GIS MODEL TO EVALUATE THE ACCESSIBILITY TO MAJOR TRANSPORT WAYS

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Abstract. In order to ensure a balanced accessibility to major transport ways, supporting spatial development and economic growth, a GIS model to assess accessibility it was proposed. The model is measuring the average cost of travel (by car, usually) from a point to a predetermined number of destinations measured in units of time (minutes). Using the ARCGIS Spatial Analyst module, accessibility territorial indicators were calculated and presented as cartograms and maps that are outlining the accessibility to major transportation routes and to major cities. The proposed model to assess accessibility was tested for Tulcea county (NUTS III level) and for the South East region (NUTS II level).

Key words: territorial cohesion, ESPON, disparities, Digital Terrain Model, travel cost

1. General frame

The Europe 2020 Strategy stipulates that territorial cohesion can be achieved by ensuring a balanced accessibility to major transport ways. Good accessibility and connectivity are crucial factors in deciding on a location for economic activities (Spiekermann & Wegener, 2011).

Concerning the accessibility, our national spatial policy is referring to: (a) the need to develop advanced tools and techniques of spatial planning at national, regional and county level, in order to provide statistics and information on the accessibility to the main ways of communication ("accessibility" being a key factor in the territorial development and competitiveness), and to (b) the possibility to assess accessibility using Geographic Information Systems, in accordance with European practices in the field (especially the ESPON research program), in order to strength the national territorial integration within the European territory.

1.1. Territorial cohesion and accessibility

Territorial cohesion aims a more balanced territorial development by reducing existing disparities, avoiding territorial imbalances and ensuring coherence of sectoral policies with spatial impact (European Parliament, 2007). According to Europe 2020 Strategy, the objectives of the policy aiming strengthening territorial cohesion are defined as:

- Increasing the strength and diversity / identity of urban centers / networks, as drivers of spatial development in Europe;
- **Improving accessibility and territorial integration in the EU;**
- Maintaining and developing the quality and safety of natural and cultural values in Europe and developing sustainable links between urban and rural areas.

Accessibility is a key factor in spatial development and competitiveness. The First ESPON 2013 Synthesis Report highlights the closed link between accessibility of regions, on one hand and their economic performance, on the other hand. Territories with high accessibility are advantaged in the current economic climate. The geographic challenges which are facing a number of European regions (such as isolation, rural character, dispersed population) can be managed through integrated territorial strategies, adapted to local particularities and to the scale of analysis (Keeble *et al.*, 1982). In Romania, the main barriers in the development of this kind of regions are their **poor transport infrastructure** and a limited access to basic services. In such areas, increasing local transport accessibility (increased connectivity to nearby urban centers), as well as improving their local environment potential, are the main solutions proposed by ESPON 2013 research.

There are many definitions and concepts referring to accessibility. Usually accessibility is measured by indicators (Spiekermann and Neubauer, 2002). *"Accessibility indicators describe the position of an area in terms of opportunities, activities or economic assets occurring in that area compared to those in other areas, "area" meaning a region, a city or a corridor"* (Wegener *et al.*, 2002). Accessibility indicators may have different complexity. The most complex accessibility indicators take into account the connectivity of transport networks, distinguishing between themselves and other network activities or opportunities that become available through these networks.

1.2.GIS and accessibility

Geographic Information Systems (GIS) are used as a scientific and methodological tool to measure the accessibility, monitor produced indicators, identify spatial inequalities and give solutions in order to support territorial planning (Tsatsaris, 2006). The present research presents a GIS model, created in order to obtain and represent a set of accessibility indicators, using as spatial elements three transport ways: on land, water and air. The set of cartographic and statistical data created with this GIS model of accessibility is providing the necessary support to decision makers in order to perform a spatial analysis of the whole national territory in terms of transport infrastructure. This data set helps to clarify several important spatial planning issues such as, locating spatial disparities, explaining their occurring, evaluating alternative development scenarios or fund allocation. A spatial transport typology was created for 2 areas: Tulcea county (NUTS III level) and the South East Region (NUTS II level).

1.3.Methodology

According to the methodology of the digital accessibility model, a GIS model was created in order to calculate the cost indicators to a number of established destinations, using land, water and air transport nodes. The value of travel cost for each cell on the surface represents the absolute travel time to the nodes or to specific linear elements of the network.

In the digital accessibility model, significant is the accuracy of the Digital Elevation Model, in our case cells having dimensions of 26.62 m x 26.62 m - ASTER GDEM in GeoTIFF format. This cell size is enough in order to obtain adequate results according to the study requirements, but due to increased processing time on computer software a resolution of 80 x 80 m was agreed, which provides both an adequate processing speed and reliable results within the application.

