

Spatial differentiation of daily commuting to work in Slovakia by modes of transport

Štefan GÁBOR, Loránt PREGI

Abstract: *Commuting to work is one of the most important forms of spatial mobility of the population. The mode of transport is one of its key characteristics. However, its spatial variability has so far been little explored, which is also due to the lack of reliable statistical data. The census in Slovakia in 2021 addressed this issue, offering an opportunity to examine the use of individual modes of transport at various spatial levels, and in relation to the characteristics of commuters. Therefore, the aim of this paper is to evaluate the spatial differentiation of intra-municipal and inter-municipal daily commuting to work according to the main mode of transport used, and in relation to the age of the commuters. The basic spatial framework of the study is the system of functional urban regions in Slovakia. By applying statistical methods and cartographic visualization, the results demonstrating the spatial variability in the mode of transport were achieved. Regularities were also identified in relation to various age categories of commuters. In addition, the study indicated a significant influence of the social-economic conditions and orography of specific territories on the preference for commuting mode. The results have the potential to contribute to more effective spatial planning or investments in various forms of transport infrastructure. At the same time, it is an initial study that encourages the examination of spatial patterns and forms of daily commuting in relation to other characteristics of commuters or geographical characteristics of the affected areas. The knowledge from this study is partially transferable to countries where similar statistical data are not available.*

Keywords: *daily commuting to work, mode of transport, age, commuter, functional urban regions, Slovakia*

Introduction and theoretical background

There are several basic types of spatial mobility, with migration and commuting being the most common. While migration contributes to a permanent or long-term change in a person's residence, commuting is characterized by daily periodicity or periodicity with other frequencies. Various forms of commuting can be distinguished based on the type of destination. This includes commuting to school, work, services, healthcare, etc. Nonetheless, commuting to work and school are the most significant. They involve the largest number of commuters and, in many countries, including Slovakia, are recorded directly in the population censuses. Important commuting parameters include the time and distance that the commuter overcomes to reach the destination. When it comes to commuting to work, the destination is a place of employment.

Despite the fact that much attention is paid to the issue of commuting, there are basically no works that deal with its definition. We have encountered the concept of work commuting as such in literature since the mid-19th century (cf. Muller 2004). Kung et al. (2014) distinguish between the concepts of commuting and commuting to work. Commuting is wide concept including any repeated journey and spatial interaction between two or more places.

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However, when commuting to work concerned, these places have to be defined by the address points of the residence and the workplace, so they should be fixed (cf. Gregory et al. 2011). Murphy (2016) emphasize the frequency as a substantial feature of commuting. According to him, commuting to work should be very frequent, ideally every day. Various frequency of commuting to work is also covered by the data from censuses in Slovakia (SOSR 2000, 2021) allowing for separate evaluation of daily commuting to work.

Michniak (2005a) distinguishes two approaches to the study of commuting to work. They are generally based on the type of data used and the subsequent method of their analysis. The first approach is objective-quantitative and based on detailed statistical data. The analysis focuses mainly on the structural characteristics of the population performing a selected type of spatial mobility, also taking into account the number and distribution of employment opportunities. The second type is a qualitative approach, which reflects the subjectivity of the respondents, expressed in the form of questionnaires or surveys, etc.

In terms of the structure of commuters, research emphasises characteristics such as age (McQuaid and Chen 2011, Horner, Schleith and Widener 2015, Newbold 2022), gender (Cristaldi 2005, Silveira Neto, Duarte and Páez 2015, Beige and Axhausen 2017), race and ethnicity (Jang and Yao 2014, Preston and McLafferty 2016, Hu 2021), education (Charreire et al. 2021, Vrtiška and Maier 2022), structure by economic sector of employment (Yue and O'Kelly 2023a, Yue and O'Kelly 2023b). Very often, commuting to work is assessed on the basis of its relations with other geographical phenomena. As a form of spatial mobility, it is usually studied together with its other forms, especially with migration (Renkow and Hoover 2000, Brueckner and Šťastná 2020, Kornstad, Skjerpen and Stambøl 2023).

Patterns of migration and commuting to work in the post-socialist countries of Central and Eastern Europe changed significantly after 1989. The main direction of migration and commuting to work in socialism was rural-to-urban (Szelényi 1996). In the post-socialist era, rural-to-urban migration changed into the suburbanization which significantly contributes to an increase in the volume of commuting to work (Tammaru 2005, Novák and Sýkora 2007, Lukič 2009, Krisjane et al. 2012) and also increases the importance of inter-municipal cooperation, especially in metropolitan regions (cf. Kunc et al. 2023).

The basic variables that can be used to describe the commuting to work are distance and time. Commuting expresses an effort to optimise the spatial mobility of individuals, i.e. to maximise profits or benefits and minimise costs (e.g. transport costs, reducing commuting time and distance), which as a result provides individuals a satisfaction (Székely 2006). Rouwendal and Rietveld (1994) also emphasize the importance of this issue, because the growth in the length of commuting flows has also become a subject of political interest due to the traffic situation and the volume of traffic flows that periodically concentrate at a certain time of day and cause congestion problems as well as an environmental burden. Numerous papers address distance as one of the most important features of commuting to work (e.g. Helminen and Ristimäki 2007, Sandow and Westin 2010, Raza et al. 2021).

The commuting to work is also substantially affected by the way in which residents are able to get to the place of work, i.e. the mode of transport used. When residents walk to work, it brings a range of environmental, social and health benefits (Liu, Zhou and Xiao 2021). Walking can also be a certain prototype of a simple, convenient, cheap and sustainable mode of transport. It contributes to easing traffic congestion, reducing emissions and improving social interactions (Litman 2010, Maizlish, Linesch and Woodcock 2017). However, the distance that can be reached by walking is limited. Several of the benefits of walking are common with commuting by bicycles (Kroesen and Handy 2014, Jia and Fu 2019, Banerjee et al. 2022) or currently also scooters (Caspi, Smart and Noland 2020, Edel, Wassmer and Kern 2021). Another traditional modes of commuting, especially for longer distance, are cars (Turgeman-Lupo and Biron 2017, Pfertner et al. 2022), trains (Jensen 2020, Phan et al. 2022) or public transport generally (Wang et al. 2021).

In addition to the structural characteristics of commuters, the preference of commuters also plays an important role in commuting. It is a set of several factors such as mode of transport, time, distance, costs, traffic situation, safety or quality, but also psychological and personality factors that affect commuters and are manifested in various commuting patterns. When mode of transport concerned, scholars often address preferences for choosing a car and public transport – train, bus, metro (Calastri, Borghesi and Fagiolo 2019, Hansson et al. 2019, Urbanek 2021), or alternative transport – walking, bicycle, scooter (Hatamzadeh, Habibian and Khodaii 2020, Ek, Warell and Andersson 2021, Esztergát-Kiss, Tordai and Lizarraga 2022).

In Slovak geographical works, commuting to work is most often presented in the context of changes between censuses (Michniak 2005b, 2005c, 2016a, Székely 2006), focusing on the structural characteristics of commuters, commuting to economic sectors, larger commuting centres (over 500 commuters) or changes in regional and settlement structure. Special attention was also paid to the research of commuting in regions of poverty (Michniak 2016b). Michniak (2003) confirms the number of commuters decreases with the increase of the distance of commuting flow. Beside the duration of the transport it can be related with the costs of transport. Study by Horňák (2012) is dealing with transport costs as a barrier to commuting is the work. It reveals that the costs of the transport in a region with relatively low wages become a barrier to commuting in the distance between 30 and 40 km. This causes that as the distance from the commuting center increases, the proportion of people for whom it is more efficient to be unemployed than to be a commuter increases.

None of the scientific geographical studies published so far in Slovakia addressed the modes of transport in the daily commuting to work comprehensively. Thus the main goal of this paper is to assess the intra-municipal and inter-municipal daily commuting to work in Slovakia by mode of transport, based on data from the 2021 population and housing census at the level of functional urban regions.

Study area, data, methods

Commuting patterns can be studied within various spatial units or regional systems. Usually, these are the administrative or statistical units, i. e. districts and counties. Several authors (Drewett and Rossi 1981, Korec 2011, Novotný 2014) agree that these administrative units on a regional level often act as a constraint in the sense of studying processes in residential systems, they are artificially set without regard to geographical aspects and ignore the existence of functional relationships in space. Since commuting-to-work data were used to delimit functional urban regions (FURs), we propose to use these regions instead of the standard administrative units. Several authors (Bezák 1990, 2000, 2014, Novotný 2014, Halás et al. 2014, Klapka and Halás 2016) consider the concept FURs to be the most appropriate method and spatial unit in the study of individual population mobility and related phenomena.

In Slovakia Prof. Bezak delineated six FUR systems (Bezák 1990, 2000, 2014). The result of regionalisation from the 2001 census data (Bezák 2014) are three systems, marked with the letters A, B and C. All systems were created on the basis of two conditions based on the definitions of daily urban systems – internal coherence and external closure in terms of daily commuting to work. In the regionalisation of types A and B, a further condition was applied in addition to this condition, i.e. the regions were allocated taking into account the minimum number of inhabitants, expressed by the number of inhabitants of the region in the 2001 census. In the FUR 01-B regional system, the minimum size of 15,000 inhabitants is applied and the result is 62 FURs. In our study, based on the above FURs characteristics, we consider the FUR 01-B system to be the most appropriate to use (fig. 1).

