Development of a User GIS Interface to Manage the Circuits of Solid Waste (Case Study)

El Hassane SEMLALI and Victor BADA, Morocco

Key words: GIS, user interface, solid waste, circuit of collection.

SUMMARY

The management of waste is an environmental problem which worries several countries of the world. In Morocco the annual production of waste rises to approximately 6,5 million tons, that represents 0,75kg per habitant and per day. This quantity of waste is eliminated without adapted sorting, which generates an environmental degradation, and a considerable loss of time.
Considering the urban expansion of the cities, the companies of collection of solid waste are daily confronted to the problem of finding the fastest circuit to borrow for the rounds of collection. The majority of these companies are using manual or traditional methods to manage these circuits.
GIS constitute an efficient tool for management, decision-making and planning the management of waste.

The goal of this study is to show how GIS could contribute to the management of solid waste and to optimize their circuits of collection. In order to achieve these goals, the next steps were followed:

- Design a data base which includes all the semantic data related to the collection of waste, and enabling to easily manage the human resources and equipment.
- Integrate the road network, administrative limits and the districts of a city.
- Develop suitable algorithms to determine the shortest way for a given round.
- Develop the appropriate programs for a user GIS interface to manage solid waste and optimize their circuits of collection.

The user interface was tested successfully by means of case study data; it concerns one district within the city of Rabat. The developed interface possesses the following qualities:

- Generate an optimized circuit for the collection of solid waste.
- Simulate the volume of a dump for a given date.
- Visualize the plans of sectors and districts.
- Plot graphs related to the daily collected quantities of solid waste.
- Provide significant information on the household waste and the staff.

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1. INTRODUCTION

The management of solid waste is an environmental problem which preoccupies several countries of the world. In Morocco, millions of tons of waste are eliminated, which is about 0,75kg per habitant and per day. This quantity of waste is eliminated without suitable sorting, which generates an environmental degradation, has negative impacts on the economy and consists in a considerable loss of time.

Considering the urban expansion of cities, the companies of collection of solid waste are daily confronted to the problem of finding the fastest circuit to borrow for the rounds of collection. The majority of these companies are using manual or traditional methods to manage these circuits.

In addition, a real problem to which are confronted companies of management and cities concerns the optimization of the circuits of collection of solid waste.

In Morocco, the production of solid waste is increasing rapidly. This increase is marked mainly by the farming exodus, the extension of activities generating waste and the change of the mode of the consumption habits.

Currently, the management of the household waste is characterized by:
- A bad collection process that creates problems of public healthiness and drags important sanitary risks.
- An insufficient collection that overnights to the purification network of the city and plugs the sewers.
- The presence of household waste dumps within the urban zones that hinder the development of the economic and touristic activities.
- The wild dumps that pollute underground water.

Regarding the fast urban expansion of cities, the services in charge of the collection are daily confronted to the problem of finding the fastest circuit to borrow for the tours of collection. The contribution of GIS appears to be very obvious. Indeed, integrating the road network of the district, some suitable algorithms can be developed to find out the shortest itinerary, this can have suitable effects on time saving and economy.

The present research paper aims to show how GIS can be used as a powerful tool for decision support for the management of household waste, by developing a GIS tool capable to analyze and to perform various treatments and analysis regarding waste

2. METODOLOGY

In this study we first begin by a survey of the existing data and interviews with future potential users for the determination of their needs. Then, an inventory of existing documents and data is established. In addition to data related to the circuits of collection and set to our disposition, some other data such as administrative limits and topographic maps have been collected.

After these interviews, the users' needs and existing data allowed us to fix the general orientations to follow for developing the future GIS interface.

Regarding the goals to be achieved in this study, we have developed a methodology to follow in order to contribute to the management of solid waste and optimize their circuits of collection. This methodology is composed of the next steps:

- Design a data base which includes all the semantic data related to the collection of household waste, and enabling to easily manage the human resources and equipment.
- Data acquisition: integrate the road network and administrative limits with other data.
- Develop suitable algorithms to determine the shortest way for a given round.
- Develop the appropriate programs for a user GIS interface to manage solid waste and optimize their circuits of collection.