1.4.Data acquisition and preparation

Data on transport network, settlements and administrative boundaries of Tulcea County were obtained in digital system by digitizing 1:100000 IGFCOT plans and updating the data sets for the year 2012. Some data had an appropriate format, while other data was further processed to meet study standards. The following data was used:

1. Digital elevation model - ASTER GDEM in GeoTIFF format, latitude-longitude coordinates and precision of 1 arc-second (30 meters) elevation;
2. The road network, developed in URBANPROIECT by digitizing the IGFCOT plans at 1:100000 scale. The dataset was updated. The network was classified according to the average travel speed and to the road type:
    a. Motorways - speed 130 km/h;
    b. European roads - speed 110 km/h;
    c. National roads - speed 90 km/h;
    d. County roads - speed 70 km/h;
    e. Local roads - speed 50 km/h;
    f. Ferry crossings - speed 10 Km/h
3. The rail network, developed in URBANPROIECT by digitizing the IGFCOT plans at 1:100000 scale. The dataset was updated. The network was classified according to the average travel speed - 60 km / h.
4. The railways stations were digitized; the datasets were processed and updated according to the Trains Timetable;
5. The ports network was digitized, processed and updated;
6. The airports network was digitized, processed and updated in accordance with EU rules;
7. The built-up areas of settlements were digitized, processed and updated where there was information;
8. Administrative boundaries were digitized and updated for all NUTS levels (I, II, III and V);
9. The hydrographic network was developed in URBANPROIECT by digitizing the IGFCOT plans at 1:100000 scale. The dataset was corrected and updated using modern techniques such as GPS, satellite images etc.

2. Constructing the accessibility model

The GIS Modeling Scheme to determine the accessibility was designed as follows:

2.1. The GIS modelling scheme

1. Starting points:
    - Road network, in vector format;
    - Railway network, in vector format;
    - Railway stations, in vector format of point type;
    - Ports, in vector format of point type;
    - Airports, in vector format of point type;
    - Built-up areas of localities in vector format;
    - Municipalities and towns in vector format of point type;
    - Administrative limits in vector format (NUTS II, III, and V).
2. Converting the road network from vector format into raster format.
3. Converting the studied area as a travel area with average travel speed of 5 km/h, except for the road network in raster format.

4. Calculating the slope using the Digital Elevation Model.
5. Converting the studied travel area network according to slope and removing the hydrographic areas.
6. Converting the analyzed raster area from speed indicator into time indicator.
7. Calculating the cost indicators: access to national roads, railway, railway stations, airports, ports, county capitals.

2.2. Cartographic representations

According to this scheme, the following cartographic representations were obtained, in the order described in the following paragraphs.

2.2.1. Convert road network from vector format into raster format

The road network from Tulcea county was obtained by digitization of IGFCOT plans, scale 1:100000, then processed in digital format using the GIS system, i.e. the ARCGIS software. For accuracy, the digital dataset has been corrected and completed using the results of other research projects of URBANPROIECT that used the Global Positioning Systems (GPS) to obtain the digital road network.

According national road classification, the database containing travel speeds for each road in the county was completed (e.g. speed for national roads - 90 Km/h). Given the existence of ferry crossing in Tulcea County, the crossing speed from one bank of the Danube to another bank was considered as about 10 Km/h.

The first step was represented by the conversion of the road network from vector format (Fig. 1) into raster format using the Spatial Analyst module of ARCGIS (Fig. 2).

Then, the whole area of Tulcea county (except for hydrographic and road networks) was converted in raster format and considered as being a travel area with an average speed of 5 km/h (Fig. 3).

