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Reverse logistics practices for recovering mobile phones in Spain

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Abstract

The main objective of this paper is to characterize the reverse logistics system for mobile phones in Spain. The study includes the characterization of the different actors involved in the reverse logistics system and the description of the most common logistics practices in the sector. We will also propose alternative practices for managing this complex reverse logistics system and finally, we will analyse the challenges of the current reverse logistics model. Some alternatives for the current model are: location of reception points for end-of-use mobiles, the need to legislate the second-hand mobile phone market and the location of the necessary recycling centres according to current legislation.

Key words: Reverse logistics, e-waste, mobile phones, recovery practices, collection practices, Spanish case

1: INTRODUCTION AND LITERATURE REVIEW

Generation of electronic waste is currently an important problem in modern society. The European Union (EU) JRC/IPTS report of Savage et al. (2006) states that electro-scrap is the fastest growing waste stream, growing at 3-5% per year, which is three times faster than average waste source. Each EU citizen produces 17-20 kilograms of technological waste per year (Savage et al. 2006). PCs and mobile phones make up the bulk of office and communication waste (Zoeteman et al. 2010). They also contain many toxic substances which pose a threat to human health and the environment. As a legal response to this problem, all EU Member States producers have been required to organise collection and environmentally sound management of all electronic equipment put on the market since 2005 (Directive 2002) and for batteries since 2008 (Directive 2006). The directive of the European Parliament and of the Council on Electrical and Electronic Equipment Waste (WEEE Directive 2002), dated 13th of February, 2003, seeks the prevention of generation of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes in order to reduce waste disposal. Collection rates of at least 4 Kg WEEE per inhabitant and year, as well as recycling and recovery targets for 10 different categories of WEEE, have to be fulfilled. More specifically, mobile phones are included in category 3 (IT and telecommunications equipment). For this category, producers were to fulfil the following target by the 31st of December, 2006: the rate of recovery should have been increased to a minimum of 75% by an average weight per appliance, while the rate of reuse and recycling of components, materials and substances should have been increased to a minimum of 65%. The management of this waste is a relatively new problem as it is shown by the literature reviewed. We have revisited international scientific literature that analyzes the impact of the implementation of the WEEE Directive in different countries, such as: Walther and Spengler (2005) for Germany case, Hischier et al. (2005) in Switzerland, Festzy et al. (2003) in Scotland; or in another countries like: Hicks et al. (2005) in China, Yoon and Jang (2006) in Corea or Streicher-Porter et al. (2005) in India. In the Spanish context, the relevant legislation on the subject is Royal Decree 208/2005. Spain has a population of close to 47 million inhabitants (*Instituto Nacional de Estadística* (*INE*: national institute of statistics)), 2008) distributed in several autonomous communities, each of which has environmental responsibilities whereby they comply with environmental legislation by means of specific Waste Processing Programs. As there are 17 autonomous communities in Spain, the problem of disposing of this waste is, at best, complicated.

If to the above we add that most of the components of a mobile phone are recyclable: 40% plastics, 15% glass and ceramics, 15% copper and compounds, etc. (MPPI 2008), a research study of the problem, from the perspective of reverse logistics management, acquires special interest[1].

The literature review made shows that research on cell phones in particular emerged around 13 years ago, when they were targeted by European policy makers (Clift, 1997). The European Trade Organization for the Telecommunication and Professional Electronics Industry (ECTEL) trials, through their so-called Cellular Phones Take-back Working Group conducted a series of publications which include some recommendation of end-of-life mobile phones management (Clift & Wright, 2000) or a life-cycle energy model for take-back and recycling mobile phones (McLaren et al. 1999). Mobile Phone Partnership Initiative (MPPI) created in 2002 developed guidelines through volunteer working groups within the framework of the Basel Convention, with special focus on environmentally management of end-of-life mobile phones (MPPI, 2008). In 2004, and more focus on life cycle assessment of mobile phones, Huisman applied his own environmental assessment methodology of e-waste to mobile phones (Huisman, 2004). Guide and Van Wassenhove (2001) published their article for managing product returns for remanufacturing, and in 2005 Guide et al. published the Recellular Inc. Case (2005), which includes the so called USA remanufacture case of mobile phones. More recently Geyer and Doctori Blass (2010) try to quantify the economic performance of reuse and recycle operations for end-of-use mobile phones based on a research study conducted in U.K in 2003 and in USA in 2006.

2: OBJECTIVES AND METHODOLOGY

The main goal of this paper is to characterize the reverse logistics system for mobile phones in Spain. The study includes the characterization of the different actors involved in the reverse logistics system and the description of the most common logistics practices in the sector. We will analyse the challenges for reverse logistics practices with the Spanish mobile phone case. We will also identify the causes for the inefficiencies in the system and finally, we will propose some solutions for managing this complex reverse logistics system.

