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IMPROVING THE EFFICIENCY OF THE PORTUGUESE WEEE COLLECTION SYSTEM BY USING A WEB-BASED GIS APPLICATION

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ABSTRACT

This project focuses on optimizing the location of the collection points for waste of electrical and electronic equipment (WEEE) and the required routes for bulk collection of the material. The problem consists of determining a set of locations to install a network of gathering equipment and the definition of the routes to be used by the vehicles. It is implemented using open source technologies following the current tendency of the present software market situation. In particular, the software application developed provides a visual way to control an entire logistics network of WEEE collection and sorting points. It is expected that the implementation of this network will increase the amount of WEEE collected and consequently will produce environmental benefits of reducing poor waste disposal. The algorithms developed to solve the location and vehicle routing problems will lead to important reductions in operating costs concerning transportation, storage and sorting and will contribute for reductions in pollution and energy consumption levels.

Keywords: Reverse logistics, location problems, vehicle routing problems, WEEE.

1. INTRODUCTION

In the last decade in Europe the growth of Waste from Electrical and Electronic Equipment (WEEE) was about three times higher than the average municipal waste stream. WEEE is made of all electrical waste (including all components, subgroups and consumables) that is an essential part of electrical and electronic equipment (EEE) at the time it is rejected.
This project is based on Amb3E- Associação Portuguesa de Gestão de Resíduos de Equipamentos Eléctricos e Electrónicos (Portuguese Association for the Management of Waste from Electrical and Electronic Equipment), a non-profit association under private law, which on March 13th 2006 received its licence from the Minister for Economy and Innovation and the Minister of the Environment and Territorial Planning, Amb3E. (2010). This licence gave it the right to manage electrical and electronic waste in Portugal, distinguishing it as a type of WEEE reverse supply chain management company. Amb3E arranges also for the treatment and recycling of waste electrical and electronic equipment from authorized collection points, on behalf of its producer members. The objective is to provide cost effective compliance for producers to meet the requirements of the WEEE regulations whilst minimising the cost to the consumer. In 2010 Amb3E is responsible for more than 60% of WEEE collected in Portugal; and has 60 associated companies. In summary the main objectives of this work are to determine if the costs that logistics operators are currently applying are appropriate or exaggerated to determine the routes for collection and to estimate cost benchmarks to facilitate the negotiation of new contracts with the logistics operators;

2. WEEE COLLECTION NETWORK

In the Amb3E collection network (Figures 1 and 2), there are several places where consumers can deposit their old EEE. These are the collecting points for EEE over a widespread area. The material deposited at the different collecting points is gathered by the waste collector vehicles of a logistic operator which in turn transports the material to a CSF. The routes EEE collecting points (some are transfer stations), are typically linked by point to

point types of transportation in which the transport is made directly to a gathering centre. In some special cases, there is the possibility to transport the EEE directly to the re-processing unit. The other EEE collecting points are scattered and do not follow a typical filling pattern, so these points are a typical problem for the vehicle routing solution.

Figure 1 – Number of collecting points (by Portuguese districts) in the Amb3E WEEE network.

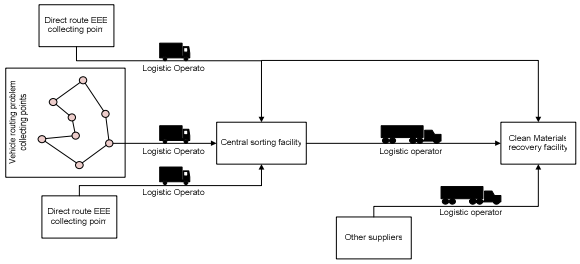

Figure 2 – WEEE supply chain system.

The material is weighted, separated according to its operational flow categories (ten categories according to volume and typology criteria), and stored for transportation. When circumstances permit, a logistic operator transports the separated EEE again by a logistic operator to a re-processing unit. The re-processing unit will remove the dangerous substances and strip the EEE components for the forward supply chain unit (production or distribution) or the disposal facility.

3. LOCATION AND ROUTING PROBLEMS

The main questions to be answered are related to the choice of the location and the routes for the vehicles. The choice of a particular location incurs a certain "cost" versus "gain", which can be estimated ahead of time. The purpose of this problem is to obtain a valid solution to "minimize" and "maximize" the sum of all "costs" and "gains" associated with the allocation of equipment at selected locations, while still respecting all capacity constraints.

