

EFFECTIVENESS ANALYSIS OF ELECTRONIC WASTE COLLECTION MODELS

Topic problem explanation

Electronic waste (e-waste) is the most rapidly growing segment of the municipal waste stream. It contains toxic materials such as lead, barium, mercury, and cadmium that require proper management as well as valuable resources that should be recovered. Agencies that collect, transport, recycle, or dispose of e-waste need specific guidance to assure that the growing waste flow of end-of-life electronic products is managed in a way that protects public health and the environment and conserves resources. The volume, weight, storage needs, and costs of e-waste management present special challenges, as compared to managing solid waste or household hazardous waste.

The problem of the e-waste management is a topical for the most of the developing countries where primitive methods and technologies are used for its burning and processing, there is no recycling infrastructure and legal regulations of e-waste management. One of the most important stage of e-waste effective management development in Ukraine is to choose and implement the right models of its collection. This subject is learnt in a number of foreign authors works such as Washington C. [1], Davis S. [2], Matthews H. [3], Tonetti R. [4], Remolador M. [5] and others. Researches of Ukrainian and Russian scientists in this area are limited. That is why it is important and necessary to make the analysis of the e-waste collection models operating in developed countries and scientifically explain the suitability of the chosen models. That is the aim of the present work.

A number of models for e-waste collection are available. These models are used in the most of developed European countries for collection of recyclables, bulky goods, and household hazardous waste. The most common currently used collection models are the following:

1. drop-off event (one-day or multiple days);
2. permanent collection facility;
3. collection on request (curbside collection);
4. retail collection;
5. nonprofit/thrift retail collection.

1. Drop-off event (one-day or multiple days). A drop-off event is a one-day or multi-day program that allows residents to bring their electronic waste to a central location for recycling or reuse. Typically, the sponsor chooses a well-known and centrally located site to conduct the program. On-site activities include unloading

vehicles and sorting and packaging wastes, followed by transportation to a recycling facility. At the end of the event, the facility or parking lot returns to its original function. Most special waste collection programs begin as one-day events. Some programs go on to provide services at permanent facilities, while others find that special events are a better solution. Special events are a good way to serve residents in geographically large and diverse regions, because services can be brought to residents.

2. Permanent collection facilities. Permanent collection facilities offer regular collection hours for residents to bring electronic waste for recycling. These facilities are often combined with other municipal services such as recycling centers, household hazardous waste facilities, or solid waste disposal facilities. If the facility already has a fee collection infrastructure and staffing, sharing those resources may be a possible cost savings solution. Permanent programs require a larger up-front investment than one day collections, but they have the potential to reduce costs through use of municipal employees instead of contractors.

3. Collection on request. Curbside collection programs often are available in urban areas to handle bulky waste. These programs may operate as special spring or fall cleanup events, on-call pickups, or regularly scheduled pick-up. E-waste can be added on to an existing curbside program. Waste haulers can deliver the electronic waste to a central consolidation point or directly to a recycling facility.

4. Retail collection. A local store might be willing to allow residents and/or small businesses drop off specific types of e-waste at their retail location. This type of partnership is most often made with a business that sells electronic products. Sometimes the business is willing to give discounts on the purchase of new equipment if the resident brings in their obsolete equipment at the time of purchase.

5. Nonprofit/thrift retail collection. This collection model is similar to the retail collection model but is focused on nonprofit or thrift stores. These types of stores already accept donation of other used items (such as clothing, furniture, etc.) and have a complete infrastructure in place to do so.

Before making conclusion about the most suitable collection model it is necessary to make a comparative analysis which is presented in the table 1.

