THE DEVELOPMENT OF A SPATIAL DECISION SUPPORT SYSTEM FOR THE LOCATION OF PUBLIC GOODS

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ABSTRACT

Site Selection analysis, regarding to Public Goods, is a complicated procedure that all the Local Authorities have to deal with. It is complicated due to the amount of data, the restrictions and the different scenarios that arise. The decision making process for finding the optimal site must be based on the principles of efficiency and equity. The contribution of Geographic Information Systems (GIS) to the decision making process in planning issues is important and no other tool or set of tools can substitute them. Taking this fact into consideration and in order for the complicated situations described above to be resolved, a GIS based Spatial Decision Support System (SDSS) was developed under the name Public Facility Location Tool (PFLT). This tool is destined to the Local Authorities of a Municipality, who seek the optimal selection of the site of a Public Facility in the area of their competence. The particular SDSS tool, helps the Local Authorities to solve complicated problems, and gives them the choice of analysis, data manipulation and visualization. In particular, the specific tool gives the ability of solving two basic spatial problems: the assessment of the social service coming from an existing Public Facility location and/or the selection of a new optimum site for a Public Good. PFLT was built on the ArcGIS 9.3.1 software using Visual Studio and ArcObjects. The descriptive and spatial data that PFLT uses are at urban scales and especially at 1:1000, 1:2000 and 1:5000. These data are used for standard spatial analysis as well as allocation and location-allocation procedures. In brief, the data in use are: city blocks, road network, land use, hydrographic network, contours, seismic information, cadastral and topographic infrastructure of the Municipality area, census information etc. The user communicates the main tool through a specially designed Graphical User Interface (GUI), which was based on rules that reinforce the user's perception. The GUI consists of two basic parts. The first part contains the commands of the main application as a Decision Support System and produces results in the form of reports, derived GIS layers, choropleth census maps or maps that come from the combination of various initial and/or derived data themes according to the user's wish. The second part of the GUI manages the spatial and non-spatial data needed for the procedures of allocation and location-allocation, for customized spatial queries etc. A special attention was given to the compilation of the thematic maps, since a wrong representation of the map data may unfavorably influence the public policy decisions. Using PFLT, the decision makers become both map users and map makers. Having the proper thematic map, the user has the ability to visually communicate the results in a way that they can be easily understood. This is of a great importance to the

decision making process since the user can have a clear view of the location problem conditions, cases and results. In conclusion, PFLT aims at the prosperity and generally at the continuous improvement of the quality of life for Municipal citizens.

1. INTRODUCTION

Spatial problems are complex because they are semi-structured or ill defined (see e.g. Malczewski, 1999; Gao et al., 2004) in the sense that the goals and objectives are not completely defined. Spatial problems are multi-dimensional and often related to non-spatial information. Each spatial problem can have a large number of decision alternative solutions. Finding the optimal site to locate a Public Good is a complicated spatial problem. Decisions are based on social criteria and their goal is to maximize the social benefit. To support Spatial Decision Making, a variety of systems have been developed. These systems include Geographic Information Systems (GIS) and Spatial Decision Support Systems (SDSS, see e.g. Armstrong & Densham, 1990; Densham, 1991; Keenan, 2003). According to Miller & Shaw (2001, pp. 292). "An SDSS is a set of linked technologies for generating and comparing alternative solutions to a geographic problem or alternative future geographies". These computer-based geo-processing systems are designed to support a decision research process for solving complex spatial problems in a user-friendly environment.

