THE ROAD CONNECTIVITY INDEX APPLIED TO THE SETTLEMENTS OF BANAT USING GIS

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ABSTRACT – Based on previous works on the connectivity index applied to the settlements of Banat (Rusu, 2007; Rusu, 2008), the paper assesses the road connectivity index for the same settlements using a slightly different approach, based on the road distance from every settlement to the nearest central places, ranked on nine levels. Therefore, it is not the position on a certain road that counts, but the means by which specific groups of people (either urban or rural communities) might access a set of services or facilities deemed socially necessary and located in the above-mentioned central places. The welfare of the communities depends mainly on the standards of connectivity and accessibility to such services or facilities. We considered that the most valid measure of connectivity would then be the assessment of the space (distance) needed to be crossed for the population of every settlement to reach specific destinations. The overall values for each settlement have been interpolated using GIS in order to produce a map of the road connectivity index in Banat. The map clearly shows the existing disparities between well-connected regions, especially around the main cities, and isolated areas, usually in the mountains, the hills or along the borders.

Keywords: road connectivity index, settlements, Banat, accessibility, isolation, GIS

INTRODUCTION

In geographical space organization, an important part is played by the lines of communication and transport. They create large and complex networks, covering the territory in all directions. However, only some of these communication lines are really "power lines" of the territory, as they represent polarising axes for the neighbouring space. The settlements located along them have obvious benefits and, in many cases, their social and economic development is strongly connected to their access to a main line of communication and transport. Eventually, many of these settlements reach the status of "central place" (Christaller, 1933) due to the functions generated by historical and geographical factors. One of such factors is often the location on a main transport axis or, even better, at the intersection of such axes. On the contrary, the settlements located at distance from these "power lines" are disadvantaged and the larger the distance, the higher their isolation. Connectivity may therefore be defined as the degree in which a settlement is connected to the transport network.

However, accessibility to the main roads is just one aspect to be taken into account. In fact, the role of the communication lines is to give access to higher-grade central places, like towns or cities, which provide goods or services that one cannot find at home. Centrality is therefore crucial for the understanding of accessibility. Centres, ranked according to certain criteria, are usually convergent nodes in the transport network, as most settlements around them organize their transport infrastructure

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in such a way as to reach the centres in the minimum time possible. Accessibility is then the degree in which one can get to a certain place in space.

The approach would be to consider the position of specific groups of people in specific locations (either rural or urban communities) and postulate the means by which they might access a set of services or facilities deemed socially necessary. The welfare of the communities depends largely on standards of connectivity and accessibility to such services or facilities. The most valid measure would be the assessment of the space (distance) and time budgets needed for the population of every settlement to reach specific destinations (Nutley, 1980).

METHODOLOGY FOR ASSESSING CONNECTIVITY

In the Romanian geographical literature, different manners of assessing the connectivity or isolation of settlements have been used recently. Mureșan (2008) presented an isolation index for the settlements located in the contact area between the Apuseni Mountains and the Transylvanian Plateau, taking into consideration criteria like distance from the main roads or railways, but also demographic factors (natural growth, demographic ageing, weight of people employed in services) that are rather effects of isolation. On the other hand, Oprea (2011) calculated a coefficient of accessibility of the territorial units in the Transylvanian Basin based solely on the distance from the main roads. Máthé (2011) used the GIS technology in assessing the accessibility of the settlements in the Centre Development Region of Romania reaching inconclusive results. On the contrary, Muntele et al. (2010) made proper use of the concepts of accessibility, centrality and connectivity, but applied them only for assessing the quality of transport infrastructure in the Moldavian rural space.

All these works make reference to more or less recent foreign geographical literature (Haggett and Chorley, 1969; Taaffe and Gauthier, 1973; Weibull, 1976; Chorley and Haggett, 1976; Weibull, 1980; White and Senior, 1983; Spiekermann and Wegener, 1996; Cairncross, 1997; Schürmann, Spiekermann and Wegener, 1997; Miller, 1999; Spiekermann and Neubauer, 2002; Lumsdon and Page, 2004; Duval, 2007; Olsson, 2009; Rodrigue et al., 2009, to point out only some of the references), but made little or no reference to each other or to other relevant Romanian works on the topic of connectivity, accessibility, or isolation.

The methodology used in this analysis is largely based on our previous works (Rusu, 2007; Rusu, 2008) on the same subject. Nevertheless, while then a general connectivity index was sought for, this paper focuses solely on the road connectivity index, using a slightly different approach and GIS techniques.

