Waste Management 35 (2015) 247–254

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Estimation of retired mobile phones generation in China: A comparative study on methodology

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ARTICLE INFO

Article history:
Received 7 June 2014
Accepted 11 September 2014
Available online 1 October 2014

Keywords:
Mobile phone
Retired
Generation
Estimation
WEEE
Waste management

ABSTRACT

Due to the rapid development of economy and technology, China has the biggest production and possession of mobile phones around the world. In general, mobile phones have relatively short life time because the majority of users replace their mobile phones frequently. Retired mobile phones represent the most valuable electrical and electronic equipment (EEE) in the main waste stream because of such characteristics as large quantity, high reuse/recovery value and fast replacement frequency. Consequently, the huge amount of retired mobile phones in China calls for a sustainable management system.

The generation estimation can provide fundamental information to construct the sustainable management system of retired mobile phones and other waste electrical and electronic equipment (WEEE). However, the reliable estimation result is difficult to get and verify. The priority aim of this paper is to provide proper estimation approach for the generation of retired mobile phones in China, by comparing some relevant methods. The results show that the sales&new method is in the highest priority in estimation of the retired mobile phones. The result of sales&new method shows that there are 47.92 million mobile phones retired in 2002, and it reached to 739.98 million in China in 2012. It presents an increasing tendency with some fluctuations clearly.

Furthermore, some discussions on methodology, such as the selection of improper approach and error in the input data, are also conducted in order to improve generation estimation of retired mobile phones and other WEEE.

1. Introduction

The mobile phone has become the most ubiquitous electronic product. At the end of 2013, it was estimated that there were 6.66 billion mobile phone subscribers globally (ITU, 2014), of which 1.23 billion were in China (MIIT, 2014). Meanwhile, the rapid technology innovation with better functions and models impelled the customers to change mobile phones more and more frequently, which leads to the short lifetime of mobile phones and rapid generation of retired mobile phones. Due to the relatively small sizes, retired mobile phones can be easily stored and forgotten or thrown out with the municipal waste (Canning, 2006; Darby and Obara, 2005). And many retired mobile phones are not disposed in the proper way (through reuse or recycling) but stockpiled (Geyer and Doctori Blass, 2009; Nokia, 2008; Wagner, 2009).

In many regions and countries, the retired mobile phones are classified as waste electrical and electronic equipment (WEEE) (Li et al., 2006; European Commission, 2012), which is one of the priority waste streams. Main reasons for the concern of WEEE are very fast growth rate of the waste stream and its complex composition with a potential negative effect on environment and human health (European Commission, 2012).WEEE stream can be divided into large WEEE (e.g. refrigerators, washing machines, etc.) and small WEEE (e.g. mobile phones, digital cameras, music players, etc.) (Martinho et al., 2012; Sole et al., 2012). The retired mobile phones is a kind of typical small WEEE with the characteristics such as big amount, high reuse/recovery value and fast replacing frequency (Ongondo and Williams, 2011a; Polak and Drapalova, 2012). The retired mobile phones seem to have a minor share on the amount of WEEE generated. However, considering the huge amount of the mobile phones subscriptions around the world, their contribution to total environmental impacts of WEEE should not be neglected (Wu et al., 2008; Nnorom and Osibanjo, 2009).

Legislations and policies have been enacted to manage the retired mobile phones, such as the European WEEE Directive

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http://dx.doi.org/10.1016/j.wasman.2014.09.008
0956-053X/

(European Commission, 2012) or California's Cell Phone Recycling Act (CPRA) (California State Congress, 2004), which are usually based on the principle of extended producer responsibility (EPR) (Ongondo and Williams, 2011b; Silveira and Chang, 2010). However, in China, mobile phones have not been included in the WEEE management framework (Chi et al., 2011; Matsuto, 2014).

Estimation of waste quantities is the fundamental work to waste management. However, it is difficult to make valid estimation and to prove it. The reliable estimation can provide fundamental information to construct a sustainable management system of retired mobile phones, but there is still no such achievement in China. The goal of this contribution aims to make reliable estimation of retired mobile phones in China. In addition, some discussions on methodology, such as the common source of uncertainties in the previous studies are also conducted in detail in order to improve generation estimation of WEEE.

2. Literature review

There are various approaches used to estimate the generation of WEEE or retired mobile phones in particular all around the world (Araujo et al., 2012; Chung et al., 2010, 2011; Dwivedy and Mittal, 2010a,b; Gutierrez et al., 2010; Polak and Drapalova, 2012; Steubing et al., 2010; Walk, 2009; Yang et al., 2008; Yoshida et al., 2009). These approaches can be classified into the following models: input–output model, time-series model, factor model, econometrics analysis and direct waste analysis.