The methodology used to achieve these objectives is mainly based on the inductive approach principles of case study research (Eisenhardt, 1989; Ellram, 1996). To build the case, we have first reviewed the scientific literature about reverse logistics management for e-waste, specific literature of the sector (mobile phones) and current legislation related to the topic and secondly, we have visited Spanish treatment plants (one locate in Madrid and another one in Vizcaya -the most important one in Spain for WEEE) and enterprises engaged in the collection of mobile terminals (more specifically, we have contacted with two take-back enterprises operating in Spain). Additionally, interviews have been held with the logistics managers of these companies. We have completed the field study with reports published for Spanish companies and by following professional forums where logistics managers from different industries discuss their main business concerns (sustainability symposium, Green TIC congress). The experience acquired in the field study has enabled us to characterize the reverse logistics practices of used and end-of-life mobile phones in the Spanish sector.

The remainder of the paper is organized as follows. In section 3, we include a description of the product architecture of a mobile phone, describing the environmental implications of hazardous materials included in this equipment. Next, in section 4 we present the characterization of the current logistics system for managing mobile phone waste in Spain, including a detailed description of the main actors operating in the Spanish system. After that, in section 5 we analyse the challenges for reverse logistics practices in the Spanish mobile phone case. Finally, in section 6 we present our conclusions and future research proposals.

3: PRODUCT ARCHITECTURE AND HAZARDOUS MATERIALS

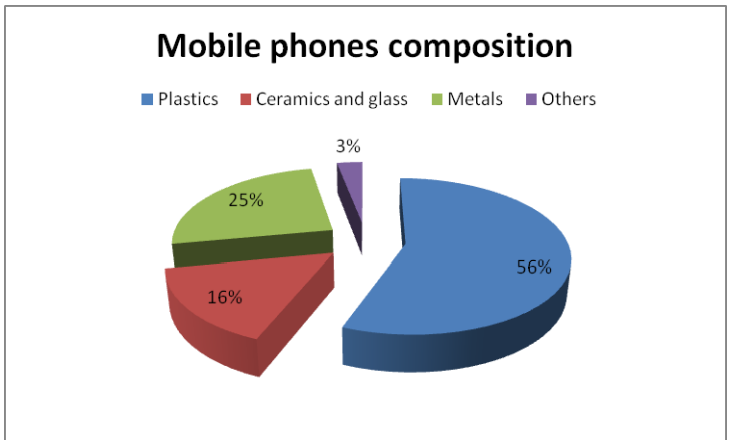
Mobile phones are complex devices which include more than 400 components. The three basic components of a mobile phone include (1) the handset, which includes a case (usually plastic), liquid crystal display screens-LCD, keypad, antenna, printed circuit board-PCB, microphone and speaker, (2) the battery and (3) the battery charger and other accessories (such as a carrying case, earphones and connecting cables) (MPPI, 2009a).

Mobile phones composition may differ from manufacturer to manufacturer, and from model to model. Thus the substances in any mobile phone will be somewhat different from the

[1] This paper stems from the participation of the authors in a research project funded by Plan Nacional de I+D+i, reference DPI2007-65524, title DOLI "Análisis y desarrollo de técnicas para el Diseño y la Operación de

substances in another, dependent upon design, manufacturer, and age of product, etc. For example, in larger parts such as the case, most mobile phones have a plastic case, but some might use aluminium, or magnesium. A detail explanation of substances contained in mobile phones can be found in the *Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones* elaborated by the MPPI (MPPI, 2009a). However the general composition is similar among all mobile phones. As an example, we include in Figure 1 the percentage in weight of the main types of materials and components contained in Nokia´s mobile phones (not including batteries or accessories) estimate by the Fraunhofer Institute (Nokia, 2000). The chart is very similar to the one presented in Vodafone report (p. 39, Vodafone 2005).

Figure 1- Mobile phone composition (% in weight) Source: Nokia & Fraunhofer Institute (2000)



Batteries are the most contaminating substance of the telephone's components because they could contain nickel, cadmium, lead, lithium and metal hydride. Arsenic (in chips made of gallium arsenide), antimony, beryllium, cadmium, lead (used in tin-lead solder), nickel, palladium, silver, gold, tantalum, zinc, bromine compounds and mercury are found in one way or another in the components that compose a mobile phone. Many of these metals (arsenic, barium, cadmium, lead, mercury, silver) are considered hazardous by the United States Environmental Protection Agency (EPA). The toxic materials of interest under European Union's Restriction of Hazardous Substances (RoHS) Directive are lead, mercury, cadmium, hexavalent chromium, polybrominated biphyenyls (PBB), and polybrominated diphenyl ethers (PBDE). Of these hazardous constituents, the only ones routinely found in mobile phones today are lead (0.638 g/phone) and hexavalent chromium (0.820 g/phone) (Lindholm, 2003). According to a report issued by the Mobile Phone Partnership Initiative of the Basel Convention (MPPI, 2009a), nickel-cadmium batteries have been phased-out in mobile phones and are rarely found today, except in older phones still in use; there are no

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known current uses of mercury in mobile phones; and the two brominated flame retardants most used in mobile phones today are tetrabromobisphenol-A (TBBPA) and decabrominated biphenyl ether (DBBE), which are currently not restricted under RoHS. The environmental concerns regarding mobile phones come for their content of heavy metals (they are not biodegradable or chemically degradable) or toxic flame retardants substances. So, *Environmentally Sound Management*, used and end-of-life mobile phones should be diverted from disposal practices such as landfilling and incineration to the more environmentally sound practices of reuse, refurbishment, material recovery and recycling.

