Development of Funding Model in E-waste Management Systems for Households Products in Indonesia

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Abstract. Indonesia is one of the developing countries that does not have e-waste management system yet. Previous research has outlined the conditions of the formal and informal sectors in Indonesia. The results of the previous research indicate that informal actors are a major force in the collection and sorting of electronic waste, especially e-waste source from the household. It became a challenge to develop e-waste management system in Indonesia. Developing such systems in Indonesia needs government commitment and awareness from EEE producers as the first step to do the initial project. The purpose of this research is to provide fund management proposal under the current condition of Indonesia and the financial model that can describe the implementation of the pilot project and when developed to a larger scale. The proposed funding management and techno-economic model is expected to illustrate the real conditions in Indonesia and can assist decision analysis for an investment of e-waste processing system in the future.

1. Introduction

E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of reuse [1]. The term ‘discarded’ implies that the item is considered waste by its owner and becomes a critical point where the goods change from a useful product to waste. Electronic equipment comprises harmful components, materials, and substances [2]. If the electronic product is unusable, it will be detrimental to human health, environmental stability, and contribute to the greenhouse effect [3]. E-waste from household significantly contributes to the total e-waste in the world.

The initial phase is the EEE product manufactured by the manufacturer. The second phase when the EEE product is in the hands of the consumer, this phase is called the phase of use. Discard phase is the phase when the owner of the EEE product decides to discard or not discard the product. Discarding indicates that the item becomes e-waste, meanwhile not discarding or reuse shows it is not e-waste. Preparation for reuse phase is the phase in which the EEE product to be reused in terms of functionality, meets the requirements of the next potential owner or not. In this phase, EEE products that are considered ineligible may enter the recycle phase [1]. Recycling is defined as the process of converting waste materials into new products to not dispose of potentially useful materials, reduce raw material consumption, cut energy use, reduce the need for traditional waste disposal (landfills and incineration) that could have a negative impact, and lower greenhouse gas emissions [4]. In 2015, Cucchiella, D’Adamo, Koh, & Rosa conducted a study assessing the economic value of e-waste. It can be utilized if the e-waste is treated with the right treatment, such as recycling and recovery [5].

Recycling is one of the main activities in e-waste management system. There are some different
models of e-waste management system in the developing and developed countries. Previous studies have outlined the variables in e-waste management system based on the conditions in some developed and developing countries. Five variables the systems are e-waste specific regulation, funding source, e-waste collection mechanism, e-waste recycling industry and consumer behavior in disposing of e-waste [6]. The purpose of determining these variables is to develop the initial model of e-waste management system in Indonesia. Indonesia is a developing country that has no specific regulation regarding e-waste, and informal sector dominates the flow of e-waste management system. The important variables in e-waste management system are the role of government in establishing regulation and funding management to finance the system. Some countries are implementing Advanced Recycling Fee (ARF), take back systems or subsidies from the government to finance their e-waste management system [7, 8].

In the previous studies, there was several techno-economic analysis to assess the feasibility of recycling project in e-waste management system. D’Adamo, Rosa, & Terzi (2016) assess the benefits of the e-waste processing industry in Germany, Italy and the UK for mobile plants and field plants [9]. Ghodrat, Rhamdhani, Brooks, Masood, & Corder (2016) analyzed techno-economic in a specialized refinement black copper processing industry on PCB e-waste in Australia [10]. Most of the studies are conducted in the developed countries. Taiwan used EPR as the basic principle of e-waste management system [11]. EPR is a concept of the responsibility of producers especially for take back, recycling and disposal of the product [12]. China conducted several pilot projects to start the implementation of e-waste management system. The pilot project requires government subsidies as a first step in funding the system [8]. There were difference funding mechanisms in e-waste management system between the developed and developing countries. These differences included terms of regulation, the implementation of e-waste management system, the actors who play a role in the system as well as the funding scheme required in the system. This study aims to develop a funding scheme of e-waste management system models in a developing country, specifically Indonesia.

This study consists of the following works which are interrelated among each others. This research step is divided into model conceptualization for the proposed model of e-waste management system, optimization of fund management model for e-waste management system in a pilot project scale and developing a financial model of e-waste management system in a regional scale.