The aim of this paper is the presentation of the development and functionality of an SDSS, which was based on Geographic Information Systems and has the name Public Facility Location Tool (PFLT) (Voutsa, 2009). More specifically, the research concerning PFLT aimed: a) at the creation of an SDSS capable of providing full decision support to the Local Authorities of a Municipality for the selection of the optimum location of a Public Good and b) at the creation of a simple and user friendly Graphical User Interface (GUI) which accents the SDSS's effectiveness and easily guides to results. The system's development was based on the elements of ArcGIS 9.3.1, as well as Visual Studio (Microsoft, 2003) and ArcObjects (see e.g. Zeiler, 2001; Burke, 2003; Chang, 2005). In paragraph 4, a tour of the PFLT capabilities is attempted. For this purpose spatial and descriptive data from the Municipality of Stavroupolis, Greece were used. This specific Municipality offers a cultural centre currently located at a site not selected according to SDSS specifications. The PFLT was used to solve the following semi-defined problem: "Assess the service coming from the current location of the cultural centre of Stavroupolis. Then, if the service is not adequate, find a new optimum site for the centre inside the Municipality's area and assess the appropriateness of this new site". Through the procedure followed for answering this problem, a sufficient number of the PFLT's potentialities as well as its GUI's conveniences are presented.

2. PUBLIC FACILITY LOCATION TOOL. DATA AND PROCEDURES

PFLT, as a decision support tool was designed in such a way so that it follows the basic architecture of an SDSS and the decision making process. The system includes all the necessary tools for the analysis of data and the creation and evaluation of the alternatives. Using PFLT even a "novice" decision maker can follow the steps of the decision making procedure, described by Simon (1960). Through the system's GUI the user follows a logical sequence of procedures and tests in order to reach a final evaluation of the solutions. The decision maker through PFLT manages the layers of spatial information, explores the database system, builds queries, identifies and assesses the best location and finally has the possibility of visualizing the different scenarios that are created. This tool can be regarded as a multi-criteria SDSS, as the decision maker takes into account a number of spatial and non spatial criteria to determine the optimum location of a Facility.

As the case is the location of a Public Good within a Municipality area, all spatial and descriptive information the PFLT uses, is at urban scales 1:1000, 1:2000 and 1:5000.

Thereby, all the distances used are not Euclidean but they are measured on the city's road network. The data layers required for PFLT are: the road network, city blocks, land uses, contours, the hydrographic network, the seismic and geological faults of a greater area, geomorphological information, and cadastral and topographic infrastructure. The System's database includes files containing for every city blocks information about population (number of people, age, gender), files containing each block's building terms and files containing information about electricity pylons and gas stations inside the Municipality area. The PFLT uses two of ArcGIS 9.3.1 basic tools: spatial analysis and network analysis (see e.g. ESRI, 1994; Korte, 2001) with the allocation and the location-allocation procedures (see e.g. ESRI, 1994; Birkin et al., 1996).

The PFLT's user applies the allocation procedure to find the number of the citizens who live inside a Public Facility's service area. The service area is user defined at a specific distance from the Facility's location. Considering the number of the serviced citizens, the user can assess the service supplied from the particular Facility (Papadopoulou, 1997; Voutsa & Papadopoulou, 2002). If the resulting number of citizens is adequate, then this ascertainment can be considered as one of the documentations that are necessary to prove the appropriateness of the current Facility location. The PFLT's user can also choose a new site if the current one is proved improper, or for the first time detects a proper site for the Facility. This new site is the optimum among a number of candidate ones. The user finds this location easily since he has at his disposal all the location-allocation models that are commonly used for the location of a Public Facility (see e.g. Richard et al., 1990; Benguin et al., 1992; Church & Meadows, 1979). All the PFLT's data mentioned above, apart from the demographic ones, help the user to: a) assess, along with the results coming from the allocation procedure, the appropriateness of an existing location, b) decide if a certain candidate site must be included or not in the location-allocation procedure and c) reinforce the documentation of a site's selection.

The PFLT produces results which are reports, derived GIS layers and thematic maps. The derived layers are the results of different spatial analysis scenarios for allocation and location-allocation processes or answers to other GIS queries. As far as the thematic maps are concerned, a special attention was given to their compilation. In particular, with this tool the user has two choices. The first choice is the production of choropleth density maps, based on the Municipality's demographic census data. For the efficient representation of the results, the decision maker is able to use different classification methods, as well as sequential ramps and various number of classes (fig. 6). The second choice is the compilation of any thematic map as a combination of initial and/or derived GIS layers, according to the user's wish (fig.10).

