0	2.8
Zenith	TV	C	94	Zenith	18.3	198.8	<1.0	54.5
Zenith	TV	C	94	Zenith	15.8	7.1	<1.0	1.6
Zenith	TV	C	77	Zenith	<1.0	97.7	<1.0	21.9
Zenith	MON	C	85	Toshiba	7.5	92.1	<1.0	21.5
Averages					8.6	75.3	0.2	18.5

Appendix C

Process Flowchart of Glass-to-Glass Recycling (Menad, N., 1999)

Appendix D**Toxics Release Inventory (USEPA, 1995)**

Chemical Name	Total Releases lbs/yr		
	Printed Wiring Board	CRT	Semiconductor
1,1,1-Trichloroethane	11080	37472	10507
1,2-Dichlorobenzene	3930	0	24717
1,2,4-Trichlorobenzene	0	0	3260
2-Methoxyethanol	15320	0	0
Acetone	18869	223964	19136
Ammonia	5029	12583	5071
Ammonium Nitrate	0	0	0
Arsenic Compounds	0	2	0
Antimony Compounds	0	0	24
Ammonium Sulfate	16667	0	83
Barium Compounds	250	487	0
Chlorine	474	0	0
Chlorine Dioxide	0	0	10
Chromium Compounds	0	37472	0
Cobalt Compounds	0	0	7
Copper	132	330	6
Copper Compounds	355	215	0
Dichloromethane	44141	0	0
Ethylbenzene	2850	0	738
Ethylene Glycol	1800	0	788
Formaldehyde	836	0	0
Freon 113	13423	39945	11455
Glycol Ethers	9491	0	12471
Hydrochloric Acid	1226	948	996
Hydrogen Fluoride	125	5935	991
Lead	375	0	0
Lead Compounds	325	3171	0
Methanol	14074	78763	10422
Methyl Ethyl Ketone	6466	126823	21598
Methyl Isobutyl Ketone	0	13916	5038
N-Butyl Alcohol	0	0	105
Nickel	0	10	0
Nickel Compounds	0	50	0
Nitric Acid	344	79840	931

Chemical Name	Total Releases lbs/yr		
	Printed Wiring Board	CRT	Semiconductor
Nitrilotriacetic acid	0	0	10
Phenol	1750	0	932
Phosphoric Acid	169	0	431
P-Xylene	0	0	430
Sulfuric Acid	598	1732	818
Toulene	21775	520823	19583
Trichloroethylene	40920	544591	11968
Tetrachloroethylene	35200	0	13887
Xylene	17560	70488	10510
Zinc Compounds	375	5386	0

Appendix E**List of Major Software Companies Contacted**

3CX, Inc 2085 Hamilton Avenue Ste 300 San Jose, CA 1-877-300-8587	Cisco Systems 170 W Tasman Dr. San Jose, CA 408-526-4000	2 Wire Inc 1704 Automation Pkwy. San Jose, CA 408-428-9500
Action Point, Inc 1299 Parkmoore Avenue San Jose, CA 1-877-467-8879	Everypath, Inc 2211 N Ist Street San Jose, CA 408-562-8000	Asante Technologies, Inc 821 Fox lane San Jose, CA 408-435-8388
Adobe Systems Inc, 345 Park Avenue San Jose, CA 408-536-6000	Foundry networks Inc 2100 Gold St. San Jose, CA 408-586-1700	At POS COM, Inc 3051 N First Street San Jose, CA 408-468-5400
Agile Software 1 Almaden Blvd. San Jose, CA 408-975-3900	Fujitsu America, Inc 3055 Orchard Dr. San Jose, CA 408-432-1300	BlueArc Corp 225 Baypointe Pkwy San Jose, CA 408-576-6600
Aspect Communications 1310 Ridder Park Drive San Jose, CA 408-325-2200	Gadzoo Networks 5850 Hellyer Ave San Jose, CA 408-360-4950	Brocade Communications Sys. 1745 Technology Drive San Jose, CA 408-487-8000
Backweb Technologies 2077 Gateway Place, Ste 500 San Jose, CA 408-933-1700/ 1-800-863-0100	HPL Technologies 2033 Gateway Place San Jose, CA 408-437-1466	Calcico Commerce, Inc. 333 W San Carlos,. Ste. 300 San Jose, CA 408-975-7400
BAM! Entertainment Inc. 333 W Santa Clara St. Ste 930 San Jose, CA 408-298-7500	Hybrid networks 6049 Guadalupe Mines Rd San Jose, CA 408-323-6500	Infortrend Corporation 2674 North 1st Street San Jose, CA (408) 954-8888
BEA Systems 2315 N First Street San Jose, CA 800-871-4232	Immersion Corp. 801 Fox ln San Jose, CA 408-467-1900	Alteon Web Systems 50 Great Oaks San Jose, CA 95119 408-879- 3900
Lynux works, Inc 2239 Samaritan Dr San Jose, CA 408-943-1234	Komag Corporation 1710 Automation Pkwy San Jose, CA 408-576-2000	Microe 2516 Samaritan Drive San Jose, CA (408) 358-6615
Blaze Software Inc 150 Almaden Blvd San Jose, CA 1-800-876-4900	TTI San Jose, CA	Cadence Design Systems, Inc 2655 Seely Avenue Bldg. 5 San Jose, CA (408) 934-1405