2. Development the initial project of e-waste management system in Indonesia

The first step of this research is model conceptualization. The conceptualization of the model has been done in previous research by mapping existing e-waste management system (EMS) in the developed and developing countries, determining the variables in EMS and then mapping some pilot project for EMS in developing countries to compare with the current condition in Indonesia. The conceptualized model became the basis of the proposed model for EMS in pilot project scale as an initial stage to develop e-waste management system in Indonesia.

2.1. Current condition: E-waste in Indonesia

Currently, Indonesia has no regulation about e-waste management. E-waste management in Indonesia is divided into the formal and informal sectors. The formal sector consists of several recycling companies. The informal sectors are like scavengers, aggregators, classifier, processors, and recyclers. According to one of recycling company on formal sector, only 10% of the volume e-waste in Indonesia turns over to the formal sector. It shows that the most activities for e-waste collection dominated by informal sectors [13]. This situation happens because no specific regulation that controls the flow of EEE after the end of their life. Informal sector knows that e-waste has economic value, but the process of recycling is not appropriate for environmental health.

Based on this situation, the formal sector is running into difficulties in collecting the volume of e-waste to be recycled. The material flow of e-waste, especially from households, is difficult to dispose of in the formal sector because consumers consider their e-waste still has economic value, so they prefer to sell their e-waste to the informal sector rather than being disposed to formal sector [14]. It is
a major challenge to build EMS in Indonesia. The government, EEE producers, and recycling companies need to cooperate to build EMS in Indonesia. One of the activities that had been done by the environmental city council of Jakarta government is putting e-waste drop box in the car-free day so that the consumers can drop their e-waste to the dropbox. The other program is providing pick up services to the residents. For at least 5 kilograms of e-waste, Jakarta resident can dispose of their waste with free transportation. E-waste recycling industry then will recycle this collected of e-waste. However, consumer enthusiasm has not been much [15]. The study uses sales volume data from DKI Jakarta because the city is a capital city that has a diversity of types of electronic waste products and consumer behavior is consumptive. This study considered television, desktop, and mobile phone as the input for the model under study.

2.2. Proposed funding management model for EMS in pilot project scale

Proposed funding management model for EMS have been done by mapping some pilot projects in the developing countries that have similar characteristics to the current condition in Indonesia. The pilot project is conducted when the country does not have specific regulations regarding e-waste and consumer characteristics in removing e-waste similar with Indonesia. Based on this mapping, the proposed funding management model for EMS in pilot project scale can be seen in Figure 1. The funding scheme comes from a government subsidy where funding comes from several manufacturers of EEE products like television, desktop, and mobile phone. E-waste collection mechanism involves the formal and informal sector in this pilot project.

Hsu Shih (2017) developed a funding model for e-waste management system in Taiwan [11]. Taiwan already has an EMS with EPR as the basic concept, but there is still a weakness in collecting e-waste that does not flow into the formal sector of the e-waste processing industry. The government applies reward incentives to consumers who give their e-waste in the system according to product type. This reward incentives offer did not show increasing amount of e-waste in collection phase. The uncertainty of the amount of e-waste affects financially from the processing industry. To develop the model of funding management for a pilot project in Indonesia this study has adapted the model of Hsu Shih (2017) and then apply the data from current condition in Indonesia.

Maximize $\alpha\,$

Subject to:

a) Positive fund balance

$$\left(\frac{1}{1+i}\right)^{t-1} C_{rt} W_t \geq \left(\frac{1}{1+i}\right)^{t-1} (C_{ct} C_{t} W_t + A_{rt} W_t), t = 1, \ldots, T \quad (2)$$

b) Recycling industry’s profit

$$\left(\frac{1}{1+i}\right)^{t-1} (C_{ct} C_{t} W_t + C_{kt} C_{t} W_t) \geq \left(\frac{1}{1+i}\right)^{t-1} (C_{rt} + C_{pt} - C_{gt} C_{t} W_t), t = 1, \ldots, T \quad (3)$$

c) System fund balance

$$\left(\frac{1}{1+i}\right)^{t-1} (C_{rt} W_t + C_{kt} C_{t} W_t) \geq \left(\frac{1}{1+i}\right)^{t-1} (C_{rt} + C_{pt} + A_{R} W_t), t = 1, \ldots, T \quad (4)$$

d) Environmental cost coverage

$$\left(\frac{1}{1+i}\right)^{t-1} A_{rt} W_t \geq \left(\frac{1}{1+i}\right)^{t-1} (1 - \alpha_{t}) C_{R} W_t, t = 1, \ldots, T \quad (5)$$