Electronic waste collection models comparative analysis [1, p. 33]

Collection model	Advantages	Disadvantages
Drop-off event	<ul style="list-style-type: none"> -low up-front (setup) costs; -possible sponsorship opportunities; -may use volunteers to offset labor cost; -media attention to raise awareness; -collect large quantities in short time; -cost control by limiting hours and frequency of collection events; -turnkey contracts eliminate need to hire additional municipal staff; -could be adjunct to an existing program using special events for collection; -suitable model for rural communities and first-time collections; -short time to implement (no permitting/construction barriers). 	<ul style="list-style-type: none"> -requires extensive staff planning time; -publicity is primary driver for participation and will increase demand for service; -limited time for diverting equipment for reuse; -expensive contract costs; -long waiting lines to drop off e-waste; -may conflict with other events; -setup and breakdown must be done for each event; time consuming; -hard to predict participation numbers without appointment system; -hard to plan proper staffing levels; -difficulties in finding a site.
Permanent collection facility	<ul style="list-style-type: none"> -increased access to collection by extending hours of operation; -economies of scale possible because equipment is stored onsite; -extended time for diverting material for reuse; -can be an adjunct to another program (solid waste recycling; household hazardous waste); -year-round collection; -no setup/breakdown needed; -participants become familiar with site; -permanent workers have no training curve with each event. 	<ul style="list-style-type: none"> -need permanent staff; -increased operational hours can increase staffing needs; -existing sites may not have adequate storage; -new construction is cost-prohibitive; -difficult to find location to permit facilities; -permitting and construction takes a long time; -solid waste facilities are often isolated and not convenient to participants; -not mobile; cannot move to accommodate different geographic areas.
Collection on request	<ul style="list-style-type: none"> -convenient for residents; -could be adjunct to existing program (bulky waste); -can be operated as neighborhood cleanup or by resident appointment; -neighborhood-specific promotion possible; -promotion through solid waste or utility billing; -cost per pound may decrease with increased volume. 	<ul style="list-style-type: none"> -program (not resident) becomes responsible for transportation costs; -e-waste could end up dumped illegally; -cleanup events encourage illegal dumping from other jurisdictions that are not contributing financially to the program; -overall costs higher due to higher labor costs and increased quantity of waste; -more difficult in rural areas.
Retail collection	<ul style="list-style-type: none"> -program flexibility; -retailer can promote new equipment sales (take-back program in return for product discount); -retailer gets "green" reputation; -opportunity to pursue shared costs of transportation and recycling with retailer. 	<ul style="list-style-type: none"> -retailer recycling contracts may not meet agency environmental requirements; -retailers may not have adequate storage space; -take-back is not a core retail business activity; -difficult to get corporate approval to participate.
Nonprofit/ thrift retail collection	<ul style="list-style-type: none"> -drop-off infrastructure availability; -pickup infrastructure availability; -better potential for resale and reuse as compared to other models; -provides nonprofit with inventory source; -possible job training opportunities. 	<ul style="list-style-type: none"> -possible increase in illegal dumping at donation stations; -no trained staff for refurbishing/repairing electronic equipment; -may not have adequate storage; -may not be able to resell due to technical obsolescence.

It is possible to have one or more of these models in place for the collection of other types of materials, and it's important to decide whether to collect e-waste onto an existing program or hold a separate event. The use of more than one model is applicable. Considering all

advantages and disadvantages of e-waste collection models and also European experience of the e-waste collection in this work is recommended to use two models:

- 1) retail collection;
- 2) collection on request.

Table 2

The results of survey

N	The variants of the answers on the first question	The quantity of answers		The variants of the answers on the second question	The quantity of answers	
		number	%		number	%
1.	Leaving it home	48	50,5	No	79	83,2
2.	Resell it	26	27,4	Yes (considering the collection points' proximity, equipment sizes etc.)	16	16,8
3.	Dump it	12	12,6			
4.	Present it	5	5,3			
5.	Other	4	4,2			

The suitability of these two models for the use is explained further.

The most of Ukrainian population prefer to leave their outdated electrical and electronic equipment at home than to bring and give it to the collection points of e-waste free of charge. It is confirmed by the results of the survey made among the group of people. The respondents' selection was made on the basis of the spontaneous sampling.

For the purposes of the sample representativeness the following formula was used for its calculation:

$$n = \frac{0,25 * T^2 * N}{A^2 * N + 0,25 * T^2}, \quad (1)$$

where n — the volume of the sample;

N — the volume of the general totality;

A — the confidence level of sample;

T^2 — the coefficient, which considers sample error and confidence probability.