Appendix F**Questionnaire Used in the Survey**

This questionnaire is intended to estimate the quantity of obsolete computers generated in the City of San Jose. Based on the survey data and an assessment of the existing options for computer recycling, a model will be proposed for effective handling of obsolete computers in San Jose. Please provide factual figures.

<u>TARGET AREA – RESIDENTIAL</u>	
What is your area Zip Code?	
How many computers are in use?	
How many obsolete computers are stored?	
How many computers are you planning to buy in the next 6-12 months?	

Thank you for your time.

Appendix G

Survey Result on Household Computer Usage Pattern and Obsolete Computer Generation*

94089	0	1	1	95112	1	0	0	95120	2	0	1
94089	1	1	0	95112	1	1	0	95120	2	1	1
94710	1	1	0	95112	1	1	0	95120	2	1	0
95008	1	1	0	95112	1	3	1	95120	2	2	1
95014	1	1	0	95112	2	0	0	95120	3	0	0
95014	2	0	0	95112	2	0	0	95120	3	0	0
95014	2	0	0	95112	2	0	0	95120	3	1	0
95014	3	0	0	95112	2	1	1	95121	0	0	0
95016	0	0	0	95112	2	2	0	95121	0	0	0
95032	1	0	0	95112	2	2	0	95121	1	0	0
95035	1	0	1	95112	3	1	0	95121	1	0	0
95035	1	1	1	95112	3	2	0	95121	1	1	0
95035	3	1	0	95112	3	10	0	95121	2	0	0
95050	1	0	0	95116	0	0	1	95121	2	0	0
95051	0	0	0	95116	0	0	0	95121	2	0	0
95051	1	0	0	95116	0	1	0	95121	2	1	0
95051	1	0	0	95116	1	0	0	95121	3	0	0
95051	3	0	2	95116	1	3	0	95121	3	4	1
95070	1	0	0	95117	1	0	0	95121	6	2	0
95070	1	1	1	95117	1	1	0	95122	1	0	0
95070	2	0	0	95118	1	0	0	95122	1	0	0
95070	2	2	1	95118	1	0	1	95122	1	0	0
95070	3	2	0	95118	1	0	1	95122	1	1	0
95110	0	0	0	95118	1	1	1	95122	1	1	0
95110	0	1	0	95118	1	1	1	95122	1	1	0
95110	1	0	0	95118	1	3	0	95122	1	1	0
95110	2	0	0	95118	2	0	0	95122	1	3	0
95110	3	3	1	95118	2	0	0	95122	2	0	0
95111	0	0	0	95118	2	0	0	95122	2	0	0
95111	0	0	0	95118	2	1	0	95122	2	2	1
95111	0	0	0	95118	2	2	0	95123	0	0	0
95111	1	0	1	95118	3	1	1	95123	0	0	0
95111	1	0	1	95118	5	0	1	95123	1	0	0
95111	1	0	0	95119	1	0	0	95123	1	0	1
95111	1	0	0	95119	1	0	0	95123	1	0	0
95111	1	1	0	95119	1	0	0	95123	1	0	0
95111	1	1	0	95119	2	1	0	95123	1	0	0
95111	1	2	1	95120	0	0	0	95123	1	0	0
95111	3	0	0	95120	1	0	1	95123	1	0	0
95111	4	2	1	95120	1	0	0	95123	1	0	0
95111	6	0	0	95120	1	0	0	95123	1	0	0
95112	0	0	0	95120	1	0	0	95123	1	0	0
95112	0	0	0	95120	1	0	0	95123	1	0	0
95112	0	1	1	95120	1	0	0	95123	1	0	0