The location and vehicle routing problems are divided into three major problems: 1) minimization of distances, 2) maximization of service and 3) maximum coverage. These problems can be supplemented with additional restrictions that provide limits to the maximum capacity and maximum distances between depots and customers.

Given the wide variety of EEE in terms of physical characteristics (weight, volume, etc.) and the final destination, it might be advantageous to the existence of accumulation points of WEEE to optimize the cost of transport to the recovery centres. The number of points of accumulation, their location and area of influence are critical to the performance of the collection operation of WEEE, as they significantly affect its efficiency. In fact, in many situations, transport costs can be significantly reduced if the volume of cargo to be transported is considerable, allowing the use of means of transport more economically efficient.

4. PROPOSED METHODOLOGICAL FRAMEWORK

In order to properly analyse and solve the most part of the above mentioned location and routing problems of the company, some research work has been carried out on developing a computerized application (hereafter referred as GISWEEE). In particular, the system architecture and the software components of this application were designed to control different fleets of waste collector vehicles, from different logistic operators, between several collecting and CSF points, and consequently between the reception point and consolidation/reuse point within a client-server type architecture (Suárez *et al.*, 2009). It is a service supply oriented architecture, which creates the integration and chaining of several services by processing the geospatial data distributed through the Web. The geospatial positions are available in Amb3E by means of information stored in a historical database. Therefore a spatio-temporal data modeling in GISWEEE is needed to show and analyze space-time information (Carvalho *et al*, 2010). It is possible to distinguish the cartographic maps, roads, utilities, etc, that do not typically change in a short period of time as a static spatio-temporal data information model. Even though the locations of the geospatial objects are static (Figure 3), their attributes may change over a short period of time making this a model of dynamic spatio-temporal data information (Nadi & Delavar, 2003).

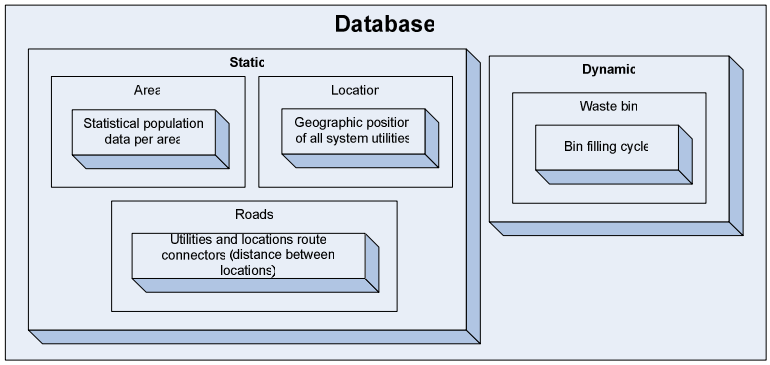

Figure 3 – GISWEEE system integration with spatio-temporal static and dynamic database.

In order to implement an accurate and efficient GISWEEE, the GIS module integrates high-quality data models, queries and temporal information analysis. The main building blocks that make a typical GIS are databases, its visualization and analysis (Figure 4). In the database, the historical and real time data, such as bin retrieval, time duration, and flows (types of EEE), are stored for visualization and analysis. Dynamic visualization shows the system by means of animations or 2D representation. To find an optimal route or location for a given area in this system, an operational management or strategic analysis is requested, considering the updated information in the temporal database and the static spatio-temporal static information database (Nadi & Delavar, 2003). Currently, the VRP module is using a set of simple alternative solution methods based on constructive heuristics. The module automatically and dynamically creates matrix distances by calling Google Maps free services to determine the shortest path between every two points.

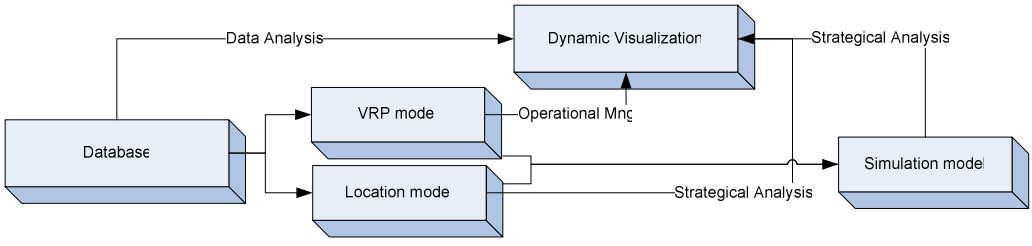

Figure 4 – GISWEEE temporal relationships between the temporal database, temporal analysis and temporal visualization.

