Assessing Base Level of Service for Electronics Collection and Recycling Programs: Seattle-Tacoma Case Study

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Abstract

The National Electronics Product Stewardship Initiative (NEPSI) was established by the US EPA to examine issues associated with electronics recycling, engage in discussions to build consensus among all stakeholder groups, and recommend a strategy for developing a national electronics recycling program. One of the tasks of the NEPSI Infrastructure Subgroup was to study programs of other nations and the various pilot projects and state initiatives here in the US and develop guidelines for a base level of service for collection and recycling which would apply across the country. Fundamental to the concept of base level of service is the need to balance convenience with cost-effectiveness and operational efficiency. To better understand the concept and underlying principles of base service, this project was undertaken to construct and evaluate realistic collection and recycling program scenarios for the Seattle-Tacoma urban area. The results of this study provide a better understanding of the collection, transportation and recycling infrastructure needed for a defined collection service area with associated operational requirements and costs.

Keywords

Electronics recycling, collection infrastructure, cost models and analysis, base level of service, NEPSI, material flow simulation.

INTRODUCTION

The National Electronics Product Stewardship Initiative (NEPSI) was established by the US EPA to examine issues associated with electronics recycling, engage in discussions to build consensus among all stakeholder groups, and recommend a strategy for developing a national electronics recycling program. The NEPSI program is focused on household electronics, consisting of televisions, computers, monitors, and peripherals. One of the tasks of the NEPSI Infrastructure Subgroup was to study programs of other nations and the various pilot projects and state initiatives here in the US and develop guidelines for a base level of service for collection and recycling which would apply across the country. Fundamental to the concept of base level of service is the need to balance convenience with cost-effectiveness and operational efficiency [1]. To better understand the concept and underlying principles of base service, this project was undertaken to construct and evaluate realistic collection and recycling program scenarios for the Seattle-Tacoma urban area. Through this case study, specific examples of the collection and recycling infrastructure needed to achieve a base service level program have been investigated. The results of this study provide a better understanding of the collection, transportation and recycling infrastructure needed for a defined collection service area with associated operational requirements and costs.

Various collection scenarios have been developed ranging from single, large drop-off facilities theoretically placed in the center of the service area to a highly-distributed set of micro-collection facilities co-located at existing retailers, charities and municipal facilities. Collection of electronics may require modification or build-out of the existing facility, but base service cost considerations will include only the marginal cost of electronics collections rather than the full costs of a facility solely dedicated to electronics collection. In addition to fixed drop-off facilities, some of the scenarios include holding special collection events at parking lots and other locations in the study area. The Census 2000 database was used in conjunction with the area highway network by the GIS specialist to map locations, determine population and households within the service areas and calculate travel and transport distances. For each collection site in a scenario, an estimate of e-waste collected was determined from which the facility and operational requirements and associated costs were then calculated. A set of cost models has been developed that directly estimate capital costs, operational fixed costs and operational variable costs. With these general models, the incremental and marginal costs for providing electronics collection at existing facilities were then determined. A product/material flow simulation was developed to depict operational behaviors, reuse potential, consolidation options and overall costs and recovery value of components and basic materials.

This paper describes the base service assessment study, presents the computer-based support tools developed to design, model and simulate the collection, transportation and recycling scenarios, and summarizes lessons learned.

SCENARIO DEVELOPMENT

The case study is focused on Snohomish County one of the main counties in the greater Seattle-Tacoma metropolitan statistical area. Snohomish County was chosen for two reasons: first, the study team includes county planners and their technical staff; consequently, there is sufficient local knowledge and understanding of the existing collection and recycling infrastructure and community characteristics necessary to develop realistic scenarios. Second, the Seattle-Tacoma area is a typical moderate-sized, large metropolitan statistical area (3.5 million people and 1.5 million households) consisting of high-density core areas with surrounding urban communities. Snohomish County has a population of 606,000 people and 225,000 households.