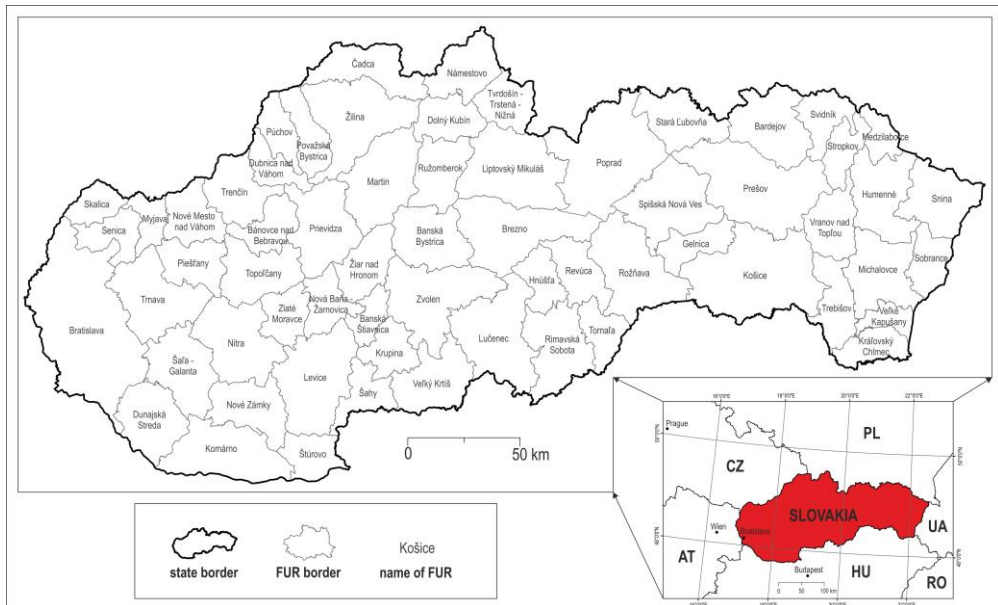


Fig. 1. Functional urban regions of Slovakia (system FUR 01-B); Source: Bezák (2014a)

In addition to the FURs delimited above, there are other systems, e.g. approximated FURs, which Korec (2009, 2011) has used in his works. They were created by modifying the FUR 91-A system, i.e. based on the 1991 census data. Other FUR systems were delineated by prof. Halás. The basis for editing and delimiting the FUR was the methodology of Coombes et al. (1986), known as CURDS (as well as Bezák's FUR), based on data from 2001 (Halás et al. 2014). The result of his delineation is three systems, referred to as functional commuting regions (marked as FRD-1, FRD-2, FRD-3). FUR delimited on 2011 census data is used by Halás et al. (2019), Halás and Klapka (2020) and creating another system that can be used in geographic research.

Despite the systems using more recent data, we have chosen FUR 01-B system and there are several reasons for this. The first is the fact that the 2011 census in Slovakia was accompanied by a major media scandal in terms of a threat to respondents' anonymity and also a negative political campaign, which may have worried respondents and significantly influenced the census results. Benkovičová (2013) addresses this issue in more detail in her paper. Bezák (2014a) also agrees with this statement and at the same time provides critical remarks that can be made about all previous censuses and that may affect the results obtained. The FUR system by Halás et al. (2019) is also based on data from 2011, but according to them there are no major differences compared to regions from 2001 data. Among other things, FUR by Halás et al. 2014 modify the CURDS methodology in several steps. The most important feature is the use of other algorithms to calculate the constraint function. It is defined by the minimum size and the closure of the region. When interpreting the resulting regions, it is also important to mention that the municipalities included in the process of the calculation algorithm are assigned according to the principle of connection to the region and not to the city or the centre of the region. From this point of view, there may be a situation where municipalities that lie on the border of the influence of two identical units can be assigned once to one and once to the other unit. These facts are manifested in some border situations and have an impact on the course of the borders of the regions themselves.

The issue of research of commuting to work is related to the availability of relevant statistical data. The only direct source that collects and publishes data for the Slovak Republic is the Statistical Office of the Slovak Republic, which carries out regular population censuses at ten-year intervals. This paper uses data from the last census from 2021 (SOSR 2021). Regarding to the population census, we must talk about two important remarks. The first is the fact that some aspects of commuting were not recorded compared to the last census in 2011 (e.g. the mode of transport we investigated), which makes it impossible to compare with the results of previous censuses. The second note is that the data collection in the last census was carried out at the time of the COVID-19 pandemic, which could have distorted the results to some extent.

The difference between the results of the 2011 and 2021 census lies in the address of the permanent or current residence of the inhabitants. In 2011, after some ambiguities, the Statistical Office of the Slovak Republic decided to publish the results only for the addresses of permanent residence of residents, although the current place of residence was also determined during the census itself. The 2021 results already reflect the commuting flows of the resident from the place of current and non-permanent residence to the place of employment. In our opinion, this could reflect more realistic spatial patterns, because the address of the current residence may not be the same as the place of permanent residence of the commuter.

Another critical methodological aspect concerns the procedure utilized to identify primary modes of transportation within the census questionnaire. Respondents were instructed to indicate only one mode of transport that they use when commuting to work, with a specific emphasis on the predominant mode along the most extended segment of their journey. In results interpretation, it is important to rigorously address potential inconsistencies, especially in cases where commuters use multiple modes of transport – an aspect that is not comprehensively accounted for in the census results.

Database contains information on commuting of the population from the places of current residence to the places of employment at the level of municipalities in Slovakia (i.e. also small commuting flows between municipalities of less than 10 trips), which are marked with their own code. The database also contains information on the purpose of commuting (to work, to school or unknown). Periodicity is expressed on a daily basis, not daily or as not recorded. The database also records selected structural characteristics of the commuters – age (5-year categories), gender, and modes of transport used on the journey to work. Within mode of transport in database from Statistical Office we register 8 categories - car, train, urban public transport, public transport, bicycle/scooter, walking, other and unknown. All this information is expressed by the number of commuters in the municipalities (LAU2) of Slovakia.

Since the data are only available at the level of the municipalities, the first step was to aggregate them to the level of the FURs. We implemented this step by using the function of linking the known municipality code to the municipality codes in the FUR 01-B system. We then filtered the data. We selected only data for registered daily commuting to work. We only monitored flows to municipalities in Slovakia where an address was given – we deleted flows heading abroad, without providing an address or even undetected flows.

In the last step, we filtered out flows that reached a daily distance of more than 100 km within the municipalities of Slovakia. We used the Euclidean distance, which is one of the most common and easiest methods to determine the distance (Wang, Zhang and Feng 2005). This method is commonly used in school commuting and commuting to work research (Sandow and Westin 2010, Buczkowska et al. 2019). A very important step was to determine the distance limit in kilometres, where we no longer assume actual daily commuting to work. We determined it using the 100 km limit. This distance is also used by Bezák (2014), who applied it when delimiting the FURs of Slovakia on 2001 census data. In FURs with a pronounced

relief (e.g. mountainous regions with natural barriers), the Euclidean distance may misestimate the actual commuting distances, but we consider it sufficient to eliminate unrealistic daily commuting distances (more than 100 km). Helminen and Ristimäki (2007), who applied it in the research of commuting flows in Finland, also consider the limit of 100 km for daily commuting as limiting. According to their research, this distance creates a very strong assumption among commuters that they will either secure accommodation close to work or reduce the commuting by working from home (telework).

Even in our database, quite a few flows appeared over very long distances, e.g. between Bratislava and Košice, which commuters have to manage daily. Another problem was related to various municipalities or settlements with the same name (e.g. the settlement of Nová Polianka in the town of Vysoké Tatry in the Poprad district, and the Nová Polianka municipality in the Svidník district). Thus, there were errors in the census data, where the commuting flow was clearly attributed to the wrong spatial unit. We tried to identify such errors on the one hand by Euclidean distance, on the other hand by individual control of spatial units with identical names. We have corrected the detected errors, but it cannot be ruled out that there are still some incorrectly attributed streams in the database.

After editing and processing the data into the required form, we monitored daily commuting to work at the intra-municipal (within one municipality) and inter-municipal (crossing the administrative border of the municipality) level. In the case of the two largest cities in Slovakia – Bratislava and Košice, we proceeded to monitor commuting within their administrative boundaries (we did not distinguish between their urban districts even though they have a status of municipalities).

We monitored commuting to work according to the modes of transport. In this case we proceeded to aggregate the data into four categories from the original eight: 1. car, 2. public transport (bus, urban public transport system and train), 3. active form (walking and bicycle or scooter), 4. other and unknown. The designation of the third category, commuting to work by walk, by bicycle or scooter, can raise questions. Terms such as alternative form (Luiu et al. 2018), non-motorised transport mode (Rietveld 2001), healthy modes of transport (Zahran et al. 2008) are used as standard. Considering that commuters use their own physical activity on the journey to work, we have opted for the term active form of commuting.