A thorough search has been accomplished among various Greek Municipalities, concerning the methods used by the Greek Local Authorities for the selection of a Public Facility location. The search revealed that in Greece, the decision making process is always accomplished without the support of an SDSS and without documented results. According to this ascertainment, PFLT is the only, for the time being, existing decision making tool for the Greek Municipalities.

3. THE GUI OF PFLT

All the procedures mentioned above are executed in a user friendly and easy to use GUI. The user interface should support decision makers through all decision making phases, and is the key to successful use of any decision support system (Sauter, 1997, p. 442). According to Malczewski (1999, p. 392) a GUI must have: accessibility, flexibility, interactiveness, ergonomic layout and must be processing-driven. All these principles are implemented in this particular GUI, which consists of two sections (fig. 1).
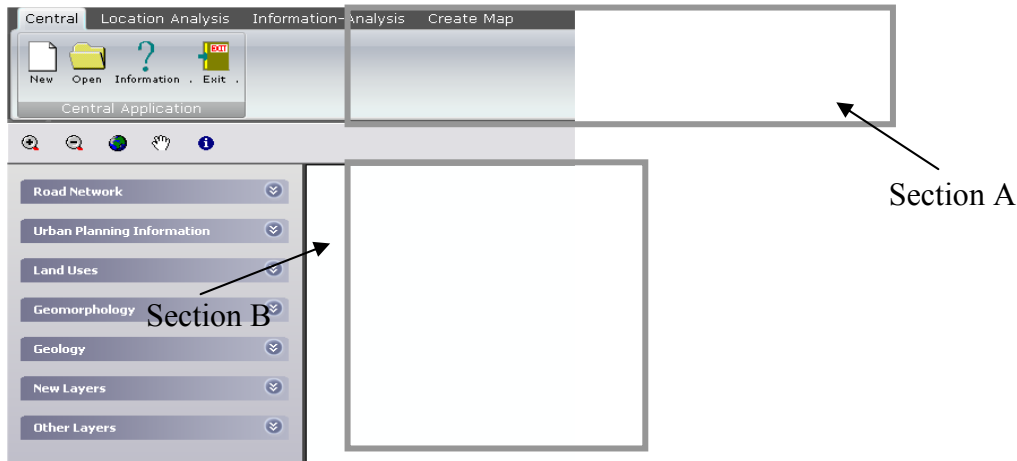
Figure1. The two sections that PFLT's GUI consists of.

Section A contains all the commands of the main application as a decision support system. This section was developed using the characteristics that are encountered in Microsoft's Ribbon menu (Microsoft, 2009). The Ribbon is an innovation in the design of a graphical environment that Microsoft introduced in Microsoft Office. This menu is designed to help the user find quickly the commands that he needs to complete a task. All the commands are organized in logical groups, which are collected together under tabs (see fig. 2). When the user selects a command, routines and the system's dialogue windows are activated. For example, the «Information - Analysis» menu and the forms that are activated enable the user to assess whether a place can be a candidate for the location of a Public Good or not (fig. 3). With the choices "Terms Laws", "Land Uses and property value" and "Demographic Data", the decision maker has the information concerning: a) the site's construction system and the regulations in force, b) the city blocks population c) the land uses and d) the land values. Apart from that, the user can make queries in the system's database to determine the appropriateness of the selected site. The creation of buffers zones is another step in the evaluation process. Criteria concerning the exclusion of sites that are located inside forbidden zones are very common. The Geological analysis is used to determine whether the candidate sites correspond to particular criteria concerning the behaviour of the soil of the location area so that the antiseismic protection for all the future constructions can be ensured.
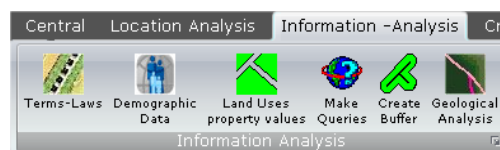

Figure 2. The "Information –Analysis" menu with all the choices – criteria.

