Using Geographic Information System Software for a Digital City Map Construction[*]

Izabela ŚLIŻ, Poland

Key words: Geographic Information System, digital city map, geodatabase, network analysis

SUMMARY

Digital city maps become more and more popular. The rich descriptive data base connected with graphic part, allows the user to obtain information, which are not available from analogue city map. The wide range of accessible tools highly simplify going through the plan and its full usage. This article presents the process of creating that kind of map, where each stage leading to its formation is presented including the structure of database, collecting essential information to complete this base, visualization of two-dimensional and three-dimensional spatial data. There have been analyzed the most important tools offered by the GIS programs, which are used for building city maps. Also the way of working each useful function and its usage are described in this article.

[*] The thesis realized within statute researches of Geomatics Department at AGH University of Science and Technology in Cracow

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1. INTRODUCTION

Among other things, Geographic Information System found application in interactive city plans construction. Tourists visiting foreign cities, people who stay in a foreign city for other reasons like a business trip, but also native citizens expect access to up-to-date and easily accessible information. On cities areas there are more and more new commercial, service, industrial or tourist centers appearing therefore creation of digital city plan whose updating is simple seems to be a very useful solution. Thanks to network analysis their users can organize their time more effectively because network analysis can help them to find, for instance the closest facilities or the most attractive route to visit a city.

Presented process of construction of a city plan has many advantages. First of all, using GIS software significantly shortens time needed for a city plan construction. It gives the opportunity to eliminate many mistakes and clear obstacles which stand on the way to analogue technology. Furthermore, digital city maps allow the user to make spatial analysis and present its results. In more effective way they make it possible to adjust to the user's needs. For these reasons, this article presents the process of creating that kind of map, where each stage leading to its formation is presented including the structure of database, collecting essential information to complete this base, visualization of two-dimensional and three-dimensional spatial data. There have been analyzed the most important tools offered by the GIS programs, which are used for building city maps. Also the way of working each useful function and its usage are described in this article.

2. THE DIGITAL CITY MAP CONSTRUCTION

The process of the digital city map construction consists of many stages. That whole process is always depended on data and software which will be used. There is the list of stages below leading to the city map creation:

- Gathering data
- Database structure designing
- Data conversion
- Importing data to the database
- Topology
- Completion of descriptive information about objects
- Adding hyperlinks
- Creation relationships between tables

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- Geocoding
- Creating routes

The GIS softwares have wide range of various tools which can be used on every stage of the city plan creation. Below there is a more detailed description of every stage of the proposed process of building the city map which can be realized by these kinds of softwares.

Gathering data. Raster and vector data can be used to work out a city plan. For example, vector data might present building contour, axis of the road or Digital Terrain Model. Raster data can be used as a background for vector layers or to vectorization. Pictures, photos and detailed descriptive information of historic, commercial or institution buildings are very desirable by users. Those kinds of information may be gained from brochures or the reconnaissance.

Database structure designing. In the next step, the gathered data should be organized. To do it properly, designer has to take into consideration how many tables and what kinds of ones will be contained in the database, what kinds of attributes will be described features, what kinds of relationships will be between tables etc. One good solution is to create a geodatabase. A geodatabase tool allows a designer to define relationships between objects and rules to maintain referential and topological integrity between objects. The geodatabase organizes geographic data into a hierarchy of data objects. These data objects are stored in feature classes, tables, and feature datasets. A table in the geodatabase stores nonspatial data. A feature class is a collection of features with the same type of geometry and the same attributes. A feature dataset is a collection of feature classes that share the same spatial reference.

Converting and importing data. The data for the project comes from several different sources. Some of them are in different data formats or in different coordinate systems. The data which will be imported to the database must be in specific format which is supported by software, so it is necessary to convert these data. Usually there is no problem to convert the data, because most of GIS programs implement suitable tools which allow in easy way to convert data. These tools ensure interoperability between programs.

Topology. To model correctly geographic features, designer of the geodatabase has to take into consideration that some features that have spatial relationships with other features around them. For example, bus stops may be modeled in such a way that they must always occur in a street. These relationships are maintained in the geodatabase through an association called a topology. The topology contains rules that define how features share space. To create a topology, designer must specify which feature classes will participate in the topology and what rules will govern the interaction of features. All feature classes participating in a topology must be grouped in the same feature dataset.