4: CURRENT LOGISTICS SYSTEM FOR MANAGING END-OF-LIFE MOBILE PHONES. SPANISH CASE

In this section, we are going to present the Spanish reverse logistics system that is typically used in the sector for the collection and treatment of end-of-life mobile phones. This research is focused on end-of-life mobile phones, that is, a mobile phone that is no longer suitable for use and it is destined for material recovery and recycling. The reuse option for used or end-of-use mobile phones (which include repair and refurbish) is not analyse in deep in this paper (out of scope of the paper). The model presented has been drawn up based on the field study done as part of this research and therefore, is representative of the Spanish context.

In accordance with existing regulations in all EU member states, users of electrical and electronic equipment should be able to return this waste at the least free of charge. Thus, the management and financing of the recycling of these devices is the responsibility of the producers (producer has been defined by OECD as being manufacturer, importer or distributor of a product as part of Extended Producer Responsibility – EPR- principle), from reception at the different collection points, storage, transport and treatment to the correct elimination of all waste.

The points at which mobile phones potentially generate waste are: end users (who discard the product), distributors (i.e.: returned products) and producers (obsolete batches, defective products, etc.).

Regarding selective collection points for mobile phones in Spain, the basic points are:

- Recycling centres (in Spain called *puntos limpios*) and other municipal waste collection centres, where users can deposit their WEEE in general and mobile phone waste in particular.
- Sales outlets of mobile phones.
- Shopping centres that have containers for selective collection of used mobile phones.
- Large distributors (Carrefour, Eroski, etc.) that have containers for selective collection of used mobile phones.
- Public institutions (schools, universities, town halls, etc.) that have containers for selective collection of used mobile phones.

The rest of mobile phones, that is those that do not end up in one of the currently existing selective collection points, wind up in landfills as uncontrolled waste (with the consequent environmental damage that this waste can cause), or in the drawers of the houses of the users that have stopped using them (it is estimated that a scarce 1 in 5 mobiles is recycled, Nokia 2008).

The collection systems in Spain (which are described in section 4.1) are responsible for transporting the mobile phones collected to appropriate storage facilities. These can be:

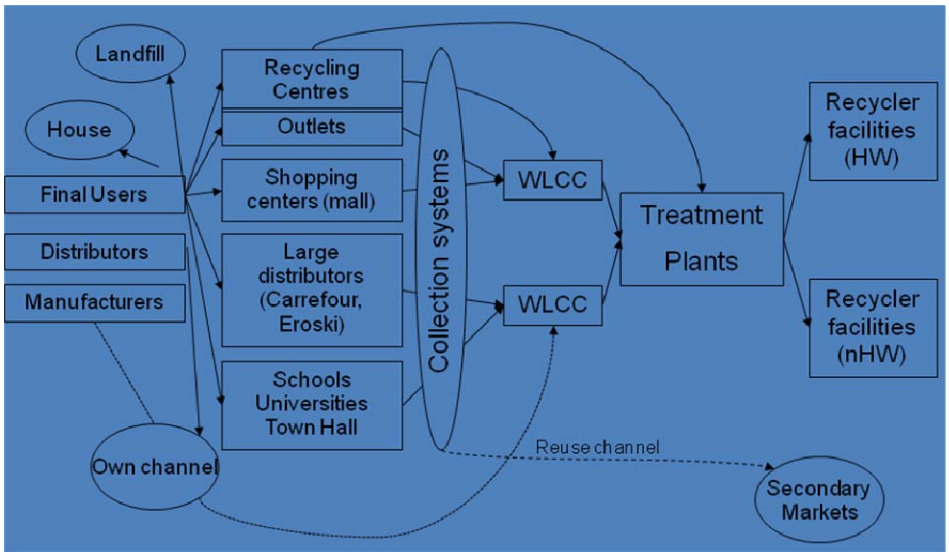
- Storage facilities of the distribution companies.
- Waste Load Consolidation Centres (WLCC) that receives the WEEE from the municipal waste collection centres and from the different selective collection points, in order to consolidate waste loads before transporting them to the corresponding treatment plants. There is usually at least one or various per province. The object is to lower the cost of transport to the treatment plant.

Once the terminals are collected and storage, there are two main options for them: reuse channel for used mobile phones (with refurbishment or little repair for resale in secondary markets - detail explanation of this option in section 4.1.2) and recycling option (which includes material recovery and recycling).

