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Optimal Modelling of a Transportation Network at the Level of Cluj County by Using ArcGIS Network Analyst

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Abstract. This paperwork presents a model of transportation network which uses a package of programs allowing the creation, processing, integration, analysis and posting of geographical data at various levels. ArcGIS was used, extension ArcGIS Network Analyst**,** with which the area of influence of an economic objective on any location from the map may be identified, representing the network, as well as the data base obtained following the Digital Romania National Project. In the model created by the road network 16 points of interests were added on the map of Cluj County, divided into two themes: *Agricultural holdings*: Aghireş, Baciu, Beliş, Berind, Floreşti, Huedin, Steluța; *Livestock holdings*: Apahida, Cojocna, Copăceni, Dej, Iclod, Floreşti, Răscruci, Someşeni, Tureni. The modelling of transportation network from this paperwork contains three phases:

a) The travel of path through all points of interest having as starting and return point the city of Cluj-Napoca without barriers and without the optimization option;
b) The introduction of several restrictions on the previous path;
c) The optimization of path with barriers, as well as without them.

Keywords: organization of transportations, network modelling, ArcGIS, optimization

INTRODUCTION

The modelling through GIS is performed with the help of procedures contained within the spatial analysis, which finally leads to a prevision in order to take decisions. The operations involved in modelling may be performed directly on the layers of maps and in combination with the related attributes. Due to the complexity of modelling processes, as well as of particular details of the modelled field, there is no universal language for modelling in GIS until now.

The spatial analysis represents more a concept than a program component of a GIS. The operations of spatial analysis are contained in various modules of GIS. In principle, each soft product has its own organization system of programs, which represents the operations of spatial analysis. At large, the spatial analysis must allow:
The spatial interrogation; Interrogation attribute (sometimes the a-spatial term is used);
Generation of a set of new data from the existing ones. In fact, this last requirement is the most representative for the spatial analysis and it represents the essence of processing geographical data.

The election of operations, as well as of the order of action on data, within a modelling process, it is not very simple, this is why it must receive the highest degree of attention. This is very difficult and represents the key of success in achieving the purpose suggested. (Chou, 1993).

The spatial analysis which has as basis linear structures is called network analysis. The domains involved: roads, railways, phones, electricity, gas, water-channel. A network consists of a number of interconnected arches. Each arch, as the definition points out, has a start node and a final node, its path being directed by points (in ArcGIS verticies). The topographical relations defined by nodes determine the network connectivity. (Imbroane and Moore, 1999).

One of the main applications of such type of analysis can be found in the planning of transportations, where the main issue is represented by the identification of best paths which correspond to certain criteria, such as finding the shortest path or the lowest cost between two or several locations, the identification of all locations which fit a certain cost (time or financial).

A network model may be defined as a line graphic, composed of links representing linear circulation channels of the flow (matter, energy or information) and nodes representing their connections (Lupien, 1987).

MATERIALS AND METHODS

ArcGIS Network Analyst represents an extension of the programme ArcGIS used within the spatial analysis on structures type network. The application fields of such extension contain: the analysis of localization of phenomena or processes, the time to go through a path and the modelling of spatial interactions.

The data type network which may be analyzed in ArcGIS contain:
Analysis of paths; Analysis of localization of phenomena; Neighbouring analysis of certain cervices.

By using ArcGIS Network Analyst we may identify the area of influence of a certain economic objective on any location from the map representing the network. The function of determination of the vicinity allows the establishment of the minimum distance between a certain point from the network and the closest social-economic objective, by mentioning the number of objectives which must be taken into account and of the maximum time granted to the movement.

The data basis which achieved this model of network transportation was obtained following the national project „*Digital Romania*" and refers to railroads, surface of villages, roads, surface of the county and shape, localities, rivers.

RESULTS AND DISCUSSION

In order to elaborate the map of Cluj County the essential order ArcMap of the package ArcGIS was used. The document map contains several cartographic compositions, called data frames. The thematic layers within a frame must refer to the same territory, in the present case the surface of Cluj County.

