

Multimodal spatial accessibility to the primary and secondary education network: case study Bucharest-Ilfov Region

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Abstract: Education is, or at least should be, a daily activity for the entire youth population. Given the clear role of education in human capital construction, the study of spatial accessibility to educational facilities is an important research subject. The present paper examines the multimodal spatial accessibility to the primary and secondary school network in Bucharest-Ilfov region, one of the most demographically and residentially dynamic regions of the country. By using 1 km² population grid data and geocoded locations of school units, a travel time isochrone analysis has been computed for three modes of transportation: walking, private car and public transport, by using GIS analysis. All travel times have been calculated for five threshold intervals: 5, 10, 15, 20, and 25 minutes and linked to the distribution of the school-age population. Results show that the school network broadly follows the spatial pattern of the youth population and that most children can reach the closest school within 10 minutes by all three transport modes. However, pronounced intra-metropolitan inequalities exist. Bucharest displays a compact configuration, with the vast majority of pupils located within a 5- to 10-minute travel time. At the same time, Ilfov County shows a more dispersed pattern, with a considerable number of school units requiring over 20 minutes to reach, especially when relying on public transport or walking. These findings highlight how rapid suburbanisation and uneven transport provision generate spatial disparities in effective access to compulsory education units, and underline the need to integrate school location planning into transport and housing policies.

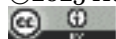
Key Words: *spatial accessibility, education, school network, Romania.*

Article Info: Received: April 16, 2025; Revised: November 3, 2025; Accepted: November 20, 2025; Online: November 30, 2025.

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Introduction

Education is a fundamental human right contributing to personal development and societal progress (McCowan, 2011). Access to education fosters better employment prospects and health outcomes, and reduces poverty (Breton, 2013; Camilleri & Camilleri, 2016; Leoni, 2025). Each additional year of schooling is associated with higher individual earnings, underscoring education's role in economic development (Spada et al., 2024). Countries with a more educated population tend to experience sustained economic growth, stronger institutions and greater social stability (OECD, 2024). In this context, expanding equitable access to education has become a priority (Chemulwo & Ali, 2019).

Every day, millions of students around the world set off on their journey to school. The length and difficulty of this journey could impact several aspects of their education. In many regions, especially rural areas, long commuting travel times between home and school can be a significant barrier to education (Local Burden of Disease Educational Attainment Collaborators, 2020; Rodriguez-Segura & Kim, 2021). European students' commuting patterns differ by age group and country. In many European cities, most students can walk or cycle to school in under 15 minutes, which not only saves time but also contributes to daily physical activity (Van Stralen et al., 2014). For example, in England, the average length of a one-way school journey is around 19 minutes for students aged 5-16 years old (Van Ristell et al., 2015).

Despite this, rural areas of Europe still face challenges with school accessibility, and urban areas contend with traffic congestion that can contribute to longer travel times. In the United Kingdom (UK), authorities consider 45-75 minutes to be a reasonable maximum one-way travel time for older students, indicating that some students travel quite far for schooling (for example, to attend specialised or high-performing schools in other areas) (UK Department for Education, 2019). A recent cross-country study using time-use data found that, for example, primary students' daily travel times are significantly shorter than those of secondary students across all 14 surveyed countries in Africa, Asia, and Europe (Sauerwein & Rees, 2020). Across multiple countries, older students tend to travel farther than younger pupils: primary school children have, on average, shorter commutes, while secondary school students travel farther (and tertiary students farther still) (Fast, 2020). The preferred mode of travel also differs by country, infrastructure and social context. In several European countries, such as Italy, Spain, and the UK, active commuting (walking or cycling) is common, while in other countries, motorised transport is preferred. On average, European students devote a substantial amount of time each day commuting to school. One analysis reported that students in the UK and Canada travel 52 minutes per day to attend school, while those in Italy average ~60 minutes and in Spain ~65 minutes per day. By contrast, United States students had shorter average daily travel time to school, around 34 minutes (Giménez-Nadal et al., 2022).