Section B manages the data needed for spatial procedures like allocation, location-allocation, usual GIS queries, e.t.c. Through this section, the user may choose the layer of spatial information that he wants to be activated on the screen or the layer that is necessary to the completion of the former procedures. The basic idea for designing section B, as a vertical menu, came from the explorer bars of Windows Explorer, which most computer users are familiar with.

This GUI was tested, by future PFLT users throughout the entire stage of its development. The testing process was accomplished by engineers, who work for the Technical Department of various Greek Municipalities. The engineers were experienced users and familiar with GIS

procedures through popular GIS softwares, but they weren't familiar with SDSS procedures. Their comments, suggestions and impressions, both for the entire graphical environment, and the stages of the implementation of procedures, were crucial for the development and improvement of the GUI.

4. A TOUR OF THE PFLT

In this paragraph, a tour of the PFLT capabilities is attempted, using the scenario of solving the problem described in §1. The data came from the Municipality of Stavroupolis (fig. 3), which lies to the west of the City of Thessaloniki and has a population of 30,000 citizens.

Figure 3. Stavroupolis city blocks and the current place of the cultural centre.
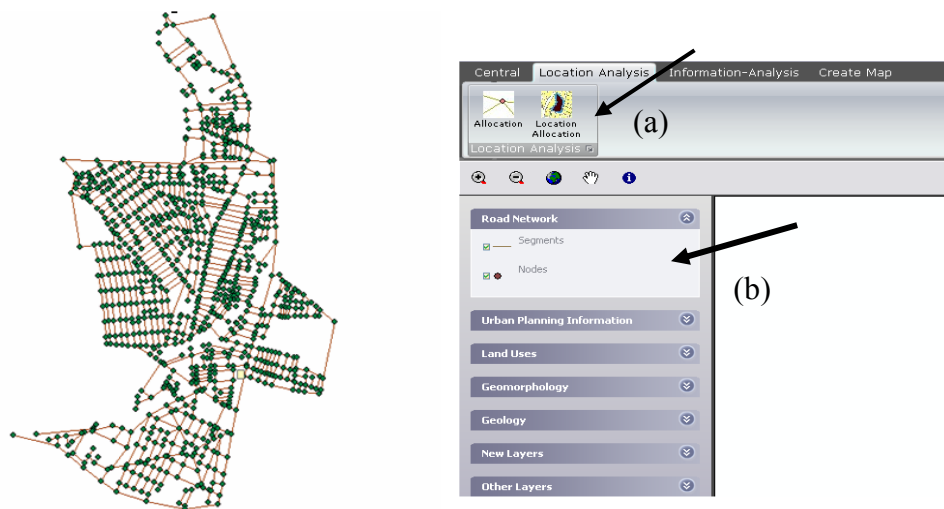
Figure 4. The location Analysis tab with the choices of "Allocation" and "Location - Allocation" (a) and the activation of the segments and nodes of Stavroupolis' road network from the vertical menu (b).

This procedure is accomplished through the Location Analysis Menu with the options "Allocation' and 'Location-Allocation' (fig. 4a). The first phase of the location analysis is the assessment of the service from the existing cultural centre to the citizens. The layers needed for the allocation analysis are the nodes and the segments of the road network (fig. 4b).

