SPATIAL IMPACT OF THE ROAD INFRASTRUCTURE DEVELOPMENT IN ROMANIA. AN ACCESSIBILITY APPROACH

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ABSTRACT – This paper compares the spatial structure of accessibility in Romania before and after the implementation of some major national and/or European road infrastructure projects. This study suggests a new index for accessibility measurement by combining gravity-based models with Place Rank and adapting it to the Romanian system of settlements. Based on the GIS estimation of travel time, this index evaluates not only the geographical position of a specific community relative to the road network, but also the level of accessibility of rural and urban communities to the social services located in central places. The GIS-based maps indicate the existing disparities (between well-connected and isolated regions in terms of accessibility to the central places) and the impact of new infrastructure projects on these disparities. The resulting maps can be used as efficient tools for transport planning and development at different scales (international, national, regional and local).

Keywords: network analysis, accessibility, road infrastructure development, central place, Romania

INTRODUCTION

In the recent years, Romania, like many other EU countries, is in the process of rapid transport infrastructure development. The Romanian Government by the Ministry of Transport is planning to finalize around 3,000 km of motorways and expressways by 2025. Financed mainly by EU funds (TEN-T Core and TEN-T Comprehensive FEDER), state budget and public-private partnership (PPP) arrangements, the development of transport infrastructure will modify the existing spatial accessibility at the national and regional level.

The priority axes for EU Investments in the infrastructure development in Romania are the following: Modernization and development of TEN-T priority axes aiming at sustainable transport system integrated with EU transport networks; Modernization and development of the national transport infrastructure outside the TEN-T priority axes aiming at sustainable national transport system; Modernization of transport sector aiming at higher degree of environmental protection, human health and passenger safety and Technical Assistance (European Commission, 2013).

The advantage of economic competitiveness offered by a higher accessibility index is already visible in the Romania's economic system (Ionescu-Heroiu et al., 2013). For this reason, the spatial

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distribution of accessibility improvement represents a concern in order to prevent the deepening of local and regional disparities and the uneven development of the communities.

The main objective of the present study is to analyze the accessibility implications of the road infrastructure development by applying the time-based connectivity index to three levels: assessing the existing conditions, TEN-T infrastructure development and road development according to the National Master Plan (Romanian Parliament, Law 363 of 2006).

This paper is structured as follows. Section 2 summarizes different methods to estimate accessibility. The study area is briefly described in Section 3, while methodological aspects used in this study are presented in Section 4. Section 5 presents the results and discussions on the accessibility analysis. Lastly, the conclusions are summarized in Section 6.

MEASURING ACCESSIBILITY

Definitions

The social, environmental and economic impact of accessibility has been a longstanding preoccupation of the regional planners and transportation researchers. The concept of accessibility is frequently used in transportation studies being a direct expression of mobility (Rodrigue, 2013), even if there is no general consensus about its definition (Handy and Niemeier, 1997; Vandenbulcke et al., 2009; Paez et al., 2012).

Accessibility is commonly defined as the measure of the capacity of a location to reach different locations (Rodrigue, 2013) or the ease of some specific activities (opportunities) to be reached using a transportation system from a specific location (Vandenbulcke et al., 2009; Johnston et al., 2000). These approaches rely on two key concepts to define accessibility: location and system of transport (Handy and Niemeier, 1997) which involves network connectivity as the basic measure of accessibility (Rusu, 2008; Rodrigue et al., 2009; Rodrigue, 2013). The commonly used elements by the planners to assess accessibility are land-use, transportation, temporal and individual components (Geurs and Ritsema van Eck, 2001).

To characterize areas with low level of accessibility (mostly to economic activities) the term “peripherality” it is often used (Keeble et al., 1988; Vandenbulcke et al., 2009), however there are some regions with a high level of economic development in spite of low accessibility indices (Vandenbulcke et al., 2009).

Measurement of accessibility

Accessibility is a very complex concept, widely used in scientific research with a wide range of applications, difficult to quantify and there is no best method to approach it (Geurs and Ritsema van Eck, 2001; Vandenbulcke et al., 2009; Vega, 2012). According to the purpose of the study and the indicators used for spatial assessment of accessibility, different approaches generate different results (Handy and Niemeier, 1997).

In the scientific literature, accessibility measurements were classified into many categories. Handy and Niemeier (1997) used three categories: isochrones (based on travel time, travel distance and travel cost from origin to destination), gravity-based measures (correlation between accessibility and travel time to destination) and utility-based measures (economic benefits of a location derived from the ease of access to spatially distributed services). Geurs and Ritsema van Eck (2001) used four categories: infrastructure-based measures, activity-based measures, person-based measures and utility-based measures.

The review by Curtis and Scheurer (2010) attempted to consolidate the range of accessibility measures using seven categories: spatial separation methods (quantifies the distance between infrastructure elements), contour measures (uses travel time around a node and quantify the number of opportunities in that area), gravity measures (the actual travel time for each opportunity is identified using a generic distance decay function), competition measures (an additional social/economic dimension is added to accessibility measures), time-space measures (a predefined time interval is used to measure opportunities), utility-measures (quantifying the benefits to the society derived from accessibility to opportunities) and network-measures (based on the identification of topological network components: nodes and edges).

