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ASSESSING ACCESSIBILITY AND TRANSPORT INFRASTRUCTURE INEQUITIES IN ADMINISTRATIVE UNITS IN SERBIA'S DANUBE CORRIDOR BASED ON MULTI-CRITERIA ANALYSIS AND GIS MAPPING TOOLS

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Abstract

The Danube Regions, especially the sub-national units of governance, must be ready to play an active role in spatial development policies. A precondition for this is good accessibility and the coordinated development of all transport systems in the Danube corridor. The main contribution of this paper is to provide a multi-criteria model for potential decision making related to the evaluation of transportation accessibility in Serbia's Danube Corridor.

Geographic Information Systems (GIS), based on maps, indicate the existing counties' transport infrastructures inequities (between well-connected and isolated counties in terms of accessibility to central places). Through the research, relevant indicators have been identified. This provides an outline of transportation perspectives regarding the development achieved and also fosters the increase of transportation accessibility in some peripheral Serbian Danube administrative units – counties (Nomenclature of Territorial Units for Statistics level 3 – NUTS 3).

Keywords: accessibility, Danube Corridor, county, multi-criteria analysis, GIS, transportation.

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1. Introduction

The Danube is pivotal to the European transportation system, as this resource has been recognized by incorporating the river into the Pan-European Transport Networks as Corridor VII. The waterway was interrupted by a dramatic fall in the waterfront capacity used by upstream and downstream waterways (ÖIR, 2000; Donauregionen Plus, 2010; European Commission, 2010; ICPDR, 2014). The improvement of the transportation systems sets the center of the development strategies of the Danube Space countries, along with the Accession Countries. Therefore, the European Union (EU)-wide multi-modal Trans-European Transport Network (TEN-T) 'core network' defined by the new TEN-T guidelines of 2013 should be fully functional by 2030. The core network must ensure efficient multi-modal links between the EU capitals and other main cities, ports, airports, key land border crossings, as well as main economic centers and flows. The efforts should focus on the construction of missing links and on the upgrading of existing infrastructure. The length of the existing high-speed rail network should be tripled by 2030. In Serbia, nine administrative counties (Central Banat, South Banat, West Backa, South Backa, Srem, City of Belgrade, Danubian County, Branicevo and Bor County) are primarily very suitable geographically and as transport position in the Danube Corridor. A comparative analysis of these counties in the Danube's Corridor is pointing to different network levels of quality and accessibility among them (Vulevic, 2013).

Accessibility is the main 'product' of a transportation system as it determines the locational advantage of a region relative to all regions, including itself (Schürman, Spiekermann and Wegener, 1997). It is assumed that accessibility is continually changing and is monotonically distributed along a corridor, but it displays discontinuities between regions (Vickerman, Spiekermann and Wegener, 1999; ESPON, 2015). Some analyses show the relative peripherality of regions in relation to the capital city and should be taken into account and that the accessibility assessment is intrinsically dependent on the size of the country (ÖIR, 2000). The peripherality of certain regions is much higher in large countries. The analysis demonstrates clearly the change on accessibility from West to the East (ÖIR, 2000; ESPON, 2015). The same infrastructures may have polarizing effects if we move to a national level and investigate how disparities change within national boundaries (Gutiérrez and Urbano, 1996; Martín, Gutiérrez and Concepcion, 2004). The same problems are faced if the scale is changed to the corridor level (Gutiérrez, Condeço-Melhorado and Martín, 2010).

The paper aims to highlight the choice and the description of accessibility indicators; statistical methods, among other methods, are applied based on the model in the Regional Classification of Europe (ESPON). Throughout the paper, we show a combined accessibility analysis based on six criteria and a proposed multi-criteria decision analysis method (TOPSIS) as a support tool for evaluation, which can be used for the transport accessibility development in nine counties in Serbia's Danube Corridor. The study also underlines the importance of improving secondary networks and foreseeing an increase of accessibility by road and rail transport in some peripheral Serbian Danube counties.

2. State-of-the-art

An increasing number of studies and researches about transportation and accessibility have been developed over the last few years. In the transportation policy plans of European countries, improving accessibility seems to have critical impacts on economic development (Geurs and Ritsema van Eck, 2001). ESPON accessibility indicators (ESPON, 2004; ESPON, 2015) use a method to assess potential accessibility, based on what physical infrastructures could provide, regarding transportation flows. Combining GIS tools, statistical-cartographic data and indicators result in a suitable database for decision makers. Some concerns with those issues are that there is no unanimity among researchers regarding a common set of infrastructures variables (Snieska and Simkunaite, 2009). There are several accessibility indicators defined in a literature (Shimbel, 1953; Vickerman, 1974; López, Gutiérrez and Gómez, 2008; Gutiérrez, Condeço-Melhorado and Martín, 2010). The first accessibility method that was developed was location based – measure of the accessibility of a zone or a neighborhood; this method is useful to compare the accessibility levels between areas.

Accessibility can be measured using a single transportation mode, it can be applied several times, using different transportation modes, and then a comparison can be conducted. The results can then be compared to identify underserved areas or locations that need a close monitoring of their accessibility patterns. The length of roads and rail tracks is usually used as a proxy for a quantity of transportation infrastructures. The motorway or railway density/km^2 or inhabitant is sometimes used in comparing the coverage of transport networks in different countries. Different accessibility types have their own strengths and weaknesses. Travel time and daily accessibility indicators are easy to understand, as well to communicate, though they generally lack a theoretical foundation. Potential accessibility contains parameters that need to be calibrated; also, their values cannot be expressed in casual units (Castanho *et al.*, 2017).

