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THE STATE ROAD NETWORK AS A FACTOR OF SPATIAL INTEGRATION OF SERBIAN COMMUNITIES IN KOSOVO AND METOHIJA: GIS ANALYSIS

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ABSTRACT

Following the armed conflicts in Kosovo and Metohija at the end of the twentieth century and the establishment of the United Nations Mission administration, a large number of members of the Serbian population were displaced, resulting in significant changes in their spatial distribution. In the twenty-first century, Serbs in Kosovo and Metohija predominantly reside in a limited number of municipalities with a Serbian majority or a pronounced Serbian population, as well as in spatially isolated enclaves comprising individual settlements or clusters of smaller settlements. These areas are characterized by complex living and security conditions, as well as pronounced spatial isolation. Given their demographic fragmentation, spatial dispersion, and dependence on institutional, educational, healthcare, and service centers, transport connectivity represents one of the key factors of the spatial and functional integration of the Serbian population. The aim of this paper is to determine, through the application of GIS analysis, the relationship between the state road network and the areas in which the Serbian population has persisted, as well as to assess their level of accessibility in relation to the main Serbian centers. The study employed isochrone and isotel accessibility models derived from the state road network. The analysis reveals a strong correspondence between the routes of state roads and the areas inhabited by Serbian communities and enclaves. The findings confirm that the state road network in Kosovo and Metohija serves as an important integrative factor in maintaining spatial connectivity and supporting the everyday functioning of Serbian communities, while also showing that physical proximity to road corridors alone is not sufficient without adequate travel-time and spatial accessibility to the main Serbian centers.

Keywords: State roads, Spatial integration, Serbian population, GIS analysis, Kosovo and Metohija.

INTRODUCTION

The armed conflicts between Serbs and Albanians, which took place in the Autonomous Province of Kosovo and Metohija within the Republic of Serbia at the end of the twentieth century, ceased in June 1999 with the signing of the Kumanovo Agreement, i.e., the Military-Technical Agreement (Milentijević & Stanković, 2017). Subsequently, pursuant to United Nations Security Council Resolution 1244, the United Nations Interim Administration was established in Kosovo and Metohija, accompanied by the presence of international civilian and security structures operating within their mandated responsibilities (Ristić et al., 2020). In accordance with the Agreement, international peacekeeping forces were deployed throughout Kosovo and Metohija, while Serbian armed forces withdrew from the territory.

Since June 1999, a large-scale outmigration of the Serbian and other non-Albanian populations has taken place, significantly altering the ethnic composition of the Province. According to Milosavljević & Medojević (2020), approximately 320,000 people were displaced during this period. The position of the Serbian population changed dramatically after 1999, and its presence in major urban centers of Kosovo and Metohija, such as Priština, Prizren, Peć, Uroševac, Gnjilane, and the southern part of Kosovska Mitrovica, was reduced to a minimum. The Serbian population largely remained in isolated rural settlements, commonly referred to in the literature as "enclaves" (Milosavljević & Medojević, 2020), as well as in a limited number of municipalities with a Serbian majority. These areas are characterized by complex living and security conditions, as well as pronounced spatial isolation.

Given that the daily activities of the Serbian population are largely confined to enclaves and that these communities are highly dependent on institutional, educational, healthcare, and service centers, transport connectivity represents one of the key factors of their spatial and functional integration. In this study, roads are conceptualized not merely as components of physical transport infrastructure, but also as carriers of spatial interactions that facilitate the functional integration of the Serbian population in Kosovo and Metohija. Accordingly, this paper examines to what extent the state road network contributes to the spatial and functional integration of Serbian communities and enclaves in Kosovo and Metohija, measured through their spatial and travel-time accessibility to the main Serbian centers.

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Spatial integration is a multidimensional concept. In the context of regional and transport planning, it may be understood as the degree of physical and functional connectivity between different spatial units. In this sense, areas characterized by higher levels of communication, mobility, and accessibility through transport infrastructure can be considered more integrated (Uszkai, 2015a). Spatial integration also refers to the degree of connectivity and interaction among spatial units, manifested through population mobility, the exchange of functions, access to services, and the functional connectivity of transport systems operating at different hierarchical levels (Uszkai, 2015b).