Handy and Niemeier (1997) identified four key-elements that must be considered before measuring accessibility: level of data disaggregation in spatial and socio-economic terms, origins and destinations, network impedance and the attractiveness of a destination. In this paper we consider a complex matrix of origins and destinations (according to the rank of each settlement) to estimate travel time. The network impedance is a result of road type and average travel speed on every segment of the network.

Recently, several manners of assessing connectivity and accessibility have been presented in different geographical papers. One may remark the work of Mureșan (2008), who calculated the isolation index for a number of settlements located at the contact between the Apuseni Mountains and the Transylvanian Basin. The author used criteria like distance from roads or railways, but also population elements (natural growth, demographic ageing, weight of people employed in services) whose values may be considered as effects of isolation. Muntele et al. (2010) used the concepts of accessibility, centrality and connectivity only to assess the quality of transport infrastructure in the rural areas of Moldavia. Oprea (2011) computed a coefficient of accessibility of the administrative units in the Transylvanian Basin based only on their distance from the main roads. Máthé (2011) made use of GIS in computing the accessibility of the settlements in the Centre Development Region of Romania, but his results were inconclusive.

STUDY AREA

This paper assesses road accessibility in Romania, a central-European country, EU member state since 2007, with more than 20 million inhabitants (21,768,788 on January 1st, 2012) dispersed on a total area of 238,390 km^2. Romania's administrative organization includes various types of administrative units (urban and rural communities): cities (103), towns (217) and communes (2861), comprising 12,957 villages.

Approximately 55% of the population lives in urban areas (cities and towns) (NIS, 2013). The largest Romanian city is Bucharest, the national capital, having about 1.9 million inhabitants.

The Romanian road network is formed by public roads having a total length of 84,185 kilometres (NIS, 2013) classified in four categories: European and National roads (20% of which 3%, that is 620 km, are motorways), county and commune roads (80%) (NIS, 2013). Based mainly on some older strategies (Figure1) (TEN-T infrastructure development and National Master Plan – Law 363 of 2006) a new strategy for road infrastructure development has been set up (Romanian Government, 2013).

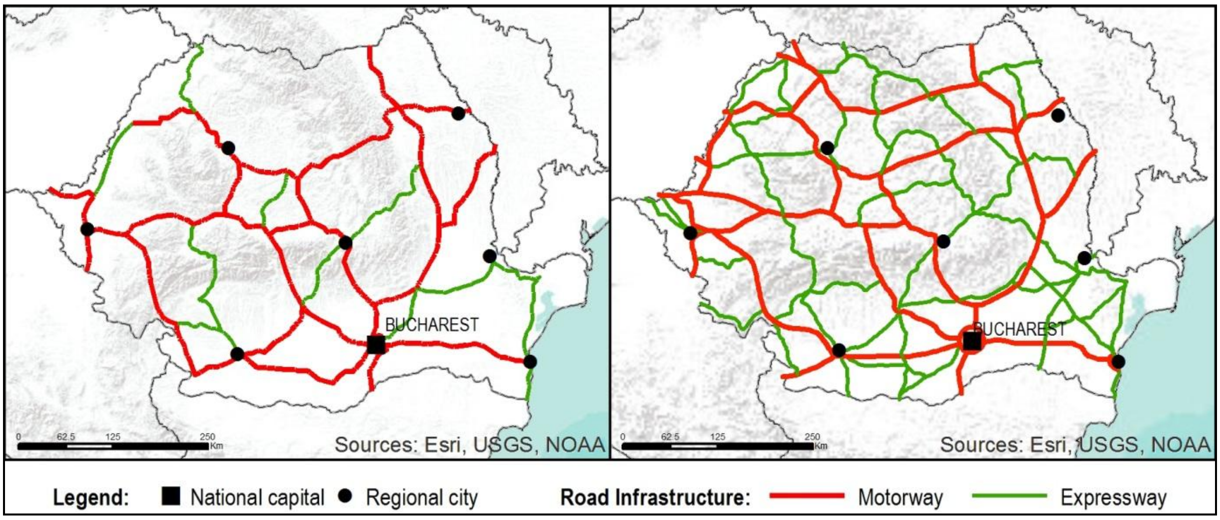

Figure 1. *Road infrastructure development scenarios: TEN-T (left), National Master Plan (right)*

The main objective of these strategic plans is the development of the road infrastructure in order to shorten the distance to large markets globally, to improve connections between competitive areas within Romania for the efficient concentration or resources and to improve connective infrastructure between cities and their surrounding areas to expand their economic mass (Ionescu-Heroiu et al., 2013).

METHODOLOGY

The main lines of communication have always played an important role in defining the axes of development. They form large and extensive networks, covering the territory, but only some of them achieve a certain degree of importance. Most of the times, towns and cities have emerged and developed along the main communication lines, especially at the junction of two or more such axes. Therefore, the polarizing and attraction force of these "power lines" of the territory has usually increased and is ever increasing due to the constant development related to urban growth, strongly linked to the access of such cities to a main transport line. As a result, many of the "central places" within a territory (Christaller, 1933) are usually those settlements that benefit from a good accessibility, apart from other urban functions generated by geographical and historical factors. On the other hand, settlements located away from the development axes are disadvantaged and their isolation increases with the distance and poorer accessibility.