Handy and Niemeier (1997) classified the available measures into three categories: (1) isochrones, (2) gravity-based measures, and (3) utility-based measures. Isochrones represent a number of destinations accessible within a given travel time or distance or cost from an origin. A gravity-based measure indicates a reduction in accessibility as the travel time to destinations increases. Utility-based measures assess the accessibility at the level of the individual (Handy and Niemeier, 1997; Drobne and Paliska, 2015; Vulevic, 2016). Geurs and Ritsema van Eck (2001) established other classifications, or Geurs and van Wee (2004), who have suggested four basic perspectives: (1) infrastructure-based measures; (2) activity-based measures; (3) person-based measures, and (4) utility-based measures.

The accessibility model put forward by Schürman, Spiekermann and Wegener (1997) uses centroids of NUTS-3 regions as origins and destinations; the accessibility model calculates the minimum paths for the road network, (i.e. minimum travel times between the centroids of the NUTS-3 regions). Statistical measures, ratios between the highest and lowest regional accessibility values give an overview of the accessibility distribution values between regions.

A European transport policy truly committed to that goal would have to significantly shift the focus of the trans-European networks investment program to transportation links within and between peripheral regions (ESPON, 2015). Furthermore, transport infrastructure investments positively influence the economic growth of an area if three conditions are met: (1) increase of accessibility within a region; (2) stronger economic power and (3) the infrastructure does not have major environmental influences (Berechman, 1994; Gutiérrez, Condeço-Melhorado and Martín, 2010).

The results of these studies depend on the nature of the accessibility method used, the nature of the high-speed rail implementation, and the features of the study area (Martín, Gutiérrez and Concepcion, 2004; Martín and Reggiani, 2007). Ortega, López and Monzón (2012) presented a GIS based method, which analyses changes in the territorial distribution of accessibility resulting from high-speed rail investments. It has been estimated that the implementation of a European network of high-speed trains could reduce weighted travel times between major European cites approximatively by half. Implementation of a single international line would have a much smaller effect across Europe – reducing weighted travel costs by 5%, or increase a potential market of accessibility by only 2% (Gutiérrez and Urbano, 1996). If the study is conducted at a national scale, a new high-speed line might reduce rail travel times by 10%, or lead to a broadly similar increase in market potential measures (López, Gutiérrez and Gómez, 2008).

Other authors have analyzed the influence of accessibility on labor supply; a positive effect of accessibility on labor supply is reflected in the fact that reduced travel time will lead to more time available for both work and free time. It will have a positive influence on the amount of labor those individuals are willing to supply (Ozbay, Ozmen and Berechman, 2006; Du and Mulley, 2007; van den Heuvel *et al.*, 2014; Vulevic, 2016).

Regarding population, Chi (2010) examines the role that highway expansion plays in the process of population change and the author proposes an integrated spatial regression approach to study the impacts of highway expansion on population changes during the 1980s and 1990s in Wisconsin. The findings suggest that an impact of highway expansion on population differs across rural, suburban, and urban areas: there are only indirect effects in rural areas; both direct and indirect effects in suburban areas; and no statistically significant effects in urban areas because infrastructure development reaches maturity. Further extra investment in infrastructure does not result in the development of the area (Chi, 2010; van den Heuvel *et al.*, 2014).

3. Model developed on the basis of multi-criteria analysis

The concept aims to establish combined indicators for series of thematic fields based on adding combinations of individual indicators. There are six relevant criteria for roads, railroads and water transports identified, and the relative priorities between those defined criteria. Air traffic is not valued/included since it is not used at the level of daily migrations. Multi-criteria analysis, which uses diverse indicators in order to integrate different issues at the same time, provides a better framework for the administrative units. The individual transport endowment and other indicators represent only a part of the solutions, thus giving selective and incomplete insights about a specific field.

For calculating the final alternatives' values, authors suggest the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) (Hwang and Yoon, 1981). This is one of the best-known and most widely used methods for decision-making; within the context of multi-criteria decision-making, TOPSIS allows the direct comparison of different units' measurements. The detailed analyses were used to depict administrative units in corridors with particular handicaps. This method can help transit authorities identify the most suitable types of transportation infrastructures or routes that a county should implement to improve the accessibility level. The mitigations or recommendations are then made to rectify the specific transportation aspects or major attributes to the fragile measures into a county with a low level of accessibility.

4. Methodological approach

Considering the purpose of the present research, a significant amount of time and attention was dedicated to the development of the methodological framework since the study required the use of several methods throughout the research. In this regard, the methodological approach presented in Figure 1 was divided into four main phases.