Thus, in a previous work (Rusu, 2007), *the connectivity index* was conceived as consisting of two subordinate indexes: *the road connectivity index (ROADCI)* and *the railway connectivity index (RAILCI)*. So:

CI = ROADCI + RAILCI

In the same work (Rusu, 2007), in order to compute the road connectivity index, the following aspects were taken into consideration: the total number of classified roads passing through or near the settlement, the traffic on that road, and the distance (on the road) to the upper ranked central places (cities, towns and commune centres). Therefore, according to this statement, the road connectivity index (ROADCI) of a settlement depends on the rank and quality of its roads (RQ), the average annual traffic on each road (RT) and the distance to the nearest central places (RD):

ROADCI = RQ + RT + RD

Special attention was given to the first indicator, the rank and quality of the roads (RQ) and points were given to settlements according to their position on or near classified public roads (Rusu, 2007; Rusu, 2008). However, data regarding traffic (RT) were outdated and did not cover all classified roads, while the distance to the nearest central places (RD) was more difficult to compute.

In this paper, the focus was on the road connectivity solely and we relied only on the last element of the above-mentioned formula, the distance to the nearest central places (RD). We considered that the rank of the road does not necessarily indicate the quality of that road while traffic data are available only for certain roads and only once in five years (when traffic censuses are conducted) if their results are made public.

Therefore, in order to assess the connectivity of settlements in Banat, we have first taken into consideration all classified roads within the territory of the analyzed region, and all the settlements. Distances by road were calculated (using GIS) from each settlement to the nearest central place of every rank (except for rank 3, where distance to the county seat was compulsorily considered). For this, a preliminary study was needed to determine the ranks of the settlements within the analyzed territory, and even in the neighbouring areas. We relied our assessment on such a hierarchy, based on a previous analysis (Rusu, 2007), which classified the settlements into 12 ranks or levels, starting from the national capital city, Bucharest (rank 0) down to the most underdeveloped villages or hamlets, with almost no inhabitants and no elementary services (rank 11). However, for the purpose of this study, we have only taken into account the first nine levels (rank 0 to rank 8, commune centre), considering that smaller villages (ranked 9 to 11) are irrelevant as central places (Table 1). Central places belonging to any rank are also included as central places for all the ranks below. For instance, Timișoara, ranked 1, is also considered as ranked 2, 3… down to the lowest rank, as it provides not only high services, specific for regional centres, but also basic goods, available in any low-grade settlement.

Table 1. *Ranking of central places considered for Banat*

Rank	Short description	Cities, towns and commune centres in Banat	Cities and towns outside Banat
0	National capital city		Bucharest
1	Regional centre	Timișoara	Cluj-Napoca, Craiova
2	Sub-regional centre	Arad	Oradea, Sibiu
3	County seat	Reșița	Deva, Drobeta Turnu Severin, Târgu Jiu
4	Important middle-sized city	Lugoj, Caransebeș	Hunedoara, Petroșani
5	Small city or town with large area of influence	Lipova, Ineu, Sebiş, Chișineu Criș, Sânnicolau Mare, Deta, Făget, Oravița, Moldova Nouă, Bocșa, Oțelu Roșu	Salonta, Ștei, Brad, Hațeg, Orșova
6	Small town with minor area of influence or urban-like commune centre	Pecica, Nădlac, Sântana, Curtici, Pâncota, Gurahonț, Recaș, Gătaia, Ciacova, Jimbolia, Buziaș, Băile Herculane, Bozovici, Anina	Vașcău, Uricani, Baia de Aramă
7	High-grade commune centre	Vinga, Vladimirescu, Şiria, Săvârșin, Beliu, Cermei, Ghioroc, Șimand, Vârfurile, Hălmagiu, Biled, Orțișoara, Giroc, Jebel, Cărpiniș, Lovrin, Nădrag, Peciu Nou, Periam, Dudeștii Vechi, Mehadia, Berzasca, Topleț, Carașova, Teregova	Ilia, Baia de Criș
8	Commune centre	All the other commune centres	

The values of distance were then aggregated for every settlement into a connectivity index using the following formula (Rusu, 2008):

RD = (3 – Dr0/150) + (3 – Dr1/75) + (3 – Dr2/40) + (3 – Dr3/20) + (3 – Dr4/12) + (3 – Dr5/8) + (3 – Dr6/5) + (3 – Dr7/3) + (3 – Dr8/2),

Where

RD – road distance-based connectivity index;
Dr0 – distance from the settlement ranked 0;
Dr1 – distance from the settlement ranked 1…
Dr8 – distance from the settlement ranked 8.