Students from remote rural areas often face the longest school journeys. For example, in South Africa, nearly 19% of secondary school students (14-17 years old) must travel more than 30 minutes to reach school, a situation far more common in rural areas than in cities. In some rural areas, almost one-quarter of teenage students face lengthy trips, a rate double that of their urban counterparts (Stokenberga et al., 2025). These disparities mean that rural youth spend more time and energy getting to the classroom, which can translate into lower attendance and academic performance. A similar correlation is observed in relation to their socio-economic status. A study in Germany found that children from the poorest households lived on average 5 minutes farther from their secondary school than those from higher-income families (Scheiner et al., 2019).

Long travel times are often the result of poor road infrastructure, unreliable or costly transport, and safety risks along the way. These factors can discourage regular attendance or even increase the dropout rate, as families may not be able to afford the costs, effort, and hazards underpinning attending school (Patel et al., 2021; Stein & Grigg, 2019). Also, the risks associated with long travel time are not uniform: younger children and girls may face different safety challenges than older students and boys, especially if they must travel alone (Fiala et al., 2025). Also, students living farther from school might be discouraged from pursuing their studies or be more prone to engage in other activities that could decrease their academic performance.

Research indicates that the time spent commuting to school can directly affect students' learning outcomes (Afoakwah & Koomson, 2021; Fast, 2020). When students spend excessive time travelling, they often arrive at school fatigued or late, which can affect their attendance and concentration. Empirical studies demonstrated a clear link between long travel time and lower academic performance (Ding & Feng, 2022; Hopson et al., 2024; Guan et al., 2025). Long daily travel time not only affects students' attendance but also their health and well-being. Long or difficult school journeys can impact students physically and mentally. A study by Pegado et al. (2025) found that for each additional minute of one-way travel time, students slept less at night. This relationship becomes even more pronounced over longer distances and longer travel times, with students becoming increasingly tired. To put this in perspective, a student with a 30-minute one-way commute would get, on average, 26 minutes less sleep each night than a peer with a 10-minute commute. Chronic sleep loss can impair cognitive function, mood, and immune health of students (Hyndych et al., 2025). Long travel time also means fewer opportunities for physical exercise or play, unless the commute itself is active (e.g. walking or cycling).

Students who must wake up very early to catch a bus or walk a long distance often arrive at school already tired, reducing their ability to engage and learn. Moreover, time spent commuting cannot be used for homework, leisure, or family interaction. A German study found that students with shorter school travel time gain extra hours for studying or hobbies over the course of a year, compared to peers with long travel time (Scheiner et al., 2019). For instance, research conducted in Ghana found that students who walked to school for more than 30 minutes had significantly lower English, French, and native-language reading and writing skills. This research identified missed class time and health issues associated with long walks as key factors that impair academic performance (Owusu Achiaw et al., 2025). Other research also reports that longer distances to school are correlated with higher rates of tardiness, absenteeism, and even early school leaving (Kobus et al., 2015; Ding et al., 2023; Cheng, 2025).

Despite the importance of travel time to school, there is a lack of research on this topic in Romania. Only two studies have addressed the problem of commuting to school in the context of high schools (Petre et al., 2025) and of school dropout in satellite towns around Bucharest (Petre et al., 2024). The first study shows that travel time (measured through travel distance along the road network) is a major barrier to attending high school, especially for students living in rural areas. Almost one-third of high-school-aged students must travel more than 10 km to reach the nearest high school, and about 14.6% travel between 15 and 30 km, with some exceeding 30 km. In contrast, nearly 85.5% of urban students live within 5 km of a high school. The second research demonstrates a clear correlation between longer walking or public transport travel times and higher absenteeism, particularly among students from low-income families. In towns around Bucharest, such as Pantelimon, Bragadiru, and Magurele, students who travel more than 30 minutes, often by unreliable or unaffordable public transport, are more likely to miss classes and eventually drop out. The study highlights that walking remains the primary

mode of commuting to school in these areas, but it becomes unfeasible when weather conditions are poor and travel times are too long.

