A location model proposal for collecting used portable batteries in Spain

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Abstract
The main objective of this paper is to propose a model for helping logistics managers to choose the appropriate location points in order to situate the collection points for used portable batteries. The proposed model has two parts: a static part and a dynamic part. We can conclude that this model helps managers in the decision of locating/modifying collection points in two ways: to add new collection points to a reverse logistics network that needs more points or to delete collection points from a network that has more points than those recommended.

Keywords: reverse logistics, collection points, used batteries.

Introduction
Batteries supply energy to many kinds of portable electric and electronic devices such as: telephones, radios, computers, mobile phones and even electric and hybrid cars. More than 40 billions of batteries are sold worldwide. According to this situation, countries have to decide what to do with billions of spent batteries containing millions of tons of toxic and hazardous compounds (Pistoia 2001).

According to the European and other countries´ legislation (USA, Japan) used batteries and accumulators are considered as hazardous waste. Batteries may contain toxic metals such as cadmium, mercury and lead, so their disposal must be controlled (Bernarders et al. 2004). As a legal response to this problem, the European Union has issued regulations for electrical and electronic equipment WEEE (European Union 2002a, b) and for spent batteries (European Union 2006). 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). A selective collection system is needed according to the European Batteries Directive 2006/66/EC. The collected waste batteries should be treated properly. The Directive, which entered into force on 26 September 2006, quantifies recycling targets for collected zinc carbon and alkaline waste batteries. It sets out a recycling rate of 50% for consumer waste batteries.

In the literature review made, we have found some studies dealing with different waste battery treatment options (Bernardes et al. 2004; Briffaerts et al. 2009) and other studies that have developed several recycling processes for different types of waste batteries: waste nickel–cadmium batteries (Huang et al. 2010; Zhu et al. 2003); alkaline batteries (Kuo et al. 2009); lithium-ion batteries (Li et al. 2009).

Regarding the collection and design of the closed-loop supply chain for spent batteries, the case of Germany is presented in the work of Schultamnn et al. (2003), the Iran case can be found in Zand and Abduli (2008), the Poland case in Rogulski and Czerwinski (2006). The Brazilian situation is presented in the work of Bernardes et al. (2004; 2003) and a report on hazardous household waste generation in Japan can be consulted in Yasuda´s work (2006). No scientific literature was found regarding the Spanish case.

According to Schultmann et al. (2003) the spent batteries can be divided into: (1) batteries and large accumulators for industrial purpose, (2) nonrechargeable (primary) portable batteries, and (3) rechargeable (secondary) portable batteries.

The present study is focused in the design of the reverse logistics network of portable batteries in the Spanish context. More specifically, we propose an analytical model for locating collection points in the reverse logistics network for used batteries. An analytical description of various types of collection schemes together with alternative modes of transportation are analytically presented in the work of Salhofer et al. (2007). Morrissey and Browne (2004) presented a comprehensive literature review of models used for tackling waste management problems. However, the existing scientific work is relatively restricted to municipal solid waste.

In the Spanish context, the Royal Decree 106/2008 fixes that producers are to fulfill by the 31st of December, 2011 a collection rate of 25% and by the 31st of December, 2015 a collection rate of 45%. An appropriate system of selective collection is required for used batteries and accumulators. A network of selective collection points will be created according to population density, enough number of bins, accessibility and a suitable distance so that citizens can reach them easily. This study provides an easy-to-use decision support tool for helping managers to solve this problem. On the one hand, the model proposed in this paper takes into account the legal requirement and, on the other hand, tries to improve the efficiency of the current collection system.

The main goal of this paper is to propose an analytic model for helping logistics managers to choose the appropriate location points in order to situate the collection points for used portable batteries. The objective of the model is to collect, in an efficient way, the maximum number of portable batteries. So, this model will try to achieve a more efficient use of resources and also to achieve the collection targets included in the Directive 2006/66/EC, of the European Parliament and of the Council of 6th September 2006 on waste batteries and accumulators and also in the Spanish Royal Decree 106/2008, 1st February 2008.