First, the first thematic layer was represented (layer), this being Cluj County as surface and shape. The order and positioning of the layers representing the geo-spatial entities whose surface is not disjoint (the present case) is highly important, because frequently the modality of filling in/shading the layers is not transparent, and thus, those have to be kept „over" from those which have to be "masked" which offer more coverage.

The order of layers in order to obtain Cluj map was the following: the layer adequate to the surface and shape of the county; the layer adequate to the representation of the surface of villages from the county; the layer adequate to localities; the layer adequate to the roads from the county.

The phases of adding the layers onto the ma of Cluj County were identical, thus a representation of the roads of Cluj County was obtained. From the point of view of the structure of roads, these are divided into national, European, county and village roads. Each of these attributes was added to the Cluj County's map, being obtained the following representation (Fig.1):

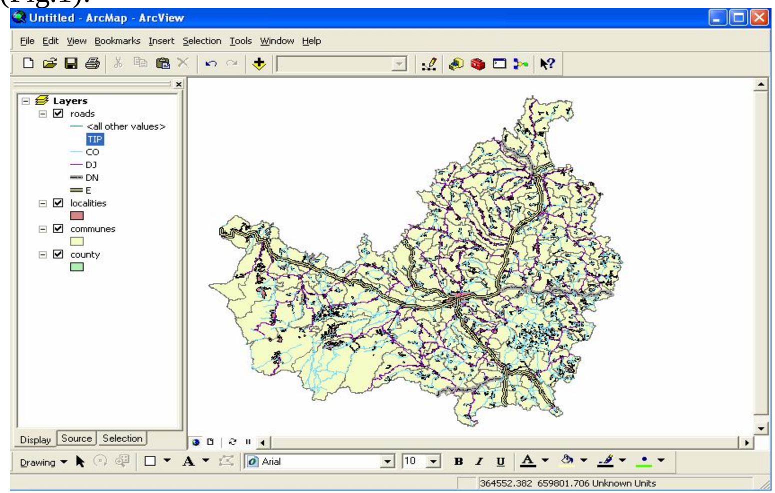


Fig.1. The classification of roads from Cluj County in relation to their type

The following phase was represented by the elaboration of layers containing the two themes: agricultural holdings and livestock holdings. In ArcCatalog a new file with the type shapefile was generated (specific format ArcGIS) through the array of orders File-New-Shapefile, and in the dialogue which followed the layer name was mentioned (agricultural holdings), its type (point) and the protection system (the Stereo National Protection System was used 1970).

The editing of interest points from the two created themes was elaborated by accessing the menu Editor from the programme Arc Map, where for each point created a registration is generated in a chart attributed attached to each theme which is filled in with specific data, in the current case with the denomination of locality in which the agricultural holding or livestock holding is situated, as well as its type (text).

Only the objectives introduced in the analysis and the county's shape, and for each the symbol was modified and the denomination with command Label Features was added, the result being posted in Figure 2. With these phases performed, the data base was finalized and the following step was to model the structures type network with ArcGIS Network Analyst.

In a first step, in ArcCatalog the road network must be prepared for analysis. The preparation shall be done through the selection of the file by representing the route network and the election of option New Network Dataset. In the dialogue which follows the layer's name is mentioned, the network connectivity rules (implicit settings suppose that the junctions should be performed where the ending node of an arch coincides with the starting point of another one, the specification of movement rules of flows on the network (if there are return passages, one way roads).

In the following phase of the construction of model, the data specific to previously generated roads were added to ArcMap and their publication was automatically performed for the network elements (including junction elements).