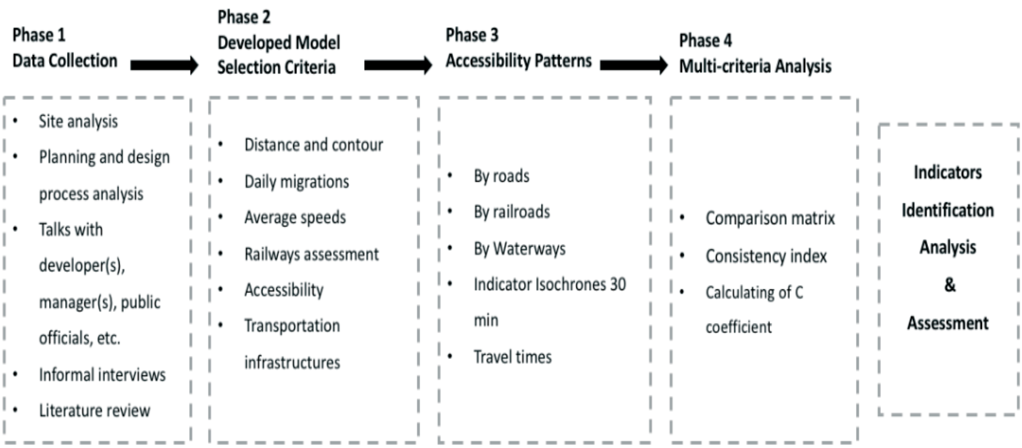

Figure 1: Methodological approach

To develop a correct model, several types of locations – based on accessibility measures (distance and contour) have been used. Relative accessibility is defined as a degree to which two places on the same surfaces are connected. Average travel time, average travel speed and distance as a standard for the maximum travel time or distance to a given location or transport infrastructure are carried out. Contour measures (isochoric measure) count the number of opportunities that can be reached within a given time or cost required to access a fixed number of opportunities. These measures are common in urban planning, geographical studies and projects (Wachs and Kumagai, 1973; Gutiérrez and Urbano, 1996; Bruinsma and Rietveld, 1998; ESPON, 2006; ESPON, 2013). Such measures 'are relatively undemanding of data and easy to analyze by researchers and policy makers, as no assumptions were made on a person's perception of transport, land use and their interactions' (Geurs and van Wee, 2004).

The research team selected the indicators of road transport based on the level of daily migrations. The networks are used to calculate travel times and accessibility between counties. In each administrative unit, the density of major highways and regional roads were calculated by dividing the total centerline lengths of the interstate with other elements of the national highway systems and also the regional roads within the county area. Further studies of individual accessibility indicators were an assessment for the National Spatial Plan of Serbia (2010-2020). Average speeds for road vehicle traveling on the highways and other used routes in the Serbian territory were introduced: 101.92 km/h – Highway; 65.14 km/h – State highway I class; and 60.06 km/h – State highway II class. Accessibility by rail was assessed by examining the networks of class I railways depicted in the National Spatial Plan of the Republic of Serbia. Data on length and density of both road and railway networks are published by the Statistical Office of the Republic of Serbia (2010). The documentation shows the present state of the equipment for all transport modes and infrastructures for a Corridor. A comparison of Census data was not carried out since the differences in data on length and density of both road and railway networks have been negligible since 1996 until today. A comparative analysis was also conducted in order to highlight regional transportation infrastructures endowments deficits for a subset of NUTS 3 units.

5. Area description

The study is focused on counties located along the Danube within the territory of Serbia, especially the NUTS 3 (Central Banat, South Banat, West Backa, South Backa, Srem, City of Belgrade, Danubian County, Branicevo and Bor County). Danube is Corridor VII – Pan European corridor defined at the second Pan-European Transport Conference in Crete, 1994 (it crosses through Germany, Austria, Slovakia, Hungary, Croatia, FR Yugoslavia, Romania, Bulgaria, Moldova and the Ukraine). The Serbian part of the Danube Corridor comprises two natural and geographic entities: the Pannonia Plain, and the Balkan Peninsula. Rivers Sava and Danube form a natural border between them. Serbia's Danube Corridor shows a good natural potential. The settlement structure is insufficiently developed, especially concerning centers of regional importance. The Belgrade metropolitan area has the greatest potential importance as a hub of Pan-European transport corridors VII and X; Corridor X passes through Austria, Slovenia, Croatia, Serbia, Macedonia and Greece and has four branches (Branch B: Budapest – Novi Sad – Belgrade is linked with Corridor X in Serbia).

The Danube region has significant sources of energy and water management potential. Regional economic development is highly differentiated as serious disparities exist between urban and rural areas, as well as between the middle Danube and lower Danube areas. The total surface of Serbia's Danube Corridor is about 2,900,000 ha.

6. Accessibility patterns

The model developed for the evaluation of transport accessibility ranks 9 alternatives (see Table 1) based on 6 relevant criteria: X1 – accessibility by roads; X2 – accessibility by railroad; X3 – accessibility by waterways; X4 – accessibility of Danube Corridor – indicator isochrones 30 min; X5 – travel time to the nearest regional center, and X6 – travel time to the nearest passenger local ports on Danube Corridor, by car.

6.1. Accessibility by roads (road transport accessibility and assessment of road network density)

The results of road transport infrastructure endowments in Danube's Corridor for NUTS 3 units are presented in Table 1.

Table 1: Road network length and density

NUTS 3/County	Area (km²)	Number of population	Roads (total) (km)	Modern roadways (total) (km)	Network density (km/km ²)	Network density (km/1,000 inhabitants)
A1 - Central Banat	3,256	197,585	449	449	0.13	2.27
A2 - South Banat	4,245	306,133	470	470	0.11	1.53
A3 - West Backa	2,419	200,951	320	318	0.13	1.59
A4 - South Backa	4,015	603,244	902	894	0.22	1.49
A5 - Srem	3,485	331,866	730	711	0.21	2.20
A6 - City of Belgrade	3,227	1,611,533	1,003	975	0.31	0.62
A7 - Danubian County	1,250	205,911	350	348	0.28	1.70
A8 - Branicevo County	3,865	193,944	707	702	0.18	3.64
A9 - Bor County	3,510	136,437	765	707	0.23	5.61

Source: Statistical Office of the Republic of Serbia, 2010

6.2. Accessibility by railroads (rail transport accessibility and railways network density assessment)

The condition of railway tracks in the Danube Corridor is not satisfactory. This is confirmed by the fact that the speed limits range from 40 km/h to 80 km/h. The major length of lines and network density is in Belgrade. The lowest length of the railway network is in Branicevo County. The lowest density is in the Branicevo and the Bor County. Of the total 1,566 km of electrified railroad, 28.8% is in Belgrade, South Backa, Srem, and Danubian County. This means that some international railways are not electrified (see Table 2) and the existence of double tracks has been shown only in three districts: Srem, Belgrade, and Danubian County.