In this study, spatial integration is defined as the degree of physical, functional, and transport connectivity between Serbian enclaves and municipalities with a Serbian majority and selected reference centers in Kosovo and Metohija. It is operationalized through indicators of transport accessibility, namely spatial and travel-time distance measured along the state road network. In this context, greater accessibility indicates a higher level of spatial integration, whereas greater distance points to peripherality and weaker functional connectivity.

MATERIALS AND METHODS

Study Area

The spatial scope of the study encompasses the territory of the Autonomous Province of Kosovo and Metohija, located in the southern part of Serbia on the Balkan Peninsula (Figure 1).

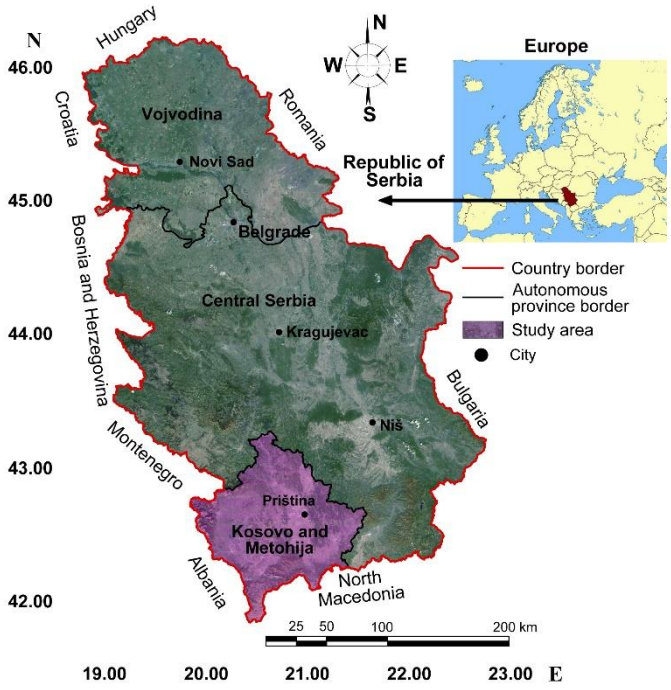

Figure 1. Location map of study area.

The Province covers an area of 10,887 km², accounting for 12.3% of the territory of the Republic of Serbia, and comprises two major geographical regions—Kosovo and Metohija (Bačević et al., 2017; Milentijević & Stanković, 2017).

According to the population census conducted in 2011, the total population of Kosovo and Metohija amounted to 1,739,825 inhabitants. The ethnic structure was dominated by the Albanian community, which accounted for approximately 93% of the total population, while the Serbian population represented only a small and spatially unevenly distributed share of the population (Milosavljević et al., 2023).

Methods

In addition to standard research methods, the study employs temporal (isochrone) and spatial (isotel) models of transport accessibility to determine the travel-time and spatial distances of Serbian enclaves and municipalities with a Serbian majority in Kosovo and Metohija. In this study, Serbian enclaves are understood as settlements or groups of settlements with a recorded Serbian population located outside the main municipalities with a Serbian majority or pronounced Serbian population, and functionally dependent on external Serbian reference centers. The temporal model represents the average travel time by car along the state road network to a selected reference point, whereas the spatial model depicts the shortest physical distance, expressed in kilometers, measured along the transport network. In this research, the northern part of Kosovska Mitrovica, Gračanica, and Štrpce were selected as reference points, as they represent major centers of concentration and functional integration of the Serbian population in Kosovo and Metohija and concentrate administrative, educational, healthcare, cultural, and service functions relevant to this population. A separate reference center was not defined for Metohija, since this area does not contain a major Serbian urban and institutional center of comparable importance, which is relevant for interpreting its more peripheral position in the accessibility analysis.

The models were generated in QGIS 3.18 Zurich, using GIS-based spatial and network analysis techniques. The state road network was first converted from KMZ format into a GIS-compatible vector layer and then classified according to road category. Based on this classified network, average travel speeds were assigned to each road category, after which the network was used to generate both travel-time isochrone zones and distance-based isotel zones in relation to the selected reference centers. Isochrone and isotel maps were developed through the application of transport network analysis tools and extensions, including the *System for Automated Geoscientific Analyses* (SAGA), as well as *network analysis* and *buffer analysis* procedures (Lukić, 2012; Ivanović et al., 2024).