e) Recycling rate of the period

$$\alpha_{t} = \Sigma_{i=1}^{T} \alpha_{t} W_t / \Sigma_{i=1}^{T} W_t \quad (6)$$

f) Production cost function of the industry

$$C_{pt} = F_{t} + b_{t} \alpha_{t} W_t, t = 1, \ldots, T \quad (7)$$

g) Causal relation between customers’ reward incentives and recycling rate

$$\alpha_{t} = \text{Ratio} \frac{C_{t}}{\text{Ratio} C_{R}}, t = 1, \ldots, T \quad (8)$$

h) Incentives price:

$$C_{rt} = \text{Ratio} C_{t} \times C_{t} \quad (9)$$

For simplicity, this model presents the core part of the formulation. The objective function of the
funding model is to maximize recycling rate. The recycling rate is a percentage of the amount of electronic waste that goes into the system for recycling by the recycling industry.

![Diagram](image-url)

**Figure 1.** Proposed e-waste management system for a pilot project in Indonesia

Decision variables are the annual subsidy and incentive ratio per year. The difference of equation used is the limitation of a causal relationship between reward incentives and recycling rate. Hsu Shih (2017) used logistic regression equations where there are parameters that map the condition of consumer behavior in disposing of electronic waste into the system [11]. Since there is no study which maps the condition, this study used linear equation by looking for the relationship between incentive ratio (0 to 1) with recycling rate. The established incentives constants will multiply the incentive ratio.

### 2.3. Analysis of Funding Management Model

The amount of e-waste is assumed based on sales volume data of imported goods for television, desktop and mobile phone products in Indonesia. This study used proportion data based on population in Jakarta. Also, the pilot project is assumed to be followed by 20% of Jakarta residents. As described earlier, a simple assumption used to convert sales volume data into the amount of e-waste is using the simple delay method. The pilot project runs for five years where \( t_0 \) is 2018. Recapitulation of required parameter data can be seen in Appendix A. Table 1 lists the results of this funding model for the pilot project. The model has been validated by experts.

| Type of product | TV | Desktop | Mobile phone |
|-----------------|----|---------|--------------|
| **Subsidy \( C_{xt} \) (IDR)** | 182,007 | 125,914 | 23,386 |
| **Reward Incentives \( C_{rt} \) (IDR)** | 70,782 | 97,326 | 21,235 |

The recycling rate above 81.05% will make the system in a positive funding condition, while if the recycling rate below that point the funding condition will be negative or loss. It shows that at least 81.05% of total e-waste in this pilot project must be processed to make this project profitable. Table 2 lists the proportion of subsidy and incentives for each product. As in equation (8) and (9), incentives ratio is a comparator value with an incentive constant having a causal relation with recycling rate per year. The recycling rate directly proportional to incentives rewards.

### 3. Result and Discussion

The results of the fund management model become the input of financial model on a regional scale. This section describes the initial scenario where the data used is the optimal result of subsidy value, recycling rate and reward incentives affecting financial parameters. In addition, the proposed scenario
analysis should be elaborated if the project is to be eligible.

3.1. Initial scenario for the financial model in regional scale

The results of the funding model on the pilot project scale are in the form of subsidies, reward incentives and recycling rates can be an illustration if the model is expanded to a regional scale. The regional scale is the city level of Jakarta. The main objective of the funding model in pilot project scale is positive funding so there has profit in the system then this study would like to see in regional scale whether the financial model analysis shows the same thing if the project of build EMS in Indonesia is realized. To develop into a regional scale, it requires some parameter to change as the scale of the project increases. The parameters are increasing amount of e-waste, the capacity of recycling industry, total processing cost and investment cost. The financial model for a regional project is assumed to run for 20 years in which year-0 is the expansion of the plant as well as the additional investment required to increase the capacity as needed. The calculation of the financial model begins with knowing the cash outflow and cash inflows that involved in the system. Net Present Value (NPV) is a parameter of profit viewed in present value. Assuming an interest rate of 10.77%, the NPV for this project is -1,023,716,254,071.18 IDR or below 0. It shows the project being rejected because the required investment is large enough for a project on a regional scale.