Romania's educational system is structured into distinct cycles, from early childhood through tertiary education, under a highly centralised governance model. The system comprises early childhood education (for children up to ~6 years, including ante-preschool and preschool), primary education (five years, 6-10 years old), lower secondary education or gymnasium (four years, 11-14 years old), upper secondary education or high school (usually four years, 15-18 years old). According to the National Education Law (Law 198/2023), all these cycles are mandatory and free. Tertiary higher education is aligned with the Bologna three-cycle framework, with state-funded tuition-free enrolment spots and tuition-based enrolment spots according to student performance ranking (Law 199/2023).

The present study uses geospatial analysis to investigate travel time to schools across the Bucharest-Ilfov Region, assessing spatial accessibility for both lower and upper secondary education levels via multiple transport modes. By analysing how quickly students reach schools based on their chosen transport mode, this research evaluates spatial accessibility through the lens of travel efficiency and the availability of transport options. This paper represents the first study in Romania to examine school accessibility using multimodal travel-time metrics and provides valuable insights for public authorities seeking to improve educational equity, reduce mobility barriers, and ensure balanced educational planning.

Materials and Methods

Data source

The data used in the study are open-source and publicly accessible. Data on the primary and lower secondary school units have been retrieved from the official Romanian Government open database (<https://data.gov.ro/>). The school units have been geocoded using the database's geographic coordinates, then manually verified and adjusted as needed. Also, data about the status of the school unit has been consulted on the same platform.

Population data have been obtained from Eurostat (<https://ec.europa.eu/eurostat>) at a 1 km² grid level for the Bucharest-Ilfov Region. The database provides population data for the 2021 Romanian Census, by 1 km² grid and age groups: youth (0-15 years old), adults (16-65 years old), and elderly (>65 years old). Additional population data has been retrieved from the National Institute of Statistics (NIS) official database.

Methodology

The geocoding of all primary and secondary school units in the Bucharest-Ilfov Region was conducted by generating points from the geographic coordinates provided by the aforementioned data source. Then, each school unit was verified to ensure it matched the exact location of the education unit. Manual corrections to the database were made to validate the schools' locations and minimise errors.

Measuring the spatial accessibility of the population to different services is a growing field that has attracted specialists' attention in recent years. Most studies focus on accessibility to health care facilities (Cioclu et al., 2024), commercial facilities (Xu et al., 2025), and recreational facilities (Zhang et al., 2011). However, education is no less

important, and recent studies analyse the spatial accessibility to educational facilities on different levels of school cycles and methods (Rekha et al., 2020; Williams & Wang, 2014; Xu et al., 2018).

When assessing spatial accessibility to different services, several measurements and methodologies could be used. Some studies measure spatial accessibility to education facilities by using distance or travel time. While metric distance remains an important measurement, especially at larger scales, travel time is more important for assessing spatial accessibility at the regional or local level (Miller, 2020). The present study uses travel time data to account for data sensitivity and to consider the role of traffic and other barriers, such as the availability of public transportation, when measuring spatial accessibility. Also, the type of distance used is very important. In urban studies, network distance yields results closer to reality than Euclidean distance (Mora-Garcia, 2018).

Travelling to school may involve different modes of transportation for each student, with private cars and public transportation being the most prevalent (Schlossberg et al., 2006). The most prevalent modes of transportation to reach an educational unit are walking, private cars, and public transportation (Zhang et al., 2017). As physical distance increases, the mode of transportation to the school switches from active (walking or cycling) to inactive (car or bus). Thus, considering multimodal transportation could provide a more comprehensive perspective and enable a more reliable comparison of travel mode scenarios and spatial accessibility to primary and lower secondary education facilities. Nonetheless, the time of day could significantly influence travel times; using an overall average travel time underestimates peak-period travel times (Bimpou & Ferguson, 2020; Lopez et al., 2017). Travel distance during rush hours can significantly increase travel time. In Romania, most schools start their school day at 8:00 AM.