In this paper, we considered accessibility by car along the road network (all existing classified roads and those proposed by scenarios) and calculate travel time from any Romanian settlement to the nearest central place of every rank. The fastest routes from origins (urban and rural communities) to destinations (central places) were modelled in a GIS environment using a topological network dataset of the existing infrastructure (a connected graph with 42,950 junctions and 53,695 arcs) and specific network-based GIS procedures. The existing network database was updated with the segments representing the new infrastructure in order to calculate the fastest routes after the implementation of the road development projects.

Before the assessment of the connectivity index, a preliminary study must be made in order to establish the ranks of the settlements within the analyzed territory and in the neighbouring areas. Therefore, our analysis relied on a ranking based on a previous assessment (Rusu, 2007), according to which settlements were classified into 12 levels, starting from the national capital (Bucharest, rank 0) to the most insignificant villages, with a very low number of inhabitants and no services whatsoever (rank 11). Nevertheless, having in view the objectives of this paper, only the first nine levels (rank 0 to rank 8, commune centre) have been taken into consideration because smaller settlements (ranked 9 to 11) can hardly be considered as central places (Rusu et al., 2013a; Rusu et al., 2013b). The central places of any level are comprised in the list of central places for all the lower levels.

Table 1. *Characteristics of the selected ranking system in the OD matrix*

Rank	Short description	Number of destinations	Coefficient considered for a score of zero (a_k)
0	National capital city	1	150
1	Regional centre	8	75
2	Sub-regional centre	17	40
3	County seat	42	20
4	Important middle-sized city	82	12
5	Small city or town with large area of influence	190	8
6	Small town with minor area of influence or urban-like commune centre	325	5
7	High rank commune centre	678	3
8	Commune centre	3178	2

To assess travel time in origin-destination matrix, each road segment in the network is characterized by a length and an average travel speed (according to the type of road, road quality, weather conditions, traffic density). In the present study, we considered the following speed: motorway – 110 km/h, national road – 70 km/h, county road – 50 km/h, commune road – 30 km/h.

The values of travel were then aggregated for every settlement into an accessibility index using the formula (Rusu et al., 2013):

$$A = \sum_{k=0}^{n}(3 - (Tr_k / a_k))$$

where: A = accessibility index
k = rank of the settlement
Tr_k= travel time to the nearest settlement ranked k
a_k = coefficient considered for a score of zero (Table 1)

The maximal value for each component of the formula is 3 at zero travel time, 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 accessibility index. Although most settlements have positive scores, values may be negative for each component and overall.

For instance, all settlements from where one can get by car to the national capital in less than 450 minutes (7 hours and a half) will have a positive score for that component. This is the case for most settlements in Romania. The coefficient value of 150 has been chosen in order to set this threshold of 450 minutes for a score of zero. The same is true for the following coefficients. The coefficient value of 75 in the case of regional centres will allow a threshold of 225 minutes (half the time needed to get to the national capital) for a score of zero in this component of the formula. Those settlements located within the 225-minute isochrone from regional centres will have a positive score. For lower ranks, coefficients were gradually lowered, so that for the lowest considered rank (commune centre), a coefficient value of 2 would mean that people should be able to reach their commune centre in less than 6 minutes for their settlement to have a positive score in this component. Although the coefficient values seem to be large enough to allow many settlements to have positive scores, negative scores are recorded for villages located far from urban centres and their commune centre.

The accessibility value of each settlement was used as input point in interpolation process using ArcGIS Spatial Analyst. The result is a raster dataset representing the spatial variability of accessibility. This dataset was used to extract the average value of accessibility for each territorial administrative unit.

RESULTS AND DISCUSSIONS

This study is based on the assumption that people will take the fastest route (or shortest in terms of time) to travel to the nearest central place. A central place is considered a settlement offering multiple opportunities according to its rank (Rusu, 2007).

Even if we computed the travel time from all settlements to the nearest central place (see Section 4), to illustrate the implications of the new road infrastructure projects on accessibility, we selected only the GIS maps showing the travel time to the national capital and regional centres (Table 1).

Travel time to the closest regional city

The national capital (Bucharest) and the regional centres (Brașov, Cluj-Napoca, Constanța, Craiova, Galați, Iași, and Timișoara) are the most important cities of Romania. The administrative, educational, social and economic functions of these large cities are the main factors for their inclusion as central places, as these functions generate most of the convergent flows towards the urban areas.

Figure 2 shows the present structure of the travel time. The existing road infrastructure generates spatial disparities in terms of accessibility, approximately 60% of the population living in remote areas (administrative units whose travel time to the closest central place exceeds 60 minutes). The population concentrated in highly accessible areas (less than 30 minutes to the central place) is less than 25% (Table 1).