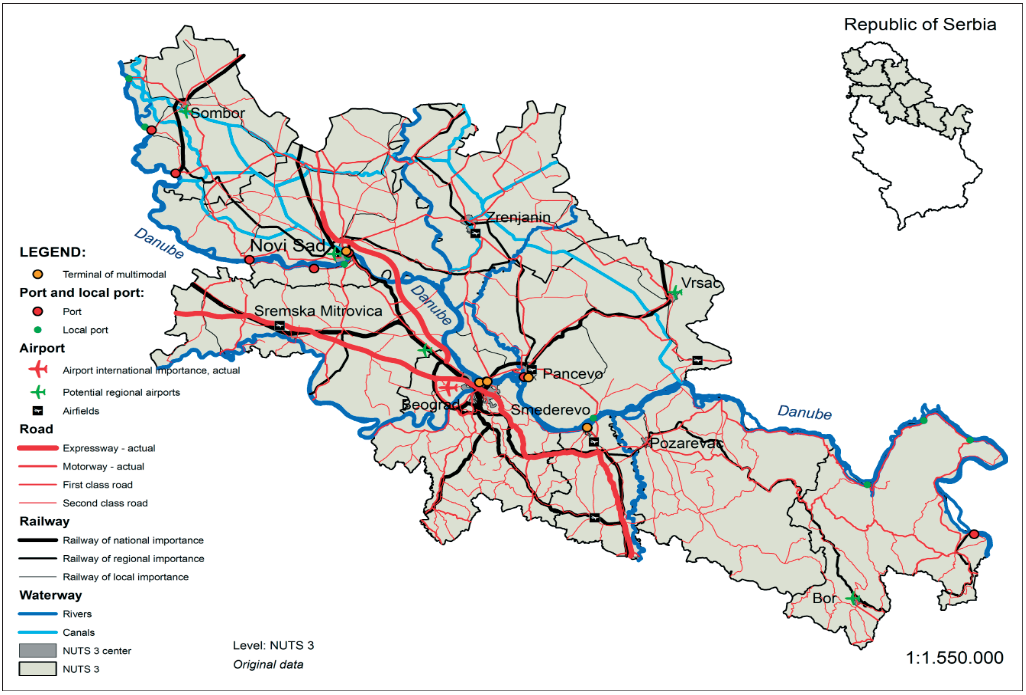

Figure 2: Transportation infrastructures in administrative units in Danube Corridor – transport endowments indicator

Source: Vulevic, 2013

Table 2: Length, density and electrification of the railroad network

NUTS3/ County	Length of the railroad network (km)	Density of the railroad network (km/km^2)	Electrified railroad (km)	Non-electrified railroad (km)
A1 - Central Banat	170.64	0.05	0	191
A2 - South Banat	256.53	0.06	58	196
A3 - West Backa	223.22	0.09	46	170
A4 - South Backa	307.40	0.08	66	253
A5 - Srem County	182.61	0.05	116	65
A6 - Belgrade	307.01	0.10	300	37
A7 - Danubian County	111.80	0.09	100	14
A8 - Branicevo county	98.68	0.03	0	102
A9 - Bor county	104.54	0.03	0	104

Source: Statistical Office of the Republic of Serbia, 2010

6.3. Accessibility by waterways

The European Agreement on Main Inland Waterways of International Importance (AGN Agreement) establishes a unique classification of all inland waterways of Europe, which are divided into seven classes of airworthiness, where the first three classes have a regional significance, and classes IV–VII have international significance. 'The class of a waterway is determined by the horizontal dimensions of motor vessels, barges and pushed convoys, and primarily by the main standardized dimension, namely their beam or width' (United Nations Economic Commission for Europe, 1996).

There are four waterways in Serbia's Danube Corridor: the Danube, Tisa, Sava, and the canal systems of Danube – Tisa – Danube, situated in Vojvodina (regions of Banat and Backa). The total length of all waterways is about 1,385 km (see Table 3). South Backa and Bor Counties have the longest sections on the Danube waterway (170 km and 164 km).

Depending on the sector, the Danube belongs to navigable classes VIc and VII. From the border with Hungary (km 1,433) to the Pancevo bridge in Belgrade (km 1,167) it belongs to category VIc. From there to the dam Iron Gate II (km 862) it falls into category VII and then, downstream, from the Dam to the border with the Bulgaria (km 845.65) it belongs again to class VIc. International waterway Sava meets requirements for navigable classes III and IV. The Tisa is also navigable on its entire course through Serbia. Presently, it has a status of inter-state waterway, which belongs to the navigable class IV. The Canal System Danube – Tisa – Danube (DTD) has a multipurpose hydraulic system, aiming to control the regime of surface and ground water. The network of canals has 51 objects. According to the United Nations Economic Commission for Europe (UNECE) criteria, 55% of the system drops into navigable classes IV and V, around 20% into navigable class III, and the remaining 25% of lower classes of navigability (Donauregionen Plus, 2010). However, the DTD system is currently in bad condition and the Great Backa Canal is not navigable.

Serbia's Danube Corridor is dominated by a passenger local port for inland waterway transport. The existing infrastructure of passenger local ports in most of the cases is incomplete and improvised. Passengers are mostly retaining in Belgrade; ships dock at the passenger terminals on the Sava River, near Kalemegdan, in Belgrade and Novi Sad. According to the Spatial plan of special purpose for waterway of Danube-Pan-European Corridor VII in Serbia, the priority is placed within Corridor VII including the reconstruction, development and modernization of the 27 local ports – 24 passengers and 3 freight ports (Donauregionen Plus, 2010; Institute of Architecture and Urban and Spatial Planning of Serbia, 2013).