The general totality of the survey is the residents of Donetsk at the age of 20-60, which according to the population census made in 2007 is nearly 55% of all the population of the city. There are 1033 thousand people reside in Donetsk [6], it means that the general totality is 568 thousand people ($N = 568000$).

The confidence level of sample is 5% ($A = 0,05$).

The coefficient T^2 according to the Student's table tends to one because a large volume of the sample is provided, i.e. $n > 30$ ($T^2 = 0,95$).

After putting the given parameters into formula (1) the value n can be obtained. The volume of the sample is 95 people.

$$n = \frac{0,25 * 0,95 * 568000}{0,0025 * 568000 + 0,25 * 0,95} \approx 95$$

It means that this volume provides the maximum of the sample representativeness.

The following questions had been asked:

1) What are you doing with the outdated electrical and electronic equipment?

2) Are you ready to transport and give outdated electrical and electronic equipment to the e-waste collection points in case of its opening free of charge?

The results of the survey after its ranking in decreasing order are presented in the table 2.

The standard deviation on the separated obtained indicator is calculated on the formula 2:

$$\text{Standart deviation} = \sqrt{\frac{\text{indicator, \%} * (100 - \text{indicator, \%})}{\text{sample volume}}}. \quad (2)$$

It means that the value of the indicator is located in the interval «indicator + standart deviation», i.e. 83,2% (table 2), which is obtained while making survey, its equal $83,2 \pm 3,83\%$ and can possess the value between 79,37% and 87,03%.

Thereby, for the general totality (568 thousand people) these values will be $450822 \leq N \leq 494330$.

The results of the survey confirm the unavailability of the population to transport and give the outdated electrical and electronic equipment to drop-off or permanent collection facility points. There are two possible variants of the population stimulation to bring their e-waste to the collection points: legislative stimulation with the use of fines in case of its breach and financial stimulation. The discounts given when purchasing the item at the retailer of the electrical and electronic equipment are the main financial stimulus. The suitability of the first collection model adoption is also explained by the possibility of the cost reduction because the retailer will cover the part of expenses on transportation and recycling of e-waste.

In the most of the EU countries the collection of e-waste by request is the additional model to the existent program of the waste collection. The main part of e-waste is bulky electrical and electronic equipment, thus

the use of this model will help to avoid the problem of the transportation outdated equipment to the collection points by people themselves. Collection of the bulky equipment is done by request, which is issued as an application, during a week.

Resume

Best management practices are guidelines for selecting the most environmentally desired methods for managing a waste stream. E-waste collection programs need guidelines to assure that products are managed in a way that protects public health and the environment and conserves valuable resources. End-of-life electronic equipment contains valuable resources such as precious metals, engineered plastics, glass, and other materials, all of which require energy to manufacture. If these resources are not recovered, additional pollution will be generated to manufacture new products out of virgin materials.

E-waste collection models which usage in Ukraine explained in this work is approved by Ukrainian enterprise AOZT "Donetskyvtorresursy-V" and by Maltese state enterprise "Malta Waste Serv. Ltd.".

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Shulayeva Y. Effectiveness analysis of electronic waste collection models

Experience of electronic waste effective collection management is summarized. The method of its estimation and assessment is offered. The results of its practical approbation are given.

Key words: effectiveness, management, collection, model, electronic waste.

Шулаєва Ю.Є. Аналіз ефективності моделей збору електронних відходів

Узагальнено досвід ефективного управління збором електронних відходів. Запропоновано метод його виміру і кількісної оцінки. Наведено результати практичної апробації.

Ключові слова: ефективність, управління, збір, модель, електронні відходи.

Шулаева Ю.Е. Анализ эффективности моделей сбора электронных отходов

Обобщен опыт эффективного управления сбором электронных отходов. Предложен метод его измерения и количественной оценки. Приведены результаты практической апробации.

Ключевые слова: эффективность, управление, сбор, модель, электронные отходы.

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