Using the allocation process for different impedances (350m , 750m , 1000m), different service areas result, showing that the existing location of the city's cultural centre is not the optimum. That conclusion arises from the number of the citizens that live inside these service areas. Specifically 3800 citizens live inside the 350m service area, 3500 live inside the 750m service area and 6742 inside the 1000m service area. This means that up to 50% of the citizens (14700) live more than 1km far from the center (fig. 5).
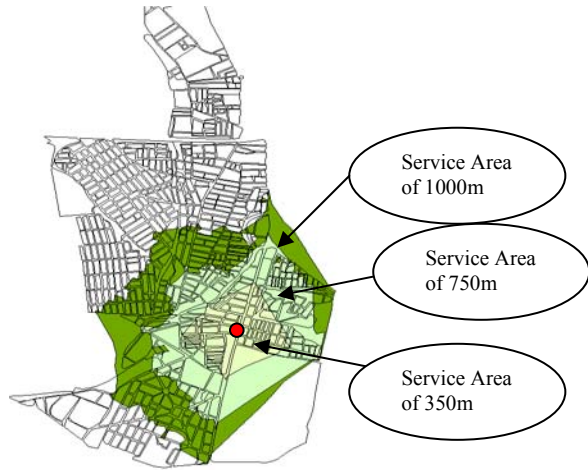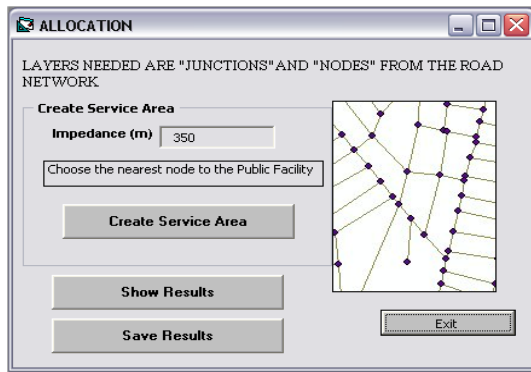
Figure 5. The results of the allocation analysis for the cultural centre using an impedance of 350m, 750m and 1000m. Each time the results appear automatically on the screen with the "Show Results" button of the "Allocation" form to the left.

The choropleth map used at this step of procedure verifies the service conditions described above (fig. 6).
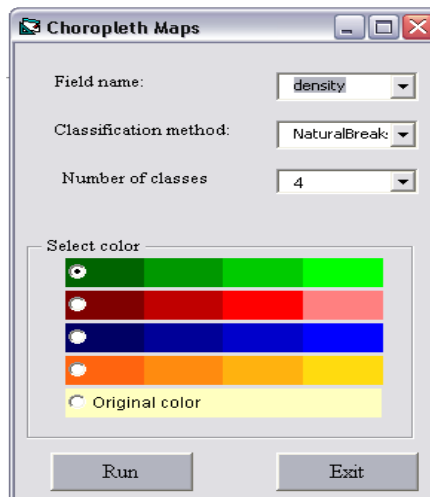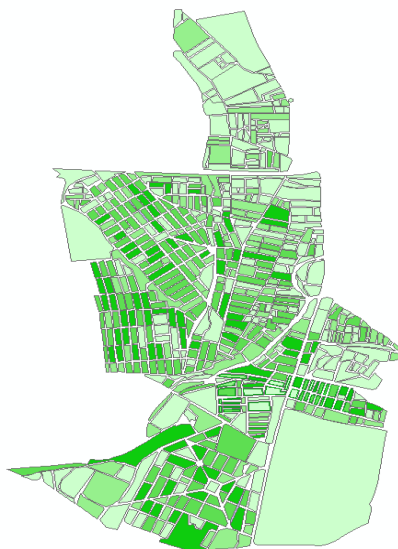

Figure 6. Choropleth map of the citizens' density and the corresponding form.