Table 3: Length (km) and density of the inland waterways (km/km^2)

NUTS 3/District	Danube	Tisa	Sava	Canal DTD	Total length	Density of the inland waterways
A1 - Central Banat	7	100	0	131	238.00	0.073
A2 - South Banat	93.5	0	0	24	117.50	0.028
A3 - West Backa	72	0	0	183	255.00	0.105
A4 - South Backa	170	74	0	153	397.00	0.099
A5 - Srem County	54	0	127	0	181.00	0.052
A6 - Belgrade	80.5	0	86.5	0	167.00	0.052
A7 - Danubian County	25	0	0	0	25.00	0.020
A8 - Branicevo County	94	0	0	0	94.00	0.024
A9 - Bor County	164	0	0	0	164.00	0.047

Source: Donauregionen Plus, 2010

6.4. Accessibility of Danube Corridor area – indicator Isochrones 30 min

Accessibility indicator Isochrones 30 min – time to market is measured by the number of inhabitants within the 30 minutes isochrones (National Spatial Plan of Serbia, 2010-2020) – of the selected centers of counties. On bases of adopted speeds, the 30-minute isochrones are determined, whereas the number of inhabitants within the 30-minutes isochrones (Table 4) measures the time to market. Using the amount of population that can be reached within 30 minutes of each NUTS 3 by available route mode the average results show that there is a clear shift of accessibility from the center to the west and to the east within the Danube Space.

While from central counties, populations of between about 1,5 and 1,7 million are accessible within 30 minutes from centers of counties, from a large part of the eastern half, the population amounts accessible do not exceed 100,000 – 300,000 people. The values for Bor County (centers of the east county) and for the center of West Backa County – Sombor are the lowest.

Table 4: Number of inhabitants within the 30-minute isochrones

The centers of the NUTS 3	Area/km^2	Number of population (2002)
A1 - Zrenjanin	3,153	207,214
A2 - Pancevo	3,184	1,544,314
A3 - Sombor	2,571	198,833
A4 - Novi Sad	3,607	610,830
A5 - SremskaMitrovica	3,211	237,960
A6 - Belgrade	3,625	1,691,098
A7 - Smederevo	2,798	393,520
A8 - Pozarevac	2,595	323,551
A9 - Bor	1,874	117,592

6.5. Travel time to the nearest macro regional centers

Accessibility of nearest agglomeration (capital and macro regional centers of international significance) from each Danube counties (measured in traveling time) shows the relative peripherality of counties (Tables 5 and 6). In terms of road transport average, access time from particular centers of Danube counties to a capital center, such as Belgrade and macro regional centers of Novi Sad and Kragujevac, indicates the accessibility towards one, two or three centers of international significance. The values of travel times were ranked in five categories (Table 5). We should take into account that peripheral borders counties have high assessment accessibility to transboundary areas, a fact that is not considered in this paper due to the lack of data related to transboundary centers. The data for the Bor district, indicating the travel time is well below average. The less accessible counties are those of the eastern and west part of the Danube Corridor; Central counties Podunavski, Central Banat, Srem County, as well as South Backa (centers on the main corridor directions) have better values of accessibility (above and high above of average).

Table 5: Travel time indicators rank

Rank	Counties
Well below average 1 (over 120)	Bor County
Below average 2 (102-120)	West Backa
Average 3 (80-102)	Belgrade, Branicevski, South Banat
Above average 4(59-80)	South Backa, Podunavski
High above the average 5 (to 59)	Central Banat, Srem County

Table 6: Travel time to the nearest macro regional centers Belgrade, Novi Sad, and Kragujevac (minutes – equivalents)

The centers of the NUTS 3	Zrenjanin	Pancevo	Sombor	Novi Sad	Sremska Mitrovica	Belgrade	Smederevo	Pozarevac	Bor	Kragujevac
A1 - Zrenjanin	/	65	114	48	91	68	121	120	236	157
A2 - Pancevo	65	/	170	93	78	18	45	62	180	103
A3 - Sombor	114	170	/	82	150	153	190	204	320	241
A4 - Novi Sad	48	93	82	/	47	76	112	127	237	164
A5 - Sremska Mitrovica	91	78	150	47	/	49	101	100	218	136
A6 - Belgrade	68	18	153	76	49	/	45	55	171	91
A7 - Smederevo	121	45	190	112	101	40	/	39	182	66
A8 - Pozarevac	120	62	204	127	100	55	39	/	114	69
A9 - Bor	236	180	320	237	218	171	182	114	/	128

Table 7 shows the values of travel time by car from the center of the county to the nearest local passenger port on the Danube.

Table 7: Travel time from the centers of counties to nearest passenger local ports on the Danube Corridor, by car (minutes – equivalents)

Local ports	Sombor	Novi Sad	Sremska Mitrovica	Zrenjanin	Belgrade	Pancevo	Vrsac	Smederevo	Pozarevac	Bor
Bezdan	44.9									
Apatin	32.9									
Novi Sad-centar	169.4	0.0	92.1	96.2						
Belgrade-Sava			88.9	138.0	0.0	40.1	158.1			
Smederevo						65.2	162.6	0.0	60.7	
Donji Milanovac										136.8
Tekija										195.3
Kladovo										233.7
Prahovo										187.9

7. Multi-criteria analysis – TOPSIS method

After all alternatives and relevant criteria are defined, the relative priorities between these elements should be determined. Firstly, the expert's consistency should be calculated, and if it is satisfied, one of the methods for multi-criteria analysis can be applied.

Step 1: In order to check the expert's consistency, the eigenvector method is applied. The pair-wise comparison matrix, which presents relative preferences among criteria, is generated (see equation 1).

Matrix 'A', the elements of which are: a_{ij} (i=1,...,n; j=1,...,n), whereby n is a number of criteria, shows the experts' priority of one element over the others. Matrix 'M', with elements a'_{ij}, is the normalized matrix 'A'.