Completion of descriptive information about objects. In the next stage, fields of tables should be filled out using earlier gathered and prepared information. It can be descriptive text,

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numbers, photos or animations. That two latest elements are closely connected with the next step of the city plan construction.

Adding hyperlinks. GIS programs allow to provide additional information about the features like documents or Web pages. To access these related information to features , it is necessary to define hyperlink. They can be one of two types: document type, URL (Uniform resource locator) type. If a document is specified as a hyperlink, program opens that document or file in the application with which that file type is currently associated. If a Web address is specified as a hyperlink, program launches a Web browser and displays the Web page.

Creation relationships between tables. Objects in a real-world system, such as building database often have particular associations with other objects in the database. For example, in a building database it will have one or many locals inside. These kinds of associations between objects in the geodatabase are called relationships. Relationships can exist between spatial objects (features in feature classes), nonspatial objects (rows in a table), or spatial and nonspatial objects. Relationships can have one-to-one, one-to-many, and many-to-many cardinalities. Cardinality describes how many objects of one type are related to an object of another type. In the local-building example, a single building may consist of more than one local, but a local can only be inside one building. The relationship between buildings and locals is one-to-many: one building which is an object in the origin class of the relationship, to many locals, which is an object in the destination class of the relationship (ESRI webhelp.esri.com).

Geocoding. This partial relationship and object oriented structure of database entails necessity of geocoding. Geocoding also known as address matching is the process of creating geometric representations for descriptions of locations in order to display these locations on a map and perform analyses. In other words, Geocoding is the process that assigns a latitude-longitude coordinate to an address. Once a latitude-longitude coordinate is assigned, the address can be displayed on a map or used in a spatial search (Guge 2004).

To geocode a table of addresses, it is necessary to access an address locator. An address locator stores the address attributes, associated indexes, and rules that define the process for translating nonspatial descriptions of places, such as street addresses, into spatial data that can be displayed as features on a map.

Creating routes. The economic foundation of the modern world is its infrastructure—the collection of cables, streets, and information. This infrastructure can be modeled as networks. In the geodatabase networks are modeled as an one-dimensional nonplanar graph, or geometric network, that is composed of features. Geometric network consists of two fundamental components: edges and junctions. In a streets case, streets are examples of edge whereas crossroads are examples of a junctions. Edges connect to each other at junctions; the flow from edges in the network is transferred to other edges through junctions. This structure of a geometric network allows to make network analysis.

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The basic step to perform any type of network analysis is creating the analysis layer. Network analysis layers are composite layers used to store inputs, parameters, and results of network analysis. A network analysis layer acts as an in-memory workspace for each type of input as well as the result, all of which are stored as in-memory feature classes. The analysis parameters are stored as properties of the analysis layer. There are four kinds of network analysis layers:
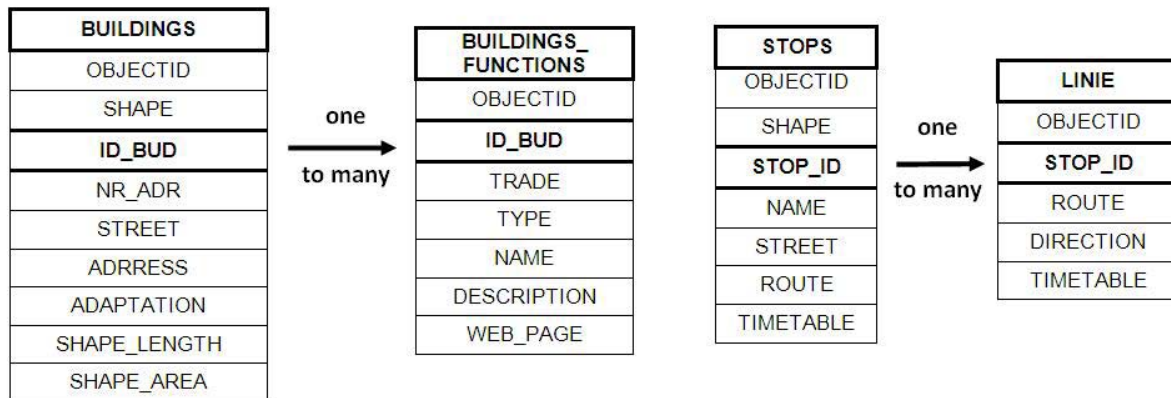
-   Route analysis layer—This layer contains the input network locations (stops and barriers), parameters, and the resultant route or routes of route analysis.
-   Closest facility analysis layer—This layer contains the input network locations (facilities, incidents, and barriers), parameters, and the resultant route or routes of closest facility analysis.
-   Service area analysis layer—This layer contains the input facilities and barriers, parameters, and the resultant service area polygons and service area lines.
-   OD cost matrix analysis layer—This layer contains the input origins and destinations, parameters, and results of OD cost matrix analysis (ESRI webhelp.esri.com).