For age, we follow three age categories: up to 34, 35-54 and 55 and more. The first category (up to 34 years) also includes commuters under the age of 18, i.e. commuters, who cannot yet hold a driving licence which affects their transport behaviour substantially. However, the volume of this age category (15-19) is very low (only 0.78% of the aggregate volume of monitored commuting flows), so their significant influence on the overall commuting patterns of the entire category up to 34 years is not expected.

It can be assumed that the majority of commuters in the category of 55 and over entered the labor market during the period of socialism. A substantial part of the 35-54 age group consists of commuters who entered the labor market in the transformational post-socialist period, and the under-34 category is represented mainly by commuters who entered it already in the post-transformation period.

In this paper the results are interpreted cartographically using a combination of choropleth map and diagrams. The size of the map diagrams expresses the number of commuters in the individual FURs (the number of commuters within municipalities or between municipalities or the number of commuters by selected age categories), and the colours of the map diagrams indicate the share of commuters by mode of transport. The maps were created in ArcMap 10.6.1 and then graphically edited in CorelDRAW X4.

Results

According to the chosen criteria, about 1.2 million trips are registered as daily commuting in Slovakia. The dominant position in terms of modes of transport is the use of the car, which is used by 57% of all commuters. In second place is the public transport (21%), closely followed by active modes of transport (walking, bicycle, scooter) with less than 20%. Another or unknown modes of transport is recorded in 1.5% of commuter flows (fig. 2).

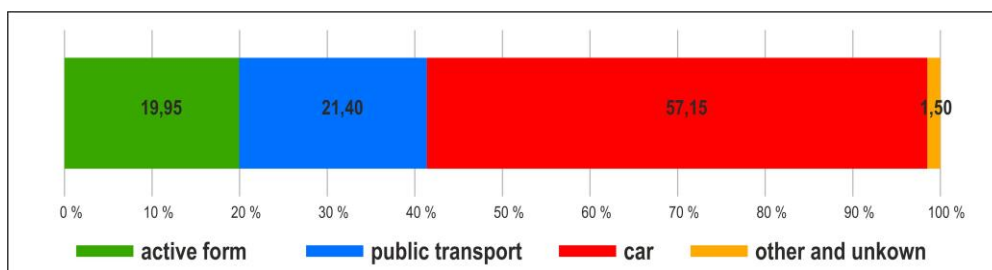


Fig. 2. Total share of commuting modes choice in Slovakia; Source: SOSR (2021)

Significant differences are recorded at the level of intra-municipal and inter-municipal work commuting by modes of transport (fig. 3). In the first case we record a total of 606,325 flows, of which most commuters use a car (42%), an active form is significantly represented (38%), and in last place is the use of public transport (18%). Inter-municipal work commuting (a total of 613,573 flows) differs from the first form by the significant use of a car (72%), second is public transport (almost 25%), and the active form occupies the last place with 2% of total flows. Tab. 1 shows more detailed information with the total number of commuters by modes of transport in Slovakia.

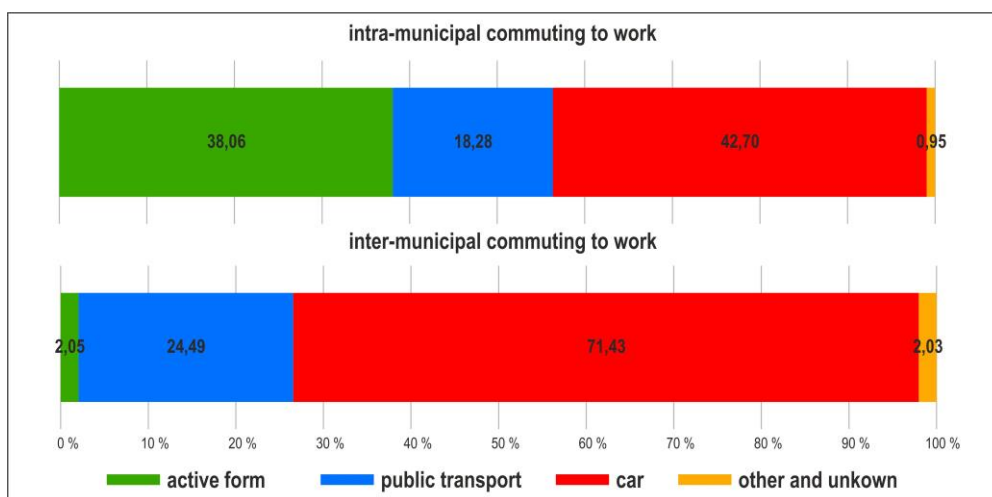


Fig. 3. Daily commuting to work by modes of transport in Slovakia; Source: SOSR (2021)

The analysis at the level of the FURs provides interesting results (fig. 4). They capture differences in the number of commuters and the modes of transport used. In the first case we observe the volume of commuters, which in the case of inter-municipal and intra-municipal transport is dominant in the FURs of the two most populous cities – Bratislava and Košice. The largest volume is also observed in the regions of the county towns (Prešov, Žilina, Nitra, Trenčín, Banská Bystrica and Trnava). In them, except for the Banská Bystrica FUR, inter-municipal commuting to work dominates. The Bratislava and Košice FURs also have

a special position, in which there is a higher proportion of intra-municipal commuting to work. On the other hand, we record three areas with the lowest volume of commuting. The first area consists of the border FURs in eastern Slovakia. The second contains the FURs located in the southern part of central Slovakia (Hnúšť'a, Revúca and Tornaľa). And the third includes regions located on the southern border of western and central Slovakia (Banská Štiavnica, Krupina, Šahy and Štúrovo).

Tab. 1. Comparison of intra-municipal and inter-municipal daily commuting to work in Slovakia by the mode of transport

Means of transport	Slovak Republic		Intra-municipal work commuting		Inter-municipal work commuting	
	Total number	% rate	Total number	% rate	Total number	% rate
Walk	187546	15,37	183077	30,19	4469	0,73
Bicycle, scooter	55810	4,57	47715	7,87	8095	1,32
Urban public transport	113455	9,30	100020	16,50	13435	2,19
Bus	119491	9,80	9917	1,64	109574	17,86
Train	28192	2,31	928	0,15	27264	4,44
Car	697162	57,15	258901	42,70	438261	71,43
Other	12307	1,01	5051	0,83	7256	1,18
Unknown	5935	0,49	716	0,12	5219	0,85
Slovakia	1219898	100,00	606325	100,00	613573	100,00

Source: SOSR (2021)

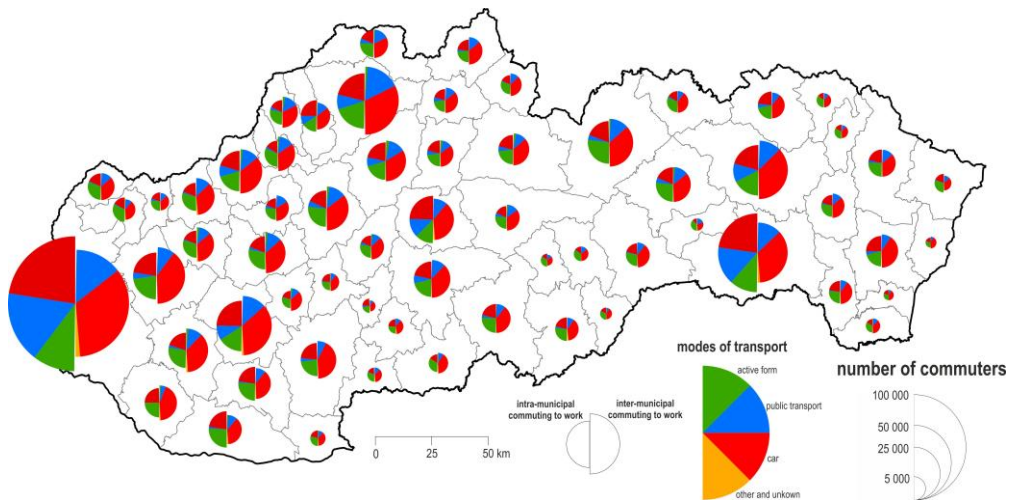


Fig. 4. Intra-municipal and inter-municipal daily commuting to work by modes of transport in Slovakia; Source: SOSR (2021)

From the point of view of the use of modes of transport, we record significant differences at the intra-municipal and inter-municipal level. In the inter-municipal commuting, in all FURs, the dominant position and percentage share is the use of car. In second place is the use of public transport. Other modes of transport have an essentially negligible share. At the intra-municipal level, the use of the car also has a dominant position, but it is closely followed by the active forms of transport. In the regions of cities and larger towns the public transport is also strongly represented. The use of an active form of transport at the intra-municipal level has the highest shares in regions characterized by the smallest volume of commuters.