The methodology used to achieve these objectives includes two main blocks. The first one is mainly based on the inductive approach principles of case study re-search (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 (portable batteries) and current legislation related to the topic. Secondly, we have visited Spanish treatment plants (one of the main batter-ies recycler in Spain located in Catalonia) and also enterprises engaged in the col-lection of portable batteries (more specifically, we have contacted with the main take-back system operating in Spain). Additionally, interviews have been held with the logistics managers of these companies. The experience acquired in the field study has enabled us to characterize the reverse logistics practices of used portable batteries in the Spanish sector. For the second block, the analytic model, the methodology we have followed is based on the

AHP multicriteria method for comparing the criteria we have identified in this study (we have used the Expert Choice program). We have also developed a quantitative tool for calculating the distance between collection points (developed in Visual Basic).

Characterization of the reverse logistics system for used batteries

The main steps in this reverse supply chain are:

- Selective collection from the consumer
- Transportation to the waste consolidation centre
- Transportation to the recycling facilities
- Sorting the collected batteries
- Recovering valuable components from the sorted fractions and transform them into secondary material

Selective collection is the point of contact between citizens (generators) and disposal operations. In the Spanish system, this collection point could be located in supermarkets, large distributors, malls, public institutions (schools, universities, town halls, etc.) or at recycling centres.

Spain is divided into 17 regions and each Integrated Management System in charge of collecting batteries and transporting them to appropriate storage facili-ties has to be authorized by each region. There are four Integrated Management System (IMS) authorized in Spain for collecting batteries: Ecopilas with 70% share of market; ERP with 25% of the market; ECOLEC 3% and ECORAEE 2%. Ecopilas is operating in Spain since year 2000 and this foundation includes the main batteries producers (Energizer, Cegasa, Philips, Sony, Kodak, etc.). This IMS collected in 2009, 1.170 ton of spent batteries (corresponding to more than 40 million batteries). There are more than 8.500 bins in the Spanish network, and the cities with more than 1000 bins are Madrid and Barcelona (Ecopilas, 2009).

The collection systems are responsible for transporting the spent batteries to intermediary facilities for storage and load consolidation: Waste Load Consolidation Centres (WLCC). There is usually at least one or various per region (for instance, there is one in Andalusia, another one in Madrid, etc.). The objective of this storage centres is to lower the cost of transport to the treatment plant.

Once the batteries are collected and store, they are sent to the treatment plant. Currently 100% of what is collected is transported to recycling plants, primarily because it is a delivery charges (€/Ton) for transporters, which makes sure that reaches 100%. In Spain are mainly three recycling plants, one in Catalonia, an-other one in Vizcaya and the third one in Valencia. There are some specific facilities for lead treatment and others only for sorting and pre-treatment (Ni-Cd and rechargeable batteries) that sends batteries to European facilities (located in France and Belgium).

An analytical proposal for collecting batteries

The need for locating battery collection containers in an efficient way, amply justify the development of analytical models to improve the currently system used in Spain.

The model presented in this article deals with selecting the most appropriate points to set up a network of centres for efficient collection, enabling more cost-effective management of resources.

The starting point is a comprehensive set of possible points where you install the centres of collecting. These items include supermarkets, schools, municipalities, companies, universities, recycling centres, etc. The postal address of each point is a necessary input for the developed tool. The proposed model serves both to configure network point candidates and to select the most suitable ones on the basis of an already established network.

An important aspect is the amount of points selected for each specific location. The initial hypothesis is to consider 1 collection point for every 1.000 inhabitants, based on studies of EPBA (European Portable Battery Association).

Another initial aspect to consider is that some points should be included in the network of collection centres by legal imperative. This is the case of the recycling centres: all cities of over 50.000 inhabitants should have at least one.

Potential candidates to join the network of collection centres are grouped into eight groups: shopping centres, supermarkets, small shops, universities, public centres, schools, businesses and individuals. The latter could correspond to large communities of neighbouring or different types of partnerships.

Our model includes two important considerations for selecting the most appro-priate points set. On the one hand, the characteristics of each specific point, which assesses the following criteria: accessibility; public fluency (frequented often); public awareness. On the other hand, the distances among the selected points are maximizing covered geographic areas in order to obtain efficient solutions.

The proposed model consists of two parts: a static part and a dynamic part. In the first part of the model (static part) we compare the potential of the eight groups considered. The second part (dynamic part) of the model deal with the influence of the distance between the candidates. A detail explanation of these two parts is included in the following subsections.