95112	1	0	0	95120	1	0	1	95123	1	0	0
95112	1	0	0	95120	1	0	0	95123	1	0	0
95112	1	0	2	95120	1	0	0	95123	1	0	0
95112	1	0	0	95120	1	0	0	95123	1	1	0
95123	2	0	0	95120	1	0	0	95123	1	1	0
95123	2	2	0	95120	1	1	0	95123	1	1	0
95123	2	2	0	95120	1	1	0	95123	1	1	0
95123	3	0	0	95120	2	0	0	95123	1	2	0
95123	3	1	0	95120	2	0	0	95123	2	0	0
95123	3	9	1	95120	2	0	0	95123	2	0	0
95123	5	2	0	95120	2	0	1	95123	2	0	0
95124	0	0	0	95125	2	0	0	95123	2	0	0
95124	0	0	0	95125	2	0	0	95136	0	0	0
95124	0	0	0	95125	2	0	0	95136	0	1	0
95124	0	0	1	95125	2	2	0	95136	1	0	1
95124	0	0	0	95126	0	0	0	95136	1	0	0
95124	1	0	0	95126	0	0	0	95136	1	0	1
95124	1	0	0	95126	1	0	0	95136	1	0	1
95124	1	0	0	95126	1	1	0	95136	1	0	0
95124	1	0	0	95126	2	2	1	95136	2	0	0
95124	1	0	0	95127	0	0	0	95136	2	2	0
95124	1	0	0	95127	0	0	0	95136	3	0	1
95124	1	0	0	95127	0	0	0	95138	0	0	1
95124	1	1	0	95127	1	0	0	95138	0	0	0
95124	1	1	0	95127	1	0	0	95138	0	1	0
95124	1	1	0	95127	1	0	0	95138	1	0	0
95124	1	2	1	95127	1	0	0	95138	1	0	0
95124	2	0	1	95127	2	0	0	95138	1	2	2
95124	2	0	0	95127	2	0	0	95138	1	2	0
95124	2	0	1	95127	2	0	0	95138	2	0	0
95124	2	0	0	95127	3	0	0	95138	2	0	0
95124	2	0	0	95128	0	0	1	95138	3	0	0
95124	2	0	0	95128	1	0	0	95139	2	0	1
95124	2	1	0	95128	1	0	0	95140	0	0	0
95124	2	1	0	95128	1	0	0	95148	0	0	0
95124	2	1	0	95128	1	0	0	95148	0	0	0
95124	2	1	0	95128	1	0	0	95148	0	2	1
95124	2	1	1	95128	1	1	1	95148	1	0	0
95124	2	2	0	95128	1	1	0	95148	1	0	0
95124	3	0	1	95128	1	1	0	95148	1	0	0
95124	3	0	0	95128	2	0	0	95148	1	1	0
95124	3	0	0	95128	2	0	0	95148	1	1	0
95124	3	0	1	95128	3	0	1	95148	1	1	0
95124	3	1	0	95128	6	2	1	95148	1	3	0
95125	0	0	0	95129	0	0	0	95148	1	5	0
95125	0	0	0	95129	0	0	0	95148	2	0	1
95125	0	0	0	95129	0	0	0	95148	2	0	1
95125	1	0	0	95129	1	0	0	95148	2	0	0
95125	1	0	0	95129	1	0	0	95148	2	0	1

95125	1	0	0	95129	1	0	0	95148	2	1	0
95125	1	0	0	95129	1	0	0	95148	4	1	0
95125	1	0	0	95129	1	1	0	95129	2	1	0
95125	1	0	0	95129	1	1	0	95129	2	2	0
95125	1	1	0	95129	1	1	1	95129	2	2	0
95125	1	1	0	95129	1	1	0	95129	3	0	0
95125	1	1	0	95129	1	1	0	95129	3	0	0
95125	1	1	0	95129	1	2	1	95129	3	0	1
95125	1	1	0	95129	2	0	0	95129	3	1	0
95125	1	2	1	95129	2	0	0	95129	3	5	1
95125	2	0	1	95129	2	1	0	95130	0	0	0
95130	1	0	0	95130	1	0	0	95130	0	0	0
95130	1	0	0	95135	0	1	0	Unknown	1	0	0
95130	2	0	0	95135	1	0	0	Unknown	1	0	0
95130	6	6	3	95135	1	0	1	Unknown	1	0	0
95131	1	0	0	95135	1	0	0	Unknown	1	0	0
95131	1	0	0	95135	1	0	0	Unknown	1	0	0
95131	1	1	0	95135	1	0	0	Unknown	1	0	0
95131	3	0	0	95135	1	0	0	Unknown	1	0	1
95132	0	0	1	95135	1	0	0	Unknown	1	0	0
95132	1	0	0	95135	1	0	1	Unknown	1	0	0
95132	1	0	0	95135	1	0	0	Unknown	1	0	0
95132	1	0	0	95135	1	0	0	Unknown	1	0	0
95132	1	1	0	95135	1	1	0	Unknown	1	0	0
95132	2	0	2	95135	1	1	1	Unknown	1	0	0
95132	2	0	0	95135	1	1	0	Unknown	1	0	0
95132	2	1	1	95135	2	0	0	Unknown	1	0	0
95132	2	2	0	95135	2	0	0	Unknown	1	1	0
95133	1	0	0	95135	2	0	0	Unknown	2	0	0
95133	1	1	0	95135	2	0	0	Unknown	5	2	0
95133	2	0	0	95135	2	1	0	Unknown	0	0	0
95133	3	0	0	95135	2	1	1	Unknown	0	0	0
95133	3	0	0	95135	2	1	0	Unknown	0	0	0
95134	2	0	1	95135	4	0	0	Unknown	0	0	0
95135	0	0	0	95135	5	3	0	Unknown	1	0	0
Unknown	0	0	0								