The maximal value for each component of the formula is 3 at zero distance, meaning that the settlement belongs to a rank above or equal to the one considered. Therefore, the formula takes into account a highest possible value of 27 in the case of the capital city of Bucharest. All the other settlements nation-wide have smaller values of the connectivity index. Although most settlements have positive scores, values may be negative for each component and overall. Negative values are obtained for settlements located at more than 450 kilometres of the capital city (rank 0), more than 225 km from settlements ranked 1, more than 120 km from settlements ranked 2, more than 60 km from the settlements ranked 3, more than 36 km from the settlements ranked 4, more than 24 km from the settlements ranked 5, more than 15 km from the settlements ranked 6, more than 9 kilometres from the settlements ranked 7, and more than 6 kilometres from the settlements ranked 8 (commune centres) (Table 2).

As distances were calculated from every settlement using classified roads, one may face the issue that not all the settlements are actually located on roads, or at least the point representing the settlement is not on any road. Therefore, a range of 4 kilometres to the nearest road has been taken into consideration for Banat settlements, as 32 villages are not reached by any public classified road (Rusu, 2007). The range may of course vary according to the analyzed region.

To calculate distances a networks dataset was generated using ArcGIS Network Analyst Extension. This dataset included all the roads categorized by types and all the nodes (access points to the network). Based on these the shortest route from each locality to the nearest attraction point was calculated. The final step was to calculate the RD index. The RD value for each settlement was used as input point in interpolation process using ArcGIS Spatial Analyst resulting a raster dataset representing the spatial variability of RD.

Table 2. *Distances considered for a score of zero in every component of the formula*

Rank	**Distance (in km)**
0	450
1	225
2	120
3	60
4	36
5	24
6	15
7	9
8	6

Obviously, the highest the rank, the better classified the settlement, as 3 points are given for all the components equal or below the rank of the settlement. The overall values for each settlement have been interpolated to produce a map of the road connectivity index in Banat (Figure 1).

RESULTS

Banat is a region located in South-Western Romania, near the border with Hungary and Serbia. It comprises three counties, Arad, Timiş and Caraş-Severin, and there are 917 settlements, grouped in 5 cities, 23 towns and 225 communes. Only a small part of Arad County is historically part of Banat region, but for statistical and geographical reasons (Rusu, 2007), the whole county was included in the analysis. Similarly, a few administrative units of Mehedinți County were historically part of Banat but they are not analyzed in this paper for the same reasons.