Thus, the present study evaluates the spatial accessibility to primary and secondary schools in the Bucharest-Ilfov Region, using a multimodal transport mode approach: walking, private car, and public transportation. This is intended to provide a broader perspective on spatial accessibility patterns in one of the country's most active areas in terms of demography and spatial processes.

The methodological framework of this study consists of performing a network analysis by using ArcGIS Pro 3.3. and QGIS 3.40 software. Firstly, travel time isochrones for walking and private car travel were generated for five time intervals: 5, 10, 15, 20, and 25 minutes. Then, travel time isochrones for public transportation were generated using the OpenTripPlanner (OTP) plug-in in QGIS. The process consisted of adding the OpenStreetMap (OSM) road network and public transport data for Bucharest in GTFS (General Transit Feed Specification) format. To obtain the isochrones, the OTP server used an Application Programming Interface (API) key to calculate travel times based on the public transport schedule and station locations. All travel data has been generated for a 7:00 AM scenario. The population grid was overlaid with each isochrone, and the population proportion for each travel time interval was calculated.

Study area

The study area comprises Bucharest, the capital city of Romania, and its surrounding county, Ilfov, as defined by Law 246/2022. Bucharest had a total population of 2,123,457 at the beginning of 2025, while Ilfov County had a total population of 531,598. Thus, more than 2.5 million inhabitants live in the Bucharest-Ilfov Region. Bucharest city is divided into six local administrative units (LAU2s) called sectors, and Ilfov is composed of 40 LAU2s.

The region is located in southern Romania (Figure 1) and is the most developed of the eight development regions, with the highest GDP per capita (Constantin, 2012). The Bucharest-Ilfov Region is also prone to very active residential changes, with residential patterns shifting on the outskirts of the capital city, thereby creating suburban settlements and neighbourhoods that are continuously expanding (Preda et al., 2022). These areas need proper planning and better access to daily services such as commercial services, health care facilities, recreational spaces, and, therefore, education.

According to NIS, the age intervals for primary school in Romania are 6 to 10 years old, and for lower secondary school (gymnasium), 11 to 14 years old. The total primary and secondary school-age population in the Bucharest-Ilfov Region is 230,302. The primary school-age population is about 130,654 inhabitants, and the gymnasium population is about 99,648 (Table 1). However, when looking at the spatial distribution of the population, it is clear that Bucharest accounts for 75.8% and 76% of the primary and gymnasium school-age populations, respectively. In contrast, only one quarter of the primary and gymnasium age populations live in Ilfov County (Figure 1).

The school network comprises 404 primary and secondary school units. Most of them are in Bucharest (269), while only 135 are in Ilfov County (Table 1). Most schools are located within Bucharest's administrative boundaries, with the spatial distribution correlated with the youth population (Figure 1). 20.7% of the primary and secondary school units in Ilfov county and 23.0% of those in Bucharest are private institutions. Admission to private school units is dependent on specific factors distinct from the school's catchment area and may entail different admission requirements, conditioned by fees or admission exams. Thus, these institutions have been excluded from the analysis.

The Bucharest-Ilfov area functions as an urban-rural continuum, with the spatial relationships between the two administrative units being administratively integrated for public transportation. The public transport network in Bucharest is the most extensive in the country, covering metro, buses, tramways and trolleys (Popescu et al., 2025). Five companies provide the public transport network in the Bucharest-Ilfov Region, the main ones being STB (Bucharest Transport Company) for above-ground transportation and Metrorex for metro transportation. According to the STB official website, the company's public transportation routes, totalling 1,849 km, of which 605 km are regional lines, ensure a coverage of 1,335 km² in the Bucharest-Ilfov Region (<https://www.stb.ro/statistici>). The metro transportation infrastructure comprises 77.77 kilometres of track and 64 metro stations, five lines, and a total of 1,071 million trips in 2024 (<https://www.metrorex.ro>). The usual price for an above-ground public transportation ticket is 3 RON (~0.6 Euro), while the price for metro transportation is 5 RON (~1 Euro). An above-ground public transport pass for all reroutes in the Bucharest-Ilfov region costs 80 RON (~16 Euro), and an underground transportation pass costs 100 RON (~20 Euro). Under Government Decision no. 810/2023, all students are entitled to free transportation, making it a viable option.