For recycling option, they are transport from storage facilities to recycling facilities (treatment plants in Figure 2). At these plants the products are decontaminated, potentially hazardous components of the WEEE are removed from the handset by manual separation (batteries, integrated circuits and crystal liquid displays), accessories and packaging are also

sorted and separated manually from the mobile phone handset and the different recyclable components of the handset are separated manually (e.g. case) or using magnetic separation (ferric and non-ferric metals, plastics, etc.). Once separated they are recycled at the plant (if it is prepared to do so) or they are sent to authorized recycling facilities. These are divided into: hazardous waste recycler facilities (HW), such as authorized batteries recycler and non-hazardous waste recycler facilities (nHW) such as steelworks, smelting plants, plastic recyclers, etc. Figure 2 presents a schematic version of this model.

Figure 2 - Logistics system for used and end-of-life mobile phones. Source: own development



4.1: Collection Systems in Spain

Spain has a population of approximately 47 million inhabitants (46,661,950 as of January 1, 2009 according to the *INE*). It is the fifth most populated country in the European Union; nevertheless, its population density (92.4 hab/km² *INE* 2009) is lower than the majority of other Western European countries. Population density is one of the parameters that affects how collection facilities for end-of-use mobile terminals are established in a municipality.

The government of each autonomous community is responsible for authorising the Integrated Management Systems (IMS) that work within its autonomous territory, therefore granting the distribution of competencies related to recycling in Spain to each autonomous community. This means that 17 different IMS situations for collection and treatment of WEEE co-exist in Spain. However, some of these IMS are working in the majority of autonomous communities and can therefore, be considered to provide services on a national basis. This is the case of ECOTIC, ECOLEC, ASIMELEC, ERP, and ECOLUM. Additionally, ASIMELEC

(*Asociación Multisectorial de Empresas de Tecnología de la Información, Comunicaciones y Electrónica*) includes three others: TRAGAMOVIL, ECOPILAS and ECOFIMÁTICA.

Considering that EEE are classified in ten categories, the authorisation given to a particular IMS in each autonomous community is limited to specific categories. The authorisations granted by each of the autonomous communities must be published in their official bulletins.

Concretely, mobile phones belong to category number 3: IT and telecommunications equipment, directive 2002/96/EC.

Some of the initiatives for collecting mobile phones which have been developed in Spain will be briefly described in the following sections. It is important to point out that there is a notably dynamic component among the entities interested in collecting end-of-use mobile phones, motivated to the value that many used mobile phones have and the possibility of sale them on the second-hand market.

4.1.1: Tragamovil Foundation

The "Fundación Tragamóvil" was set up by Asimelec in 2003 as a non-profit organisation to manage waste from telephone and communications equipment and their accessories.

Its objectives are primarily environmental since it works to prevent pollution by selective recycling of mobile phones, encouraging recycling and making millions of users aware of the need to deposit this type of device in the appropriate place.

Tragamóvil is an initiative promoted by mobile phone manufacturers and telephone providers, such as Telefónica, Vodafone, Nokia, Motorola, etc.

The "Fundación Tragamóvil" locates its own containers for the collection of end-of-use mobile phones at Collection Points. The 851 points published in its website are located all around Spain and are basically situated in: Telephone Sales Outlets; Technical Service Providers; Recycling Centres; Town Halls; Universities; Shopping Centres.

Once the containers are filled with end-of-use mobile phones, they are transported to the so-called Waste Load Consolidation Centres (WLCC). These centres have the aim of consolidating loads so as to apply transport economies of scale. There may be one or more WLCC per province, depending on load volume. Finally, mobiles are sent to recycler facilities for treatment and recycling processes. In 2008, the "Fundación Tragamóvil" treated 1150 tons of telephone and communications waste, including fixed telephone waste (based on primary data collected).

4.1.2: "Dona tu móvil" (collection by charitable organizations)

"Dona tu móvil" is a campaign began in 2004 by the Spanish Red Cross, the *Fundación Entreculturas* and *Alboan*, and has the collaboration of the British company CMR (Corporate Mobile Recycling). The Red Cross is an international humanitarian institution, the *Fundación Entreculturas* is linked to the Jesuit religious order and works in the education sector while *Alboan*, also linked to the same religious order in the Basque Country and Navarre, works in development aid. Therefore, it is an initiative on the part of non-governmental organisations (NGO) who are seeking funding for their humanitarian and social projects through the donation of mobiles.