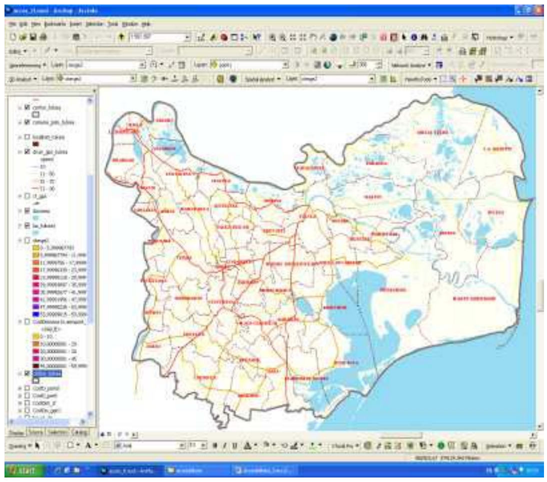

Fig. 1. Road network in vector format

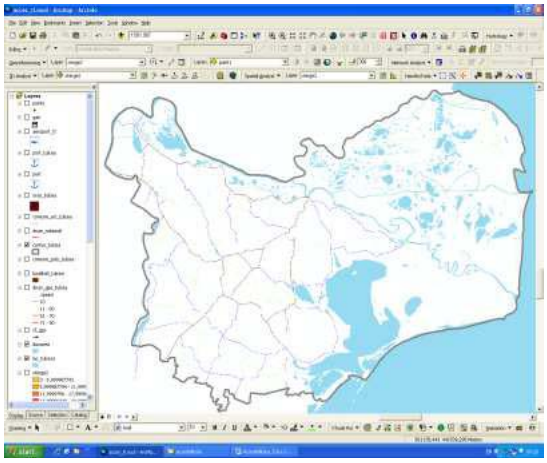

Fig. 2. Road network in raster format

2.2.2. Calculating the slope of travel area based on digital terrain model

The digital elevation model of Tulcea county (Fig. 4) allowed to calculate the slope of travel area (Fig. 5), using the Spatial Analyst software. In order to obtain correct results of accessibility, the model required a relationship between travel speed and the landscape of the area, namely with the slope generated by the elevation of study area. To simplify the digital model, the presented above slope raster was reclassified as described in Table 1.

Thus, raster representing speeds of travel on the surface of the studied region was recalculated according to the slope coefficients reclassification (Fig. 6).

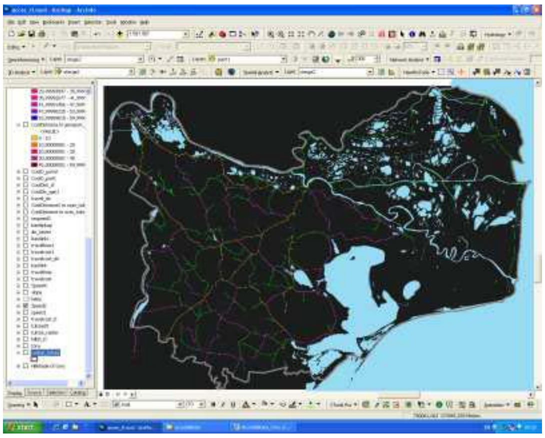

Fig. 3. Whole area converted in raster format

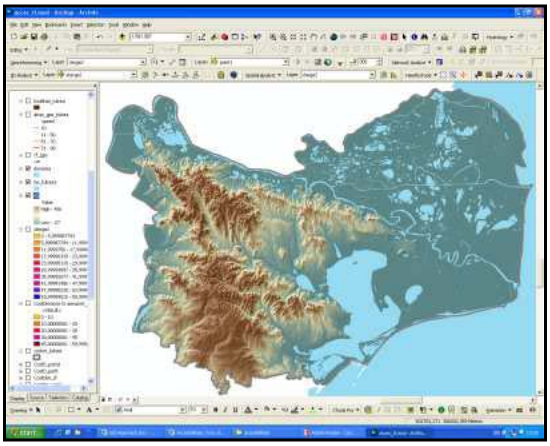

Fig. 4. Digital Elevation Model for Tulcea county

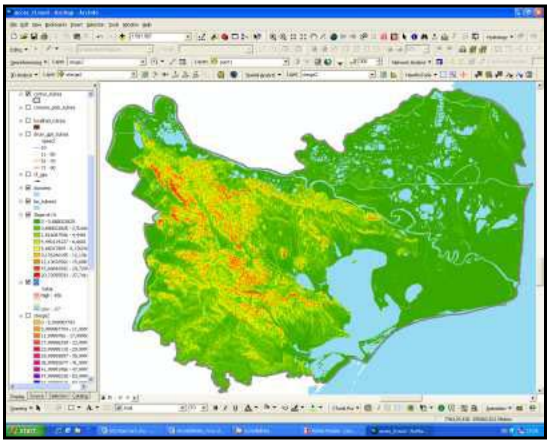

Fig. 5. Slope calculation

Table 1. The slope raster

Slope	Coefficients of slope reclassification
0 – 5 %	1
5,1 – 10 %	1,2
> 10%	1,5

2.2.3. Calculating the cost of travel

Indicators of travel cost measure the cumulative or average cost of travel to a predetermined number of destinations (Spiekermann & Wegener, 1999).