Static part

The essence of the static part is to compare the candidates on the basis of the established group points. It will therefore analyze the most advantageous group for the location of collection centres. At the conclusion of this analysis, a numeric value between 0 and 1 will be allocated to each group, which quantifies the adequacy of the points that make up the group to be selected as collection points. The sum of the numeric values of all the groups considered in this research is the unit.

The comparison between the eight defined groups (shopping centres, super-markets, small shops, University, public centres, schools, companies and individuals) is done considering three criteria: accessibility, public fluency (frequented often); public awareness. For tackling this problem the AHP multicriteria method was used and the Expert Choice program was selected to perform binary comparisons

Using the multicriteria decision tool AHP, we have compared and analyzed groups pairwise according to the criteria, as well as the weight of each criterion in the location of collection points. For these comparisons have been used the opinions of experts in the field of used battery collection. Figure 1 includes the final result of this comparison.

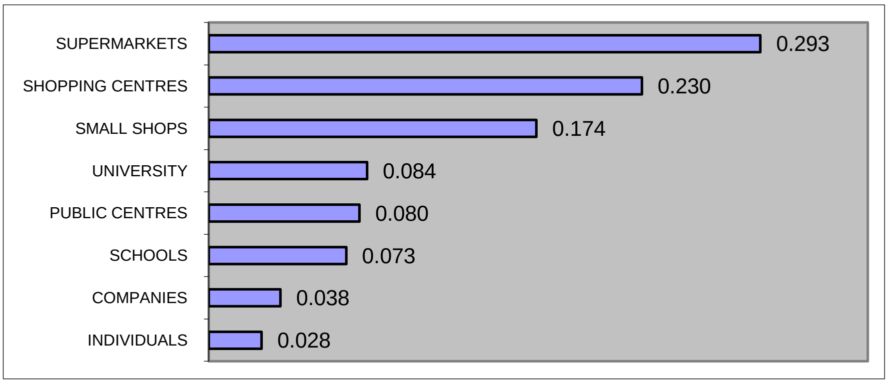

Figure 1 – Final result in static part

Dynamicc part

In the dynamic part the model provides a tool to quantify the value of each candidate point depending on the proximity of previously selected points. In particular, the considered distance is the smaller of the distances to the set of points that have already been selected.

Again a numerical value between 0 and the highest value obtained in the static part, which in our case has been 0,293 will be allocated to each candidate. Than bigger lesser distances of the candidate to the previously selected items, point more attractive is that point to be selected and, consequently, greater numeric value assigned in the dynamic part of this tool.

The objective of the dynamic part is the geographical dispersion of the points selected, thus avoiding the excessive concentration of points in the same area.

Calculation of distances between points has been through the coordinates of each point. We have used the Routing Maps Geocoding tool for the conversion of address of the candidate points in geographical coordinates. The algorithm for the calculation of the distances between points, selection of the lesser of the distances of each candidate point in relation to the selected points and allocation of the corresponding numerical value has been programmed with Visual Basic in Excel 2007.

For the use of the tool, the user has to enter the number of collection points that will join the network, as well as the valuation assigned in the static part and the dynamic part. This allocation will depend on the characteristics of the town to study (density of population, geographic dispersion, etc.). In the study presented here, we have assigned a factor of 0,6 to the static part and 0,4 to the dynamic part.

The developed tool will provide a list of the most appropriate points to form the network of collection centres. The amount of points selected matches the number previously assigned.

Results and discussion

The model we have developed is applicable to any area or city which knows the applicant points to select the most appropriate. You can also apply to the case of having to reduce the existing collection points.

The case study selected for the application of the tool has been the Spanish city of Valladolid. This medium-sized city has a population of 288.900 inhabitants. Using the ratio of 1 container per 1.000 inhabitants, 289 collection points need to be located.

According to data provided by Valladolid town council, the City currently has 654 collection points. This data tells us that it would be necessary to remove 365 containers for the design of a network of centres for efficient collection according to the studies of the European Association EPBA.

The proposed model selected the 289 most appropriate points in a total 671 minutes time. For the top ten points, the tool used only 16 minutes. However, the time required for successive points has increased due to the increased number of matrices used in the programmed algorithm as it increased the number of selected points.

Figure 2 shows the final distribution of 289 items selected according to their geographical coordinates of latitude and longitude. This figure shows greater density of points in the central part of the city opposite lower density in the peripheral part of the same.