***Notes:**

1 – Zipcode

2 – Number of computers in-use

3 – Number of obsolete computers

4 – Number of computers planned to purchase in the next six to twelve months

0 – Unsure about the purchase of new computers

Appendix H

Details of Recycling Activities of Major Recycling Companies in San Jose

Area covered	Activities	Name of the Company
United Datatech	Various locations	Refurbish & Resell / Demanufacture & Recycle
Berman's Diversified Industry	Predominantly San Jose	Refurbish & Resell/ Demanufacture & Recycle
Best Metal Process	Various locations	Refurbish & Resell
C & H Electronic	Out of Business	
CILS	Predominantly San Jose	Shipped to China
Crisis Computers	Do not handle computers	
Fox Electronics	Various locations	Demanufacture
Hackett Enterprises	Bay area	Demanufacture
Markovits & Fox	Out of Business	
Valley Recycling	Various locations	Sold as Scrap
Valley Gold and Silver	Do not recycle anymore	
Silicon Valley Laser	Do not handle computers	
San Jose Metals	Do not handle computers	
Back through the future Microcomputers Inc.	Moved to a new location	
Computer Liquidation & Services	Moved to Santa Clara	
Urban Computer Distribution	Do not take old computers	
VP Electronics, Inc.	Moved to a new location	
Weird Stuff Warehouse	Bay area	Demanufacture and sold as scrap
Tung Tai Group	Various locations	Disassembled and sold as scrap
Micro Metalics Corp	Various locations	Preprocessed and Shipped to Smelter in Canada

Appendix I

List of Major Electronic Stores Contacted

Fry's Electronics, Inc 550 E Brokaw Road San Jose, San Jose	Circuit City 4080 West Stevens Creek Blvd. San Jose, CA
Best Buys 1763 Monterey Hwy. San Jose, CA	Dell Computers 2222 Trade Zone Blvd. San Jose, CA
Gateway Computers 1092 Blosson Hill Road San Jose, CA	Compaq 5300 Stevens Creek Blvd. San Jose, CA
Office Depot 932 Blossom Hill Road San Jose, CA	Office Depot 2510 Channing Avenue San Jose, CA
Computer Online 780 Montague Expressway #202 San Jose, CA	Computer Ware 3215 Stevens Creek Blvd. San Jose, CA
Computerland 5035 Almaden Expy. San Jose, CA	Compusa 634 Blossom Hill Road San Jose, CA

Appendix J

Details of Pilot Studies Conducted under CSI Program

Location	Population	Type of Collection Program	Inflow, lbs	Cost/lb
Somerville, MA	72,280	One-day drop-off event: Spring, 1997	13,723	\$0.21
Binghamton, NY	53,000	One-day drop-off event: Spring, 1997	9,031	\$0.34
Rahway, NJ	25,327	Curbside Collection (part of bulky item collection): 96-97	26,500	\$0.34
Linden, NJ	36,701	Curbside Collection (part of bulky item collection): 96-97	87,060	\$0.18

There were many variations in the implementation of the above pilot studies. The pilot studies conducted at Somerville, MA, Binghamton, NY used volunteers which reduced the labor cost. The transportation cost for Somerville project was lower than Binghamton project due to close proximity of recycling facility. The total cost values include cost of transporting materials to the demanufacturer and cost of demanufacturing waste electronic equipment (computers, printers, microwaves etc.). The Rahway and Linden projects in New Jersey were similar and the total cost included cost of transportation, cost of demanufacturing and disposal costs for scrap and CRTs. The project cost for Rahway was higher than Linden due to frequent trips to the demanufacturing facility.

Appendix K

Comparison of Various Models on EOL Electronic Products Management (MFF, 1999)

Project	Period days	Targeted Population	E-O-L Products Collected in lbs	Total Cost ¹	Revenue	Net Cost/lb
Oakland Pilot Project	10	3692	15,623.00	15,369.00	1,357.94 <i>IC Board recovery, scrap metal sale and export to CRT</i>	\$0.9/lb
SF - Super Recycling Day	See note.	13,392	Combined	10,628.25	1,022.44 <i>IC Board recovery and scrap metal sale</i>	\$0.66/lb
SF - PDRA Recycling Day	10	Not Pre-determined	14,600			
Hayward Drop-off event	1	221	9,791	10,385.93*	71.38 <i>Scrap sale</i>	\$1.05/lb

Note: 1 = Cost includes collection, labor, transportation, CRT recycling and advertisement
 * = Cost includes collection, labor, disposal, advertising and landfill