Application of GIS Technology for Town Planning Tasks Solving

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Abstract. For developing territories, one of the most actual town-planning tasks is to find out the suitable sites for building projects. The geographic information system (GIS) allows one to model complex spatial processes and can provide necessary effective tools to solve these tasks. We propose several GIS analysis models which can define suitable settlement allocations and select appropriate parcels for construction objects. We implement our models in the ArcGIS Desktop package and verify by application to the existing objects in Primorsky Region (Primorye Territory). These suitability models use several variations of the analysis method combinations and include various ways to resolve the suitability task using vector data and a raster data set. The suitability models created in this study can be combined, and one model can be integrated into another as its part. Our models can be updated by other suitability models for further detailed planning.

1. Introduction
The planning of urban area, including optimal allocation of objects for industrial, public, transport and recreational construction, is required for effective use of urban region. Integral assessment of region includes analysis of large number of natural and anthropogenic factors, which all together determine suitability of the area [1]. For such assessment, multiple data from several specialized maps could be usually compiled onto a single map, which appeared overloaded by many objects and details. Than, the site corresponding to criteria required can be selected basing on evaluation of factors, sometimes visually.

In these cases, it is expedient to use the geographic information system (GIS), which allow to model complex spatial processes sufficiently reliably. GIS offers broad opportunities for geographical data processing: resolution of cartographic tasks, spatial analysis and editing of data, and data management [2]. By this means, GIS allows to analyze vast volumes of geographic data, which are used in urban region planning [3,4].

GIS analysis covers a wide range of tasks and applications: from calculating values in a table to performing spatial analysis. The ultimate goal of analysis is to get more information from geographical data to make a better decision. The actual methods for particular use can be simple or complex: from selecting feature having a given value to building model that combines many layers of data [5]. GIS analysis is a process that follows a basic set of subsequent steps [2].
For developing territories, finding of suitable sites for settlement allocation and defining of appropriate parcel for particular construction object are most essential tasks. Creating of the GIS analysis models for finding of these sites and parcels were the main goal of this study.

A model of searching and selection of optimal parcels for placement of various urban construction objects must consider various factors and criteria depending of the type of object [6].

At the initial stage, we created the model flowchart, aiming to determine required source data, to choose GIS analysis methods needed, and to define sequences of analysis steps for each model. Then, we implement the models in GIS and verified models by application to specified objects in Primorsky Region.

2. Materials and Methods
Existing built-up area was used for verification of the model for searching settlement optimal placement. For second task that was verification of the model for selection of optimal urban construction parcel, the object Sports Center was considered.

Source data required for GIS analysis were gathered into joined geodata base. Some vector data were converted into raster data set for spatial analysis. Data were taken from official open access Internet sites of corresponding services or provided to us for development. Some parts of the data were digitalized by students during of production-focused practical training.

For model realization we used ArcGIS Desktop (ESRI), which includes broad set of GIS analysis functions. We used distance analysis functions to measure the distance between features, find the features within a given distance of the other features (buffer), create a continuous surface of distance from a set of features (such as distance from roads or streams) or over terrain. Overlay analysis was used to combine layers that share a geographic extent (or at least overlap) to create a new layer that has the attributes of the input layers. This lets find relationships between features on different layers, for example, identify features that meet some combination of criteria.

ArcGIS lets perform geographic and spatial analyses on a variety of datasets. For spatial modeling, we used datasets including vector data (feature) and raster. The type of data and features determined the using specific analysis methods and tools. The tool applies a function to existing data to get new data. We used several ArcGIS tools subsequently to perform sets of various steps. Most tools for analyzing vector data are provided with ArcGIS application ArcToolbox. Extension product ArcGIS Spatial Analyst was used for analyzing the relationships between raster datasets. Along with tools for managing and processing raster datasets, we used Spatial Analyst functions for overlay analysis and distance analysis.

3. Results and discussion

3.1. Choosing suitable location
The finding of the suitable area for settlement localization at the municipal region was based on the analysis of several natural and anthropogenic factors. Criteria, which combined determine suitability of the area, are: slope of terrain (less than 3°); distance to sources of water supply (less than 1000 m); distance to utility networks (less than 500 m); distance to road and railroad (less than 2000 m).