3. DATABASE DESIGN

Designing a data base is a complex operation implying number of objectives, a staff as well as constraints among which the financial aspects (Laurini & Milleret, 1993).
Designing a database consists in describing data and their associations, independently of the physical aspects. First, a Conceptual Data Model (CDM) is established to represent data. Then, the database is designed using the Entity Association formalism (Flory, 1987). The CDM represents data as entities, which are associated using well defined relations; each relation is defined by two pairs of cardinalities. Finally, the CDM is transformed to a Physical Data Model respecting the rules of passage (Bisson, 1997).

To establish the CDM of our Database we start making an inventory of entities and their attributes. In our case, this CDM composed of 13 entities and 13 associations as shown in figure 1.

Once the CDM is established, the Physical Data model is obtained using the Power AMC software, and the tables of attributes are generated.

In the physical model Data, we have a database constituted of 13 tables related to each others by relations one to many. Two other tables have been added, one to manage the users and the other contains the coordinates of the nodes.

In order to be able to integrate the alphanumeric data into the GIS application we proceed to the generation of the alphanumeric data base in Access format, recognized by ArcGIS software.
Afterwards, we perform the crossing of spatial and non spatial data to conceive a Personal ArcGIS Geodatabase.

4. DATA ACQUISITION

This step consists in describing the graphic and alphanumeric data necessary to conceive the conceptual data model. The different available data are supplied by Veolia company, data are in different formats, they are as follow:

- Topographic plans at 1/5000 in dwg format:
- Topographic maps at 1/5000 in JPEG format and support paper
- Coordinated of the Trash cans as text files

These data present some insufficiencies and require to be restructured before their integration into the future GIS interface. The necessary corrections and updating are:
- Structuring the graphic entities
- Constructing the topology
- Adopting a System of projection
- Making Georeferenciation
- Conversion of text files into Shapefiles