The temporal model is based on scientifically established parameters of network analysis and isochrone classifications

(Jonard et al., 2007; Jonard et al., 2009; Goerlich et al., 2016; Gajić Protić, 2022), adapted to the characteristics of the study area. Isochrone maps were generated algorithmically, taking into account the average travel speed of passenger vehicles on different categories of state roads.

The following average travel speeds were adopted in the analysis:

- Motorways – 100 km/h;
- Class IB state roads – 70 km/h;
- Class II state roads – 60 km/h.

The average travel time, expressed in minutes, was calculated using Equation (1) (Gajić Protić, 2022):

$$T = \frac{D}{V} \times 60. \quad (1)$$

where T denotes travel time in minutes, *D* is distance in kilometres, and *V* is the average travel speed in km/h.

It should be noted that the accessibility model is based on average travel speeds and does not include potential variations caused by traffic congestion, road surface quality, weather conditions, security circumstances, or administrative delays.

Based on Equation (1), and through the application of GIS tools and predefined isochrone threshold values, an isochrone map of travel-time accessibility was generated and the corresponding numerical indicators were derived. The following isochrone intervals were adopted in the study: up to 15 minutes, 15–30 minutes, 30–45 minutes, 45–60 minutes, and more than 60 minutes. According to Gómez Valenzuela and Holl (2024), a travel time of 45 minutes may be regarded as the upper limit of acceptable daily travel; therefore, areas located beyond this isochrone were considered more remote and less spatially integrated.

In the spatial (isotel) model accessibility was analysed based on the shortest distance along the transport network to the selected reference points, independently of travel time. The adopted isotel threshold values were: 0–15 km, 15–30 km, 30–50 km, and more than 50 km. A distance of 30 km was defined as the threshold of spatial accessibility, as settlements located beyond this value, in line with contemporary accessibility research, exhibit stronger peripherality and weaker functional connectivity (Neumeier, 2016; Gómez Valenzuela & Holl, 2024).

Materials and data

The study utilised three main datasets, obtained from relevant public sources, namely competent institutions and public enterprises.

The first dataset is the Register of Spatial Units (RSU), part of Serbia's National Spatial Data Infrastructure, which was used as the primary spatial layer for the representation of administrative boundaries of municipalities and settlements. The RSU data were obtained from the Republic Geodetic Authority of the Republic of Serbia via the specialized GeoSrbija portal (RGA, 2026).

The second dataset consists of demographic data required for the analysis of the spatial distribution of the Serbian population in Kosovo and Metohija and for the identification of areas with a Serbian majority population. These data were obtained from public sources, primarily the Statistical Office of the Republic of Serbia and the Kosovo Agency of Statistics. Since not all results from the most recent population census have been published, the study relies on and cartographically presents data from the 2011 census (Kosovo Agency of Statistics, 2013). These data also include the Annex with estimates for municipalities in northern Kosovo and Metohija, which forms an integral part of the census publication. Therefore, the demographic indicators used in this study refer to the 2011 census dataset together with the estimated values for areas with incomplete census coverage.

However, the literature frequently highlights the limited reliability of the 2011 census data, particularly regarding the coverage of certain ethnic communities (Milosavljević & Punišić, 2011). Furthermore, Milosavljević et al. (2023) note that population censuses in Kosovo and Metohija over the past three decades have been conducted under highly complex socio-political conditions, often accompanied by boycotts from certain ethnic communities, resulting in incomplete population coverage. Given the political and institutional context in which the 2011 census was conducted, data on the share of the Serbian population should therefore be interpreted with a degree of methodological caution. Nevertheless, despite these limitations, they remain the only available official dataset suitable for spatial analysis at this level.