3.2. Proposed scenario for the financial model in regional scale

Based on NPV parameter, the results on financial model calculations show that the project is not feasible. It considers that Indonesia has not been able to apply processing technology for e-waste. Transportation cost increased and affected the cash outflow. The new system requires a large investment, so the calculation for the initial scenario shows the losses are still quite large. From the results of this calculation, this study proposes possible scenarios by several actors in the system:

- **Consumers**: The incentives will be eliminated in the sixth year assuming the consumer is aware and willing to dispose of it in the right system.
- **EEE producers**: Penalty for 50% of recycling fee if didn’t pay the recycling fee
- **Government**: Gives full subsidy to the recycling industry (eliminated the administrative fees) and increase recycling fee by 6% progressively per year
- **Consortium manufacturing**: Prepares funds for investment in year-0, then the 5th year they provide an annual fund to make the system funding stable.

The comparison of financial model for initial and proposed scenario can be seen in Table 3. It shows that to build the proper EMS in Indonesia needs more funding besides subsidy.

| Parameter             | NPV                      | IRR | Payback Period |
|-----------------------|--------------------------|-----|----------------|
| **Initial Scenario**  | -1,023,716,254,071.18 IDR| -   | -              |
| **Proposed Scenario** | 13,528,690,697 IDR        | 11.71% | 19.28 years    |

4. Conclusion

Indonesia does not have a specific regulation regarding e-waste yet and lack of awareness of actors who should be responsible for e-waste. The first step to build a system that does not yet begin with model conceptualization and pilot project mapping in developing countries helps to describe the initial system in shaping e-waste management in Indonesia. Fund management model in pilot project-scale used parameter data that capture the current condition in Indonesia. The optimal solution shows the value of recycling rate, subsidies and reward incentives in pilot project-scale. NPV calculations still show losses because the investments cost a lot. It indicates that the project needs more funding besides the subsidy. Consortium manufacturing is required to provide additional funding until the project succeeds independently without an injection of funds. The most influential variables of NPV change is recycling rate and subsidy funding. The government’s contribution, consortium manufacturing regarding funds and consumer involvement to collect e-waste are necessary to ensure the sustainability of the system. Another effort that needs to be done is the campaign on e-waste hazard to consumers,
both from the government, EEE producers, industrial recycling, collecting points and NGOs so that consumers are aware of electronic waste and throw the e-waste in the right system instead to the informal sector.

Appendices A
Parameter and decision variable are used in the funding management model.

| Parameter & Description                                      | Value                                      |
|---------------------------------------------------------------|--------------------------------------------|
| \( b_t \) Variable cost in year t                             | 27,907 IDR/unit ; calculated by this study |
| \( C_{Et} \) Environmental cost for the un-recycled amount in year t, [11] | 9,141 IDR/unit                           |
| \( C_{ft} \) Recycling fee is given manufacturing to the government in year t, [16] | TV = 223,207 IDR/unit; Desktop = 151,398 IDR/unit; Mobile phone = 223,207 IDR/unit |
| \( C_{gt} \) Residual fee in year t, [11]                    | 4,479 IDR/unit                            |
| \( C_{kt} \) Valuable materials sold by processing industry in year t, calculated by this study | TV = 564,616 IDR/unit; Desktop = 288,345 IDR/unit; Mobile phone = 8,521 IDR/unit |
| \( F_t \) Fixed cost of processing industry in year t        | 1,362,457,091 IDR/year ; calculated       |
| \( C_t \) Percentage of incentives per product, [16]         | TV = 79,788 IDR/unit; Desktop = 109,709 IDR/unit; Mobile phone = 23,936 IDR/unit |
| \( A_f \) Administrative fee [16]                            | TV = 18,950 IDR/unit; Desktop = 5,785 IDR/unit; Mobile phone = 2,394 IDR/unit |
| \( i \) Discounted rate in this study                         | 10.77%                                    |

Decision Variable & Description

| \( \alpha \) Recycling rate | \( \alpha_t \) Recycling rate year t | \( C_{yt} \) Subsidy rate year t | \( C_{rt} \) Incentives price year t | Rat Ct Ratio of Ct |
|-----------------------------|-------------------------------------|---------------------------------|-------------------------------------|-------------------|

Acknowledgements
This research is supported by Hibah PITTA 2018 funded by Directorate of Research and Community Engagement (DRPM) Universitas Indonesia, No. 2546/UN2.R3.1/HKP.05.00/2018.

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