Specifically, this campaign has two primary objectives:

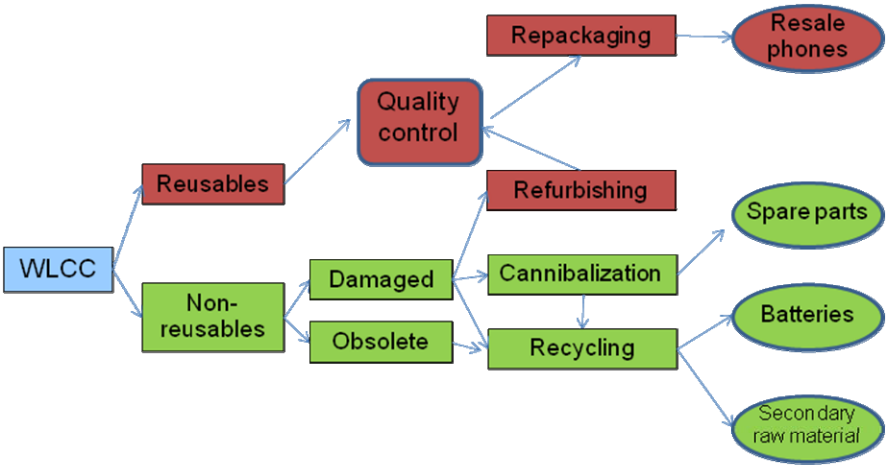
- Social Action: the income generated through the reuse of the donated mobile phones is utilised in humanitarian, social and education projects;
- Environmental Care: by promoting the reuse and recycling of end-of-use mobile phones.

A number of companies are collaborating with this campaign by providing space and safekeeping for the containers. These include companies like ADIF, Sabeco, Iberia, BBVA, Correos, El Corte Inglés and DIA. Their website states that there are more than 1900 companies and institutions that have been collaborating with them since the beginning of the campaign and there are more than 5000 collection points. Even without being a collaborating company, by making a simple phone call indicating that you have a minimum of 30 mobile phones to donate, a messenger will be sent out to pick them up.

CMR is the enterprise in charge of collecting these mobile phones (collection by charitable organizations). They have collected 400.000 mobiles from 2004 to 2009 (primary data obtained by a personal interview with the Spanish manager of the company). The average value of mobile phones collected that is given to NGO organizations is 1,8 €/phone (primary data). Once the mobile phones have been collected, they are classified into three categories: reusable handsets, damaged and obsolete. After testing and sorting, the reusable handsets undergo a quality control process. Damaged handsets undergo a possible refurbishing and repair process. Finally, a repackaging process takes place before the handset is distributed in the second-hand market (China, South Africa, India…). Obsolete or damaged handsets (that cannot be refurbished) are sent to a recycling facility locates in United Kingdom for recycling

and spare parts for cannibalization are sending to China. A brief description of this logistic process is included in Figure 3.

Figure 3 – Management model for used and end-of-life mobile phones following by "charitable organizations". Source: own development



Another initiative for collecting mobile phones is movilbank.es. In this scheme, the company buy only certain models of mobile phones (for reselling in secondary markets). If customer is interesting in selling the phone a courier will pick up it. After the inspection and testing that everything is according to specifications, company pays in the corresponding amount. Movilbank offer the option to donate all or a part of this amount to a charitable organization (they collaborate with "dona tu movil").

There are others initiatives for collecting unusable, damaged or obsolete mobile phones in Spain, like the company Biotel (Sistemas de Telefonía SL). Biotel is primarily directed at mobile telephone sales outlets and companies, both of which can accumulate a certain quantity of mobile phones. Additionally, the company has also shown interest in spare parts or complete telephones from mobile telephone technical service companies. In any case, Biotel buys the material according to its own rates. For interested companies, Biotel proposes installing the so-called eco-packaging so that employees can deposit the mobile phones in disuse. Very similar initiative is offered by fonebank for selling company or organization´s mobile phones.

4.2: Treatment Plants in Spain

There must be a minimum volume of WEEE for treatment plants to be profitable. Until now, the plants in Spain have dealt with all or a great part of the types of waste generated from EEE. The majority of these plants work with various collection systems that guarantee them a

sufficient volume for the investment made to be viable. There are currently more than 12 plants in Spain for recycling WEEE (including all categories) and only five plants in Spain that recycle waste generated from EEE including in category 3. Of these five plants (shown in Table 2) only two of them recycle mobile phones in Spain.

Table 2 – Main WEEE treatment plants located in Spain.

Facility	Location	Max. treatment capacity (ton./year)	WEEE categories treat
Indumetal Recycling	Pais Vasco	60.000	2,3,4,5,6,7,8,9
Reydesa Recycling	Pais Vasco		3,4
Recitel	Madrid	30000	2,3,4,6,7,8,9
Recilec	Andalucía	8000	2,3,4,6,7,8,9
Electrorecycling	Cataluña	15.000	1,2,3,4,5,6,7,8,9

The following is a more detailed description of the two plants that recycle mobile phones.

4.2.1: Indumental Recycling, S.A.