Intra-municipal daily commuting to work in FURs by modes of transport

The maps below provide a more detailed view of the mode of transport. A higher proportion of car use is in the FURs of county towns and other larger towns (fig. 5). A relatively compact territory consists of the FMRs extending south from the Námestovo FUR to the Rimavská Sobota FUR, where the share of commuters by car ranges between 40 and 50%. Towards the west of this imaginary border, we do not recognize a single FUR with a share lower than 30%. The situation is different in some FURs in central and eastern Slovakia, i.e. to the east of this border. The lowest share of commuters is recorded in the Hnúšťa, Revúca, Gelnica and Svidník FURs, which are among the regions with the lowest average monthly wages in Slovakia (Michálek 2023). The exception is the Michalovce FUR, which recorded the highest share of commuters by car. This indicates that the use of a car for intra-municipal commuting to work depends on the economic conditions in individual regions. FURs with the lowest values are often referred to as peripheral (marginal), with a lack of job opportunities and a lower standard of living of the population. Another factor that could affect the use of a car is the transport infrastructure.

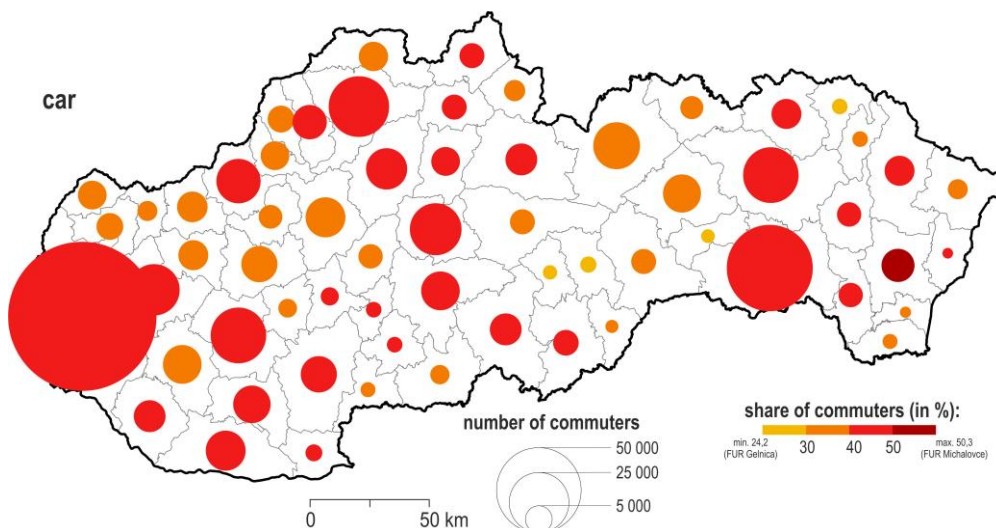


Fig. 5. Intra-municipal daily commuting to work by car in FURs; Source: SOSR (2021)

The situation is different in the way of using the urban public transport (fig. 6). Here again the Bratislava and Košice FURs come to the fore, apart from them the highest share is recorded by FURs of the county towns Prešov, Banská Bystrica, Nitra and Trenčín. In them, the infrastructure and facilities for the use of this mode of transport play an important role, which is significantly lagging behind in some peripheral, border FURs, especially in the east or south of Slovakia. Different situation is in commuting to work by bus. The highest share here is recorded by the Námestovo, Čadca and Myjava FURs, on the contrary, some FURs in the south of western Slovakia, but also those in eastern Slovakia are significantly behind. An example is the Sobrance FUR, which records the lowest share of bus commuters. Here we have to consider the relatively good functioning of the urban public transport in larger cities. In them, a significant number of commuters use this system, which is reflected in lower transport costs, reducing emissions, i.e. increasing awareness of the so-called green commuting. Among other things, there is a problem with parking in larger cities, or paid zones, which is also eliminated when using the urban public transport system, and the journey to work can be more peaceful and less expensive. In larger centers, the urban public transport system is very well timed, as evidenced by the frequent connections made several times an hour and throughout the day.

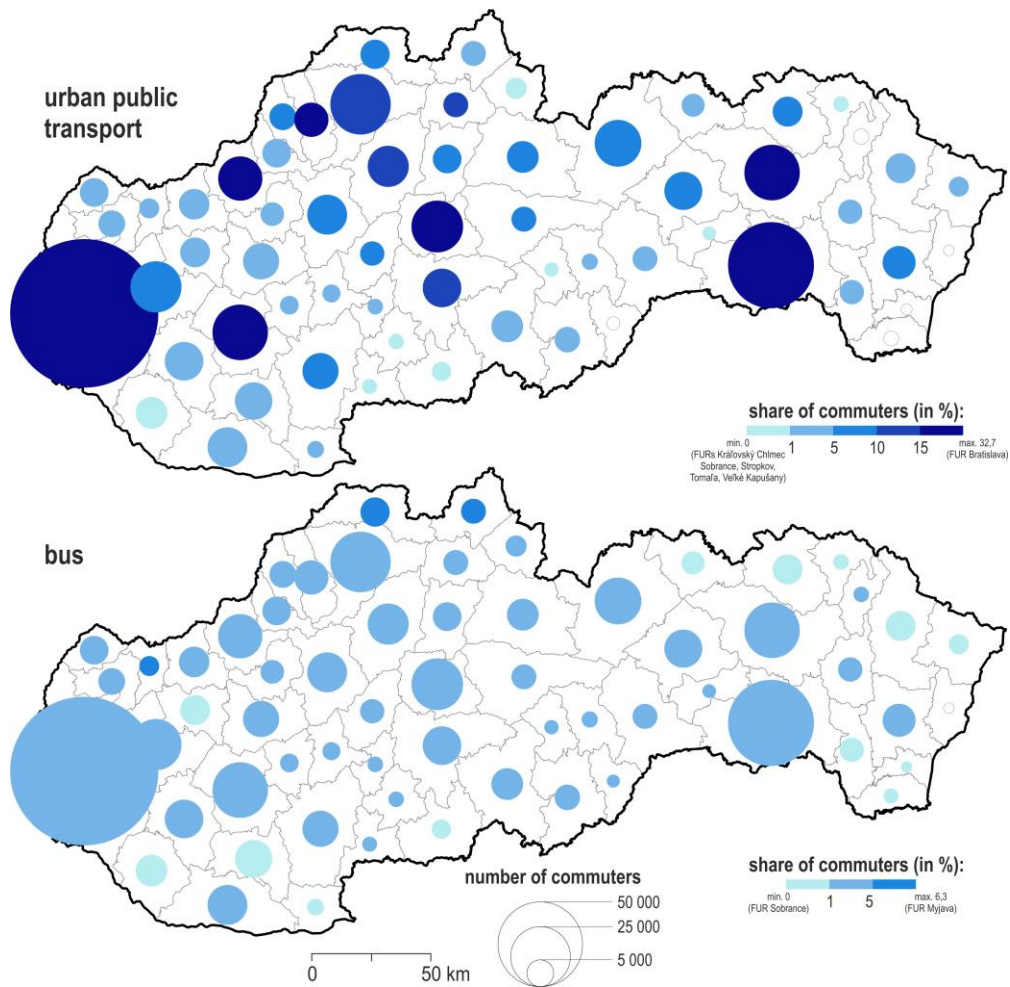


Fig. 6. Intra-municipal daily commuting to work by urban public transport and bus in FURs; Source: SOSR (2021)

An active form of commuting to work plays a strong role at the intra-municipal level. Commuting to work by walk is especially valued. It is significantly different from other modes of transport, which can be seen in the lowest values in the FURs of cities and larger towns, especially Bratislava, which even has the lowest percentage of commuters by walk. The highest shares are registered in FURs with smaller population, especially in the south of central Slovakia, in eastern Slovakia or in the northwestern part of Slovakia. Commuting to work by bicycle and scooter shows a very interesting spatial distribution (fig. 7). The highest shares of commuters are located exclusively in FURs in western Slovakia, especially in its southern part with the dominant position of the Komárno FUR, which achieves the highest share in Slovakia. The lowest shares are registered in FURs in the central part of the republic stretching towards the east. In the case of an active form, economic motivation and the reduction of transport costs can play a key role. This could explain the higher proportions of pedestrian commuters in the economically lagging FURs. Currently, the active form of transport is also relatively trendy, which has a positive effect on the environmental burden and the reduction of traffic jams in larger centers. We believe that commuters using a bicycle or scooter are also

significantly influenced by the orography, i.e. the character of the surface on which the journey to work is made. This can be seen in the distribution of the highest shares in the western and south-western parts of Slovakia, which have a flatland character compared to the northern or some central regions of Slovakia. Among other things, the infrastructure and the network of cycle paths for the use of bicycles or scooters can also play a strong factor, especially in larger towns.