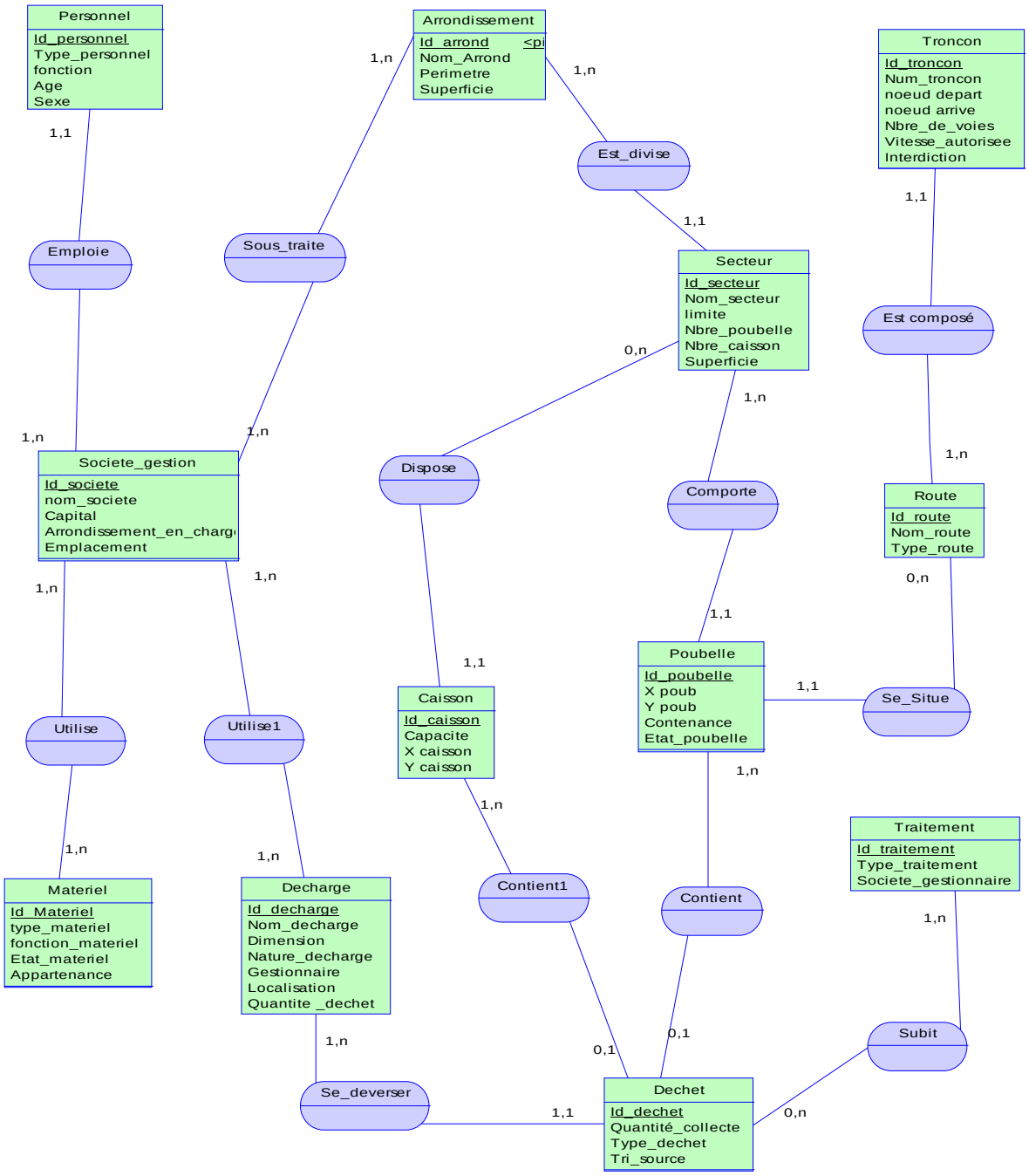

Figure 1. The CDM of the database (After Bada V., 2007)

5. BRIEF DESCRIPTION OF SOME FUNCTIONNALITIES OF THE INTERFACE

Once the Geodatabase is implemented taking into account the prescriptions of the users, we conceive a user GIS interface including a certain number of menus. The user-interface is developed using the Visual Basic programming language. The interface is composed of several menus, sub menus and tools linked to programs. The developed interface permits the following functionalities:

- Search an optimized circuit for the collection of solid waste.
- Consult, open and search a hike
- Simulate the volume of a dump for a given date.
- Visualize the plans of sectors and districts.
- Plot graphs related to the daily collected quantities of solid waste.
- Provide significant information on the household waste and the staff.

Hereafter we will give a very short description of some powerful menus of the application.

Menu "Open Hike"

It allows to open an existing hike that has been saved in format (jpg) and print it. A dialogue window invites the user to choose the hike to open.

Menu "Optimized Hike"

This menu of the application allows the optimization of the circuits of collection. The structured road network and the coordinates of the site of the trash cans are used to perform this operation. The optimization process is based on the time of course or on the distance between trash cans. The user has a choice to introduce the time passed during the collection of the trash. He might also take into account or not the interdiction restrictions.

Menu “Short Path “

The optimization of the circuits is achieved based on the DIJKSTRA algorithm. This algorithm permits to find the shortest path between 2 points (starting point and endpoint). The goal of this menu is to determine the shortest path between 2 addresses. For this, the road network has been structured in nodes and sections. The user has to specify the departure and the arrival nodes. Then, the program finds out the shortest itinerary to follow. Once the circuit found, it is displayed on the screen indicating the length of every section and the names of the streets. The application allows the user to print the found circuit or to record it for a future use.

Menu "rubbish dump "

Calculation of volume
With this menu, the user is able to estimate at any given date the volume of a given rubbish dump. For that purpose, the initial volume is computed using a digital terrain model. Then, the real time volume of the dump is approximated by adding the daily volume input to the dump. This volume can be used to decide when the dump should be closed and choose another site.

Menu "Simulation"

This menu allows the following two sub menus:
Sub menu "Daily quantity "
This menu permits to follow the daily evolution of the quantities of collected solid waste by sector within a district. This evolution is represented by a graph. The user can also determine the evolution while passing to the previous months.