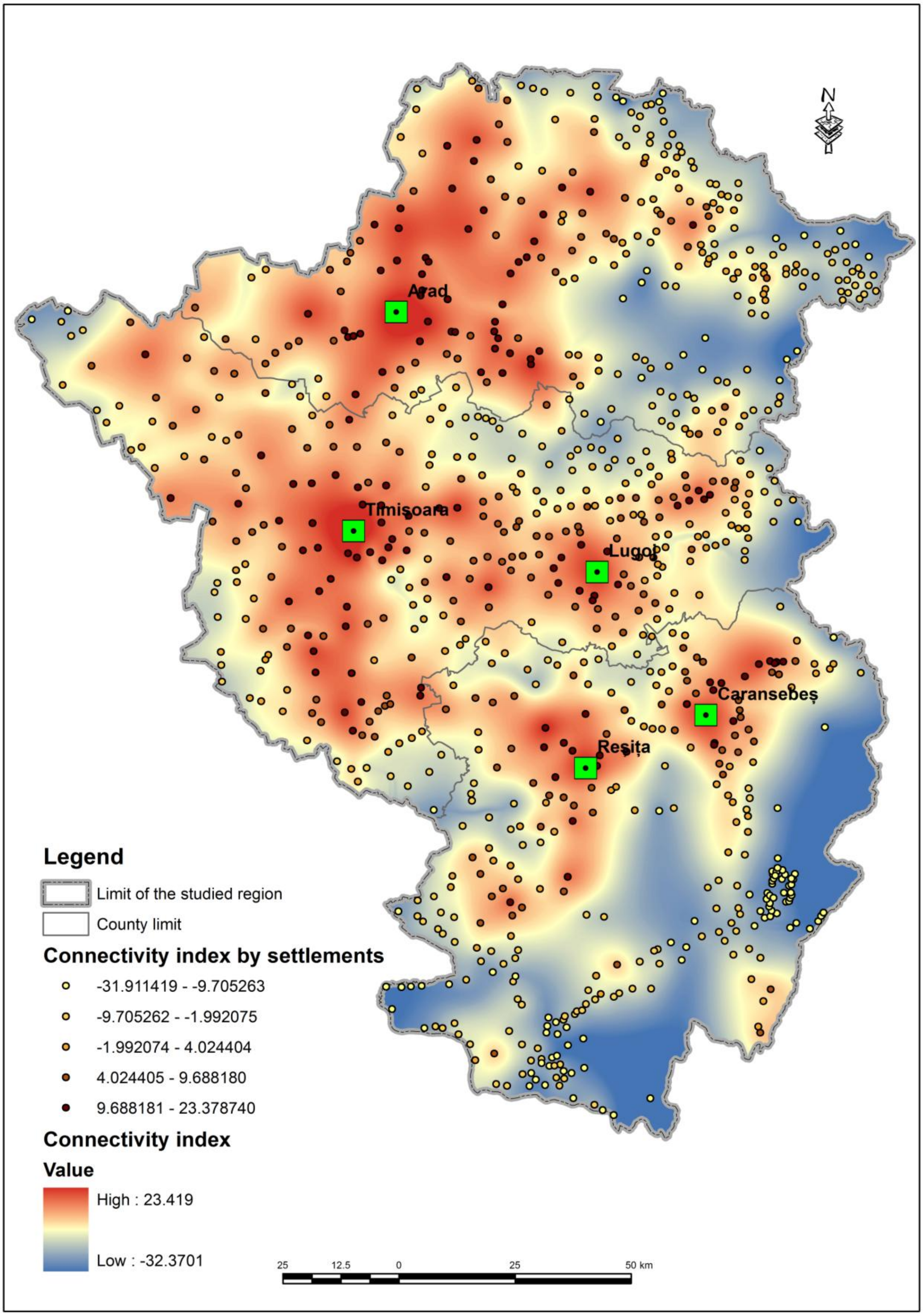

Figure 1. *The road connectivity index in Banat*

The overall score of the road connectivity index for the 917 settlements varies between 23.38 (Timișoara, also the largest urban centre) and – 31.91 (Bigăr). More than half of the settlements (523, or 57%) have positive values of the connectivity index, while the other 394 have negative values and cope with different degrees of isolation. However, most settlements (683, almost 75%) have rather average scores, between 10 and – 10. This provides us the opportunity to concentrate on the areas with the highest (more than 10) and lowest (below – 10) values of the road connectivity index.

Timișoara (23.88), Arad (22.69) and Reșița (20.10) dominate the classification, as they are also the main urban centres of the region. Large areas with positive values of the road connectivity index surround these cities. In Arad County, the area with best connectivity lies between the city of Arad and Chișineu-Criș (to the North), Pecica (to the West) and Lipova (to the East). To the South, it is connected to the area centered on Timișoara, which also extends a great deal to the East (to Lugoj and even farther) and to the South (to Deta and Gătaia).

In Caraș-Severin County, large areas with high values are situated around Reșița and Caransebeș. High values are also characteristic for towns like Sânnicolau Mare, Ineu, Sebiș, Oravița, Anina, Buziaș, Jimbolia, not too far away from the main cities. It is also noticeable that rural settlements closest to the main cities have a road connectivity index higher than a number of urban centres. Such is the case of Giroc, Chișoda, Dumbrăvița, Ghiroda (all very close to Timișoara), Vladimirescu, Livada (near Arad) or Țerova (near Reșița), that act mainly as dormitory villages.

The lowest values correspond to the least accessible areas, usually in the mountains, where road connections are weak. Therefore, the lowest score was registered for Bigăr, an isolated village in the Almăj Mountains. Similarly low values are recorded for settlements in the Metaliferi, Cerna, Țarcu and Codru Moma Mountains, as well as in the Lipova Hills, the eastern Zărand Mountains, the Almăj Basin. It is interesting to note that low values also characterize the settlements situated along the borders, like those along the Danube or the Nera. Even lowland settlements such as Iam, Lățunaș, Grănicerii, Beba Veche (the westernmost village in Romania) and their surroundings, located near the border with Serbia, have a low road connectivity. This is due to the poor infrastructure close to the borders, on the one hand, and the large distances to the main cities, on the other hand. In these cases, the political factor (the border) acts as a restriction, not the morphology, as it is the case of the mountains.

CONCLUSIONS

Based on previous works on the connectivity index applied to the settlements of Banat (Rusu, 2007; Rusu, 2008), the paper assesses only the road connectivity index for the same settlements using a slightly different approach, based on the road distance from every settlement to the nearest central places, ranked on nine levels. Therefore, it is not the position on a certain road that counts, but the means by which specific groups of people (either urban or rural communities) might access a set of services or facilities deemed socially necessary and located in the above-mentioned central places. The welfare of the communities depends mainly on the standards of connectivity and accessibility to such services or facilities. We considered that the most valid measure of connectivity would then be the assessment of the space (distance) needed to be crossed for the population of every settlement to reach specific destinations.

The overall values for each settlement have been interpolated using GIS in order to produce a map of the road connectivity index in Banat. The map clearly shows the existing disparities between well-connected regions, especially around the main cities, and isolated areas, usually in the mountains, the hills or along the borders.

The road connectivity index may represent a useful tool in the planning and management of infrastructure projects, in regional and local planning, as well as in development strategies meant to reduce territorial disparities.

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