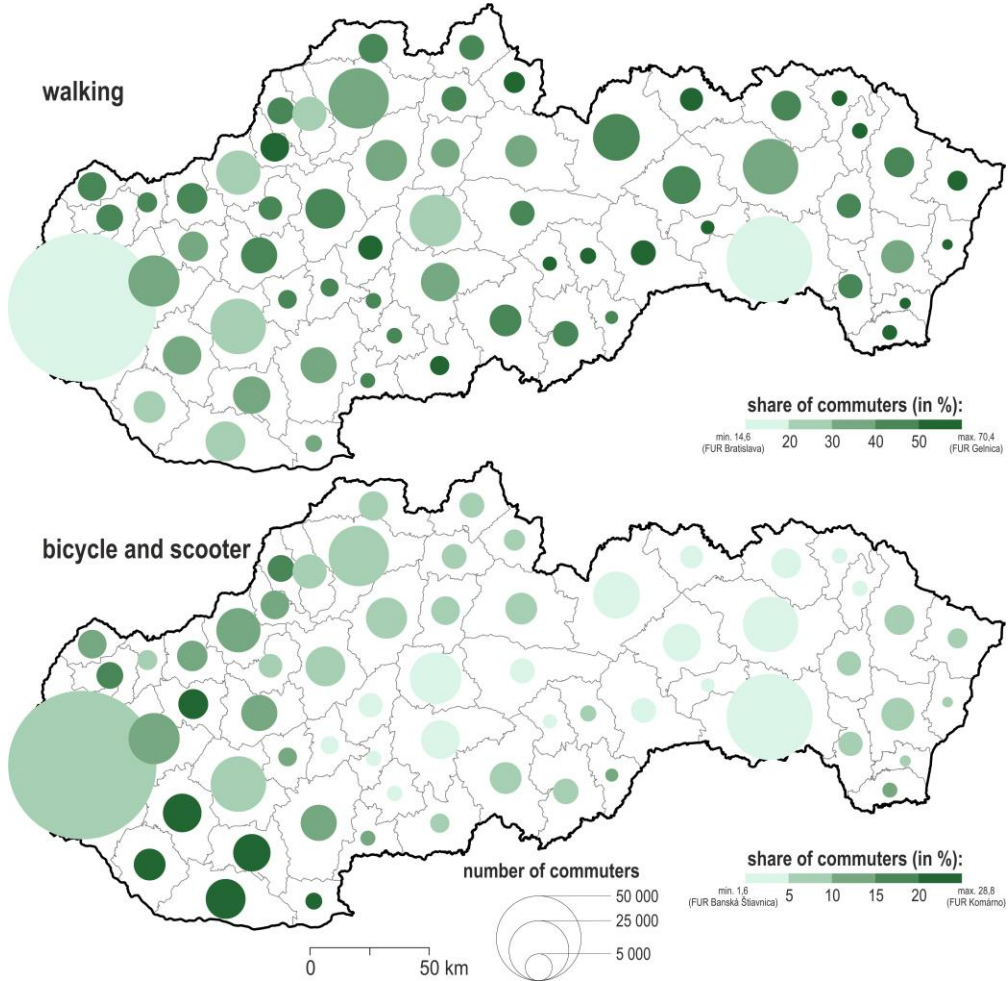


Fig. 7. Intra-municipal daily commuting to work by active form in FURs;
Source: SOSR (2021)

Inter-municipal daily commuting to work in FURs by modes of transport

The use of a car at the inter-municipal level is significantly different from the intra-municipal level (fig. 8). While in the first case FURs with a higher number of inhabitants dominated, in this case the highest share of commuters is in less populated regions in southern Slovakia and in the border regions of eastern Slovakia. A more significant cluster of regions with the lowest share is located in the north (the Žilina, Čadca and Púchov FURs), but the lowest share of commuters by car was recorded in the Gelnica FUR. In the vast majority of FURs of Slovakia, the share is more than 70% of commuters. In this case, it should be borne in mind that commuting to work over longer distances in this way is much more convenient for commuters and that less

time can be spent travelling to or from work. Among other things, this form of long-distance transport may also be economically advantageous, especially for commuters who use so-called car-pooling, where the cost of the journey is offset between the passengers in the car. In some regions, the good transport connections and quality transport infrastructure may also be an important factor.

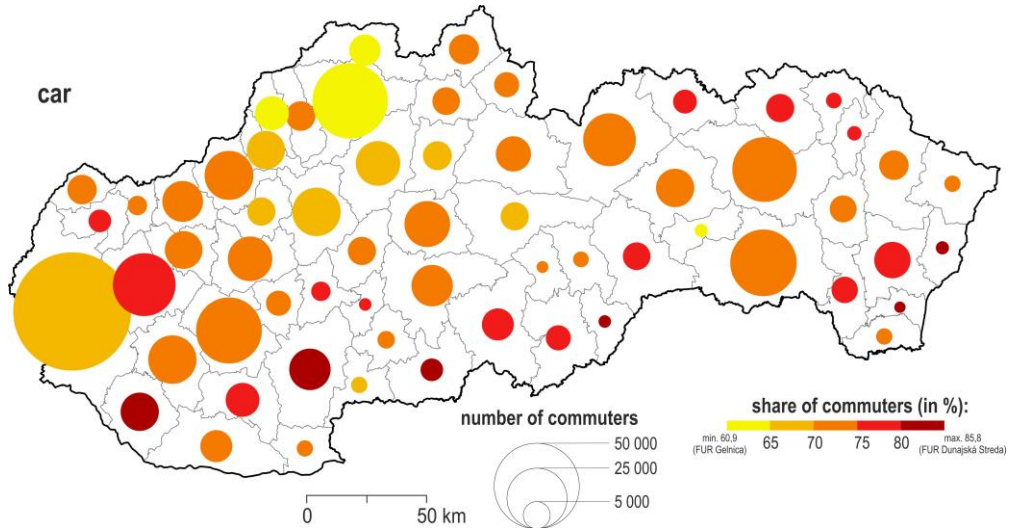


Fig. 8. Inter-municipal daily commuting to work by car in FURs; Source: SOSR (2021)

The use of the urban public transport on inter-municipal commuting to work may seem unjustified at first glance, but in some cases it works normally in the hinterland of larger towns, or traffic to adjacent municipalities or city districts (fig. 9). For this reason, we record the highest share in the Prešov, Spišská Nová Ves, Nitra, Prievidza, Martin and Čadca FURs. In this case, the infrastructure seems to play a very important role, i.e. a good transport system in the surrounding municipalities and the connection of the municipalities with urban public transport with the of the FURs' cores. We also specifically monitor daily commuting to work by bus. The most significant clusters with the highest proportion of commuters are recorded in the border regions with the Czech Republic, stretching from the Skalica FUR towards the east to the Tvrdošín-Trstená-Nižná FUR. They are followed by the Nitra, Piešťany and Prievidza FURs, and the highest share in Slovakia is recorded in the Bánovce nad Bebravou FUR. The lowest share is recorded in the Dunajská Streda FUR. In this case, commuting flows at the inter-municipal level are also recorded, which is precisely related to the existence of suburban connections, and thus they become available and relatively advantageous and comfortable for commuters.

When commuting by train, the Gelnica, Košice, Humenné and Kráľovský Chlmec FURs in eastern Slovakia show the highest share. They are followed by FURs in the north-central part – Čadca, Žilina, Martin and Ružomberok FURs, and the Bratislava FUR also records a significant share. FURs with the lowest share are those in which the train infrastructure is significantly limited. In some FURs there is no train service – e. g. the Sobrance FUR – while in others it is restricted by the relatively limited number of scheduled connections, which only run a few times a day due to the low volume of traffic and capacity utilisation. This also applies to bus transport. In this case, it is also possible to see the connection between commuting to work by bus and train, as the lack of infrastructure in one or the other case can replace their use in FURs. This can be seen at the level of some FURs in central or eastern Slovakia, where the train infrastructure is missing or is insufficient and commuting by bus shows higher proportion there.