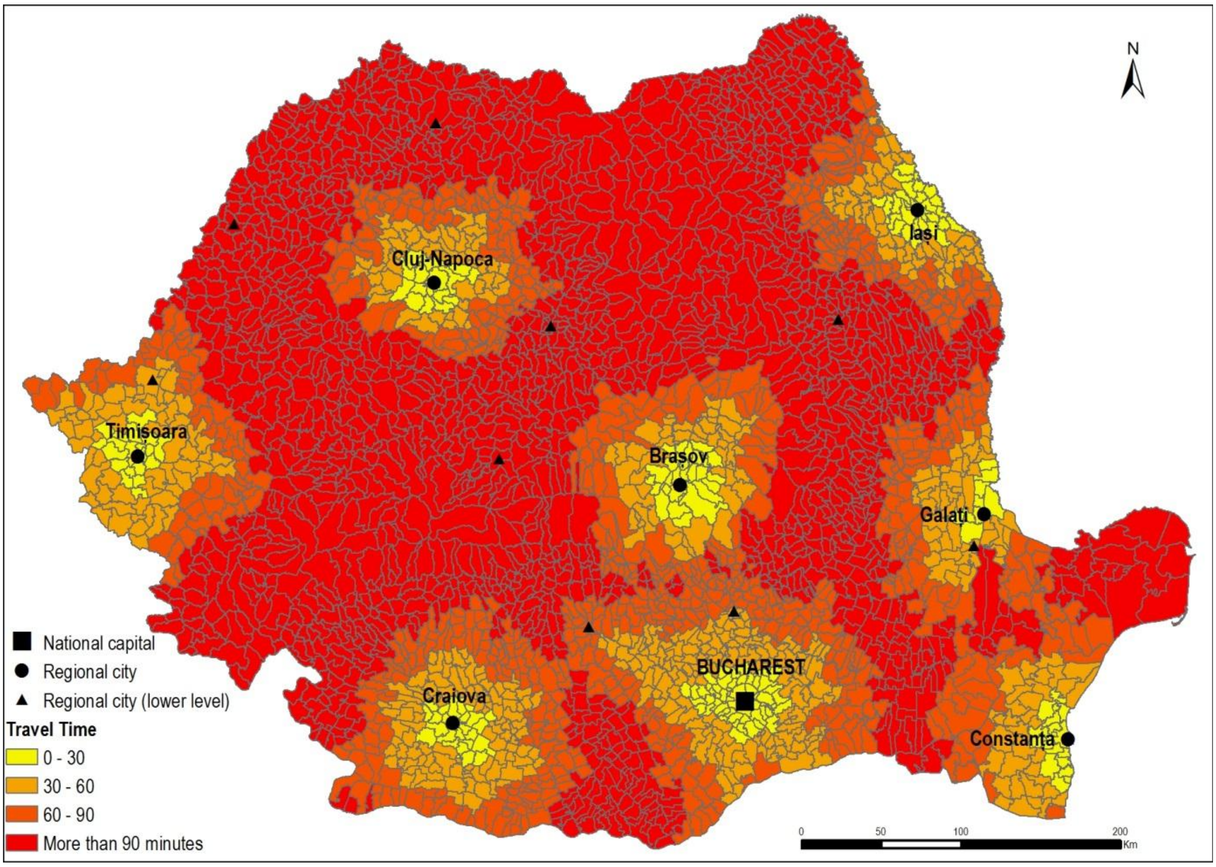

Figure 2. *Travel time (by car) to the closest regional city (rank 1)*

The spatial structure of the regional cities generates disparities especially in the Northern, North-Western, and Western parts of the country where there are a large number of urban and rural communities whose inhabitants have to travel more than 90 minutes to reach the opportunities from Cluj-Napoca, Timișoara, Iași or Brașov. The South-Eastern part of Romania has better values of accessibility, being strongly influenced by the presence of the capital city (Bucharest), but also due to the spatial distribution of regional cities in this area. Even so, some clusters of territorial administrative units with low accessibility (travel time to closest regional city exceeds 90 minutes) can be identified in the southern part of the country (between Bucharest and Craiova, Bucharest-Galați-Constanța, and north of Constanța, in the Danube Delta).

Table 2. *Travel time to the closest regional city*

Travel time (minutes)	Existing road infrastructure				National Master Plan projects				TEN-T projects			
	Population		Administrative units		Population		Administrative units		Population		Administrative units	
	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
0-30	5222687	24	180	6	6200315	29	251	8	5757183	26	274	9
30-60	3434715	16	527	17	4834727	22	896	28	5776192	26	916	28.298
60-90	3612525	17	757	24	7066330	33	1251	39	6185188	28	1160	37

If the road infrastructure will be finalized according to the TEN-T projects, then the present values of the travel time will radically change (Figure 3) and the remote areas will concentrate less than 50% of the population (mostly mountainous rural areas). The 90-minute isochrones will group more than 80% of the population. According to these projects, the interconnection between regional centres will be improved. In southern Romania, almost all settlements would be less than 90 minutes from a regional centre or the national capital. Areas with low accessibility would remain mostly in the Eastern Carpathians, Southern Carpathians, the Apuseni Mountains, the Banat Mountains and the Danube Delta.