The third dataset concerns the state road network. The network of Category I and II state roads was obtained in vector .kmz format from the Reference System of the State Road Network of the Republic of Serbia, managed by the Public Enterprise "Roads of Serbia" (Public Enterprise Roads of Serbia, 2026). This source provides a publicly accessible digital map of the state road network, in which road alignments are represented as vector data suitable for download, conversion, and integration into a GIS environment. For the purposes of this study, the segment of the state road network covering Kosovo and Metohija was extracted and subsequently integrated with administrative and demographic data layers to enable further spatial analyses.

RESULTS AND DISCUSSION

The state road network in Kosovo and Metohija is relatively well developed and constitutes the primary transport matrix for the spatial connectivity of settlements. The total length of state roads is 1,969 km, while the road network density coefficient is 0.18 km/km² (Figure 2). In terms of structure, Category IIA state roads account for the largest

share at 44.01%, followed by Category IB state roads with 31.84%, whereas Category IIB state roads make up 24.15% of the total network (Table 1). Such a structure indicates the importance of lower-order state roads in connecting smaller settlements and spatially dispersed communities, which is of particular relevance for the analysis of accessibility of Serbian enclaves.

Table 1. Structure of the state road network in Kosovo and Metohija.

	State road categories				Total
	IA	IB	IIA	IIB	
Length (km)	-	627	867	475	1,969
Share (%)	-	31.84	44.01	24.15	100.00
Road network density (km/km^2)	-	0.06	0.08	0.04	0.18

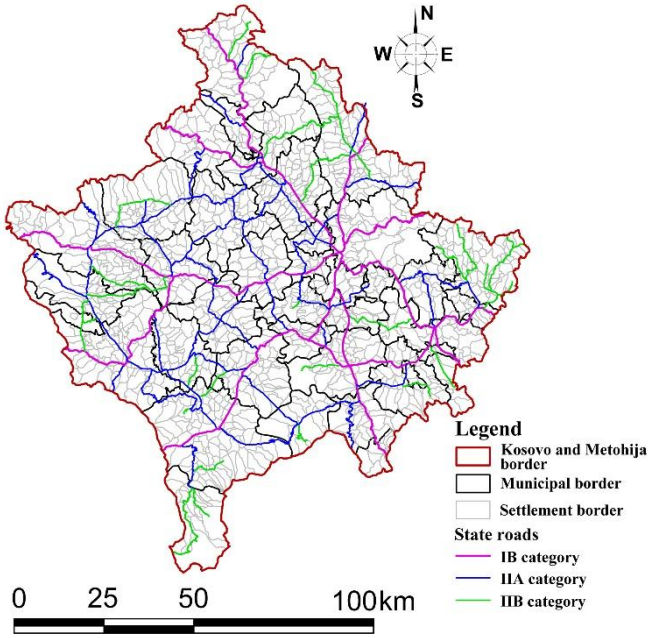

Figure 2. Map of the state road network in Kosovo and Metohija. Source: author's elaboration based on Public Enterprise Roads of Serbia, 2026.

Analysis of demographic data from the 2011 Population Census, including the Annex with estimates for municipalities in northern Kosovo and Metohija, shows that 63,157 Serbs live in the territory of Kosovo and Metohija, accounting for 3.55% of the total population. The share of the Serbian population in the total population declined from 23.6% in 1948 to 9.9% according to the 1991 census (Medojević & Milosavljević, 2019), while the armed conflicts at the end of the twentieth century further contributed to the emigration, expulsion, and spatial redistribution of the Serbian population. As a result of these processes, the Serbian population has been largely confined to specific spatial areas, primarily municipalities with a Serbian majority and smaller, spatially isolated enclaves.

The presence of the Serbian population was identified, to varying degrees, in a total of 362 settlements across 34 municipalities (Figure 3). The majority of these settlements are of a rural type: Serbs were recorded in 332 rural settlements, which account for 64.24% of the total Serbian population in Kosovo and Metohija. The remaining 35.76% of Serbs live in 30 smaller urban settlements. The settlements in which the presence of Serbs has been recorded cover an area of 2,953.28 km², or 27.07% of the territory of Kosovo and Metohija. These data indicate that the Serbian population is relatively widely dispersed spatially, but demographically unevenly distributed and often concentrated in smaller settlements with weak mutual connectivity.