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_j \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccccc} A_1 & A_2 & \cdots & A_i & \cdots & A_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1i} & \cdots & a_{1n} \\ a_{21} & 1 & & & & a_{2n} \\ \vdots & & & & & \vdots \\ a_{j1} & a_{j2} & & 1 & & a_{jn} \\ \vdots & & & & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{ni} & \cdots & 1 \end{bmatrix} \end{array} \qquad a_{ji} = 1/a_{ij} \tag{1}$$

$$M = \begin{bmatrix} a'_{11} & a'_{12} & \cdots & a'_{1n} \\ a'_{21} & & & \\ & & & \\ \cdots & & a'_{ij} & \cdots \\ a'_{n1} & \cdots & & a'_{nn1} \end{bmatrix}; a'_{ij} = a_{ij} / \sum_{i=1}^{n} a_{ij} \tag{2}$$

The vector of priorities, 'W', is an eigenvector of the matrix 'A'. The factor λ_{max} is used for the calculation of the consistency index, *CI*, of a matrix of comparisons.

$$W = \begin{bmatrix} w_1 \\ \vdots \\ w_i \\ \vdots \\ w_n \end{bmatrix}; \; w_i = \frac{1}{n} \sum_{j=1}^{n} a'_{ij} \tag{3}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \left(w_i \cdot \left(\sum_{i=1}^{n} a_{ij} \right) \right) \tag{4}$$

$$CI = (\lambda_{\max} - n) / (n - 1) \tag{5}$$

After the consistency index is calculated, the consistency ratio, *CR*, can be considered as a relation of the consistency index and the random index, *RI* (Table 8). The degree of consistency is satisfied if *CR* > 0.1. Otherwise, the judgment of a decision maker should be revised.

$$CR = CI / RI \tag{6}$$

Table 8: The values of *RI*

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

For calculating the final alternatives' weights in this model, the authors suggest the TOPSIS method. The basic assumption of TOPSIS is that the chosen alternative should have the shortest distance to the ideal solution, and the longest to the negative-ideal solution. The ideal solution is that which maximizes benefit criteria, and minimizes cost criteria; the negative-ideal solution is that which minimizes benefit criteria, and maximizes cost criteria.

Step 2: Matrix 'D', based on an expert's recommendation, shows the values of alternatives (*m* is the number of alternatives) considering all criteria (*n* is the number of criteria).

$$D = \begin{matrix} \\ A_1 \\ \dots \\ A_i \\ \dots \\ A_m \end{matrix} \begin{bmatrix} C_1 & C_2 & \dots & C_i & \dots & C_n \\ a_{11} & a_{12} & & a_{1i} & & a_{1n} \\ a_{i1} & a_{i2} & & a_{ii} & & a_{in} \\ a_{m1} & a_{m2} & & a_{mi} & & a_{mn} \end{bmatrix} \tag{7}$$

Step 3: Based on the matrix 'D', with elements a_{ij}, matrix 'T' is developed, whose elements, t_{ij}, are calculated using the following equations (equations 8 and 9), where i=1,...,n; j=1,...,m. Matrix 'T' is the normalized matrix 'A'.

$$t_{ij} = \frac{a_{ij}}{\sqrt{\sum_{j=1}^{n} a_{ij}^2}} \tag{8}$$

Step 4: The weight factor of a given criterion is w_j, representing the preference of the criterion *j*. The matrix 'V', with elements v_{ij}, is the weighted matrix 'T'. Applying equation (9), the elements v_{ij} are obtained.

$$v_{ij} = w_j \cdot t_{ij} \tag{9}$$

Step 5: The ideal solution is A^+, and the negative-ideal solution is marked by A^-. Set *B* is comprised of criteria where the goal is benefit maximization, and set *C* is comprised of criteria where the goal is cost minimization.

$$A^{+} = \left\{\left(\max_i v_{ij} \middle| j \in B\right), \left(\min_i v_{ij} \middle| j \in C\right) j = 1,2,...m\right\}$$
$$A^{-} = \left(\min_i v_{ij} \middle| j \in B\right), \left(\max_i v_{ij} \middle| j \in C\right) j = 1,2,...m \tag{10}$$

Step 6: The distance of *i-th* alternative from the ideal solution is d_{i+}, and from the negative-ideal solution is d_{i-}; this distance can be calculated as the Euclidean distance:

$$d_{i+} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{+})^2}, i = 1,2,...m$$
$$d_{i-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{-})^2}, i = 1,2,...m \tag{11}$$

Step 7: The next step is calculating the coefficient C for each alternative separately, which shows how much close the alternative is to the ideal solution. The alternative i is closer to the optimal solution when the C_i is closer to 1.

$$C_i = \frac{d_{i-}}{d_{i+} + d_{i-}} \tag{12}$$

After the equations (1-6) are applied, the final criteria weights are obtained (Table 9), showing the high preference of the 1st criterion, then the 2nd and the 3rd, and finally the last three criteria with the same lowest preference.

Table 9: Criteria weights

Criteria	Weights
X1 - accessibility by roads	0.4738
X2 - accessibility by railroad	0.1684
X3 - accessibility by waterways	0.1684
X4 - accessibility of Danube Corridor	0.0631
X5 - travel time to the nearest regional center	0.0631
X6 - travel time to the nearest passenger local ports	0.0631

For considered municipalities the TOPSIS method was applied and the results obtained are presented in Table 10; the first ranked alternative is Belgrade.