In this scenario we make the assumption that the existing location of the cultural centre meets all the spatial criteria the user sets from the beginning and the assessment is based only on population criteria. The next phase for the decision maker is the detection of the new optimum site for establishing the cultural centre, through the location analysis menu (fig. 4a) and the choice "location allocation". The form "Location – Allocation of Public Facilities" appears, which consists of three steps (fig. 7a).
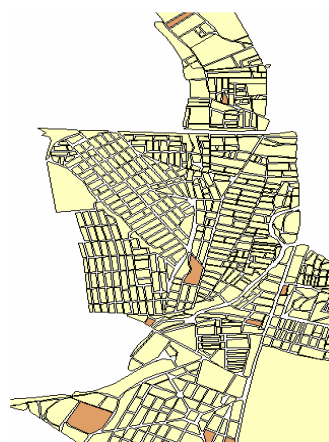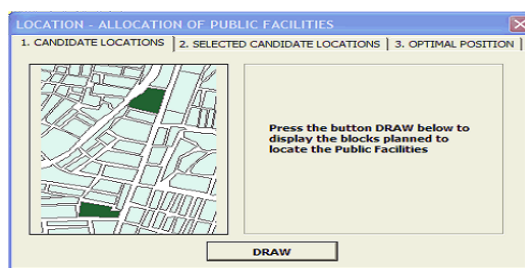
(b)

(a)

Figure 7. The "Location Allocation form" (a). Blocks planned for Facilities location in the Municipality area are given by the "draw" button (in brown colour) (b).

The first step is the "Candidate location". The user must activate the layer which contains all the city blocks that have the appropriate land use for the location of a facility (fig. 7b). In step 2, with the "selected candidate location" form, the user can select all the candidate sites or to choose selectively among them. Choosing the site on the map the internal ID of the block is directly added to the form. The form gives user the opportunity to delete an unwanted site selection choice (fig. 8a). In Step 3 with the "Optimal position" form, the user selects the appropriate location allocation model and inputs, if necessary, a distance for the selected model (fig.11). The "search" button executes location-allocation procedure.

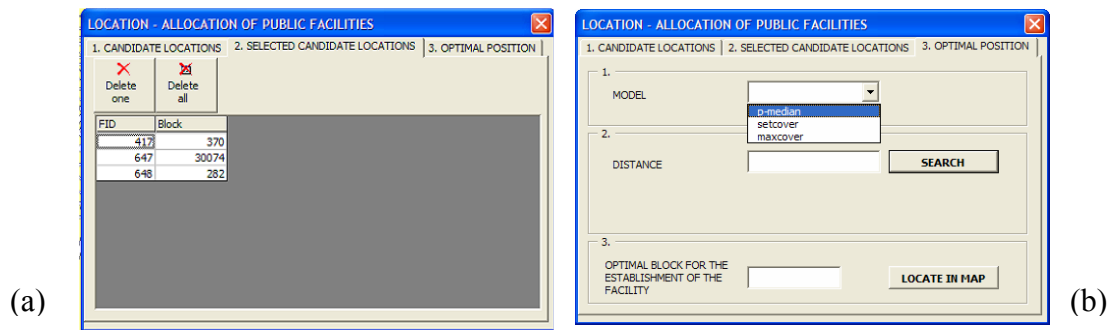(a)   (b)

Figure 8. (a) Selection of the candidate sites b) Selection of the location-allocation model

The result (the label of the Block) is shown in the box "Optimal Block for the Establishment of the Facility" (fig. 8b). The choice "Locate In Map" highlights the selected block on the Map (fig. 9).
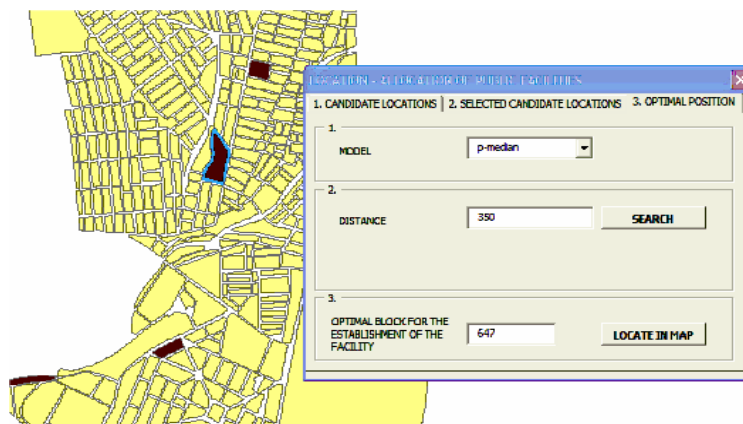
Figure 9. The location – allocation procedure in PFLT. The selected block is highlighted