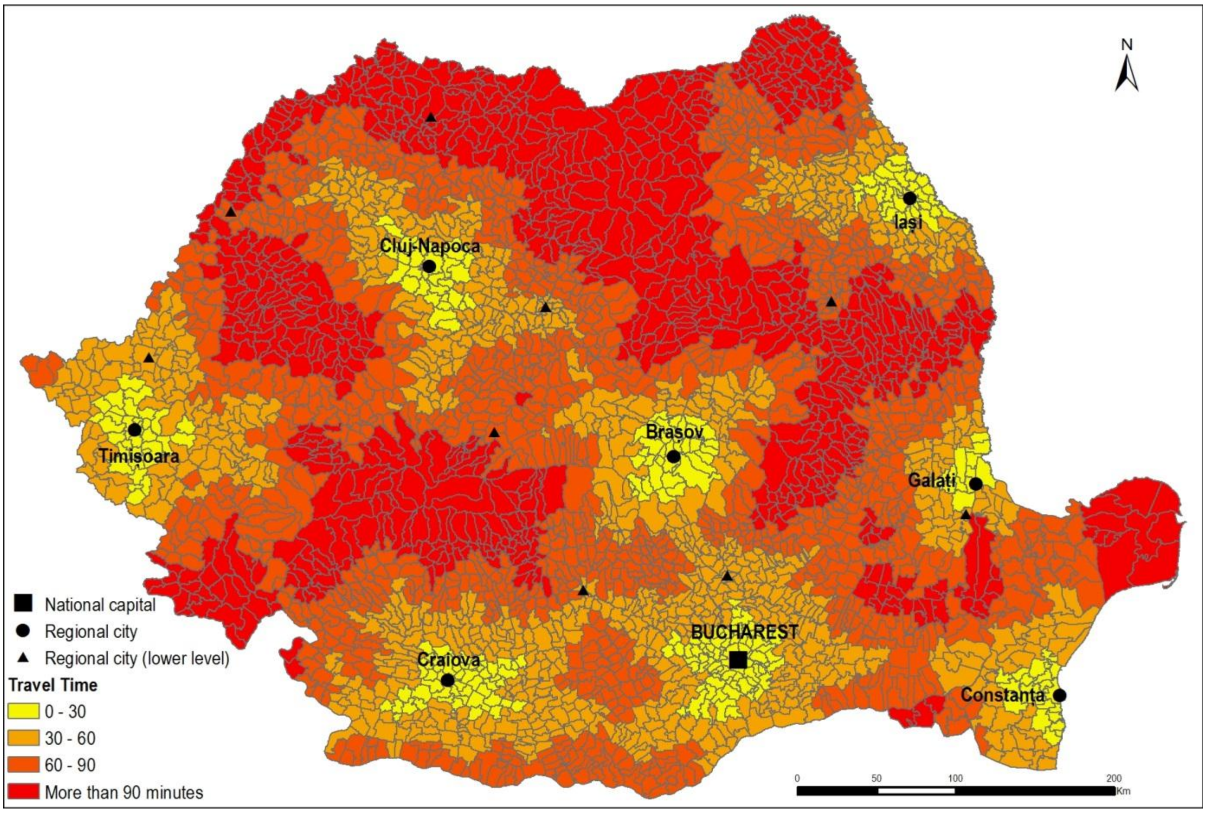

Figure 3. *Travel time (by car) to the closest regional city (rank 1) if roads are upgraded and motorways are built according to the TEN-T network*

The National Master Plan suggests a slightly different road infrastructure development. This will provide a better travel time (Figure 4) to a smaller number of inhabitants than TEN-T projects (approximately 75%), but to a higher number of administrative units, reducing spatial disparities across Romania. Another objective of this strategy (Romanian Government, 2013) is to increase accessibility to and from the 15 largest cities of Romania until 2018 (Figure 4). Areas with low accessibility would remain only along the northern border, in some parts of the Carpathians and in the Danube Delta. In the Danube Delta, increased accessibility is not necessarily a purpose, taking into consideration the need for preserving the natural assets of this biosphere reserve.