The company Indumetal Recycling, S. A. was founded in 1984 from the company Indumetal, traditionally dedicated to the mining and metallurgical industry. Among its objectives are recycling EEE as well as planning, logistics, dismantling and integral treatment of WEEE. Indumetal Recycling, S.A. is currently a reference plant for WEEE recycling services in Spain given the volume of waste they treat yearly. Furthermore, they are holders of the certificates ISO 14001 of environmental control and ISO 9001 which certifies quality control in the processes and products and Indumetal is recognised and authorised by the Environmental Ministry of the Basque Government as: Authorised recycler of hazardous waste; Authorised recycler of non-hazardous waste; Centre for Consolidation and Classification of WEEE.

They have two treatment plants. The larger of the two is in Asúa (Vizcaya) and the other in San Agustín de Guadalix (Madrid). Of the two, only the one situated in Vizcaya recycles mobile phones.

They use magnetic separation for secondary raw materials and after the separation a mobile phone handsets are shredding. Note that this facility is dedicated to treat electronic waste, so loss of precious metals will be minimized.

4.2.2: Recilec, S.A.

Reciclado de Componentes Electrónicos, S.A. (RECILEC), is a corporation founded in 2005 by the following shareholders: environmental management company (Environmental Ministry of Andalusia), *Fomento Construcciones y Contratas* and Indumetal Recycling. The company strives to provide integral services to all agents implicated in generating WEEE who need to manage this waste within the current legal framework.

The WEEE final treatment plant is in the *Parque de Actividades Medioambientales de Andalucía* (environmental activities park of Andalusia), located within the town limits of Aznalcóllar (Sevilla). They also have a new centre in the "Fuente Santa" industrial estate in the municipality of Loja (Granada). The location of these facilities means that the provinces of eastern Andalusia will have service closer by.

The logistics department of the company RECILEC processes the requests for collection from IMS, municipal recycling points and private companies. Their website even provides information about the location of all the municipal recycling points in Andalusia.

The Aznalcóllar plant is designed to treat 40,000 tons of electronic waste annually, which is equivalent to the waste generated by the populations of Andalusia, the Canaries and Extremadura (considering that the quantity generated is four or five kilos per person per year).

An evaluation of sites for the location of WEEE recycling plants in Spain is made in the Queiruga et al. (2006) study.

5: CHALLENGES OF THIS MODEL

In the previous sections, the reverse logistics system currently used in Spain for the recovery and subsequent treatment of end-of-use mobiles has been presented. The research undertaken has allowed us to identify a series of inefficiencies in the system. In the following sections the main problems identified will be described, the causes for these problems analysed and solutions for improvement proposed.

5.1: Less Volume Collected

One of the problems identified in the current reverse logistics system for end-of-use mobiles is the low recovery rate of this waste through “official” channels. In Spain, Tragamóvil recycled 1,154,084 kilos of mobile telephone and communications waste in 2008 (this figure includes mobiles and also switchboards and other types of communications terminals. Primary data), which are equivalent to more than nine million mobiles if the figures only

included recovery of this kind of terminal. Even with this, the figure is insignificant if we take into account that 21 million of these devices were sold in Spain in 2008, some 3,500,000 kilos (data provided by the Foundation Tragamóvil).

Two main causes for this situation have been identified. The first of these is that a scarce 1 in 5 mobile phones is recycled (Nokia, 2008). A study conducted by Nokia has shown that only 3% of consumers are concerned about depositing the mobile phones they no longer use in a selective collection point. According to Singhal et al. (2005), one of the main reasons for this low percentage of mobile phones that are recycled world-wide is the consumer reluctance to dispose of the phone. Real recovery rate data from the main Spanish managers in charge of carrying out recovery are not available. Even with this lack of data and with estimations that the current recycling rate does not reach 3%, it is evident that this is one of the principle problems encountered in this logistics system.

The second cause of this problem identified is the fact that this is waste that maintains a certain value and that is easily portable. This fact has caused the emergence of a large secondary market of mobiles discarded by their owners. In fact, a high percentage of this waste is being diverted toward these other channels. Other waste is easier to manage in the first stages due to the fact that they have no value except when recycled (for example, batteries). In the case of EEE waste like home appliances (washing machines, refrigerators, etc.), this problem has not arisen. This is at least in part because they are disposed of when they no longer work, while a great percentage of mobiles is replaced for a new model when they still function perfectly well. Even though these large home appliances could be valuable if they worked properly when discarded, their volume and weight make it more difficult for these other “spontaneous” channels to appear. This causes the recovery rate of mobile phones through “legal” channels to be very low (scarcely 5%) in comparison with other waste generated in the sector (for example, if we compare the case of batteries with a rate of 21%).

This fact means that more and more channels oriented toward the search for second-hand markets for these devices are arising. On the one hand is the resale market, whose aim would be to obtain income for the sale and in which the user would receive some remuneration for depositing his or her mobile phone in this channel. On the other hand, there is the donation model whose object is to bring new technologies to Third World users. In this case, the user moved by solidarity with disadvantaged countries, would opt for turning it in (donating) to

this cause. These secondary markets are causing a great part of the percentage of recovered devices to be diverted toward this channel.