Sub menu "Expectation"
The objective of this sub menu is to research the ideal site for the creation of a new dump. It allows estimating the area of a dump and the quantity of waste that will be generated in the chosen district. This simulation formula requests certain parameters such as the populationr, the quantity of waste for the chosen year, the population rate and the quantity of generated waste per habitant.

Menu "Treatment "

This part is introduced to follow the evolution of the collected household waste and has been sorted out. Therefore, the user has the possibility to consult the information concerning the quantities of waste that are sent for treatment. He can choose the date and the zone in the list, then he can make a research in the database to see all treatments that have been done to this date. When the result of research is fruitful the user obtains information like the agent company, the quantity of waste confided, the cost of the treatment by ton, and the cost generated by the treatment of the waste since the beginning of the year.

6. CASE STUDY

The developed user interface was tested successfully by means of case study data; it concerns one district within the city of Rabat. Data are supplied by Veolia company. Hereafter we present two examples of results based on these data.

Optimized Hike

For example, figure 2 shows the result of finding the optimized hike; it gives the time difference between taking into account or not the interdiction restrictions for the same circuit. It is found that this time is 663 minutes with restrictions and only 235 minutes without restrictions.

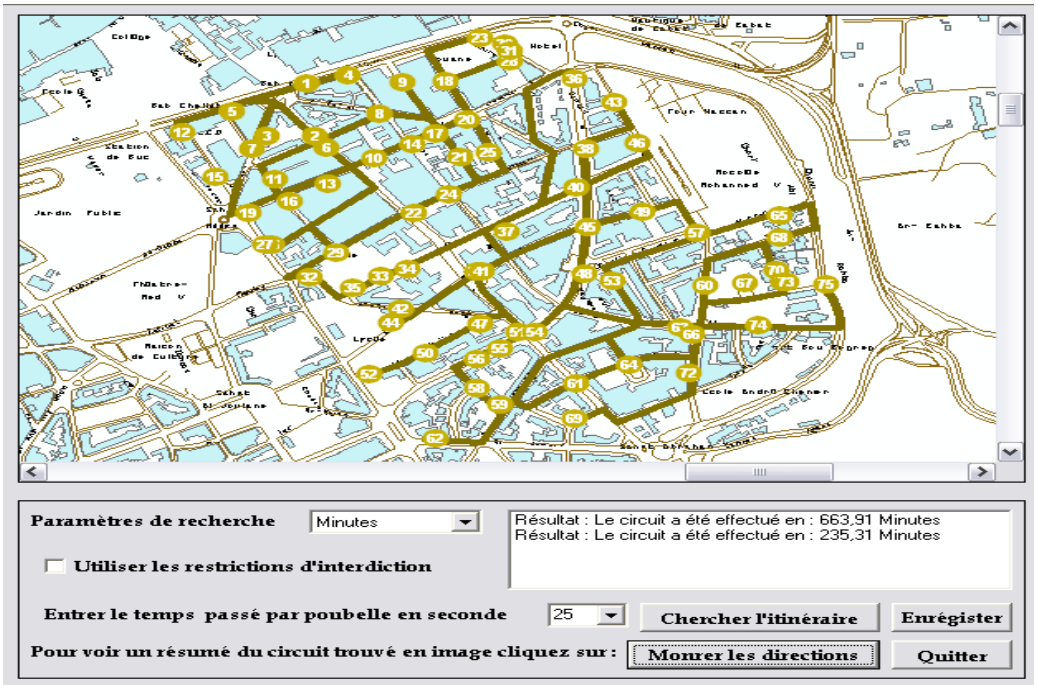

Figure 2. Optimized Hike (After Bada V., 2007)

Short Path

Next figure 3, describes the short circuit between two specified points. The circuit found is displayed on the screen, and on the right of the circuit, there is a window indicating the length of every section and the names of the streets.