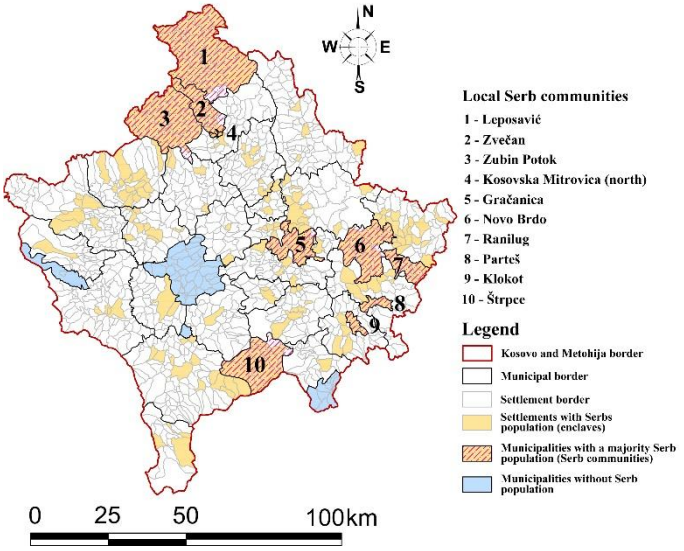

Figure 3. Spatial distribution and concentration areas of the Serbian population in Kosovo and Metohija. Source: author's elaboration based on Kosovo Agency of Statistics, 2013.

Seven municipalities have a Serbian majority population: Parteš (99.89%), Leposavić (97.65%), Ranilug (95.50%), Zvečan (94.84%), Severna Mitrovica (92.97%), Zubin Potok (84.96%), and Gračanica (67.53%). A relatively high share of Serbian population is also recorded in three additional municipalities: Novo Brdo (46.40%), Klokot (46.05%), and Štrpce (45.30%). These ten municipalities are home to 57,758 Serbs, accounting for 91.45% of the total Serbian population in Kosovo and Metohija. They represent the core local communities of the Serbian population, where conditions for survival, everyday life, employment, and institutional organization are more favourable compared to other parts of Kosovo and Metohija. In contrast, no Serbian population has been recorded in four municipalities (Mališevo, Junik, Mamuša, and Đeneral Janković).

In addition to the aforementioned municipalities, 5,399 Serbs live in a spatially dispersed pattern across 136 rural

settlements located outside the ten municipalities with the most pronounced Serbian presence. These settlements can be regarded as enclaves, i.e., spatially separated and often isolated communities of the Serbian population that are weakly connected to other Serbian settlements and institutional centers. The enclaves are distributed across several parts of Kosovo and Metohija, forming three main spatial zones: an eastern zone in the broader area of Gnjilane and Kosovska Kamenica; a central zone encompassing Obilić, Vučitrn, Kosovo Polje, Lipljan, and the suburban settlements of Priština; and a western zone covering Istok, Klina, Peć, Đakovica, Dečani, and Orahovac. In a large number of these settlements, the Serbian population is very small: in 62 of the 136 settlements there are fewer than five Serbs, while in 110 settlements fewer than 50 Serbs are recorded. Settlements with more than 100 Serbs occur in only 14 cases, indicating pronounced demographic fragmentation and a high degree of spatial vulnerability of the enclaves.

Intensive ethnic and spatial-demographic transformations in Kosovo and Metohija have also led to significant functional, administrative, and governance changes. Following the conflicts at the end of the twentieth century, the northern part of Kosovska Mitrovica began to develop as an administrative, educational, cultural, healthcare, and economic center of the Serbian community in Kosovo and Metohija (Vukoičić & Milinčić, 2020). Despite numerous political, security, and institutional constraints, the northern part of Kosovska Mitrovica has retained its role as the most important urban center of the Serbian population in Kosovo and Metohija. Its significance stems from the concentration of the aforementioned functions, which extend well beyond the local level and encompass broader areas inhabited by the Serbian population. The university and healthcare center in the northern part of Kosovska Mitrovica represent institutions of particular importance for the Serbian community, as their services are used by populations from various parts of Kosovo and Metohija.