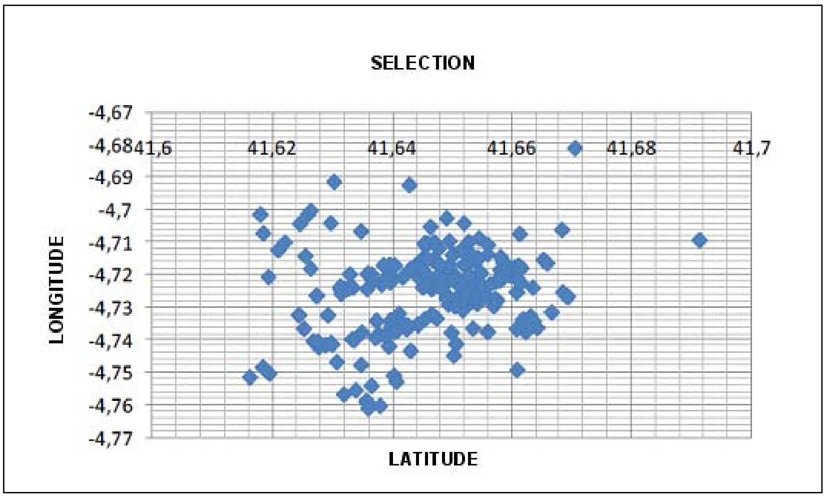

Figure 2 – Result of the distribution of the 289 selected points

Attempt to reduce the response time of the tool, has reduced the number of candidate points. The elimination of candidates may have originated in the proximity of other candidates or previous experience. In particular he returned to experiment the model with 522 and 406 points candidates. Obtained response times are reflected in figure 3.

		CANDIDATES LIST		
		406	522	654
SELECTION LIST	10	6	9	16
	20	12	20	32
	30	18	31	49
	40	24	41	67
	50	32	52	85
	60	38	62	103
	70	46	73	121
	80	52	83	139
	90	59	92	159
	100	66	102	171
	289	193	312	671

Figure 3 – Response times in minutes for experimentation

The developed model facilitates the selection of points according to previously defined criteria. In either case the objective of the model is collecting, efficiently, of more battery out of use. We can, therefore completing the model helps in the process of decision of the selection or alteration of points that will integrate collection network.

Verification and validation of the model processes can observe the quality of responses and their contribution to the addressed problem. One of the difficulties presented by the model is the high response time in case of using a high number of candidate points. The proposed tool needed 671 minutes to solve the case previously submitted when 654 candidate points were introduced. The processor used in the testing phase has been a 2.6 GHz Intel Core 2 Duo processor. Obviously, the use of more powerful equipment can significantly reduce the response time.

In either case, this limitation can become very important to apply the model to a big city such as Madrid or Barcelona. One solution to this situation to continue to implement the tool with shorter response times is the elimination of some of the candidates for different reasons. Figure 5 shows the sensitivity model response time before candidates point reduction. Another possible alternative is the fragmentation of the big city in smaller areas to use the application in each one. This latter solution has the disadvantage of not analyzing the relationship of the distances between selected points of different areas.

The tool develops sample broad possibilities for addressing the location of points of spent batteries in an analytical way.

Conclusions

As a result of the dynamic part, the model will select the recommended collection points according to the criteria defined before. The objective of the model is to collect, in an efficient way, the maximum number of portable batteries, in compliance with current regulations. We can conclude that this model helps managers in the decision of locating/modifying collection points in two ways: to add new collection points to a reverse logistics network that needs more points or to delete collection points from a network that has more points than those recommended. This paper contributes to the Reverse Logistics area, by proposing, for the first time, an analytic model with two parts: a static part and a dynamic part, for locating collection points in a reverse logistic network for spent batteries in the Spanish Case.

The developed tool has some limitations that should be taken into account when addressing the problem. These limitations are mostly imposed by the simplifying assumptions that have had to assume: 1) it has been considered an area of uniform density; 2) the tool works better when the number of candidate is less, so it works appropriate for cities but it is not enough for regions. As further developments of this research work we propose some improvements in the tool for achieving lower response times and also put modifications up for adapting the tool to tackle a wider geographic area. Another extension is to develop a vehicle routing and scheduling model for collecting portable batteries. Currently, the model used by managers of this system is a collection model based on demand. The development of a model for planning these collections could improve the efficiency of the current logistics system.

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