As indicated, the NEPSI initiative is focused on residential electronics, specifically, televisions, computers, monitors and peripherals. The e-waste generation rate for these products is assumed to be 1.75 lb per person per year. This rate is representative of the experiences seen in Massachusetts with their on-going collection program [2-3]. Consequently, the total volume of residential electronics equipment to be collected in Snohomish County each year is 1,060,500 lb (530 tons).

The underlying philosophy in constructing these scenarios is to create convenient, cost-effective and operationally efficient collection systems by augmenting existing infrastructure and leveraging previous public and private investments with additional system elements. Ten scenarios were initially defined; however, after further consideration only seven were fully analyzed and evaluated. The following summarizes the ten scenarios defined:

1. <u>One Central Drop-off Site (Theoretical):</u> A fictitious facility, ideally located at the population center of the County, to collect all 530 tons of residential electronics each year. New facility construction is assumed on existing property with one FTE staffing and administrative support. Gaylords are collected and stored at the site until full truckloads are shipped to the regional recycler in Seattle. The cost structure for drop-off sites are described in the following section.

2. <u>One Central Drop-off Site (Existing Facility):</u> Similar to Scenario 1 except space is leased at Temporary Recycling and Transfer Station (TRTS), an existing facility located in southeast Everett at the average warehousing lease rate for the Seattle-Tacoma area.

3. <u>Three Decentralized Sites (Theoretical Locations):</u> Three fictitious drop-off facilities—North, South and East—are assumed to be built from new construction on existing property in ideal locations. Service zones associated with each location are defined using GIS and highway network data to give minimum travel distance to the drop-off locations. The South location is the busiest facility serving 355,000 people; whereas, the North and East locations serve 170,000 and 80,000, respectively. There are several trade-offs to be considered in designing and operating these sites: the size of the storage space required at the facility is related to the frequency of transportation pick-ups and whether the gaylords are single or double stacked. Double stacking reduces space but requires a forklift truck which needs a higher skilled, higher paid worker. An equation giving the optimal storage requirements and pick-up frequency was derived and used to minimize costs.

4. Four Decentralized Sites (Existing Facilities): Snohomish County owns four recycling and waste transfer stations—North County, Airport Rd, Southwest, and TRTS. This scenario assumes some new construction with leasing of additional space within existing buildings. Staffing is assigned based upon estimated time to collect products dropped off at each location. Figure 1 is a GIS map showing the location of these sites and associated service zones. The population included in the service zones are 140,000, 197,000, 145,000, and 124,000 people for North County, Airport Rd, Southwest and TRTS, respectively.

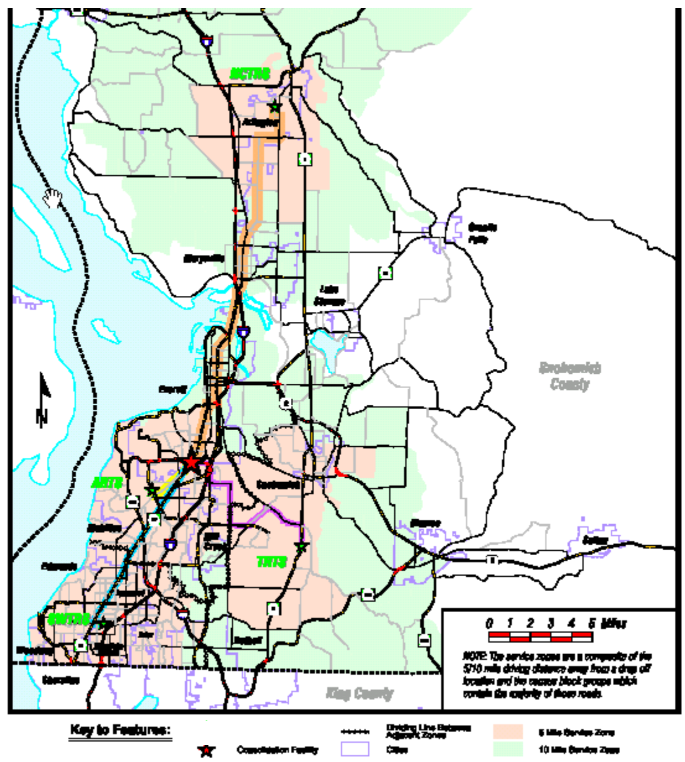

Fig. 1.Location of Four County Collection Sites: Scenario 4

5. <u>All Solid Waste Locations (*Not Analyzed*):</u> This scenario is similar to four with all county solid waste locations participating. This option was deemed impractical due to space constraints at additional county facilities.