In this project, only route analysis layer and closest facility analysis layer have been created.

Below, this is a partial relationship and object oriented structure of database which was created with GIS program (Górka, Śliż 2006).

BUILDINGS
OBJECTID
SHAPE
ID_BUD
NR_ADR
STREET
ADRRESS
ADAPTATION
SHAPE_LENGTH
SHAPE_AREA

STREET
OBJECTID
SHAPE
NAME
TYPE
ONEWAY
TIME
SHAPE_LENGTH

STOPS
OBJECTID
SHAPE
STOP_ID
NAME
STREET
ROUTE
TIMETABLE

SYMBOLS
OBJECTID
SHAPE
NAME

FUNKCJE_BUDYNKOW
OBJECTID
ID_BUD
TRADE
TYPE
NAME
DESCIPTION
WEB_PAGE

RIVER
OBJECTID
SHAPE
NAME
SHAPE_LENGTH

ARABLE_LANDS
OBJECTID
SHAPE
AR_LAND
CLASS
SHAPE_LENGTH
SHAPE_AREA

SPORT
OBJECTID
SHAPE
NAME
SHAPE_LENGTH
SHAPE_AREA

SZLAKI
OBJECTID
SHAPE
COLOR
TYPE
SHAPE_LENGTH

RAILWAY
OBJECTID
SHAPE
SHAPE_LENGTH

LINIE
OBJECTID
STOP_ID
ROUTE
DIRECTION
TIMETABLE

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Relationships between tables

BUILDINGS
OBJECTID
SHAPE
ID_BUD
NR_ADR
STREET
ADRRESS
ADAPTATION
SHAPE_LENGTH
SHAPE_AREA

one
to many →

BUILDINGS_FUNCTIONS
OBJECTID
ID_BUD
TRADE
TYPE
NAME
DESCRIPTION
WEB_PAGE

STOPS
OBJECTID
SHAPE
STOP_ID
NAME
STREET
ROUTE
TIMETABLE

one
to many →

LINIE
OBJECTID
STOP_ID
ROUTE
DIRECTION
TIMETABLE

3. CAPABILITIES OF THE CITY MAP

Correctly designed database like this and set of tools contained in GIS programs allow in various way to search for and get interesting information from database tables and visualization of monitored result of searching.

This is a standard that there is every feature class in separately layer which users can show or hide. What is more, the user can change looks of every layer, for example, by changing colour or type and width of line, choosing suitable symbols for point features etc. It is possible thanks to rich in symbols libraries connected to the software. Additionally, some of this programs allows user to make his/her own symbols.

To improve legibility of the map, the designer of this map sets a layer's visible scale range. Now, layers can be set to be automatically displayed only within the appropriate scale. Whenever the scale of the view is outside the layer's visible scale range, the layer will not be drawn. The ability to set the scale range for a layer's visibility is useful because the user can progressively display more detailed layers as he/she zooms in on an area.

GIS programs allow the user to prepare varied maps to print. The map composition, in addition to a data frame, can contain other map elements like titles, North arrows, legends, scale bars, scale text, graphs, reports, text labels, and graphics. What is more, if the map is a part of the series, the user may have a template to work on or he/she may create a new template for the series.

Interacting with the map. A lot of information can be derived from a map by just looking at it. There are times, however, when the user needs to know more. Because of this, GIS programs provide the user with the tools for querying this map in a wide variety of ways. For example:

- Use the Identify tool to see the attributes of features he/she has chosen (pic.1).

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The Identify tool allows you to see the attributes of data and is an easy way to learn something about a location on a map. Clicking the Identify tool on a location inside a view will present the attributes of the data at that location.

- Use earlier defined hyperlinks to open Web pages or documents about features.
- Find addresses, features that have a particular attribute, and route locations.