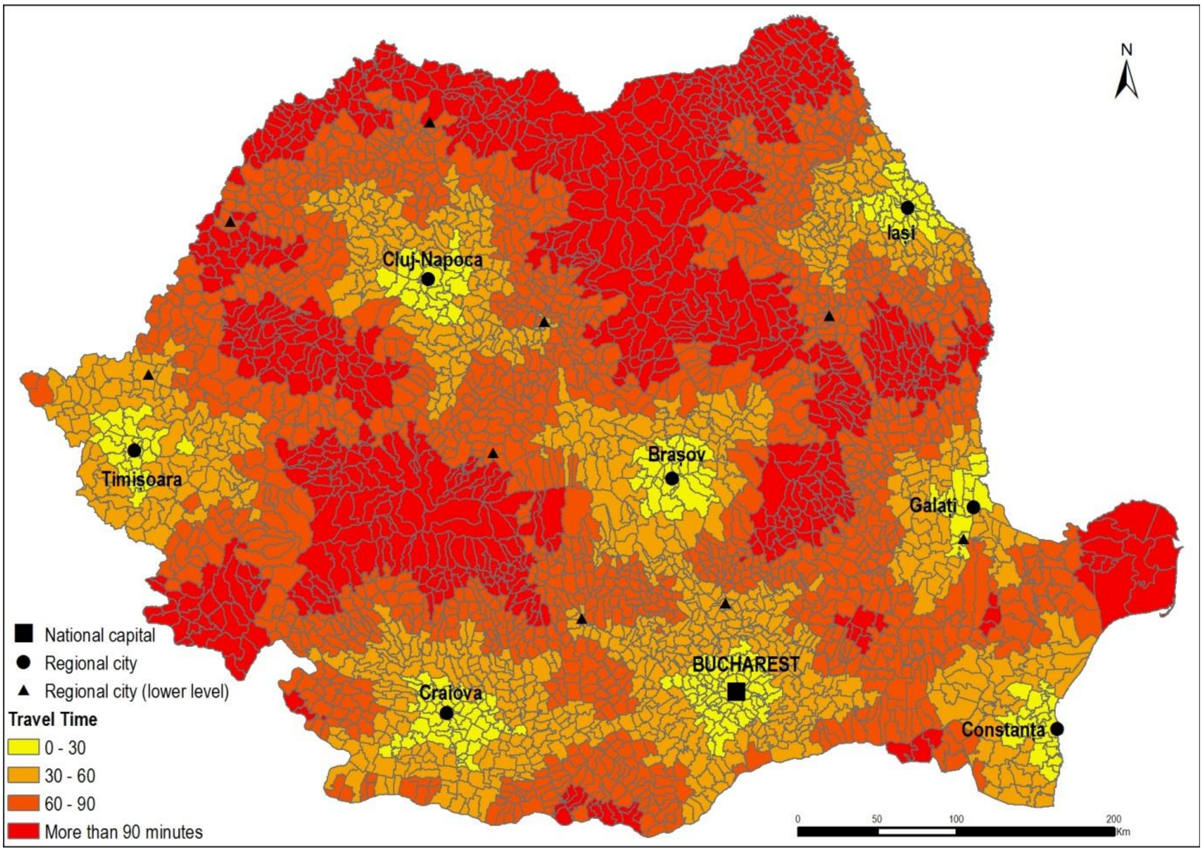

Figure 4. *Travel time (by car) to the closest regional city (rank 1) if roads are upgraded and motorways are built according to the National Master Plan*

Comparisons of time-based accessibility in Romania

Using the above-described methodology, the 3,178 Romania's territorial administrative units have been classified separately for existing road infrastructure (Figure 5), TEN-T projected infrastructure (Figure 6) and National Master Plan suggestions (Figure 7). Using GIS specific function, statistical data were extracted to Table 2.

While the maximum values are similar (constraint by the accessibility formula), notable changes are registered for the mean values of the accessibility index at the national level. As expected, the road infrastructure projects will increase the general accessibility index of the administrative units from 1.4 (current conditions) to 4.6 (TEN-T) and 5.3 (National Master Plan).

The lowest values correspond to the least accessible areas, but both scenarios will modify these values from -87.5 (actual minimum) to -37.6 (TEN-T) or -36.9 (National Master Plan).

The road infrastructure development will provide improved accessibility, the number of inhabitants located in administrative units with poor accessibility (with scores less than 0) being reduced from 16% to 9.8% (TEN-T) and 8.5% (National Master Plan). In addition, good and very good accessibility (scores higher than 0) will be ensured for a larger population from 84% to more than 90% (both scenarios) (see table 2).

At present, positive accessibility values are recorded in the areas surrounding the large cities and along the main national roads. Settlements located in the lowlands, like those in the south or in the west, usually have a good accessibility due to the higher density of the road network. Poor accessibility is characteristic for the mountain areas, but also for certain settlements in the Moldavian Plateau, the Transylvanian Plateau, Banat Hills, Dobrudja and the Danube Delta.