6. Big Box Store Hubs *(Not Analyzed)*: There are 20 large electronics retailers ("Big Box Stores") clustered in Snohomish County. Four of these retailers located in Lynnwood, South Everett, Marysville, and Monroe were selected as primary hubs for drop-off collection. Assuming nearest population, these four Big Box Stores will serve 204,000, 176,000, 144,000 and 82,000 people, respectively, with over 60% of the households within 5 miles of a Big Box Hub.

7. All Big Box Stores (Existing Locations): All 20 of the Big Box Stores in Snohomish are assumed to operate drop-off sites by leasing space in their facility and allocating staff time to support collection. Each store is assumed to be identical: each serving 5% of the population and collecting 265,000 lb per year. Based upon their actual locations, these stores have been assigned to one of three transportation pick-up routes or "milk runs". Milk Run #1 serves 6 stores with a total hauling distance of 113 miles; Milk Run #2 serves 7 stores over a 72 mile route; and, Milk Run #3 handles 7 stores with a 57 mile route. Frequent weekly pick-ups are assumed to reduce the amount of floor space that the retailer must allocate for the collection process—space to accommodate four gaylords is needed.

8. All Private Options (Existing Locations): This scenario assumes an extensive collection infrastructure consisting of the 20 big box retailers (Scenario 7) combined with 32 additional sites representing smaller electronics retailers (e.q., Radio Shacks), electronic recyclers/repair houses, and charities (e.q., Goodwill). Operationally similar to scenario 7, the 52 stores are assigned to one of nine milk runs consisting of various Big Box and smaller stores and assigned routes with distances varying from 56 to 134 miles. All big box stores, which together collect 60% of the electronics, are assumed to be equivalent in cost structure, operational considerations and volume collection potential. Similarly, the smaller stores, which collect the remaining 40%, are assumed to have identical characteristics and operate the same.

9. Big Box Store Hubs Bi-Annual Events (*Not Analyzed*): This scenario assumed two special parking lot events each year to be held at the four major Big Box Stores identified in scenario 6.

10. Mixed System. This scenario utilizes the full complement of public and private sites for collection as well as a two-day special event in the parking lot at the Best Buy store in Lynnwood and electronics collection added at city "clean ups" and household hazardous waste (HHW) events held annually in various towns in the less-urban areas of Snohomish County. The scenario collection infrastructure is composed of the following elements:

- The four existing county recycling and transfer stations described in scenario 4 collect equipment and store gaylords for weekly shipment to the consolidation/recycler in Seattle.
- Similar to Scenario 8, the 20 large retail electronics (Big Box) stores and 30 of the smaller retailers (e.q., Radio Shack), charities and recyclers operating in Snohomish County serve as micro-collection sites. Nine "milk runs" routes were defined with pick-ups scheduled for every three weeks.
- A two-day special event held in the parking lot at the Best Buy in Lynnwood, set up to handle two cars simultaneously staffed with a supervisor, forklift operator and 4 helpers. This level of operation is assumed to capture two truckloads (40,000 lb) of equipment.
- City clean-up and HHW events are assumed to be held in Darrington (75 cars), Goldbar (140 cars), Sultan (175 cars), Index (25 cars), Arlington (150 cars), Stanwood (375 cars), and Mountlake Terrace (300 cars). Each car is assumed to drop-off one piece of electronics equipment; therefore, using an average product weight of 32 lb gives a total of 39,850 lbs collected at these individual city events.