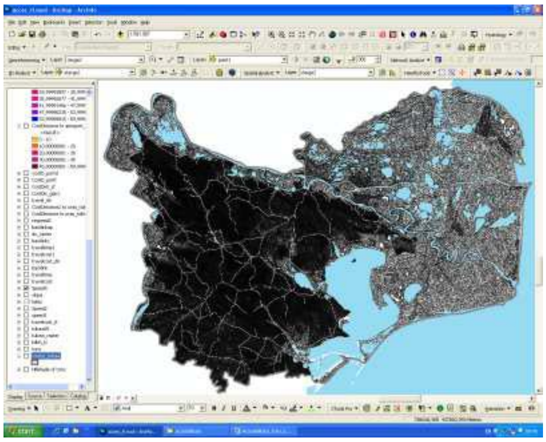

Fig. 6. Recalculation of travel area

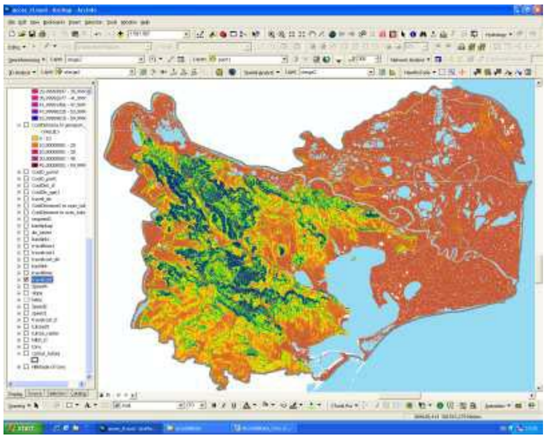

Fig. 7. Travel cost raster (TravelCost)

In this accessibility model, the cost of travel is achieved by converting the speed raster (calculated in km/h) into a time raster, measuring meters/minute. The applied formula is: 1 Km/1 h = 1000 meters/60 minutes = 16.67 meters/minute

To calculate the cost of travel (travel cost raster) was used the following formula: Travel cost Raster = 1.0 / (Speed_Raster* 16.67). Thus, it was obtained the travel cost raster displayed in Fig. 7.

3. Results and discussions

To calculate accessibility to major transport ways and to the capital of the county - Tulcea Municipality (Fig. 8), two sets of data were combined, i.e. the raster file TravelCost with each vector dataset described above. Since for determining the algorithm is acceptable any time limit, a time parameter was chosen, namely "adequate service", which is of 30 minutes to arrive to the capital of the county and to railway stations (Fig. 9), and 60 minutes to arrive at a port or airport (Fig. 12 and Fig. 13). The function of Distance weighted with the cost was applied to the model of the cost area.

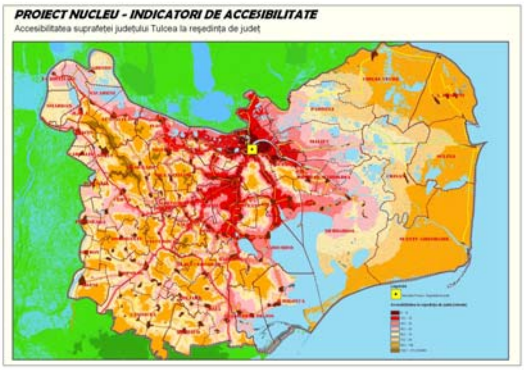

Fig. 8. Accessibility to the county seat

Fig. 9. Accessibility to the county seat in maximum 30 minutes

Analyzing the obtained cartograms on accessibility of the territory of Tulcea county at its county seat (Tulcea Municipality) by road, is observed a decreased accessibility index, explained by the specificity of Tulcea County (which is covered 30% by water), by the county location (in a peripheral area compared to the national territory), and by the lack of a road bridge making the connection with Braila-Galati area.

According to obtained cartograms (Fig. 10), accessibility of Tulcea county at national/European roads is good and very good along the road directions connecting Tulcea municipality with the capital Bucharest, with Constanta municipality and with Galati-Braila area and is low and very low in the Danube Delta, in the Macin mountains area and in the south-eastern part of the county.

