Resources, Conservation and Recycling 86 (2014) 93–106

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

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

Decision factors for e-waste in Northern Mexico: To waste or trade

Jesús. A. Estrada-Ayub[a,*], Ramzy Kahhat[b]

[a] Global Institute for Sustainability, Tecnológico de Monterrey, Campus Ciudad de Mexico, Calle del Puente, 222 Ejidos de Huipulco, Mexico, DF 14380, Mexico
[b] Department of Engineering, Pontificia Universidad Católica del Perú, Av. Universitaria 1801 San Miguel, Lima, Peru

ARTICLE INFO

Article history:
Received 13 November 2013
Received in revised form 25 February 2014
Accepted 26 February 2014
Available online 21 March 2014

Keywords:
E-waste
Used computers
Data Flow Diagrams
Waste management
Recycling
Reuse

ABSTRACT

Currently, around the globe, environmental and social problems derive from the inappropriate recycling of electronic products. Moreover, improper recycling is not the only issue to address in electronic products. Others include: energy intensity in their manufacture, employment generation related to the international trade in used electronics, and access to technology by low-income communities. Nevertheless, policies and controls created to provide socially and environmentally sound management of used electronics do not match the complexity of the system. In order to understand the e-waste system, particularly used computers, as a whole, a field study was done between 2010 and 2011 in ten Mexican cities. Ninety-five diverse stakeholders were interviewed to uncover factors regarding the decision to waste or trade still-usable computers. Structured analysis was used to create Data Flow Diagrams (DFDs) to describe the critical parts of the system. The results show that perceived value and geographical location determine the rate in which computers are disposed and the opportunities to waste or trade them, including the trade of their materials. Among businesses and other organizations, legislation has a stronger effect. Technological change is another important factor, largely driving the change in materials and new products. Designing policies responding to this diversity may prevent unforeseen problems and stimulate solutions.

1. Introduction

Wastes generated by human society are as complex as the social and technological systems that create the goods from which they originate. The massive quantities of anthropogenic waste surpass the capacity of natural and human systems to process them and waste management systems created to handle anthropogenic waste still do not match its complexity. An example can be seen in the increasing quantities of unwanted or obsolete electrical and electronic equipment known by the acronym of WEEE (for Waste Electrical and Electronic Equipment), or e-waste (Bhuie et al., 2004). Numerous, and dissimilar devices, such as refrigerators, computers and mobile phones, are classified as e-waste. End-of-use management requires different strategies for each.

In recent times, problems derived from e-waste handling by informal recyclers in poor communities in developing countries have garnered worldwide media coverage (e.g., Subramanyam, 2004; Solly and Granastein, 2008; Overlar, 2010; Vinicio, 2010; Lambert, 2011; Brown and Terra Blight, 2012; Macquarie, 2013). Informal recyclers are driven by the valuable resources contained in e-waste, such as gold and copper. The value of these materials is a powerful incentive for people to recycle them, even without technology or proper consideration of the environment and public health. Typical practices to recover valuables by informal stakeholders across the globe include: (1) open burning of insulated wires to recover copper (Umair et al., 2013); (2) soaking of printed circuit boards in acid (Ren et al., 2011; Bi et al., 2010) and (3) smashing of CRT monitors to recover copper, leaving leaded glass at the landfill site (Niu et al., 2012; Torzewski, 2009). The problems caused by these types of informal recycling methods have been widely documented. For example, in the recycling town of Guiyu, China, open burning activities have produced high air and soil concentrations, of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs) and polychlorinated dibenzo-p-dioxins (PCDD), while leaching processes have led to heavy metal contamination of water bodies and sediments (Wong et al., 2007; An et al., 2011). In addition to China, e-waste informal recycling has also lead to health and environmental problem in countries like Nigeria (Osibanjo and Nnorom, 2007), Ghana (Oteng-Ababio, 2010) and Pakistan (Umair et al., 2013), among others.

* Corresponding author. Tel.: 52614435074/2020x1527/1485.
E-mail addresses: ayubjesusangel@hotmail.com (Jesús.A. Estrada-Ayub), Ramzy.kahhat@pucp.pe (R. Kahhat).

http://dx.doi.org/10.1016/j.resconrec.2014.02.012
0921-3449/

Developing e-waste management solutions requires a larger vision, encompassing more than just the problems derived from the inappropriate recycling of materials. According to one Earth Systems Engineering and Management principle, before proposing any potential solutions to the system, "the system itself, including relevant stakeholders, [must] be understood as a whole" (Allenby, 2005). E-waste management includes a number of stakeholders, some of which are often excluded or underrepresented in decision-making spheres. Although informal recyclers are recognized, regulations are often targeted to eliminate their source of revenue instead of improving their recycling practices with environmentally friendly technology. Also, the used electronic equipment trade to developing countries is erroneously understood as trade of hazardous waste, due to an incorrect interpretation of the Basel Convention, and some used computers that are considered hazardous waste are, in reality, safe to use. In fact, not only does the used electronic equipment trade create jobs in the refurbishment sectors, it provides access to technology in low-income communities around the globe (Kahhat and Williams, 2009).