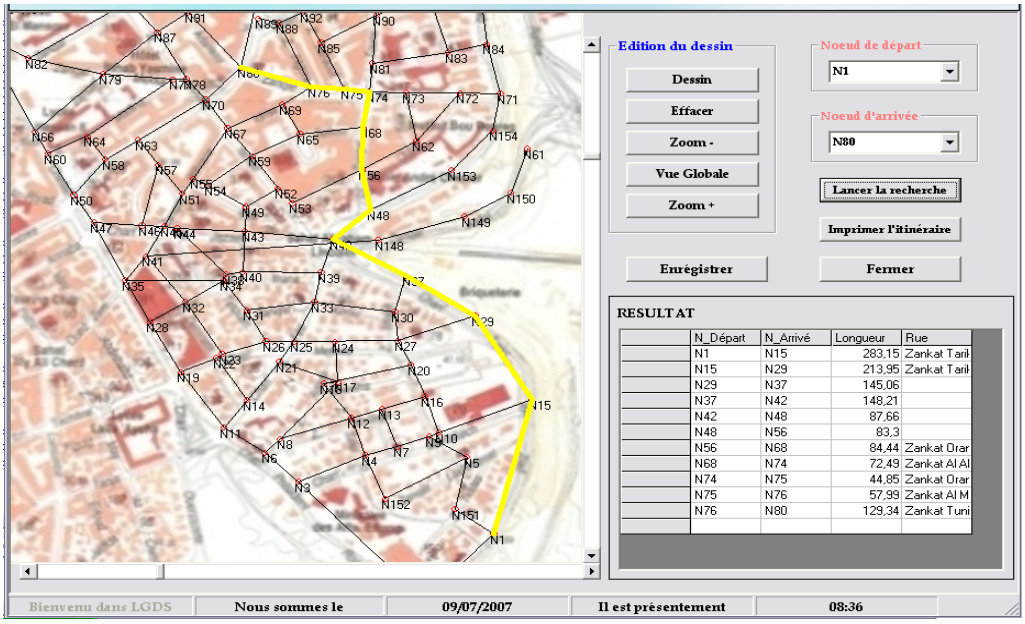

Figure 3. Short path (After Bada V., 2007)

7. CONCLUSION

Through this paper we have presented a methodology for designing a database integrating data related to the collection of solid waste, and to develop a GIS interface to solve technical problems related to managing household waste and finding the fastest circuit to borrow for the rounds of collection.

The user interface was tested successfully by means of case study data; it concerns one district within the city of Rabat. The developed interface possesses the following qualities:

- Generate an optimize circuit for the collection of solid waste.
- Consultation, Research and Addition of circuit of collection
- Respond to some specific queries on the available layers in the geodatabase
- Simulate the volume of a dump for a given date.
- Visualize the plans of sectors and districts.
- Plot graphs related to the daily collected quantities of solid waste.
- Provide significant information on the waste and the staff.

Among the performances of the interface one can mention the decision making for the creation of a rubbish dump, the research of itinerary between points, and the optimization of the collection circuits.

AKNOWLEDGMENT

The authors would like to thank responsibles of the Wilaya of Rabat, and the VEOLIA company for their cooperation and data supply.

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BIOGRAPHICAL NOTES

Professor El Hassane SEMLALI
1979: Diploma of engineer in surveying from IAV Hassan II, Rabat, Morocco
1986: Master of Science from Ohio State University, Columbus, USA
1999: Doctorate of Sciences from the University of Liege, Belgium.
Principal areas of interest are: GIS, geodesy and surveying.
Publications: database design, error propagation in GIS, parcel redistribution methodology, GIS in land consolidation, cadastral systems, GPS, development of GIS applications.

CONTACTS

Professor and researcher
El Hassane Semlali,
Institut Agronomique et Vétérinaire Hassan II, Filière de formation en Topographie,
IAV, Filière de formation en Topographie, B.P. 6202,
10101 Rabat,
MOROCCO
Tel. +212 37 68 01.80
Fax + 212 37 77 81 35
Email: e.semlali@iav.ac.ma
e.semlali@gmail.com

Surveying engineer
Victor Bada
Email. badvicfr@yahoo.fr