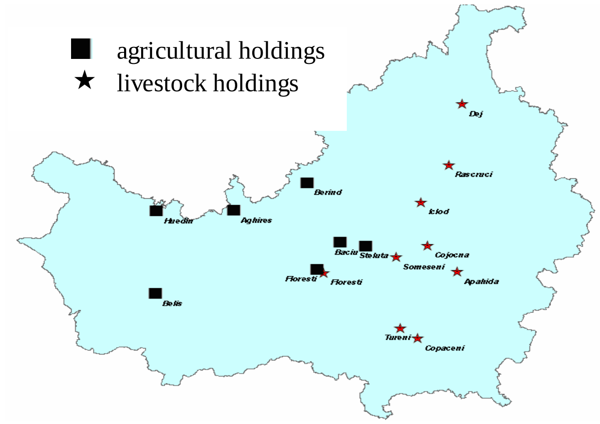
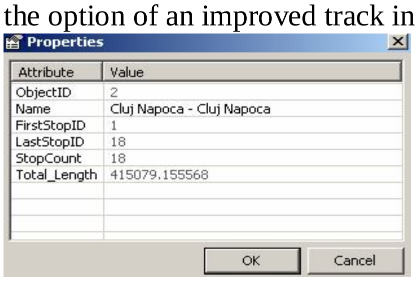


Fig. 2. Graphic representation of objectives from the model created

In order to elaborate the model of a possible path of a transportation means, which hypothetically should go by all points, on all road categories included in the network from the menu Network Analyst of the list appeared the command New Route was selected and the following were mentioned**:** the stops localized on the network, the stops outside the network, the errors, exceeding the period of time granted to the transportation (if applicable), the barriers – errors, the barriers – positioned on the network path, the barriers – positioned outside the path, the proposed final path.

In the model presented were selected the locations of all objectives having as possible starting point the city of Cluj-Napoca. The results for posting all the locations which have to be passed by are posted in Fig. 4. In the first phase of modelling was taken into calculation the passing by the path through all its points, without route barriers and without the selection of the option of an improved track in order to obtain reduced costs.



The result appears as map, as well as in the project components under the denomination Routes (1) - Cluj Napoca – Cluj-Napoca. If the properties of such path are viewed, several quantitative properties may be determined: number of stops (including the starting and ending point), the total length of the track (in the example analyzed approximately 415 km).

Fig. 3. Path characteristics

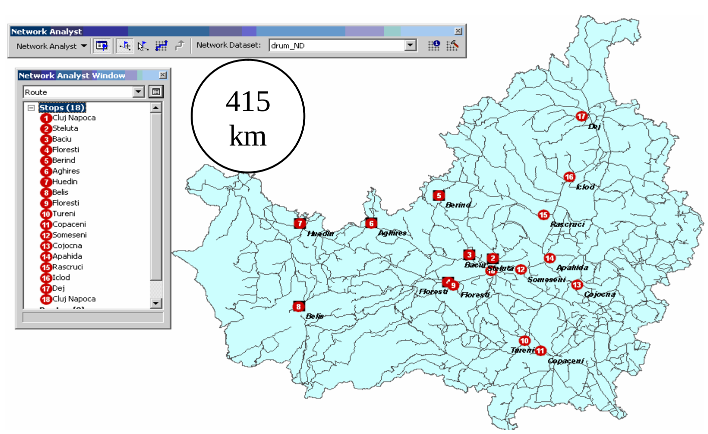


Fig. 4. Going by the path through all its points of interest

In the second phase of the model, through the selection of the category Barriers several restrictions were introduced on the previous path in the places marked on the map, and at the command Solve, the issue was settled by using another path (Fig. 5). These restrictions refer to the own technical equipment from each unit, to the roads on which such equipments may be moved and on the related period of time.