From the perspective of spatial integration, the accessibility of the northern part of Kosovska Mitrovica is of particular importance, as it represents one of the key reference points for meeting the daily, occasional, and institutional needs of the Serbian population. Accordingly, the transport accessibility of the northern part of Kosovska Mitrovica is treated in this study as an important indicator of the spatial and functional integration of the Serbian population. In addition to the northern part of Kosovska Mitrovica, Gračanica and Štrpce also play a significant but more spatially and functionally limited role, serving as local centers of administrative, educational, healthcare, cultural, and service functions for the Serbian population in central and southern Kosovo and Metohija. For this reason, these three locations are treated in the analysis as reference centers for assessing the temporal and spatial accessibility of Serbian settlements and enclaves.

A detailed geospatial analysis reveals a pronounced relationship between the routes of state roads and the areas in which the Serbian population has persisted in Kosovo and Metohija. The results indicate that Serbian communities and enclaves are largely dependent on the state road network, which constitutes the basic infrastructural framework for their mutual connectivity and functional integration. An average of three state roads passes through the territory of the ten municipalities with the most pronounced Serbian presence, while 114 out of 136 analysed Serbian enclave settlements, or approximately 84%, are located directly adjacent to a state road corridor. The remaining 22 enclave settlements are situated in the immediate vicinity of the state road network, at a distance of less than 5 km. These indicators suggest that the spatial distribution of Serbian settlements is strongly associated with the layout of major transport corridors.

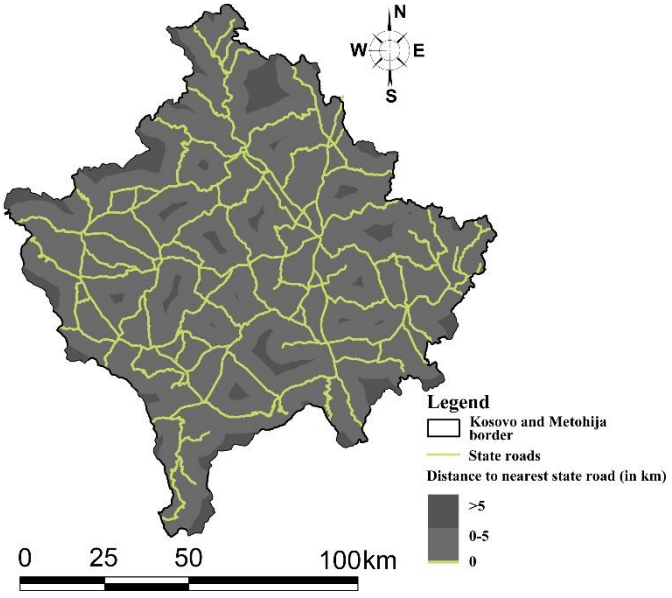

Figure 4. Buffer analysis of distance from state roads in Kosovo and Metohija. Source: author's elaboration.

Furthermore, the buffer analysis of distance from state roads shows that only 7.96% of the territory of Kosovo and Metohija is located more than 5 km from the state road network, with these areas consisting predominantly of mountainous terrain (Figure 4). This finding indicates a relatively high level of territorial coverage by state roads. However, it also demonstrates that mere physical proximity to the road network is not, in itself, a sufficient condition for full functional integration. Consequently, the subsequent analysis focuses on the spatial and travel-time accessibility of the principal Serbian centers, measured along the state road network.

Viewed as a whole, municipalities with a Serbian majority population and most Serbian enclaves exhibit a

relatively high degree of mutual connectivity. The northern, central, eastern, and southeastern parts of Kosovo and Metohija, which largely belong to the physical-geographical region of Kosovo, demonstrate favourable accessibility to the principal centers of concentration of the Serbian population. Most Serbian settlements in these areas are located within accessibility zones of up to 45 minutes of travel time (Figure 5) and within 30 km of the selected reference centers (Figure 6). These areas are favourably positioned within the functional catchment areas of the northern part of Kosovska Mitrovica, Gračanica, and Štrpce, indicating a higher degree of spatial and functional integration.