In general, to find interesting object, the user has to use the Find tool. If he/she wants to find feature they have to define a particular attribute feature and layer where the feature is located.

If he/she wants to find addresses, it is necessary to use address locators and choose the address locator he/she wants to use to find the address from the list. And then, type the address components in the text boxes.

The user can also find and identify route locations along a route feature. If he/she wants to find route, he/she chooses the Route Location tab. If he/she wants to identify route, they have to use the Identify Route Locations tool.
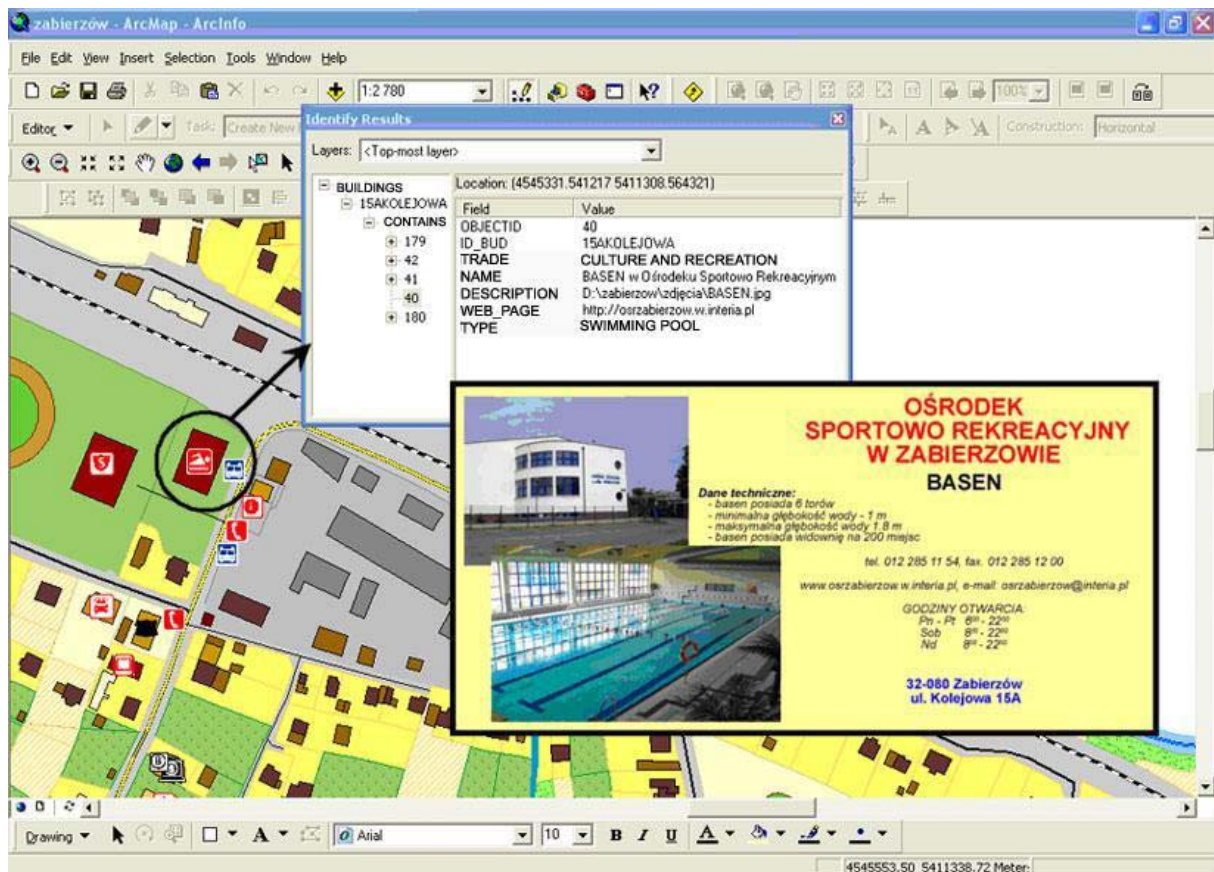
- Measure distances and areas on the map.
- See MapTips.

If the user wants to know what a feature is, he/she just pauses his/her mouse over it to display a MapTip. A MapTip pops up on the screen providing a quick description such as a street name or other attribute.