The next step, after the detection of the optimum site, is to find out if this site meets the criteria set by the decision maker. One can repeat the allocation procedure to find out the number of the serviced citizens. This time the allocation procedures show that the new site serves a larger number of citizens (about 70% of the population). At this stage the user thinks that it is also necessary to set some spatial criteria for the verification of the location's appropriateness. Firstly, the user examines the new location in accordance with the contours layer (fig. 10). The user can see that the selected site lies on smooth relief. This means easier access to the Facility, lower construction expenses etc.

Another spatial criterion the user sets is the center's distance from a gas station. According to the Greek law a centre must be located 200m far from a gas station. From the "create buffer" menu (fig. 3) the user can find out if the new site is located inside the zone of 200m from the nearest gas station (fig. 11).
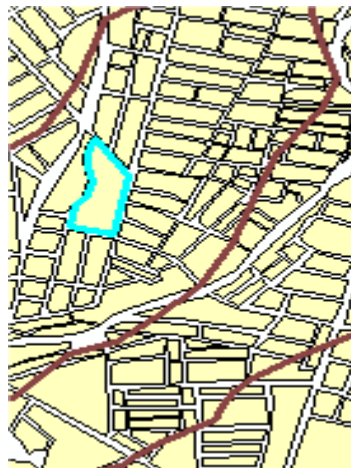

Figure 10. Activation of contours (in brown color). The selected site lies on smooth relief.

As shown in fig. 11, the site that the location-allocation procedure pointed out as the optimum does not meet the second spatial criterion the decision maker set. This means that the user repeats the same procedure excluding the previously selected site from the candidates or makes a final decision, taking into consideration that the selected location doesn't meet all the criteria set.
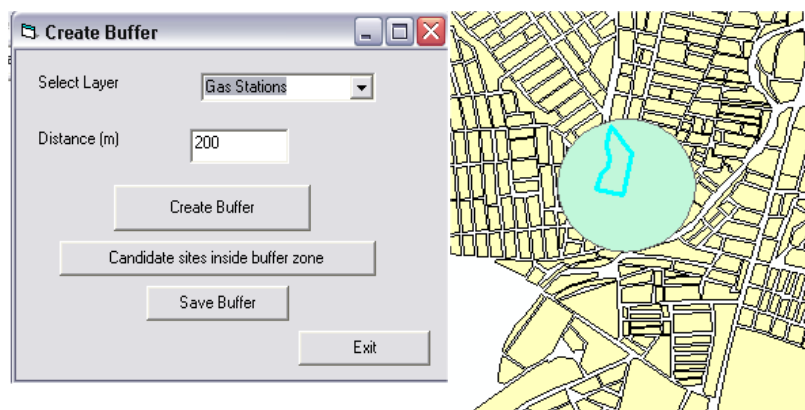

Figure 11. The form "Create Buffer" and the result of the procedure.

5. CONCLUSIONS

This particular SDSS tool, helps the local authorities to solve complicated problems, and gives them the choice of analysis, data manipulation and visualization. In particular, the user's ability to communicate the results visually in a way that can be understood by everyone is of the utmost importance to the decision making process because even novice users, have a clear representation of conditions and options. This system was designed and constructed for decision makers, mainly engineers, who work for a Municipality. While developing the system many of the above users used it and their opinions and impressions were decisive for the improvement and the further development of the tool. In conclusion, this tool aims at the prosperity and generally at the continuous improvement of the quality of the citizens' life. This SDSS leads the Local Authorities to options for making more sustainable choices and to decisions that promote a socially inclusive, fair and efficient society.

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