The Best Buy event is modeled as a typical 2-day parking lot event with costs structured as described in the following section [4]. Each city clean-up/HHW event assumes one-day events with incremental costs associated with handling electronics as marginal with only variable material handling costs and a single helper assigned to electronics. Based on these assumptions, the two special events together collect 79,850 lb of the anticipated county-wide annual volume of 1,060,500 lb. The "milk runs" (retailer sites) are assumed to collect 2/3 of the remaining volume (657,000 lb/yr) with the four county facilities collecting the rest (323,650 lb/yr). The Big Box Stores are assumed to be identical and collect twice as much equipment as a typical smaller site.

COST MODEL DEVELOPMENT

To model the incremental capital and operating costs associated with these scenarios, two infrastructure cost models were developed based on traditional engineering cost methods. The first model captures the cost structure of drop-off sites and is sufficiently robust to estimate costs for all drop-off options as well as the retailer programs visualized in the scenarios. The second estimates costs representative of special events—retailer parking lot or HHW events.

Drop-off Site Cost Model. Costs for drop-off sites can be modeled into three basic categories: capital investment cost, operational fixed costs and operational variable costs. The primary cost elements for each of these categories is described below:

1. Capital Investment Costs

   Facility Capital

   - Facility construction
   - Foundation, site work, and paved areas
   - Mechanical & electricals

- Site Engineering

Equipment

- Forklift/Pallet jack

Start-Up

- Permits
- Planning

2. Operation Fixed Costs

Labor

- Supervisor/forklift operator
- Helper/sorter
- Fringe Benefits

Facility

- Utilities
- Facility Lease
- Dumpster lease and service

Administrative

- Operations and Support
- Publicity

3. Operation Variable Costs (volume dependent)

Material Handling

- Gaylords and pallets
- Shrinkwrap and wrapper
- Forklift Maintenance

Truck loading

Transportation

- 48’ truck

Special Events Cost Model. An area of the parking lot is set aside for the collection operation. Residents drive into an unloading area as indicated by signs, traffic cones, and persons directing traffic and staff working the event unload their cars (two or three cars can be unloaded simultaneously). Equipment is sorted and loaded directly into trailers and trucked to the recycler or consolidation facility at the end of the day. Typically, the sponsoring organization or retailer participates in the event by advertising the event and donating additional personnel to hand out surveys, offer coupons and direct traffic. Also, charities are frequently involved to help identify reusable equipment and promote reuse and recycling options.

Unlike drop-off facilities, there are no capital investment costs for special events only operational cost. These operational costs can be divided into two cost categories:

1. Operational Fixed Costs

Labor

- Supervisor
- forklift Operator
- Helpers/Sorters
- Fringe Benefits

Facility

- 48 ft trailer rental
- Tent rental
- Driver Hauling Charge
- Site Lease
- Dumpster lease & service

Equipment

- Forklift rental

Administrative

- Operations, Planning & Support
- Permits
- Publicity

2. Operation Variable Costs (volume dependent)

Material Handling

- Gaylords and pallets
- Shrinkwrap and wrapper

Transportation

- 48’ truck

For each cost parameter for these models, considerable effort was expended to identify sources of data and estimate unit values appropriate for the Seattle-Tacoma area. These sources are documented in an internal NEPSI report [5]. For labor costs, the labor categories and rates for Snohomish county employees were used as guidelines. For new construction, pre-fabricated steel building over concrete slab was assumed with two 12 ft wide roll-up access doors, and heated space but not air-conditioned [6]. Much information was obtained over the Internet to establish cost basis for facility lease and equipment and material pricing. A cost of $2.50 per mile of trucking was estimated with assistance of the International Association of Electronics Recyclers. The overall cost model structure was reviewed by Snohomish County personnel as well as other NEPSI participants.

A Windows-based spreadsheet application was developed using Excel to computerize these models so that scenarios could be quickly evaluated. Fig. 2 shows part of the Excel screen with graphic representation of cost sensitivity in terms of the estimated cost per lb for variation in actual volume collected compared to expected volume. The shape of this curve is similar for all drop-off sites. As the actual volume collected falls short of the volume for which the facilities are designed, the cost per lb increases rapidly.