- Select features on a map by clicking on them or by using an attribute query or relationship with other features on the map.

The user can also select features by searching with a Structured Query Language (SQL) expression. SQL is a powerful language to define one or more criteria that can consist of attributes, operators, and calculations. For example, the user can select from this city map buildings where schools are. He /She would select the buildings with this expression: firma= 'school'.

Moreover, a user can select features by location. The user selects features based on their location relative to other features. For instance, if he/she wants to know how many homes were affected by a recent flood and he/she mapped the flood boundary, he could select all the homes that are within this area (ESRI webhelp.esri.com).

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Pic. 1. Identifying features.

Network analysis. Professional GIS programs offer users advanced tools to make network analysis. From among four accessible network analysis options, the most often used in a city plan are two of them: finding the best route and finding the closest facilities.

The first one allows to find the best way to get from one location to another or the best way to visit several locations (pic.2). Network locations are features used as input during network analysis, such as stops and barriers. The locations can be specified interactively by placing points on the screen, by entering an address, or by using points in an existing feature class or feature layer. The best route can be determined for the order of locations as specified by the user. Creating this type of route can mean finding the quickest, shortest, or most scenic route, depending on the impedance chosen. For example, if the impedance is time, then the best route is the quickest route.

The second option is finding the closest facilities. It allows the user to find the closest facilities and specify how many can be found and whether the direction of travel is towards or away from them. The user can display this route to or from them, return the travel cost for each route, and display directions to each facility. What is more, the user can specify a cutoff cost beyond which program should not search for a facility. For instance, the user can set up the closest facility problem to search for hospitals within a 10-minute drive time of the site of an accident. Any hospitals that take longer than 10 minutes to reach will not be included in

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the results. The hospitals are referred to as facilities, and the accident is referred to as an incident.

Along with every best route, program provides directions with turn-by-turn maps that can be printed (ESRI webhelp.esri.com).
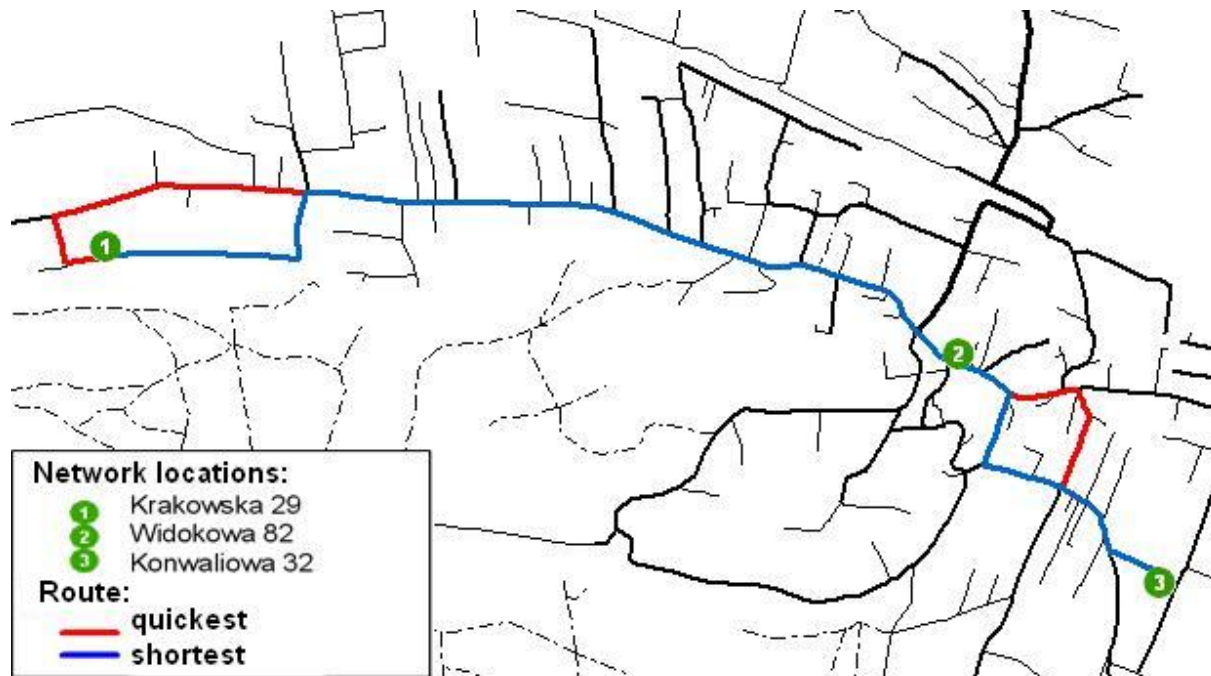
Pic. 2. The quickest and the shortest route between three network locations - comparison