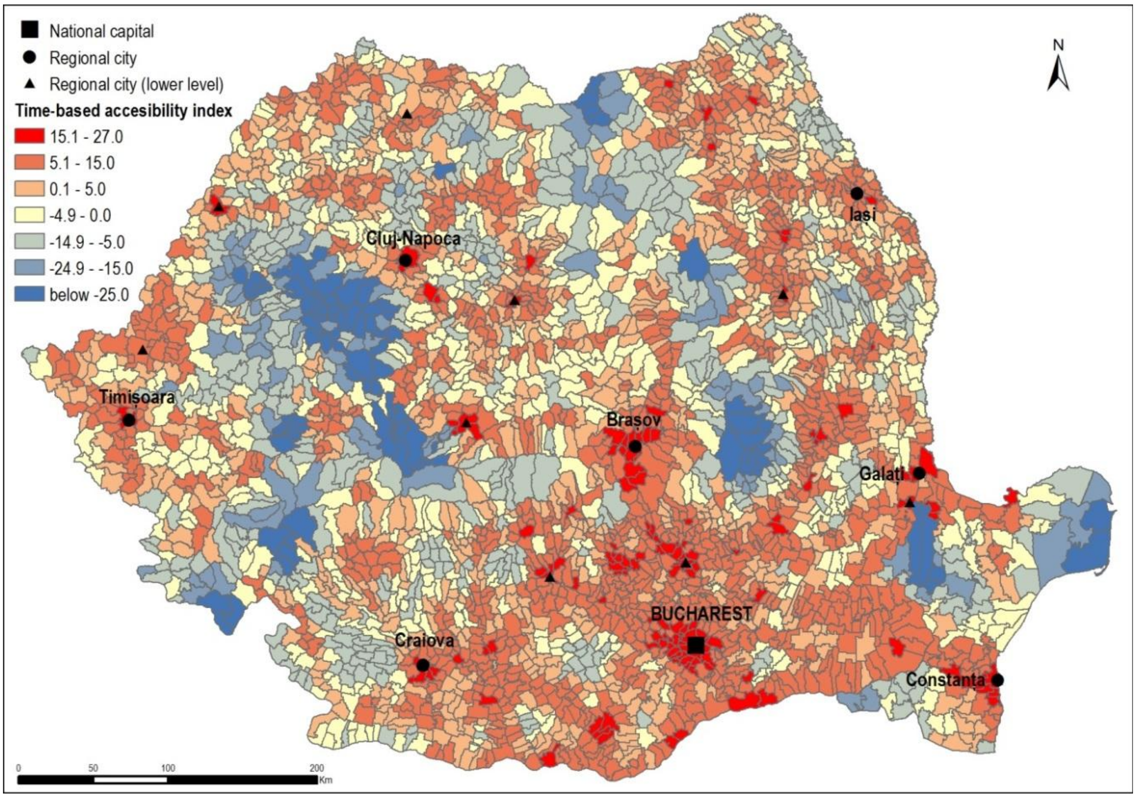

Figure 5. *Spatial variability of accessibility according to the existing road infrastructure*

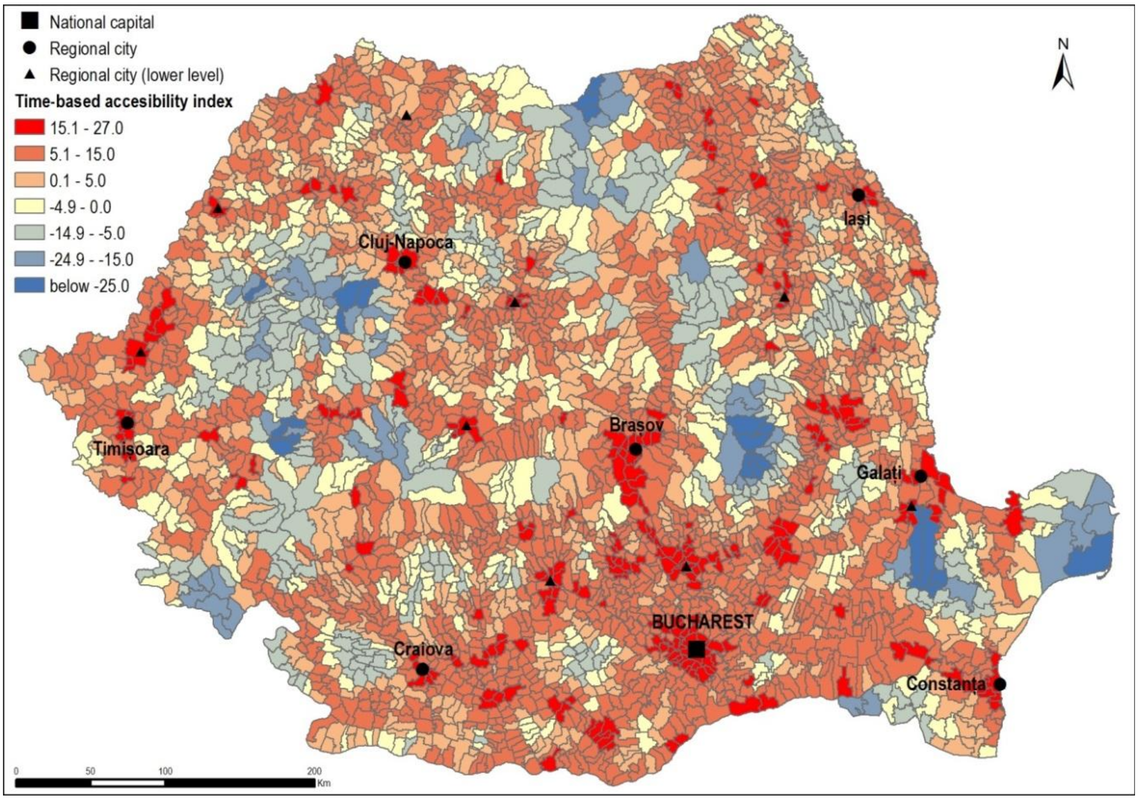

Figure 6. *Spatial variability of accessibility according to TEN-T projected road infrastructure*

Table 3. *Time-based accessibility statistics*

Accessibility Index	Existing road infrastructure				National Master Plan projects				TEN-T projects			
	Population		Administrative units		Population		Administrative units		Population		Administrative units	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
< -25	193015	0.9	81	2.5	45919	0.2	22	0.7	49970	0.2	24	0.8
-25 - -15	215799	1.0	87	2.7	112439	0.5	40	1.3	145861	0.7	54	1.7
-15 - -5	1272700	5.8	446	14.0	600422	2.8	241	7.6	789764	3.6	300	9.4
-5 - 0	1815287	8.3	549	17.3	1086450	5.0	370	11.6	1156673	5.3	393	12.4
0 - 5	3278825	15.1	790	24.9	2375974	10.9	689	21.7	2545714	11.7	716	22.5
5 - 15	7311127	33.6	1085	34.1	7523714	34.6	1556	49.0	7227574	33.2	1425	44.8
> 15	7682035	35.3	140	4.4	10023870	46.0	260	8.2	9853232	45.3	266	8.4