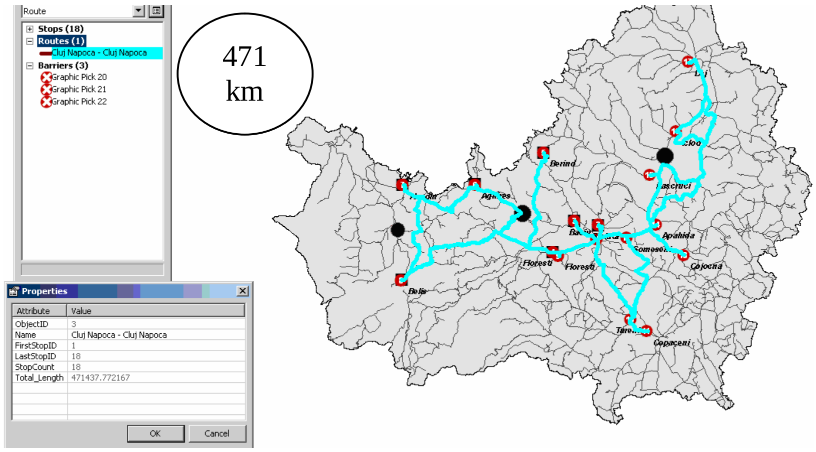


Fig. 5. Configuration of the path with barriers and the new properties

Due to the algorithm implemented ArcGIS Network Analyst has the option of the arranging the stops so that an optimal path with minimum costs for all categories of road shall be contained, with limitations, as well as without them.

One of the most important features which have to be included in any topological model of surface is represented by the impedance of by the resistance of the network. This may be represented by many quantitatively expressed characteristics and, most frequently, published in the attribute chart. The most known are the length of the network segment and the time interval for its circulation.

In this model the impedance is expressed by the length of the segment, fact mentioned at the creation of the data structure. Another necessary element at the improvement of the network is represented by the permission granted to the procedure to rearrange the stops within the model, in order to minimise the costs (Reorder Stop to Find Optimal Route) and ignoring of locations situated outside the network (invalid locations).

After these specifications, with the help of the order Solve, the programme calculates the best route, posts the path and its main characteristics (Fig. 6).

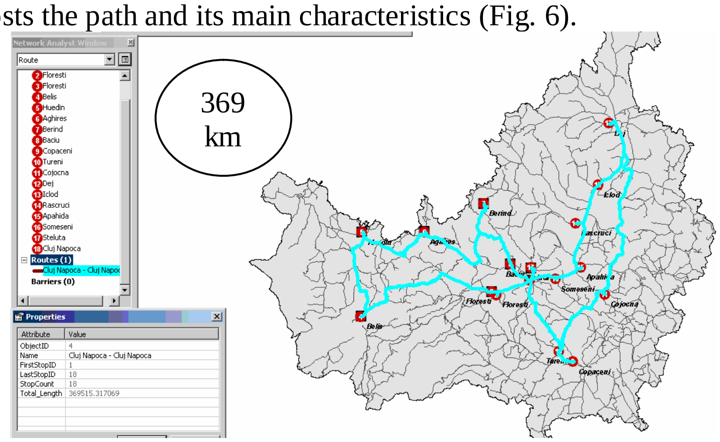


Fig. 6. Representation of the best road of the network

By analyzing the resulted map it may easily be noticed that the path is much shorter (approximately 370 km) being maintained only the starting and arrival points, the rest being rearranged so that the model should satisfy the requests mentioned.

By maintaining the restrictions from the previous model, but introducing he optimization characteristic, the results show much more efficient quantitative indexes. The number of stops is the same, the start and the stop are maintained as those introduced by the user, while the elements are rearranged, and the number of km is of approximately 416).

CONCLUSIONS

The transportations represent for most of the countries of the world a distinct branch of the economy, by ensuring the travelling in space of products and people. The dynamics of the activity from the sphere of transportations is determined by the rhythms of the development of general economy, by the evolution of material production, by the structure and its distribution in the territorial profile.

By analyzing the evolution of the route traffic on national roads, and mentioning that it is in continuous growth, it is necessary to organize and improve as much as possible the transportations in any field of activity and especially in agriculture where the issues related to transportation, in which concerns the organization, as well as in relation to the technical-material base, are far from being resolved.

The model described has the meaning to show the applicability of this sort of approach (GIS modelling on structures type network) in the optimization of transportation systems. The model built may generate more complex approaches in the case of introduction of restrictions of various types: the circulation may be done only on certain categories of roads (national, as well as county roads), at certain time intervals and with certain speeds, various limitations imposed to agricultural devices etc.

The complexity may also increase if taken into account the markets of agricultural products, respectively the distribution areas.

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