In this sense and from an environmental point of view, this option, which would lead us to the reutilisation of the product (directly or with little reconditioning), would give mobiles a second use and thus prolong their useful life, which a priori could be more beneficial than opting directly for recycling as the first option. Furthermore, this is the first option of reverse logistics contemplated in the Royal Decree (208/2005). The problem would appear if this resale or donation of the product was carried out in a country in which the disposal, which would be necessary after some time, is not regulated and this waste winds up in uncontrolled landfills. In this second case, if the environmental damage that this option could cause globally is analysed, it would clearly be more prejudicial.

This would lead us to commit to a solution that encouraged the reutilisation of these devices as a first option, but utilising safe channels (that guarantee the proper treatment of end-of-use terminals). One possible solution to this problem would be to regulate these secondary markets in such a way that the responsibilities of the organisations that sell or send these devices to other countries would be clearly delimited. The Spanish transposition of the WEEE Directive is aligned with the policy focused on an extension of producer responsibility (ERP) (Lifset & Lindhqvist, 2008) to the end-of-use-phase of their products. More specifically, it is based on the philosophy of “the one who pollutes pays”, attributing the responsibility for the waste to the manufacturer who puts the product on the market. The moment in which these secondary markets arise and the manufacturer loses control over these markets, we find ourselves facing a legal vacuum. Along these lines, we should mention the Basel Convention (MPPI, 2009b) which attempts to regulate the trans-boundary movement of hazardous waste between countries, especially from “developed countries” to “developing countries”. This agreement includes these objectives: 1) to ensure that the trans-boundary movement of hazardous wastes (printed circuit boards are considered to be part of this category) and other waste is reduced to the minimum consistent with the environmentally sound and efficient management of such waste, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement; 2) to assure control of trans-boundary movement of hazardous waste and prevent illegal traffic. The agreement focuses on waste, with the idea that waste is substances or objects whose elimination must be carried out (Basel Convention, 1989). By the year 2002, 149 countries,

including all of those of the European Union, had ratified this agreement. Accordingly, it is illegal for any European country to export electrical and electronic waste. Nevertheless, devices and electronic components that are reused without the need for any kind of process are not considered waste. This would be the case of mobile phones that are discarded by users, but which still work perfectly well and are donated or sold to developing countries where there is no existing legislation that guarantees the proper treatment of these end-of-life phones. It is precisely in these cases that a legal vacuum exists.

Regarding the proposal of solutions to increase the volume of recovered mobile phones, the following should be mentioned: citizen awareness policies (to inform them of the advantages of depositing end-of-use terminals in the appropriate channel for proper treatment); incentives to users to participate in a used mobile phone collection system (to encourage users to dispose of their end-of-use phones in the appropriate points by either paying them a certain amount or giving them a discount when buying new products, for instance the "re-mobile plan" for *The Phone House* in Spain offers 5€ discount on the purchase of new phones per each used mobile phone -including the corresponding charger- discard in the shop); improve accessibility to the collection points for final users (which facilitates collection of the devices), location of collection points in such a way that economies of scale can be taken advantage of (to reduce transport costs), collection point control (new unauthorised actors are appearing who remove the telephones from the collection points established by the authorised IMS), location of the WLCC to take advantage of scale economies in transport.

5.2: Need for High Volume of Mobiles in Recycling Plants

The second of the problems identified is related to treatment plants since they need to treat a high volume of this waste for its recycling to be profitable. The cause of this problem is that the devices being dealt with are lightweight (some weigh less than 100 grams and 10 terminals are needed to make up each kilogram of mobile phones), and are composed of 58% plastic, 25% metals like iron, copper, silver, gold and 17% glass. The metals, which are concentrated mainly in the components of the printed circuit board, are the materials which potentially have the highest index of toxicity. Once the old telephone enters the treatment plant, the first stage is to decontaminate it (the battery and liquid crystal displays are removed). Next the plastics and metals are separated. In order to recover the metals, a refining process is used for precious metals and the copper is smelted, while the plastic and other

materials which are stuck to them can be used as fuel for metal recovery. Because of the very design of mobiles many of the plastics that they contain cannot be reutilized as raw material since the contamination by metals impedes this. The most valuable components, such as the semi-precious metals (like gold and silver), or the strategic ones like coltan, only exist in very small quantities (for a single unit the precious metal content is in the order of milligrams: 250mg Ag, 24 mg Au and 9 mg Pd) (UNEP, 2009). A very high volume of this waste is necessary for their recycling to be profitable. There is currently no working plant in Spain which recycles these devices exclusively. Generally, they are treatment plants for other types of EEE, and include among these, mobile phones. The field study carried out as part of this research has enabled us to confirm that the volume of mobiles treated by one of the main EEE waste recycling plants at a national level is very low, almost trivial (less than 3%). A possible solution to this problem would be to improve recovery systems in such a way as to attain a high volume of this waste and thus make dedicating a plant or a certain capacity of a plant to this treatment profitable.