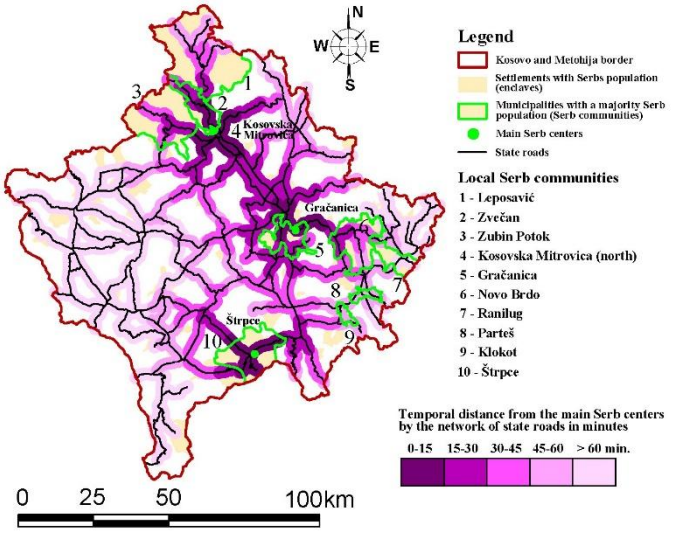

Figure 5. Travel-time accessibility model. Source: author's elaboration.

This spatial pattern is particularly evident in the connectivity of Leposavić, Zubin Potok, and Zvečan with the northern part of Kosovska Mitrovica, as well as of Novo Brdo, Ranilug, Lipljan, Kosovo Polje, and the enclaves of central Kosovo with Gračanica. Settlements located within these zones benefit not only from favourable physical accessibility to the reference centers but also from stronger functional linkages to educational, healthcare, administrative, and service facilities that are essential for the everyday life of the Serbian population.

In contrast, Metohija stands out as an area characterized by a lower degree of integration of the Serbian population and more pronounced peripherality. This position is primarily attributable to the absence of a major urban and institutional center with a substantial concentration of Serbian population in Metohija, as well as to the fact that Serbian communities in this part of Kosovo and Metohija are largely organized into small, spatially dispersed, and demographically weak enclaves. Furthermore, their greater distance from the principal Serbian centers—the northern part of Kosovska Mitrovica, Gračanica, and Štrpce—contributes to a lower level of spatial integration.

From a demographic perspective, Serbian enclaves in Metohija account for a relatively small share of the total Serbian population in Kosovo and Metohija. According to the analysed data, 1,024 Serbs live in 53 settlements in this part of the Province. Although 45 settlements, or 84.9%, are located directly along the state road network, 38 settlements, or 71.7%, with 653 inhabitants, are situated beyond the adopted thresholds of favourable accessibility to the principal Serbian centers. This confirms the more pronounced peripheral position of Metohija, while also indicating that physical proximity to the state road network does not necessarily imply a high degree of functional accessibility. However, due to the relatively small number of Serbs living in Metohija, the population located beyond the adopted accessibility threshold accounts for only about 1.0% of the total Serbian population in Kosovo and Metohija. Therefore, although Metohija represents the most peripheral part of the analysed Serbian settlement pattern, the vast majority of the Serbian population in Kosovo and Metohija remains within areas of more favourable transport accessibility and a higher degree of spatial integration.

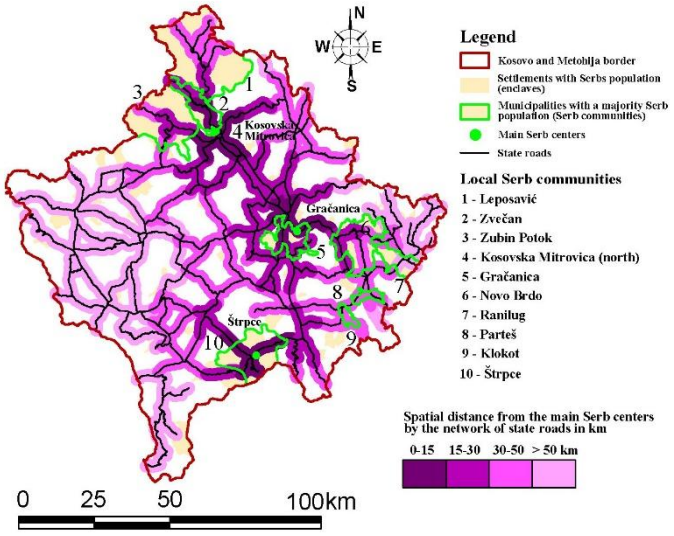

Figure 6. Spatial (isotel) accessibility model based on the state road network in Kosovo and Metohija. Source: author's elaboration.