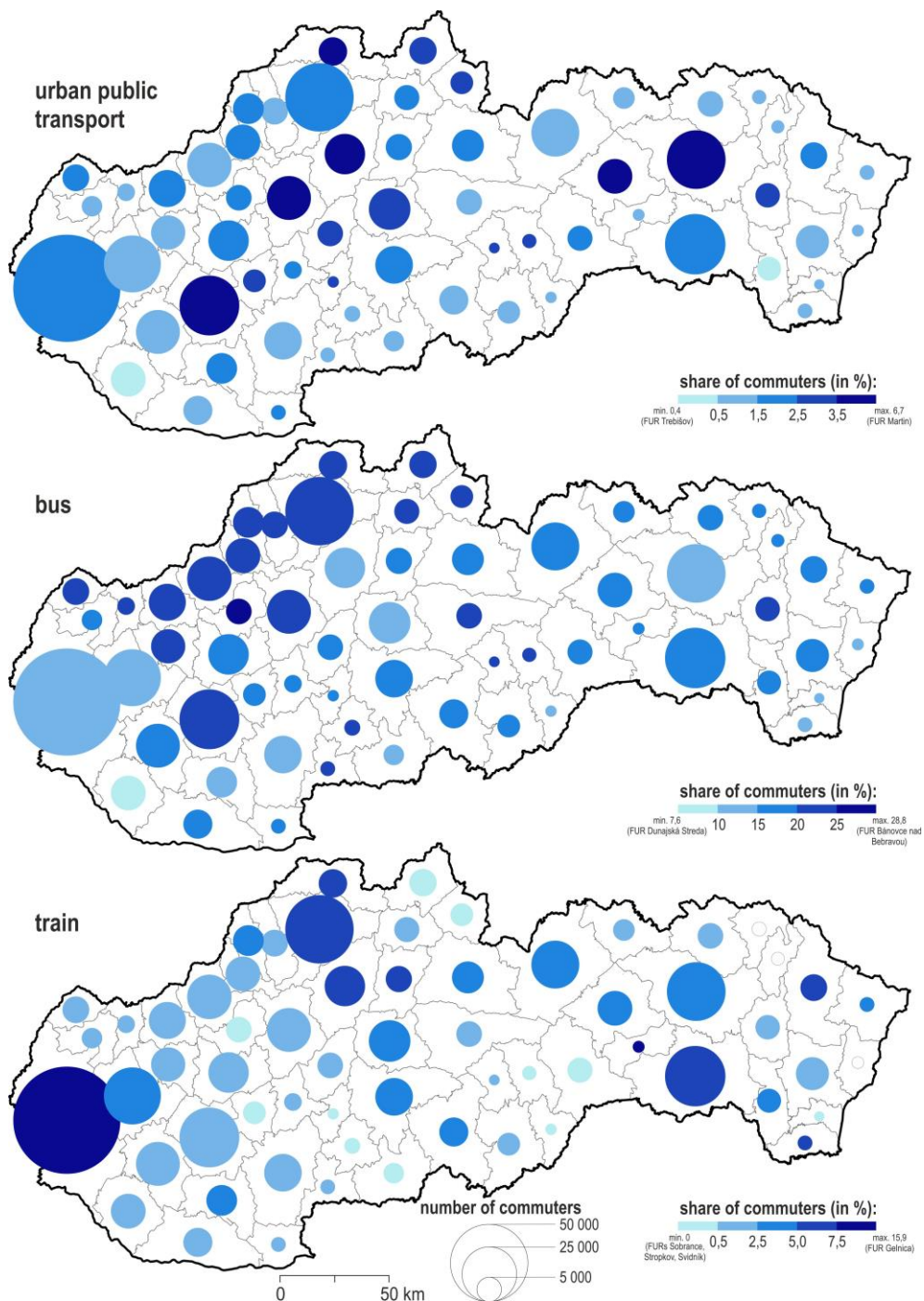


Fig. 9. Inter-municipal daily commuting to work by urban public transport, bus and train in FURs; Source: SOSR (2021)

The active form of transport on foot shows a gradient from south to north, as evidenced by the FURs with the lowest values located in the south-western and south-eastern parts of Slovakia (fig. 10). A share of such commuting rises towards the central and northern parts of Slovakia, where the highest values are recorded in the Púchov, Martin, Ružomberok, Liptovský Mikuláš, and Spišská Nová Ves FURs. Commuting to work by bicycle or scooter shows the highest values in western Slovakia, stretching from the south to the north and east, i.e. from the Dunajská Streda FUR to the Ružomberok FUR. Regions towards the east (except for the Kráľovský Chlmec and Veľké Kapušany FURs) show lower values. When pedestrian commuting to work at an inter-municipal level the settlement structure has to be considered. Especially in Martin, Ružomberok, Liptovský Mikuláš or Spišská Nová Ves FURs the surrounding municipalities are relatively close to the centre of the region, which makes walking to work possible for relatively high proportion of commuters. In the case of commuters by bicycle or scooter orography seems to be much more important factor with flatland regions recording the highest proportions of this commuting mode. Warmer climate in southern Slovakia can also play role, as well as the economic motivation of commuters especially in poorer areas.

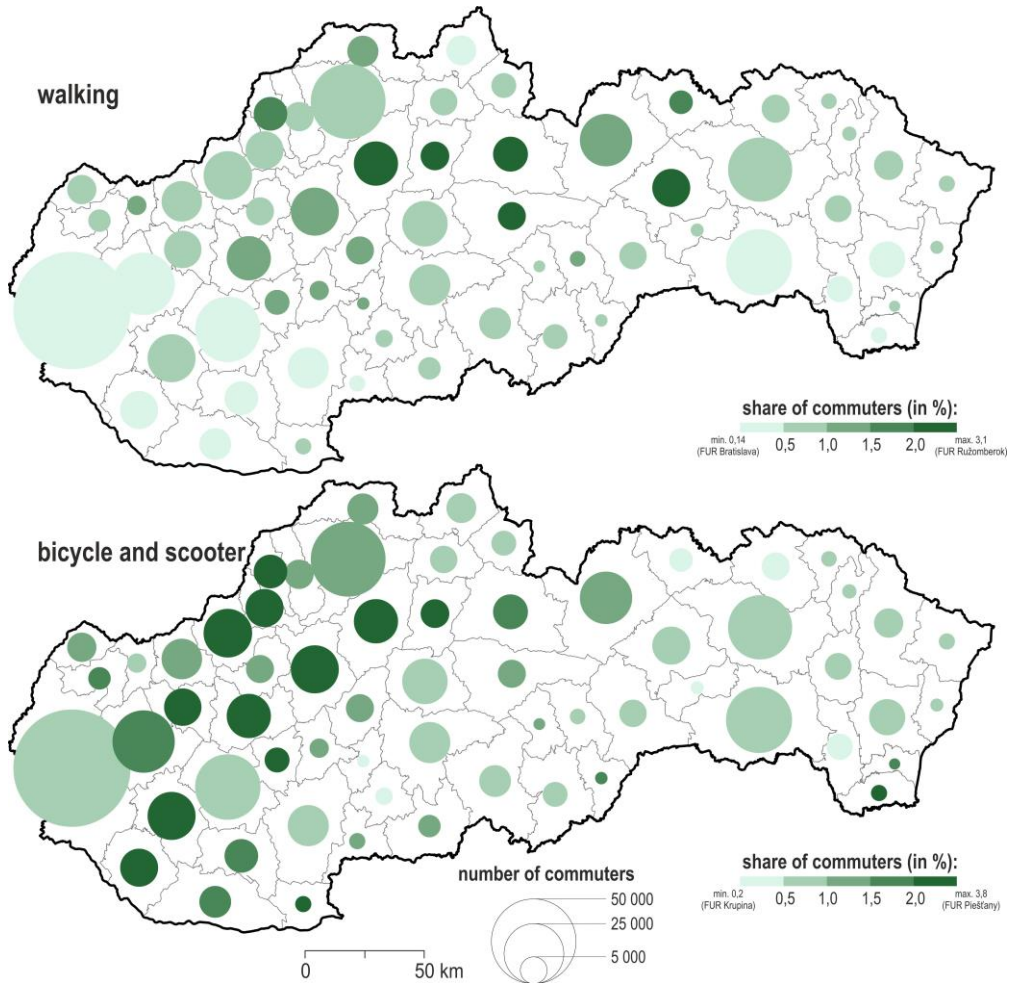


Fig. 10. Inter-municipal daily commuting to work by active forms in FURs;
 Source: SOSR (2021)

Daily commuting to work by modes of transport and age of commuters

Out of the total number of 1.2 million commuting flows to work, according to age, almost 24% of commuters under the age of 34 participate in them, the most numerous is the 35-54 category with 55% and the last place is 55+ with a value of less than 21%. At the level of Slovakia as a whole, in the category under 34 years of age, we record the highest share in the use of a car (62%), public transport (almost 21%), and 15% of commuters use an active form. In the 35-54 category, the most numerous category is again a car (almost 60%), but we record a very close difference in the use of public transport (19.72%), which is overtaken by the active form (19.86%). Compared to younger groups, 55+ use cars for commuting in smaller extent (46%), and the proportion of public transport (26.47%) and active forms (25.71%) is very small (fig. 11).

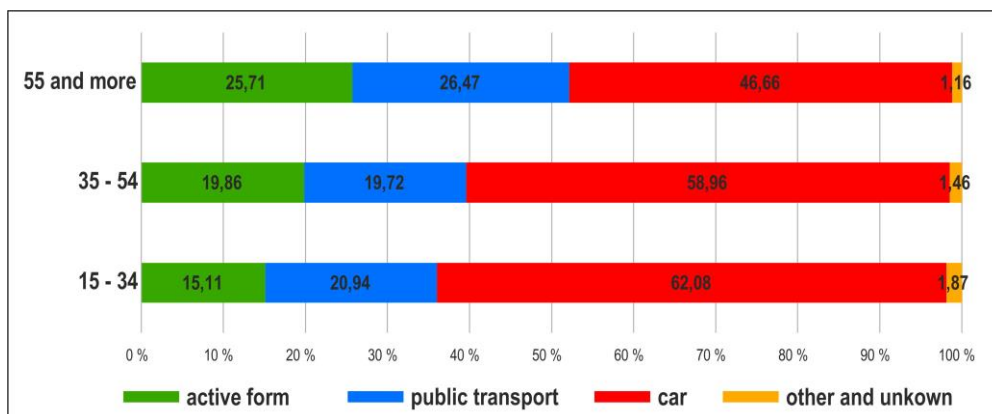


Fig. 11. Share of daily commuters in all age categories by modes of transport in Slovakia; Source: SOSR (2021)

The analysis at intra-municipal level shows a continuous increase in the proportion of commuters who use an active form with the rising age (fig. 12). While commuting by cars dominates in lower age groups, in the 55+ category largest proportion of commuters use active form (43%), the car is in second place (35%) and public transport is the least represented (21%).

The inter-municipal level (fig. 12) has a very similar character, while in all categories we observe very similar trends in the mode of transport. It is worth mentioning the 55+ category, where the use of a car compared to younger groups has the lowest share, but public transport and an active form occupy the highest values compared to younger age categories. Again, we observe slightly different preferences in the way of choosing a modes of transport.