Table 1. School-age population and school units pattern in Bucharest-Ilfov Region.

Area	School-age population		No. of schools	
	Primary school-aged population	Gymnasium school-aged population	No. of public schools (%)	No. private schools (%)
Bucharest	99,026 (75.8%)	75,728 (76.0%)	207 (77.0%)	62 (23.0%)
Ilfov	31,628 (24.2%)	23,920 (24%)	107 (79.3%)	28 (20.7%)
Total	130,654 (100%)	99,648 (100%)	314 (77.7%)	90 (22.3%)

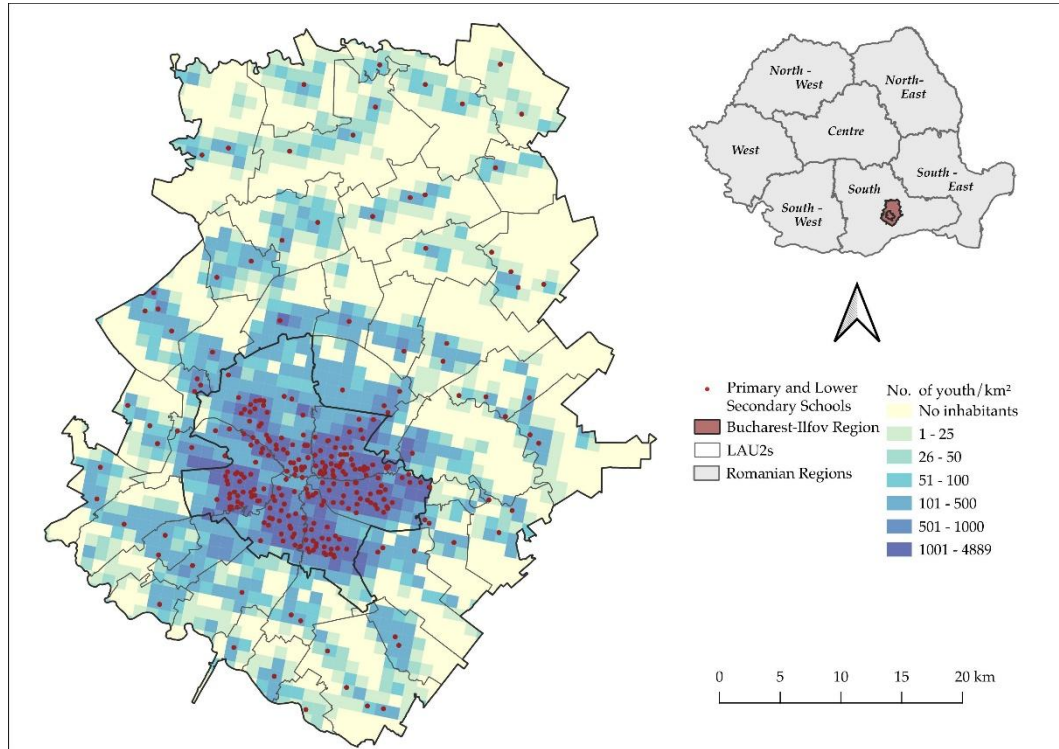


Figure 1. The spatial distribution of the primary and secondary school network and youth population grid in Bucharest-Ilfov Region.

Limitations of the study

The present study analyses the multimodal travel times to each primary and secondary school unit in the Bucharest-Ilfov Region. Being an exploratory study, it is prone to some methodological limitations. Firstly, the use of zip-codes or weighted population centroids would have made the spatial analysis results more reliable. In the absence of such a dataset, the 1 km² population grids are the only method closer to reality, as they reduce errors by providing a more detailed spatial distribution of the population across the region.