The input–output model is so far the most promising and frequently used with multiple model variations, which has been applied to estimate WEEE generation in many regional and country studies by quantitatively evaluates the sources, pathways and final sinks of material flows. In this model, information on product lifespan and a delay (equivalent to the lifespan) for electrical and electronic equipment (EEE) to become WEEE are always needed to complete the estimation. This model can develop to other approaches such as market supply method (including classic market supply method, market supply A method and Stanford method), consumption and use approach, time-step method, MFA method, use-phase analysis, ICER model and Carnegie Mellon method.

The time-series model, in which "time" is used as a predictor variable, involves the use of historical data and their distribution to extrapolate future waste trends. It can be also applied to fill in the gap of past unknown years from available datasets. The advantages of time-series model are its flexibility and limited demand of data. In many cases, only data for two variables are needed: time and the past pattern of the key variable to be predicted. Waste data measured at any kind of meaningful intervals, such as annual, monthly or even daily waste data can be used in such estimations. On the other hand, the simple model leads to the neglect of the other potentially influential explanatory variables, so the changes in the future cannot be reflected appropriately (Wang et al., 2013). The time-series model including several approaches, such as curve estimation techniques, exponential smooth, linear extrapolation, trend analysis and periodic approaches (Walk, 2004). This category of approaches usually used to make the generation estimations of municipal solid waste in various temporal and spatial scales (Chung, 2010; Matsuto and Tanaka, 1993; Navarro-Esbri et al., 2002), some case studies on WEEE are also can be found (Masui, 2005; Huisman et al., 2007).

The factor model uses factors such as socio-economic and other explanatory variables to explain and predict waste arising, which aims at making predictions on waste quantities and unveiling hypothetical causal relationships between factors for the prediction of waste generation at the same time (Walk, 2004). The explanatory variables include population, household size, residency type, age groups, employment, income level, electricity consumption, tipping fees, education, culture, geography, climate and so on (Chung, 2010). The weight of the factors may be different in the various case studies. It is the least explored method due to complex factors interaction and high uncertainty in time-series. There are several previous studies focused on the generation estimations of the WEEE can be found (Chung et al., 2011; Saphores et al., 2009).

The econometrics analysis makes generation estimations of the waste based on the econometrics indicators, such as gross domestic product (GDP) (Nordic Council of Ministers, 2009). The econometrics analysis can be regarded as the combination of time-series model and factor model. Some Nordic nations, such as Denmark (Danish Environmental Protection Agency, 2006) and Norway (Statistic Norway, 2004), make generation estimations of WEEE using this model.

The direct waste analysis uses e-waste figures obtained from collection channels, treatment facilities and disposal sites. It is seldom mentioned to estimate quantities of WEEE disposed of, practical records of WEEE receipts in all local waste facilities are the source of information that can be obtained by field determination at major end-disposal facilities (Chung, 2011). Hong Kong SAR government used this model to estimate e-waste disposal figures of the city (Environment Bureau, 2010).

Sales, possession, lifetime and distribution are usually essential information for input–output model. Historical collected (generation) amount, saturation factor, substitution effect, influential factors, econometrics indicators are needed by other models. The correspondence between the data and approaches are stated in Table 1. Some approaches have other designation in different literatures, they are also listed in Table 1 to avoid confusion.

Focusing on the retired mobile phones, there are several trials to estimate the generation with various approaches. The approaches are mainly extended from input–output model. For instance, Fishbein (2002) estimated number of cell phones retired per year in the US using the classic market supply method, Eugster et al. (2007) estimated the retired mobile phones generation in China in the same way; Gao et al. (2010) and Polak and Drapalova (2012) forecasted the generation of end-of-life mobile phones in China and Czech Republic using the market supply A method, respectively; Liao and Zhang (2012) made a comparative study based on the estimation results of discarded mobile phones in China using the classic market supply method, time-step method and approximation, respectively. With MFA method, Yu et al. (2010) and Jang and Kim (2010) estimated the generation of retired mobile phones in China and Korea, respectively. Moreover, Osibanjo et al. (2008) modelled the waste generation by the telecom sector in Nigeria by regression analysis.

The life cycle of mobile phones can be divided into six phases, which can be defined as raw materials production, manufacture, circulate/distribute, consume/use, retire/reuse/stockpile and end-of-life. Various data needed for the estimations lie in the certain phase, the concerned phases of all the approaches mentioned above are illustrated in Fig. 1.

There are several problems that can influence the accuracy and credibility of the estimation lie in the previous studies. For example, appropriate primary data are difficult to get and secure, some estimations are even based on secondary data (Chung, 2011). At the meantime, the lifetime of a certain kind of EEE are changed rapidly with the improving technology and between different countries and regions.

3. Methodology

3.1. Definition

The retired mobile phones were defined as the mobile phones that stop the service in the mobile tele-communication networks.