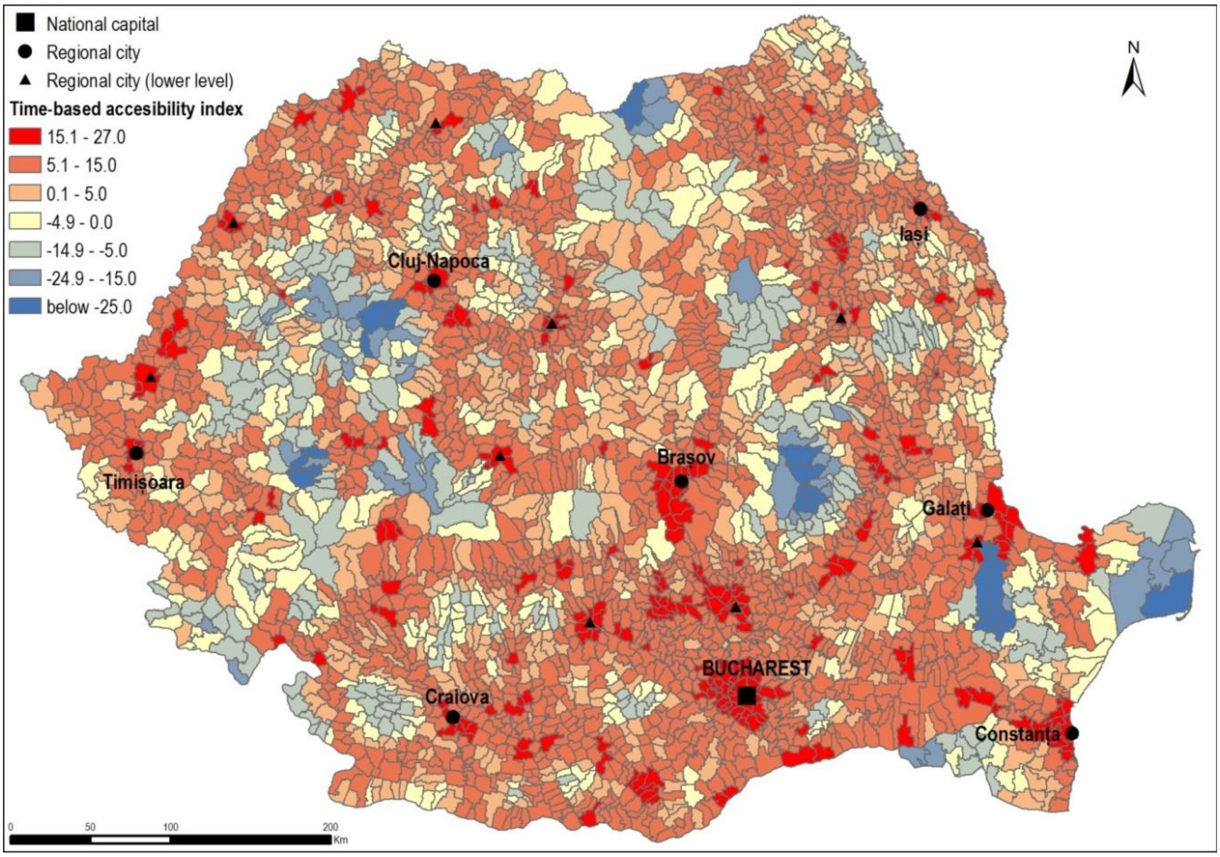

Figure 7. *Spatial variability of accessibility according to the National Master Plan road infrastructure projects*

If the roads are upgraded and motorways are built according to the TEN-T projected core and comprehensive network, a high number of settlements will benefit from increased accessibility in the West and North-West regions, as well as in the South-West, South and Centre regions, where the main infrastructure projects are to be implemented. Poor accessibility will be restricted to certain mountain areas, especially in the Apuseni Mountains, the Banat Mountains and the Eastern Carpathians, as well as in the Danube Delta and small parts of the Moldavian Plateau.

If the National Master Plan projects were implemented, almost all Romanian settlements would benefit from improved accessibility. The effects of these infrastructure projects would have a deeper impact on accessibility in Southern, Western and Central Romania.

SUMMARY AND CONCLUSION

In this study, we presented a short literature review of the main elements evaluated for assessing accessibility as a basis for a new approach. In order to calculate the accessibility index, this approach combines gravity-based models with place rank and is limited only to road transportation. Settlements with a function of central places (divided on nine ranks) are considered as destinations for our analysis. The data resulting by applying this index to more than 13,000 urban and rural communities were aggregated to the Romania's 3,178 territorial administrative units. The spatial variability of the accessibility index across Romania was evaluated using the existing road infrastructure and two scenarios for the development of road infrastructure. The empirical results clearly show that, far from being spatially uniform, the implementation of each road infrastructure project would definitely have a positive impact on accessibility. Areas with poor accessibility would remain in the mountains or in the Danube Delta, far from the main roads.

Allowing useful comparisons in terms of impact of the various scenarios implementation, the suggested accessibility 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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