However, the issue with the used grid population data is that it only provides the population count for the 2021 census results, with more recent data unavailable. Also, the dataset does not provide age groups by year and only divides the population into youth (0-15 years old), adults (15-65 years old), and the elderly (>65 years old). However, the focus of this research - the school population groups: ages 6-10 years, primary school and 11-14 years - is present in the available data. In this case, the youth age group has been included in the analysis, as it represents the most reliable dataset available, given that the population aged 0 to 5 is future primary and secondary students. Another limitation is that, in some cases, two isochrones would overlap a population grid. In this case, the isochrone covering most of the population grid was taken as the value for the entire grid.

Results

The spatial distribution of primary and secondary school units is even, meeting the population's demand. Almost every local administrative unit (LAU2) has at least one school unit that provides primary and secondary education. However, when analysing the spatial accessibility to the nearest education unit considering multimodal transportation, accessibility measurements highlight local disparities in education provision.

Private car

Travel time by private car shows good values, especially for the city of Bucharest and small LAU2s. As shown in Figure 2, in most LAU2s, a school can be reached within 10 minutes of driving time. However, important parts of the region still experience travel times exceeding 25 minutes.

Public transport

The analysis summary statistics show a more compact school configuration in Bucharest than in Ilfov County, with 260,047 young residents (96.1%) within a 5-minute travel time and an additional 10,133 individuals (3.7%) within a 10-minute travel time. Only 268 youngsters (0.1%) live within 15 minutes of any school unit, and 183 (0.1%) live within 20 minutes of any school unit, with no young residents requiring more than 20 minutes of travel (Table 3). By contrast, Ilfov exhibits a more dispersed spatial pattern, with 67.4% of young people within 5 minutes of the destination and an additional 29.0% of the target population within 10 minutes of the destination. Beyond this threshold, 1,893 young residents (2.0%) live 15 minutes from school, and 883 (0.9%) live 20 minutes from school, indicating a modest but visible increase in travel time to school. The most remote groups in Ilfov comprise 333 youth (0.3%) who require 25 minutes to reach school and 330 (0.3%) who need more than 25 minutes to reach their destination.

Table 2. Travel time intervals for the youth population (0-15 years) using a private car.

Time interval	Bucharest		Ilfov County	
	No.	%	No.	%
5 min.	260,047	96.1%	64,360	67.4%
10 min.	10,133	3.7%	27,754	29.0%
15 min.	268	0.1%	1,893	2.0%
20 min.	183	0.1%	883	0.9%
25 min	0	0.0%	333	0.3%
> 25 min	0	0.0%	330	0.3%

Table 3. Travel time intervals for the youth population (0-15 years) using public transportation.

Time interval	Bucharest		Ilfov	
	No.	%	No.	%
5 min.	33,783	12.5%	17,137	17.9%
10 min.	216,404	79.9%	25,593	26.8%
15 min.	13,456	5.0%	13,348	14.0%
20 min.	4,504	17%	13,355	14.0%
25 min	1,450	0.5%	12,045	12.6%
> 25 min	1,326	0.5%	14,077	14.7%