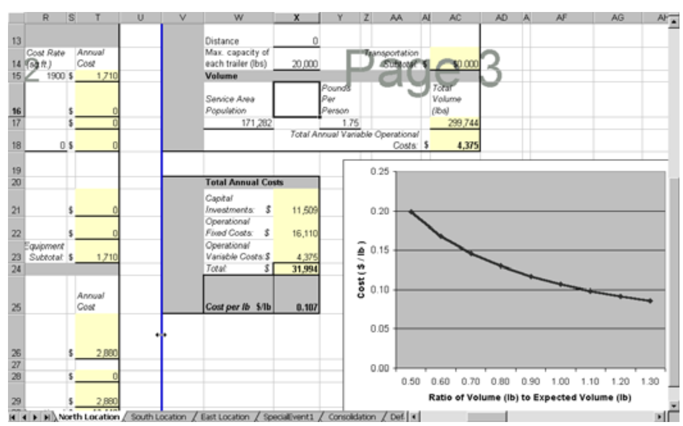

Fig. 2. Segment of a Costing Model Software Screen

Recycler Processing Cost. The cost associated with processing the collected equipment is based upon data from a recent survey of electronics recyclers. The following costs are assumed:

- Personal Computers: No Charge
- TVs and Monitors: $0.12 per lb
- Other Electronic Peripherals: $0.13 per lb

MATERIAL FLOW MODELING AND SIMULATION

To better understand the flow of the materials through the collected, transportation and recycling system and estimate operational efficiencies, a material flow model was constructed and simulated. Some of the flow modeling has already been described in terms of the transport infrastructure elements and "milk run" grouping. Here, the material flow simulation will be described.

The e-waste generation assumptions are based on data estimating the weight of equipment discarded per person per year. To model flows and estimate costs, we need both weights of materials and the quantities of products collected, transported, reused and processed. Table 1 gives the assumed distribution of each type of equipment collected and the associated average weight and weight distribution.

Table 1 – Discarded Electronics Waste Stream Profile

Product Type	Percent by Quantity	Avg Weight (lb) [7]	% Composition		
			Metal	Plastic	Glass
Computers	30	30	70	30	-
Monitors	25	30	20	15	65
Televisions	25	50	20	15	65
Other Equip	20	25	67	33	-

An average of 5% of the computers, monitors and televisions are assumed to be in reasonably good condition and acceptable for reuse. In addition, the power supply, CD drive, processor and memory chips from 10% of the computers are assumed to be harvested for reuse/resale.

A system model was developed using *PTLaser*, an application software package based on process flow modeling with an integrated framework for alternatives analysis and lifecycle costing [8]. The simulation flow models the basic collection options including drop-off sites, retailer programs and special events with the added ability to consolidate collection from King and Pierce County, if desired.

EVALUATION AND COMPARISON OF SCENARIOS

Table 2 gives a summary of the unit cost per lb, operational effectiveness and convenience measures which are used to compare the scenarios. As seen, the unit cost ranges from $0.11 per lb for a centralized drop-off facility (Scenarios 1 and 2) to $0.18 per lb for the highly distributed, mixed system (Scenario 10). However, for Scenario 10 there is a wide range of unit costs for the various elements of the system: the city HHW events ($0.06 / lb) are highly leveraged with all space and equipment associated with existing clean-up days. The Best Buy special event ($0.13 / lb) assumes that some time and effort is donated by Best Buy (or its employees) to help run the event and to provide sufficient publicity and incentives to get high participation from the community.

Table 2 –Scenario Evaluation Summary

Scenario	Unit Cost ($/lb)	Labor Productivity (lb / $)	Transport Load Factor	Percent Households Within	
				5 mi	10 mi
1	0.11	20	0.5	25	60
2	0.11	20	0.5	15	50
3	0.13	22	0.6	40	85
4	0.16	14	0.5	60	90
5	-	-	-	-	-
6	-	-	-	60	90
7	0.12	35	0.6	85	95
8	0.15	38	0.5	95	99
9	-	-	-	-	-
10	0.18	24	0.5	95	99

It is instructive to examine the scenario cost drivers, i.e., the cost components that contribute most significantly to the cost total. Fig. 3 shows the cost distribution for Scenarios 1 and 7. For the dedicated drop-off facilities in Scenarios 1-4, the primary cost component is labor (45%) followed by transportation and facility. For Scenario 7 with the 20 Big Box Stores providing drop-off collection sites, facility cost is approximately one-third of the overall cost with labor and transportation at 25% each. Whereas for Scenario 8 when over 50 retailer/charities sites are incorporated into the collection infrastructure, the cost of transportation becomes the dominate factor (almost 40%).