Table 10: Final results obtained by TOPSIS

NUTS3	TOPSIS	Rank
A1 – Central Banat	0.0576	8
A2 – South Banat	0.2385	2
A3 – West Backa	0.0697	6
A4 – South Backa	0.1164	3
A5 – Srem	0.0678	7
A6 – City of Belgrade	0.2720	1
A7 – Danubian County	0.0895	4
A8 – Branicevo County	0.0730	5
A9 – Bor County	0.0154	9

Ranges are presented in Figure 3. Existing accessibility pattern clearly indicates the differences in both central and peripheral administrative units (counties) in the Danube Corridor. The most peripheral county is the eastern County (Bor), as well as other borders counties. Although they are on the Danube development axis, some of those units have low levels of accessibility and characteristics of peripheral borders areas.

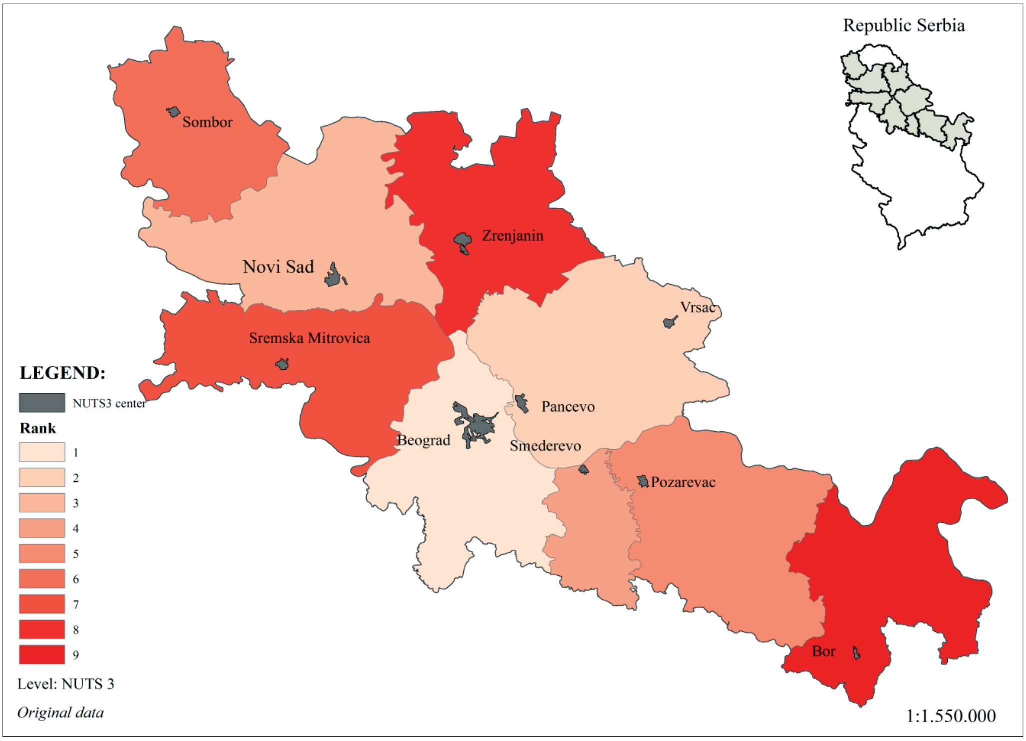

Figure 3: Accessibility level

Source: Vulevic, 2013

8. Discussion

The study shows some interesting results, as well an opportunity for future transport investments. Those findings have been presented per mode of transport. The main road arteries in Serbia's Danube Corridor belong to the European road network. These are motorway E 75 (connecting the Baltic Sea to the Mediterranean Sea) and motorway E 70 (connecting Zagreb to Bucharest). The accessibility results steer towards the future routes of transport infrastructure development in the Danube Corridor through the politics of regional spatial development and the construction of high-quality transport infrastructure systems with secondary networks. New transversal directions will accomplish a higher level of accessibility. However, investments in roads infrastructures in Serbia and the Danube Corridor were mainly focused on the reconstruction of the existing road network. Local roads are the responsibility of local administrative units (municipalities) and should be planned through municipal spatial plans.

Rehabilitation and the modernization of the existing single-track railways, which run through the territory of the Bor County, will be reflected on the accessibility of these units. The construction of transport infrastructure is planned through the reconstruction of the existing railway tracks on the routes Nis – Zajecar – Prahovo, Nis – Makedonija, etc., with branches in Romania and Bulgaria, and through constructing the E-85 (high-speed railway) (Figure 4). Railway infrastructure has opportunities for further development, depending on further investments.

Ports of international importance Beograd, Novi Sad and Prahovo are important points of the international combined transport lines. Nevertheless, ports are operating at low capacity and potential for service because the infrastructure of the railway system does not meet current requirements for combined transport. The research demonstrates that there is no good connection between rail transport and shipping. The intermodal transport developments in the Danube's Corridor were directly connected to reconstruction and construction works within the road and rail Corridor X and with the revitalization of the railroad and the construction of intermodal terminals. The important potential for development of intermodal terminals has been identified along the Corridors X and VII. The Belgrade logistic Danube platform, along the axis Belgrade – Pancevo – Smederevo (three multimodal terminals), together with the airport 'Nikola Tesla' in Belgrade, could link Corridors X and VII and create a competitive logistic platform in the Southeast Europe.

Within Serbia's Danube Corridor, some counties have the lowest accessibility levels, which represent the consequence of the lower development of the roads, railways and water transportations. Even though the road network of different classes exists, modernization and reconstruction is needed. As for the local roads, over 50% of them are unpaved. In the National Spatial Plan of the Republic of Serbia, the Corridor is reserved for planned motorway from Nis to Zajecar, as well as the potential branch construction to Vidin and to Corridor IV in Bulgaria. The modernization of existing roads and the construction of bypass roads are planned around the Bor center district. According to the proposed strategic priorities and transportation development planning solutions (see Figure 4) by the National Spatial Plan of Serbia (2010–2020), the most important positive effects concerning the accessibility increase in the Danube Corridor belong to the county with the lowest accessibility levels – Bor County (Table 10, Figure 3). The construction route of the state highway class I, number 4 (from Bor to highway E-75), will bring an end to the route equipment and arrangement of navigable-nautical Danube Corridor (through developing the intermodal port Prahovo and the docks Donji Milanovac, Tekija and Kladovo).