Management of e-waste is complex because multiple factors and dimensions affect how it can be handled. E-waste management encompasses not only the proper recycling of the materials, but also social and environmental dimensions. Additionally, cultural, social and economical decision factors (varying among communities around the globe), define access to resources and opportunities to manage e-waste. Hence, the main goal of this study is to understand these decision factors from a systems perspective. The study region is the north of Mexico. This region presents a unique opportunity to assess how decision factors considered by various stakeholders located there are affected by proximity to the United States (US).

This article focuses particularly on used personal computers, with or without reuse potential, at Mexican cities near the US-Mexico border. There is a continuous flow of people and products in the study region. Every hour, 20,000 people from Mexico enter the United States at border crossings, and around goods worth 38 million dollars are traded (Del Castillo et al., 2007). Moreover, the strategic location of cities like Tijuana, Nogales, Juarez and Chihuahua make them important manufacturing centers of new electronic equipment, such as televisions, mobile phones and computers, which are shipped to the United States after assembly. For example, 30 million televisions sets are assembled in the Mexican state of Baja California every year. In addition, numerous factories in Mexico manufacture electronic parts that are then shipped to the United States for final assembly. According to the Mexican Manufacture and Exporters Association, there are around 350 electronic manufacture plants in north Baja California, Chihuahua and Nuevo Leon (Roman Moguel, 2007).

In addition to this trade, there is a dynamic trade of used products, mainly from the United States to Mexico. Unfortunately, data related to this commerce is scarce, primarily because of the special characteristics of these activities (importation, refurbishment and resale), such as informality, and the small size and large number of companies involved, which make it a challenge for tracing by government organizations. However, the importance of this informal commerce can be inferred by the quantity of vendors that gather in flea markets in northern Mexico as well as the many years they have been in operation. For example, the *La villa* flea markets in Tijuana gathers more than 5000 vendors every Sunday, and flea markets like "*La Chaveña*" in the city of Juarez have been continuously operating for more than 30 years. At flea markets, significant numbers of used electronics dealers are present, as are small electronic refurbishers operating in the geographic area. In addition, in all cities studied, informal collectors (*pepenadores*) or scavengers are present. These informal collectors sort recyclable materials and used products out of the municipal waste stream for further sorting and dismantling. Also, in cities like Juarez and Nogales, formal collectors with experience managing ewaste from international companies provide services to dispose electronics for the public.

2. Methods

This research uses a bottom-up approach to study the systems that manage e-waste at each city. One way to overcome the complexity of describing a system which has several dimensions and in which stakeholders interact with one another is to classify, for analytical purposes, the interactions in three different levels: micro, meso and macro (Svedin et al., 2005). The first, (micro-level) represents the actions taken by individuals, the second (meso-level) represents the flow of information among organizations, while the macro-level encompasses national characteristics. The reason for including a multilevel analysis is that the decision factors which drive the flows of e-waste among stakeholders do not operate at a single level, but have impacts at all levels.

We began at the micro-level, conducting interviews with stakeholders, participants in the e-waste supply chain management system in each city.

The general procedure was: learn from each stakeholder where they acquire their material, where their products (e-waste or computers) are sold and where they dispose of their waste materials. Through this information, it was possible to identify alternatives to trading or wasting materials in each city. The interviews also provided information from stakeholders about the reasons behind their decision-making on how to deal with their e-waste. The reasons provided from these stakeholders varied from the availability of choices at their location, to more complex factors that drive the behavior from their customers and suppliers. Therefore, since their analysis of the reasons behind their decisions move from the micro-level to the macro-level, it was necessary to organize these at the meso-level and the macro-level in order to capture the emergent behavior derived from complex systems.

2.1. Study region

In order to understand, the decision factors which drive e-waste management, field studies were performed between January 2010 and July 2011 in ten Mexican cities located within a maximum distance of 200 miles from the US-Mexico border. Fig. 1 shows the Mexican border area as well as the studied cities. Some of their characteristics, such as population and main economic activity are also shown on this figure.

The selection criteria are based on geo-political, social and economic differences, as shown in Table 1. Some of the characteristics include: main ports of entry to Mexico (from California, Arizona and Texas); most populated city in the state; agricultural cities; touristic cities. The following cities were studied: Chihuahua, Cuauhtémoc, Fronteras, Hermosillo, Juarez, Mexicali, Monterey, Nogales, Rosarito and Tijuana.

2.2. Stakeholder selection process

Approximately 95 interviews were completed with different stakeholders: users (residential and business), electronic retailers, computer refurbishers, street sellers of used computers, owners of used-computer shops, Internet kiosks, electronic waste recyclers, metal recyclers, scavengers, a CRT glass recycler, and landfill operators. The study included both informal and formal stakeholders. Formal recyclers were located through e-mail to set up an appointment. Personal interviews in the field were scheduled with those which accepted to be interviewed. Informal recyclers had to be