The GIS analysis flowchart for terrain considering criteria for suitable settlement placement included following steps (figure 1):

- specifying of factors and datasets for analysis: elevation, transportation lines (roads and railroads), utility networks, sources of water supply, buffer zones (zones of the sanitary protection);
- creating of raster dataset from vector dataset;
- calculating of surface slopes;
- assessing of distances to objects, which are necessary for regular functioning of infrastructure;
- reclassifying of all raster datasets using common scale;
- combining of reclassified datasets.
We realized this model in ArcGIS Desktop using mainly the tools of extension product ArcGIS Spatial Analyst. Feature class Elevation was converted to raster dataset by Feature to Raster tool, and surface slopes were calculated by Slope tool. We used various tools that calculate distance from feature as raster surface of continuous values. Strait-line distances to sources of water supply and objects of utility networks were calculated by Euclidean Distance tool. Cost-weighted distances to roads and railroads were calculated taking into account slopes by Cost Distance tool. Vector data layer of buffer zone (zones of the sanitary protection) was converted into raster dataset by Feature to Raster tool.

Each obtained raster dataset was reclassified by Reclassify tool, i.e. the values in a grid were changed to the range from 1 to 10, where attribute signature equal to 10 corresponds to highest suitability.

![Flowchart of GIS analysis model for a region.](image)

**Figure 1.** Flowchart of GIS analysis model for a region.

For creation of single output layer, combining of reclassified raster data sets was made by Raster Calculator tool. Actual settlement boundary was added to created raster dataset layer for comparison (figure 2). On resulting suitability map, it can be seen that the area of highest suitability really coincides with actual boundary of existing settlement. This confirms appropriateness of our model and accuracy of accomplished work results.
3.2. Selection of appropriate parcels

Next task, that we intended to perform in our study, was among main actual problems of modern town-planning, namely, the selection of parcel for construction, regarding various factors depending on the object type. In our case, this object was “Sports Center”. Model for selection of appropriate parcel for this object on the city area must consider existing urban development, urban development zoning, parcel information, slope of terrain, distances from roads and utility networks, remoteness from industrial zones and flood zones, proximity to green zones.

Constructing this model, we dealt mainly with raster dataset. This condition determined the set of functions and tools that we used in this model. The selection of parcel was made by ArcGIS tools Select by Attributes and Select by Location. First, we selected all town-planning zones that satisfied to particular criterion: construction of sports centers area permitted in residential, public, or recreational zones (Select by Attributes). Than, we selected parcels, which centers were allocated in these zones (Select by Location). By this means, we had selected at first step parcels, which were appropriate according to legal characteristics. Among parcels selected, we determined free plots, which had no owners or renters (Select by Attributes). Than, we selected parcels with optimal area (20000 sq. m).

The layer of slopes was initially divided into categories depending on slope range. Early selected parcels were sorted according to terrain slopes. For this purpose, we extracted the area with the slope less than 3° and than selected parcels which centers were allocated in the area extracted (Select by Location).

As a next step, we defined buffers around objects of infrastructure, industrial zones, and flood zones. A buffer identifies the area within a given distance of feature. Defined buffer areas were used to select parcels. We created buffer around feature Road (minimal distance to the road equals 300 m) by the tool Buffer and than defined parcels that intersected buffer area and conformed to this requirement by Select by Location tool. Correspondingly, parcels intersecting buffer area of utility networks were selected. Next, buffer around industrial zones (distance more than 1000 m) was created and all parcels intersecting this buffer area were deleted by Select by Location. Likewise, buffer for the layer Flood zones (buffer distance – 500 m) was created, intersecting parcels were defined and canceled by Select by Location tool as inappropriate.

After this step, only two parcels have been remained, and both completely corresponded to criteria required (figure 3).

We calculated distances from selected parcels to green zones. These distances were minimal because selected parcels were situated in the city park area.
4. Conclusions
For performing of the complex suitability analysis, we were compelled to combine different types of analysis. However, suitability models can use several variations of analysis method combinations.

In our study, we showed two ways to resolve town-planning tasks, using vector data or raster data analyses. In the case of vector data analysis, preliminary classification of attribute values of feature into categories in accordance with criteria is needed. Later, data are selected from the category that corresponds to criterion. In the case of raster data analysis, more complex GIS analysis operations are used, for example: distance analysis and surface creation to generate input layers. Reclassification of values is performed at the end of the model for overlay analysis to combine layers. Alternative way requires more detailed data and consumes more time, but more precise results can be obtained.

Created in this study suitability models can be combined. One model can be integrated into another as its part. For example, our model of probable extension of erosion processes can be included as the factor into the suitability model for settlement. And, the suitability model for constructing object can integrates both these models and uses their suitability maps. These our models can be updated by other suitability models for further detailed planning. All models created in this study can be realized by means of other GIS, which have function of special analysis.

References
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