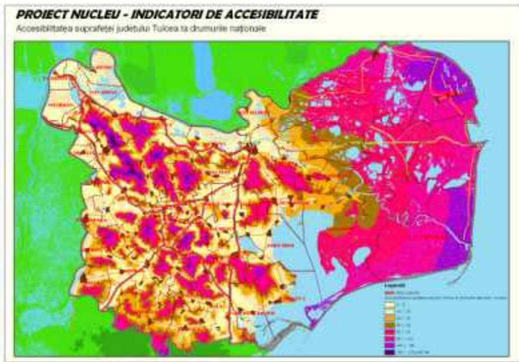

Fig. 10. Accessibility to first class roads

The cartogram reflecting accessibility of Tulcea county at railway stations in the county in maximum 30 minutes travel by car (Fig. 11) shows a very low access of population at railroad and hence a reduced use of the railway transport. Territorial accessibility and, implicitly, of the population of Tulcea county, at main ports of the county (Fig. 12) is relatively good, due mainly to Tulcea port, located in Tulcea city. Road links to the port of Sulina are insignificant for the county's population, access to this port being done on the waterway.

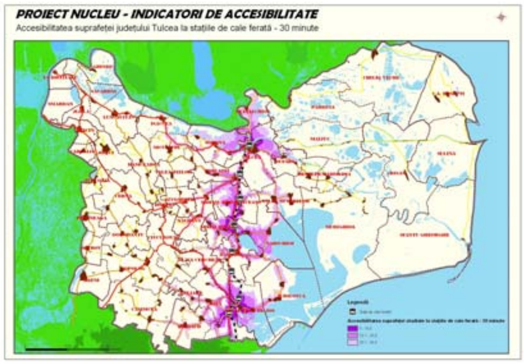

Fig. 11. Accessibility to the railway stations

Accessibility of Tulcea county at the airport "Danube Delta" is relatively good (Fig. 13), most of the county's population reaching the airport, by road, within 60 minutes of travel. Unfortunately, the passenger flow passing through the airport is insignificant, without regularly use of the airport.

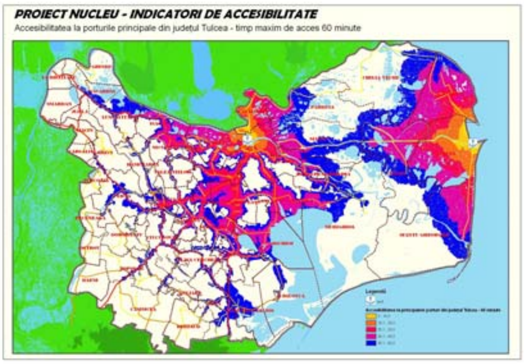

Fig. 12. Accessibility to major ports of Tulcea county, in maximum access time of 60 minutes travel by car

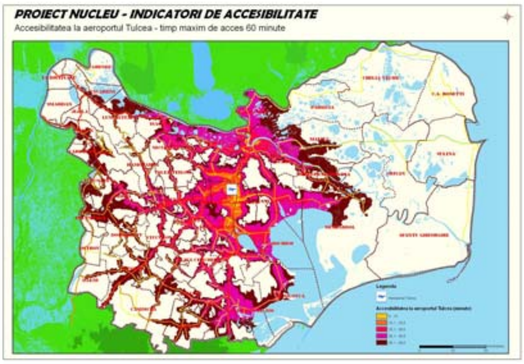

Fig. 13. Airport accessibility of Tulcea county, within 60 minutes of travel by car

4. Conclusions

The GIS systems have many capabilities, being also considered as tools that can measure transport accessibility. By monitoring the resulted indicators and identifying spatial disparities, solutions to support improvement of territorial development can be found. This is a method of estimating geographical accessibility to the main transport ways within a territory. Using this GIS method, the minimum travel cost was used to determine the population accessibility in a county (NUTS III level) to the county seat, to first class roads, to railway stations, to major ports and to the closest airport. The travel cost was calculated on the basis of the slope of travel area, using the digital terrain model. This analysis was applied to the whole territory of Tulcea county. Regarding the accessibility of population living in Tulcea county to the county seat (Tulcea city), the obtained data show that almost 19% of population need more than 60 minutes by car to attain the capital city, 57% need less than 30 minutes and 24% need between 30 and 60 minutes. Comparing to other counties belonging to the South-East region was observed that only population in Galati county has such a poor accessibility, here 24% needing more than 60 minutes to arrive the capital city by car (12.3% the regional average value).

In conclusion, using the GIS model proposed in this paper, accessibility of population to all transport ways can be determined (land, water and air). The resulted cartograms together with their attached data represent for decision factors a basis to process spatial analyses associated to the transport infrastructure from a region/county/area. The model can locate spatial disparities, determining what causes them and exploring alternative territorial development scenarios.

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