Taking a closer look at the selected age groups (fig. 13) with regard to spatial differentiation, it is possible to notice the following trends. In terms of volume, the 15-34 category is dominated by FURs, which have the centers of county towns in Slovakia. More significant volumes are recorded in western Slovakia with the center in the Bratislava FUR. Towards the south and east, the volume of commuters decreases, with exceptions. In general, the smallest shares are recorded in FURs in the south of Slovakia near the border with Hungary and in eastern Slovakia. Inter-municipal commuting significantly dominates with some exceptions – especially the Bratislava and Košice FURs, which is understandable given the number of inhabitants in the regions and also the methodological process in which we monitor mobility between individual city districts as commuting to work at this level. When looking at the mode of transport at the inter-municipal level, a significant representation of the car dominates, which is accompanied by the use of public transport. An active form is almost completely absent, which is understandable considering this level of commuting to work. Different results are brought by intra-municipal work commuting, in which an active form is also represented

in the mode of transport. It is interesting that in FURs, which record the smallest volume, the active form is most prominently represented, which is certainly related to the economic motivation of commuters in these poorer regions of Slovakia.

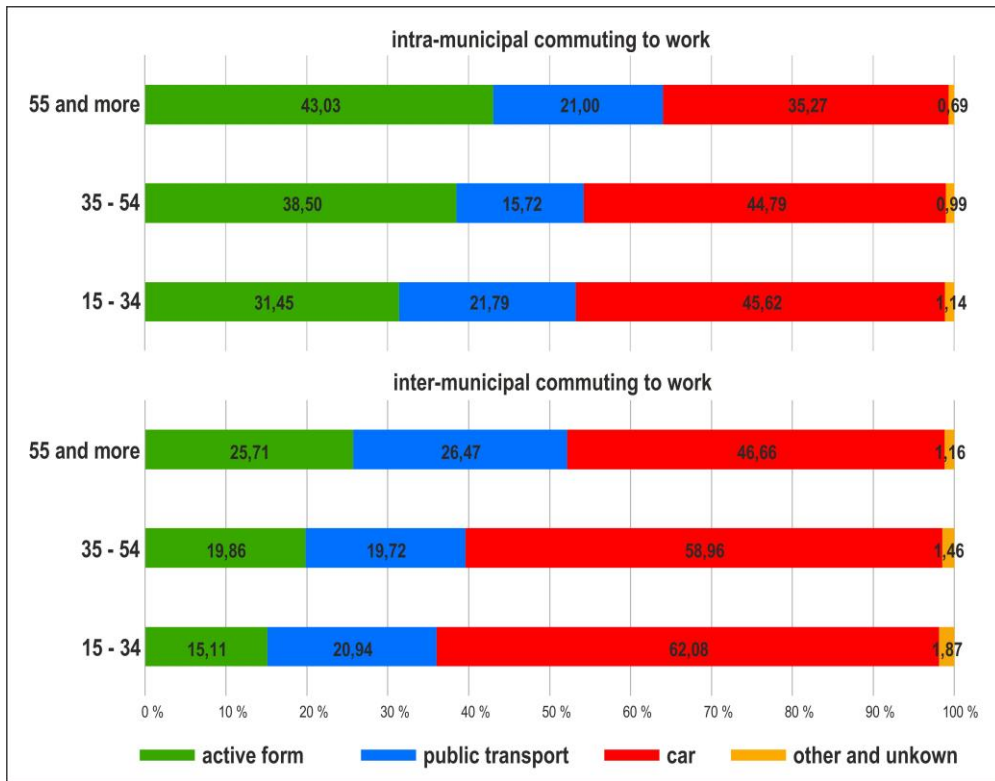


Fig. 12. Share of daily commuters in different age categories at intra-municipal and inter-municipal level by modes of transport in Slovakia; Source: SOSR (2021)

At first glance, the 35-54 category is distinguished by the volume of commuters, which is due to their highest number in this category among all commuters. These are residents of productive age who form the basis of the economic power of the state. In terms of volume, the situation is thus similar to the previous case with centers in the most populous FURs, which also offer a considerable number of job opportunities. Again, inter-municipal commuting dominates in most FURs, in which car transport and public transport have a significant proportion. The FURs, in which an active form of transport at the inter-municipal level is noticeable, are worth mentioning. These are the Liptovský Mikuláš, Ružomberok, Martin, Prievidza, Žilina, Čadca, Púchov, Trenčín, Dubnica nad Váhom, Piešťany and Topoľčany FURs. Within the intra-municipal commuting to work, the active form plays more significant role, while in some FURs bordering the Czech Republic and in FURs in the south of Slovakia near the border with Hungary, it reaches more than half of the total share. A similar pattern is also recorded in the poorer regions of central and eastern Slovakia. Compared to the younger age group, we see an increase in the use of this form of transport.

In terms of volume, the 55+ category has a very similar character to the youngest age category. It is related to the lower volume of commuters, which decreases with age. In this case, however, compared to the other groups, we record very balanced values of commuters at the intra-municipal and inter-municipal level, which could indicate that the willingness of commuters to cover longer distances decreases with the shift to an older age. The mode

of transport at the inter-municipal level is dominated by the passenger car and public transport, on the contrary, at the intra-municipal level, an active form of transport is more prominent. It has a majority representation especially in western Slovakia (except for the Bratislava FUR). Similarly in the smaller population FURs in central and eastern Slovakia.

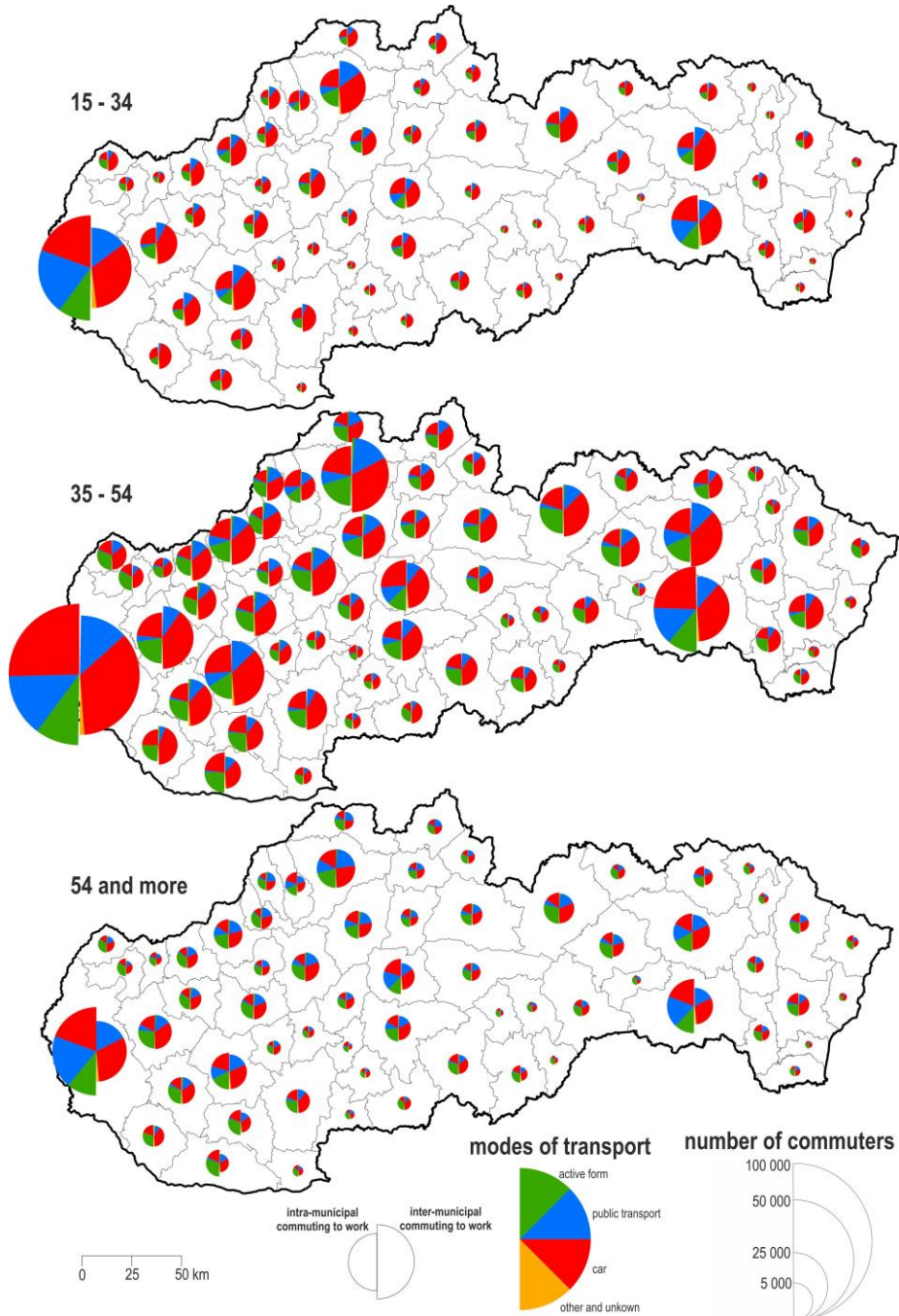


Fig. 13. Daily commuting to work by age and modes of transport in FURs;
Source: SOSR (2021)

Discussion

The analysis of commuting flows in Slovakia confirmed, based on data from the last census, the significant position of FURs of cities and towns with more than 50,000 inhabitants. These are the Bratislava, Košice, Prešov, Banská Bystrica, Martin, Žilina, Nitra, Trenčín and Trnava FURs. They show the highest absolute number of commuters on intra-municipal and inter-municipal level in all aspects, i.e. by mode of transport, but also by selected age categories. These regions already showed a dominant position in previous censuses (Michniak 2015), which is explained by an important economic aspect, especially investments in the automotive or electrical industry and several branches of prosperous companies. We could describe them as centers of economic strength and a sufficient number of job opportunities. In this period, the dominant position of the Bratislava FUR is recorded, which is exceptional in terms of commuting to work. Michniak (2015, 2016) explains this by saying that the FUR center – Bratislava is the capital of Slovakia with an administrative, cultural and economic base. In addition, it has good transport connections and infrastructure with the adjacent FURs (Székely 2013). In addition to the Bratislava FUR, the Košice FUR also plays an important role in the commuting to work, especially with the second highest absolute number of commuters.