5.3: Fragmented Logistics System

The third problem identified, more directly related to the recovery systems, is that this is a complex and fragmented logistics system. One of the causes of this situation is the fact that authorisation for IMS is granted by the Autonomous Communities for a period of five years. For an IMS to operate nationwide they would be obligated to have 17 different authorisations which at the very least, from an administrative point of view, would complicate the management of these systems. An analysis of this situation from a logistics point of view, brings us to the need of having recovery systems which cover a wide geographical area (this would mean operating in different autonomous communities), thus guaranteeing a minimum recovery volume which would in turn allow the application of scale economies in transport and subsequent treatment.

A possible solution to this problem would be to have a system that coordinates the different administrations (local, regional and national) and agents involved in the system to be able to consolidate sufficient load to reduce transport costs and to reach a high enough volume of this waste to make its recycling profitable. Likewise, besides the administrative problem that having or not having authorisation to operate in a particular autonomous community can suppose, it is important to mention the necessity of locating the treatment plants in the most

appropriate area to reduce transport costs (regardless of the autonomous community in which it is located or the one that the waste to be treated originated from). Other EU countries, like Netherlands, Belgium or Sweden, have adopted a National Collective System (monopoly). This model properly managed are considered by many stakeholders as providing the simplest and most effective route to collecting and recycling WEEE, achieving economies of scale (especially in small countries where volumes cannot create a viable market for multiple systems) (Savage, 2006). Other aspects which may influence the improvement of these systems are the investment priorities or awareness campaigns that may also be different depending on the area in which we find ourselves. This problem identified in the Spanish context not only affects mobiles, but also the rest of electrical and electronic equipment waste and the recovery of batteries.

6: DISCUSSION AND CONCLUSIONS

The expected outcome of this research is to present the current model of e-waste management, specifically for mobile phones, including the main actors and the most important logistics practices used nowadays for collecting end-of-use mobile phones in the Spanish context. The model presented includes the description of: points where waste is generated, collection points, organized management systems for recovery, transfer centres, treatment plants and recycling waste final facilities (both for hazardous and non-hazardous waste).

The characterization of the current model allows us to identify the weaknesses of this model, pointing out both the less efficient points and the ones that need to be improved. Considering the current Spanish consumption rates and the fulfilment of current legislation in Spain, we have looked for alternatives to the present model. Some of these alternatives are: location of reception centres for end-of-use mobile, incentives to increase collection rates, the need to legislate the second-hand mobile phone market and the location of the necessary recycling centres according to current legislation.

Recovery systems should have sufficient capillarity and be located in areas with an acceptable number of inhabitants or groups of population to make management of this waste profitable. On numerous occasions, compliance with the objectives established in the Royal Decree (208/2005) is at odds with profitability in these WEEE management systems. To this it must

be added that this is a complex management system, in which the competencies have been delegated to the autonomous communities (17), which in turn complicates its administrative management and causes the need for a coordination system for the different agents in order to obtain scale economies in transport and in treatment of waste. It has been demonstrated that this problem also exists for other types of waste electrical and electronic equipment.

The low volume of recovered telephones in comparison to those generated each year is due to, on the one hand, the lack of citizen awareness (users who keep old mobiles in a drawer) and on the other hand, that it is a valuable waste and easily portable which means that a large part of mobiles is being diverted to secondary markets. We should not forget that the legal framework in force in Spain holds producers responsible for the recovery and appropriate treatment of mobile phones placed on the market, applying the principle "the one who pollutes pays". Therefore, the logistics model proposed must ensure compliance with this requisite. Thus, and especially in the case of waste generated by mobile phones, special attention should be paid to the secondary markets appearing around this waste and the regulation of these alternative channels, in order to ensure compliance with the requisites imposed by the Royal Decree (208/2005) and that the proper delegation of responsibilities is carried out. In this study we advocate a management system that contemplates reuse as the first option, but doing this while utilising channels that guarantee adequate treatment of this waste at the end of its useful life. Likewise, we advocate an integral management model that takes care of the terminal as well as the battery and the rest of accessories that accompany this waste.

Regarding recycling plants, there are currently a sufficient number of plants in Spain with enough capacity to treat the volume of mobile telephone waste generated. Furthermore, at the moment there is not sufficient "critical mass" for it to be profitable for a plant to work exclusively with mobile recycling. Currently, only two of the six plants located in Spain (which also recycle other types of WEEE) recycle mobile phones. As these are small, lightweight devices, a very high volume is needed in order for the process to be profitable. The majority of these plants have agreements with various Integrated Management Systems so as to have a volume of telephones that guarantees the viability of the investment made in proper treatment. Carrying out a study on locating treatment plants in such a way that the

requisites of the Royal Decree (208/2005) are complied with and that treatment is financially profitable could be the object of future research.

The main problem identified in this study is the low volume of end-of-use mobile phones recovered for recycling. A future topic of research could be to improve the collection system of this waste so as to guarantee proper treatment at the end of useful life.

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