The operational effectiveness of the scenarios is defined in terms of labor productivity (lb/$), the ratio of amount of electronics collected to the cost of labor (including fringe benefits), and transportation efficiency, given as the average load factor or cargo weight-to-capacity ratio of the trucks. Transportation load factor is similar for all scenarios ranging from 0.5 to 0.6. However, the labor productivity ranges from a low of 14 lb/$ for Scenario 4 to a high of 38 lb/$ for Scenario 8. The high labor productivity for Scenario 8 results from two assumptions: first, that the host retailers and charities will staff the

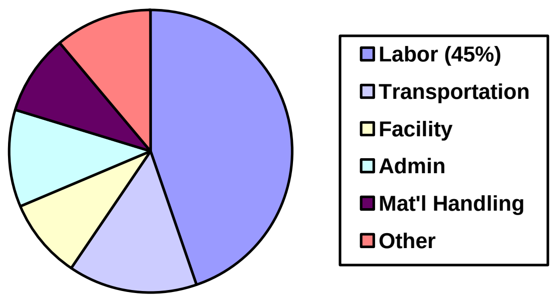

Fig. 3a. Cost Distribution for Scenario 1

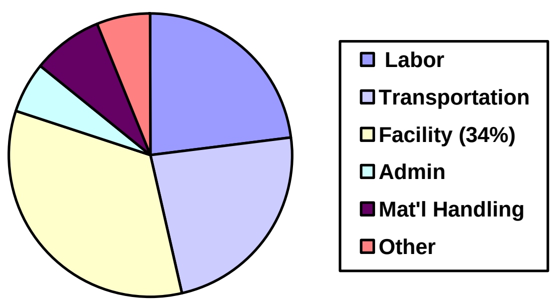

Fig. 3b. Cost Distribution for Scenario 7

collection operation charging only for the time involved in overseeing collection; and, second, that worker-level labor costs at these retailers is lower than that of a Site Attendant assumed for the County facilities.

Quantifying "convenience" is difficult; however, it is important to the concept of base level of service that the collection system be located sufficiently close to residents and be accessible so that significant volumes of waste electronics will be collected by the system. In addition, it is extremely important that the system realize collection targets established in the planning stages of the system because, as noted earlier, the unit cost per lb increases dramatically if the actual volumes collected fall short of the design volumes.

For the purposes of this evaluation, convenience is defined in terms of the proximity of collection sites to County residents. Proximity is expressed as the percentage of households within 5 miles and 10 miles of a collection site. As seen in Table 2, a single collection facility centrally located would reach 25% of the households within 5 miles while 60% would be within 10 miles. As expected, as more sites are added, convenience is enhanced. Scenario 4 has four collection sites and reaches 60% of the households within 5 miles and 90% within 10 miles. Scenario 3 with three sites places 85% of the households within 10 miles and 98% within 15 miles (not shown in Table). The national average trip to work distance is approximately 11 miles; consequently, three geographically distributed sites places almost everyone within reasonable travel distance.

SUMMARY

The Seattle-Tacoma study attempts to better understand the concept of base level of service described by the NEPSI Infrastructure Subgroup by constructing realistic collection scenarios, developing engineering-based cost models and simulating material flows through the system from collection to processing. The results are this study can be used as first-level planning tools and guidance to develop alternative collection system options, identify important cost drivers, estimate unit cost values and define service areas. Balancing cost, system performance and convenience is difficult to achieve; however, this study is an important first step in understanding the critical trade-offs involved and provides an engineering framework towards reaching this goal.

ACKNOWLEDGEMENTS

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