The typical procedure is as follows:

1. After all nodes are defined as visited we have an initial solution;
2. The genetic algorithm will work on that solution to optimize it;
3. The optimization ends when it is no more possible to improve the value of the objective function;
4. The routes defined are displayed in Google Maps.

5. OUTLINE OF SYSTEM ANALYSIS PROCESS

The web-based GIS application GISWEEE allows the analyst to visualize the entire logistical network (including the location of partners, e.g. from where the vehicles start their routes), collection routes and statistical information in the map. It is a graphical interactive application, allowing managing the location of the various logistical entities (e.g. adding new collection points or modifying the location of transport operators). These last features are of particular interest to the analyst, since they allow them to easily observe the impact of their changes on the overall performance of the system. In fact, a set of performance indicators are automatically displayed in the digital maps. (Figure 5). Currently, location and routing analyses must be performed according to trial-and-error experiments approach

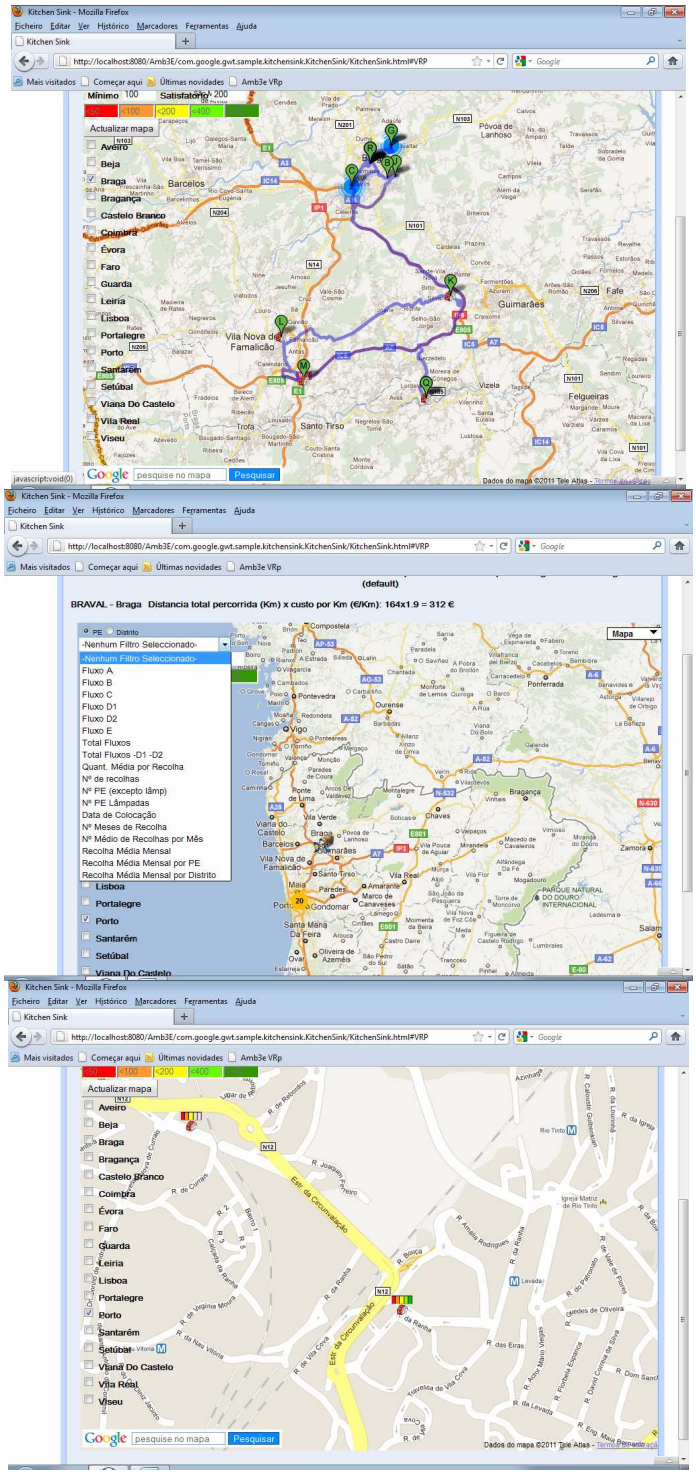

Figure 5. GISWEEE

6. CONCLUSION

This project aims to contribute to better economic and environmental performance for the national WEEE, notably through the rationalization of the logistics involved in the collection and recovery of WEEE managed by Amb3E, one of two management entities operating in our country, by increasing quantities of WEEE collected, reducing operating costs, energy consumption and pollution.

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