The most pronounced peripherality is observed in the enclaves of the western Metohija zone, as well as in the enclaves located in the far south, within the municipality of Dragaš. These areas are situated at distances ranging from 50 to 100 km from the principal Serbian centers and require more than 60 minutes of travel time, based on the adopted average travel speeds on state roads. In accordance with the adopted accessibility categories and contemporary approaches in

accessibility research, these areas may be classified as peripheral, remote, and weakly spatially integrated.

According to the analysed indicators, these zones stand out as functionally more vulnerable segments of the Serbian settlement area, characterized by greater spatial isolation and more limited access to institutional and service centers.

In contrast, the enclaves of the eastern and central zones are predominantly located within 30 km and inside the 45-minute travel-time isochrone of the selected reference centers, indicating a higher degree of their spatial and functional integration. This difference confirms that proximity to the state road network plays an important role; however, the level of integration of Serbian settlements can be assessed more accurately only when considered in conjunction with travel-time and spatial accessibility, as well as the presence of Serbian urban and institutional centers.

In summary, the results of the GIS analysis indicate that the spatial integration of Serbian communities and enclaves cannot be interpreted solely on the basis of their physical proximity to the state road network. Rather, it is primarily determined by their travel-time and spatial accessibility to the principal Serbian centers. It is precisely the combination of location in relation to the road network, demographic concentration, and the functional role of the reference centers that enables a more comprehensive assessment of the degree of spatial integration of the Serbian population in Kosovo and Metohija.

Certain limitations of the research should also be noted. The accessibility analysis is based on the state road network and does not include local roads, which may be important for the everyday mobility of smaller and more dispersed settlements. In addition, the model does not account for real traffic conditions, road surface quality, weather conditions, security factors, or possible administrative delays. Finally, the demographic component of the analysis is based on the 2011 census dataset and therefore does not include more recent demographic changes that may have occurred after the census. Despite these limitations, the applied approach provides a consistent spatial framework for assessing the relative accessibility and spatial integration of Serbian settlements and enclaves in Kosovo and Metohija.

CONCLUSION

The conducted analysis demonstrated that the state road network plays a significant role in connecting Serbian communities and enclaves in Kosovo and Metohija. The high degree of correspondence between the routes of state roads and the areas in which the Serbian population has persisted indicates that this network constitutes the principal infrastructural framework of their mutual connectivity. Particularly noteworthy is the fact that an average of three state roads passes through the municipalities with the most pronounced Serbian presence, while 114 out of 136 analysed Serbian enclave settlements, or approximately 84%, are located directly adjacent to a state road corridor, with the remaining 22 settlements situated at a distance of less than 5 km from the network.

However, the results indicate that physical proximity to the road network alone is not a sufficient condition for full functional connectivity. The level of accessibility of Serbian settlements also depends on travel-time distance to the principal Serbian centers, the demographic concentration of the population, and the availability of institutional, educational, healthcare, and service functions. In this regard, the northern, central, eastern, and southeastern parts of Kosovo and Metohija exhibit a more favourable position, whereas Metohija stands out as a more peripheral and functionally vulnerable area.

Based on the obtained results, it can be concluded that state roads in Kosovo and Metohija perform not only a transport function but also a pronounced integrative role. They provide access to centers of education, healthcare, administration, and other essential services, thereby constituting an important prerequisite for maintaining spatial connectivity, supporting everyday functioning, and contributing to the potential long-term sustainability of Serbian communities in Kosovo and Metohija. The scientific contribution of the paper lies in the methodological integration of demographic data, state road network data, and GIS-based accessibility modelling, which enables a more precise analysis of the spatial integration of fragmented Serbian communities and enclaves in Kosovo and Metohija.

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