The opening of new border crossings and the reconstruction of the existing railway, as well as the construction of a railway to Romania and Bulgaria, will be a critical factor to achieve the desired opening and integration of the region. It seems to be expected that recently planned transport routes, according to the National Spatial Plan of the Republic of Serbia (2010–2020), will change the accessibility levels in the most remote county – Bor, seeking to approximate peripheral counties to central ones. Nevertheless, all proposed or planned railroads will hardly be realized on a short-medium term, as investments are mainly focused on road infrastructures (The Regional Development Strategy of the Banat County 2009–2013; The Regional Development Strategy of the Timok Region 2011–2015).

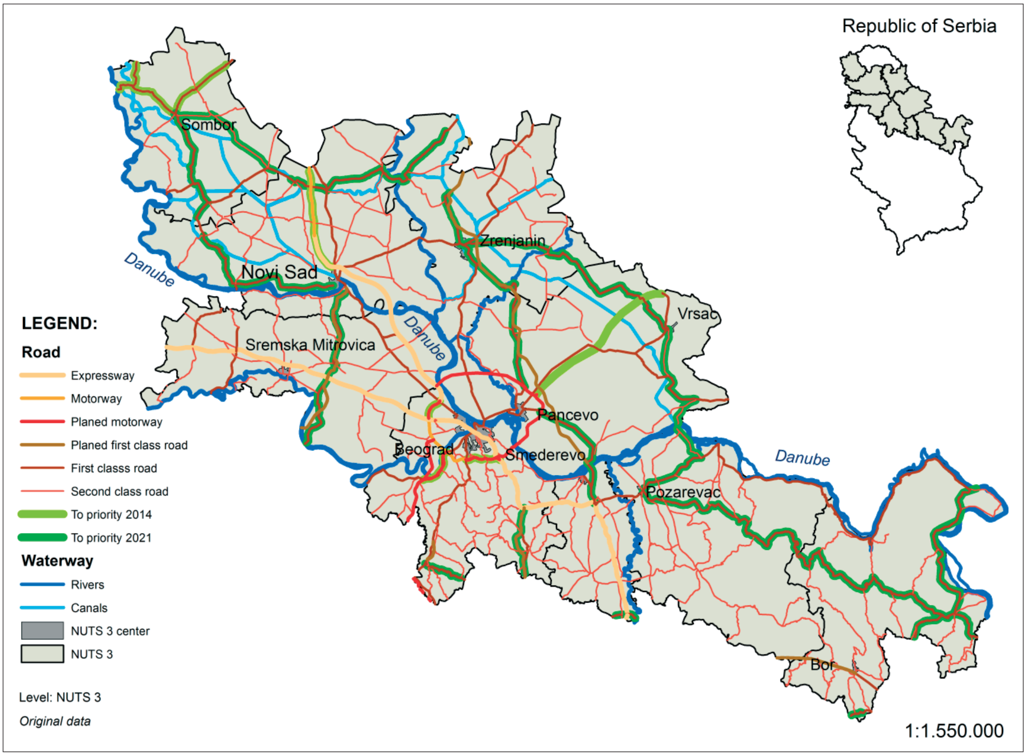

Figure 4: Planning solutions for a road in the Danube Corridor – based on planning solutions from the National Spatial Plan of Serbia 2010–2020

Source: Vulevic, 2013

The role of the Danube waterway has been underestimated and should be improved and properly valorized in the forthcoming period. The coordinated development of all transport systems is an opportunity for the creation of combined transport terminals or logistic centers in Danube ports. Furthermore, the connection of transport infrastructure to international transport corridors is necessary to strengthen cross-border cooperation in the field of waterway management.

9. Conclusions

The Danube has an activating role in the development of Serbia, however, the comparative analysis of Danube's counties in Serbia Danube's Corridor points to different network levels of quality and accessibility among them. Accessibility analysis displays discontinuities between administrative units NUTS 3 along a corridor, which clearly demonstrates the change on accessibility from West to the East and differences in accessibility between central and peripheral counties. The result indicates that the most peripheral counties in relation to Belgrade are the Eastern County (Borski), and East borders counties. Although they are on the Danube development axis, some of the studied NUTS 3 show low levels of accessibility, matching with the characteristics of peripheral borders counties.

The article highlights the importance of improving secondary transportation networks and an increase of accessibility in Serbia's Danube administrative units with low accessibility value. Planning solutions indicate that the future development of the transport infrastructure should lead to an increase of the accessibility through the construction of high-quality transport infrastructure systems, which should be complemented by a secondary network. A transversal connection allows for transforming of the overly hierarchical and centralized system of transport networks.

The accessibility indicators recognize transport network quality and NUTS 3 transportation disparities. In this regard, those indicators also enable to evaluate the impacts of projects and ascertain how policies and strategies can influence the performance and better coordination of transportation systems. Location-based measures were found to be the most appropriate for planning, once they use readily available data and are easily understood by planners, decision-makers and the public (ESPON, 2015).

The benefits of the multi-criteria analysis for the capture of possible elements of accessibility based on transportation planning were, once again, proved by this study and the learned lessons could be transferred as successful examples to other corridors/projects. The presented method can be used to identify administrative units, counties or Corridors with the lowest accessibility levels, as well to identify reliably accessible areas where no improvement or further investments would be needed (ESPON, 2015).

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