## 4. THREE-DIMENTIONAL VISUALIZATION OF THE CITY PLAN

GIS programs provide advanced tools for three-dimensional (3D) visualization (pic.3), analysis, and surface generation. They let the user make perspective view scenes in which he/she can navigate and interact with his/her geographic information system (GIS) data. That kind of presentation makes it easier to identify features which are on the city plan with the real world.

Triangulated irregular network (TIN) surface was used as a surface model for the city area. On this surface every two-dimensional (2D) features from feature classes was viewed in three-dimensional space. For feature classes like lakes, rivers, roads as z-values there were used the values in the surface. Building features were extruded using an attribute, such as building height, number of storeys or based on an arbitrary value. To point features like bus stops there were three-dimensional symbols assigned.

This visualization of the city plan was created from existing two-dimensional data. Therefore, all attributes of features and full functionality of this plan were kept.

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In addition to this 3D visualization, GIS programs allow to create video presentation. Video films portraying for example the most interesting places of a city can enhance attraction of a city plan.

To make this plan more attractive, video presentation showing a bird's-eye view of Zabierzów was created.
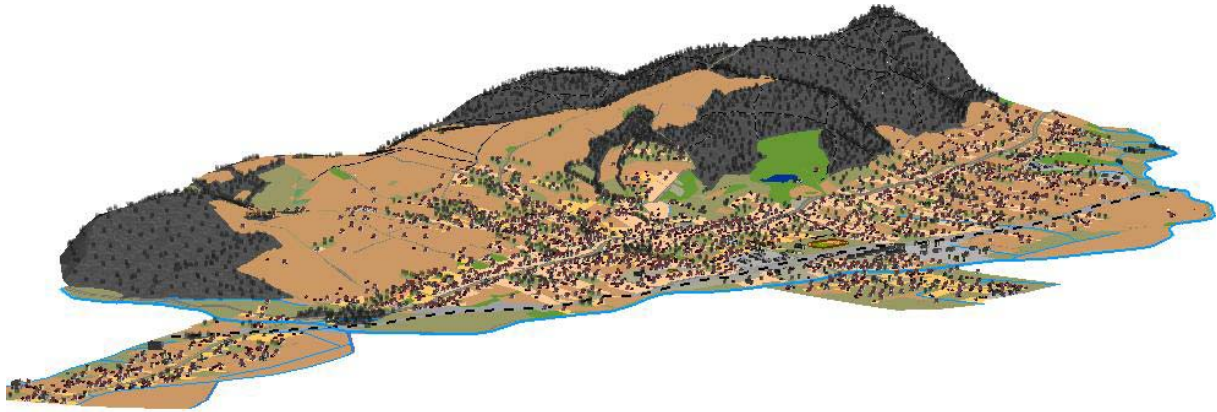
Pic. 3. 3D view on Zabierzów

5. SUMMARY

Digital city plans contribute to the development of the space surrounding us. They can be of a great use for promoting communes, searching for investment areas or drawing development plans. Thanks to them, cities presented become more attractive. Therefore creating new more and more attractive city plans is so important. Another important factor is the choice of an appropriate software to perform this task. Using Geographic Information Systems software is a good solution. Wide range tools offered by these softwares, not only these indispenisble as but also additional ones make a city plan more attractive , also speed up and make its creation process easier.

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BIOGRAPHICAL NOTES

Izabela Śliż
Academic experience:
2006: Master of Science Diploma in Geodesy and Cartography from AGH University of Science and Technology in Cracow
Specialisation: Geoinformatics, Photogrammetry and Remote Sensing
2006 to present: Doctorate Student at AGH University of Science and Technology in Cracow
I am interested in Geographic Information System and Web Map Services.

CONTACTS

Izabela Śliż
AGH University of Science and Technology
Al. Mickiewicza 30
Cracow
POLAND
Tel. +48 12 617 23 00
Email: isliz@agh.edu.pl

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