The smallest volume of commuters at the intra-municipal and inter-municipal level is achieved by FURs mainly in the south of central Slovakia and border FURs in eastern Slovakia. These regions are referred to as peripheral or poverty regions in Slovakia (Michniak 2016b). It is a case of the Stropkov, Svidník, Sobrance, Veľké Kapušany, Kráľovský Chlmec, Revúca, Tornaľa, Hnúšťa, Banská Štiavnica, Krupina, Šahy and Štúrovo FURs. Michniak (2016b) identifies the lack of jobs as the biggest problem, which is reflected in the increasing of unemployment rate and the deterioration of the economic situation of the region's residents. In this way, the attractiveness of the regions for investments is weakened and the position of the centers in the regions is also weakened, which motivates the inhabitants of the regions to leave for work abroad or other areas of Slovakia (Michálek 2023). A key factor may also be transport accessibility with rising costs of transport to larger cities, while Partridge and Rickman (2008) state that a higher rate of poverty is typical for rural areas that are more distant from larger, in this case, regional centers. This could have a very significant effect on the mode of transport in these FURs.

Considering the mode of transport, the car dominates (at both levels) followed by active modes at the intra-municipal and public transport at the inter-municipal level. Thus, even in comparison with other census results in various countries, especially in America and Europe (McKenzie, Rapino 2011, De Witte et al. 2013), the car plays a primary role in the mode of transportation to work. In addition to the factors of car use for commuting mentioned by us, De Witte et al. (2013) add that the key factor is car ownership, which in this case is related to the level of car ownership in Slovakia, i. e. 1 car per 2.3 inhabitants in 2019 (Ministry of Transport 2019). Conversely, commuters who do not own a car are mostly dependent on public transport (Cervero 2002). De Witte et al. (2008) claim that the probability of using a train connection decreases by 52% for people with a car, and even more significantly for commuters who have a company car (96%).

The use of urban public transport has a dominant position at the inter-municipal level together with the car, which is different from the intra-municipal level. We can explain this trend in addition to the ones mentioned with the increasing distance from the place of residence to the place of employment. Therefore, the results of our research can be identified with the findings of Chng et al. (2016), but also Hagenauer and Hebllich (2017), according to which the use of public transport increases with increasing commuting distance and that the distance to work is the most important factor for choosing a modes of transport.

The active form of transport has the second highest share at the intra-municipal level after the car. Even if we evaluate commuting to work primarily at the level of regions, it is intra-municipal commuting that indicates the importance of this form of transport at the level of municipalities or towns. These findings can be identified with the results of Silvestri et al. (2022), whose research on commuting to work in five European countries (Hungary, Poland, Italy, Spain and Norway) brings the finding that residents living in the urban area of town are associated with higher likelihood of commuting by active forms. This mode of transport is also related to the settlement system and urban form of cities. At the inter-municipal level, we can observe that the residential structure significantly influences active forms of commuting. Schwanen (2002) by analyzing commuting flows in some European cities claims that urban forms are an important determinant of travel or commuting patterns and also are conducive to more extensive use of public transport or active forms. It is also possible to say that this form of commuting to work is carried out over shorter distances, which is also confirmed by the research of Heinen et al. (2013). A significant share at the intra-municipal level also proves that the issue of green commuting, which is also known as environmentally friendly travel mode, is being brought to the attention of commuters. In this case, however, a strong role is played by government and non-governmental organizations, which could put emphasis on informing the urgency of protecting the environment and also are affected by a lot of determinants such as infrastructure, personal preferences of commuters, etc. (Hai and Haokai 2016).

Analysis of commuting to work by age at the level of Slovakia yields the same results and trends in the mode of transport. In addition, by shifting to higher age categories, very close differences appear in the use of active transport and public transport. More pronounced differences are manifested at the intra-municipal level, where in the highest age category (55+) the active form of transport is most represented, supplemented by car and public transport. In terms of the sustainability of transport, this fact is very interesting, especially when compared to younger age groups. There can be many factors that determine this process, but in general, economic and health aspects are considered the most important in this age category. These bring various benefits to commuters, such as financial savings or the prevention of various diseases and the maintenance of good health (Boschmann and Brady 2013, Corran et al. 2018). De Witte et al. (2013) claim that there is no connection between age and modal choice and also that increase of age and physical ability to travel tends to decline as people grow older. This can be seen in our results - in the volume of commuters in the 55+ category. However, claims that age does not affect commuting to work are refuted by the research of Charreire et al. (2021), in which they analyzed commuters by age in such age categories as our work. In them, they came to a positive correlation in the relationship with increasing age and an active form of transport. Our research at the intra-municipal level shows the same tendency. A different finding was made by Bopp, Ananian and Campbell (2014), who confirmed that older residents (50+) used active transport less than younger residents. On the other hand, the use of an active form of transport is related to the distance, in which generally younger commuters are willing to cover longer distances than older commuters (Ha, Lee and Ko 2020).

Conclusions

This study assesses the spatial differentiation of daily commuting to work, examining both intra-municipal and inter-municipal levels across individual functional urban regions in Slovakia. The study is based on data from the 2021 census, which recorded some characteristics of commuting flows and commuters for the first time in the history of censuses in Slovakia. The results confirmed the differences in the use of modes of transport for commuting to work at both spatial levels. At the intra-municipal level, commuters use cars and active forms of transport almost equally. Within these active forms, walking is a common way of commuting to work, especially in the FURs of cities or larger towns, or in peripheral areas of southern

and eastern Slovakia. The use of bicycles at both spatial levels, is influenced by factors such as topography, infrastructure, and the distance between individual municipalities within a region. The distance between the municipalities and employment centres also play a significant role. In the case of inter-municipal commuting on foot, the distance from the largest towns constituting major commuting centres, is crucial.

At the inter-municipal level, the use of cars clearly dominates in all FURs in Slovakia. To the greatest extent, this mode of transport is used in the peripheral and economically lagging regions of southern and eastern Slovakia. This is especially the case of regions where public transport services may be insufficient. On the contrary, a sufficient number and frequency of bus and train connections has significantly positive effect on the use of this mode of transport. It often concerns economically developed regions. These results suggest that an adequate public transport system can compete with individual car transport.

Differences were also confirmed among selected categories of commuters by age. With increasing age, an increase in the use of active forms of transport was observed at both spatial levels. A quarter of commuters at the inter-municipal level and almost half of commuters at the intra-municipal level aged 55+ commute to work on foot or use a bicycle or scooter. Although young people (up to the age of 34) use active forms of transport the least, one in five commuters favours public transport (which may also be related to the fact that an above-average proportion of commuters in this category do not yet have a driver's license). Commuters between the ages of 35 and 54, who constitute the major proportion of the labour force in Slovakia, favour the car transport mode only to a little lesser extent than commuters up to 34 years. In the same time they use the public transport mode the least. This differentiation according to categories by age is observable in all FURs across Slovakia. However, it also reflects the rate of use of individual modes of transport identified in the total set of commuters. I. e. in regions where active forms of commuting constitute a higher proportion, they constitute a higher proportion also in all categories of commuters by age. The same applies to other modes of transport.

This paper is an initial study serving as a basis for further investigation of the spatial patterns of commuting to work based on the characteristics of commuters. It shows some basic trends that deserve to be analysed in more detail. However, already in their current form, the results suggest some other possible patterns. Thus the challenge for further research will be to evaluate commuting at various spatial levels more comprehensively, and to incorporate other characteristics of commuters in the analysis.

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Authors' affiliations

Štefan Gábor

Pavol Jozef Šafárik University in Košice
Faculty of Science, Institute of Geography
Jesenná 5, 040 01 Košice
Slovakia
stefan.gabor@student.upjs.sk

Loránt Pregi

Pavol Jozef Šafárik University in Košice
Faculty of Science, Institute of Geography
Jesenná 5, 040 01 Košice
Slovakia
lorant.pregi@upjs.sk