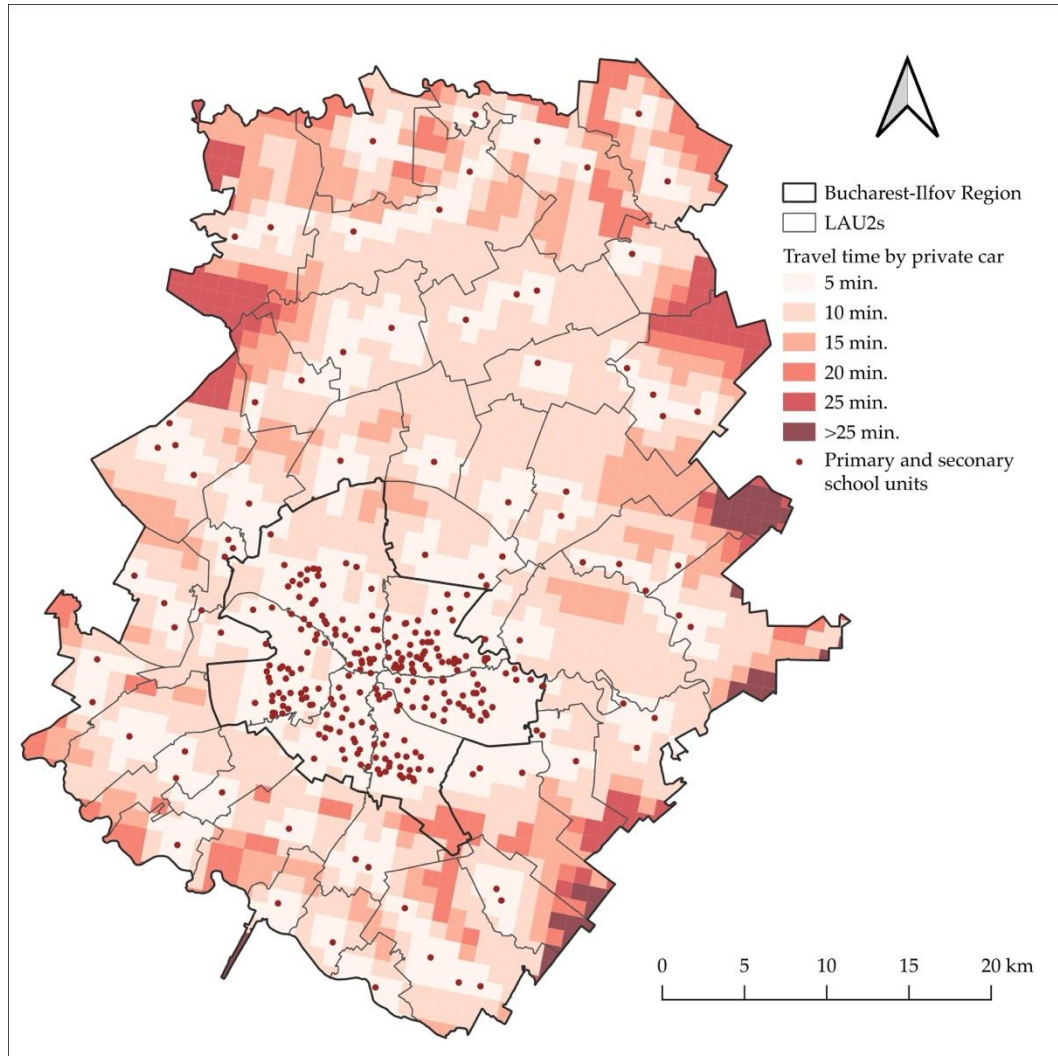


Figure 2. The spatial distribution of travel time by using a private car as a mode of transportation

Public transportation is widely used in the Bucharest-Ilfov area, as it has an integrated system that connects Ilfov with the Capital City under the STB and Metrorex. Even if the results of private car driving time show relatively good accessibility of the population to the primary and secondary school network, when looking at public transportation, most of Ilfov County falls outside the 25-minute threshold (Figure 3). However, most of these areas are sparsely populated and therefore do not affect many pupils.

In the second scenario, only 12.5% of the youth population live within 5 minutes of school, with a further 79.9% of the specific school-age population reaching school in 10 minutes. By contrast, Ilfov presents a substantially more dispersed pattern, with 17,137 youths (17.9%) being within 5 minutes and 25,593 (26.8%) within 10 minutes, so that less than half of the youth population (44.7%) is covered by the 10-minute threshold. A sizeable share of young people reside within 15 minutes (13,348 individuals) and 20 minutes (13,355

individuals). Long travel times are much more prevalent, with 12,045 youths (12.6%) at 25 minutes and 14,077 (14.7%) at 25+ minutes.

Thus, Bucharest offers comparatively higher spatial accessibility to education facilities via public transport, with nearly all youth able to reach a primary or secondary school within 10 minutes. In contrast, Ilfov County shows a pronounced peripheral area where more than one-quarter of young people must travel over 20 minutes to reach the same destination (Figure 3).

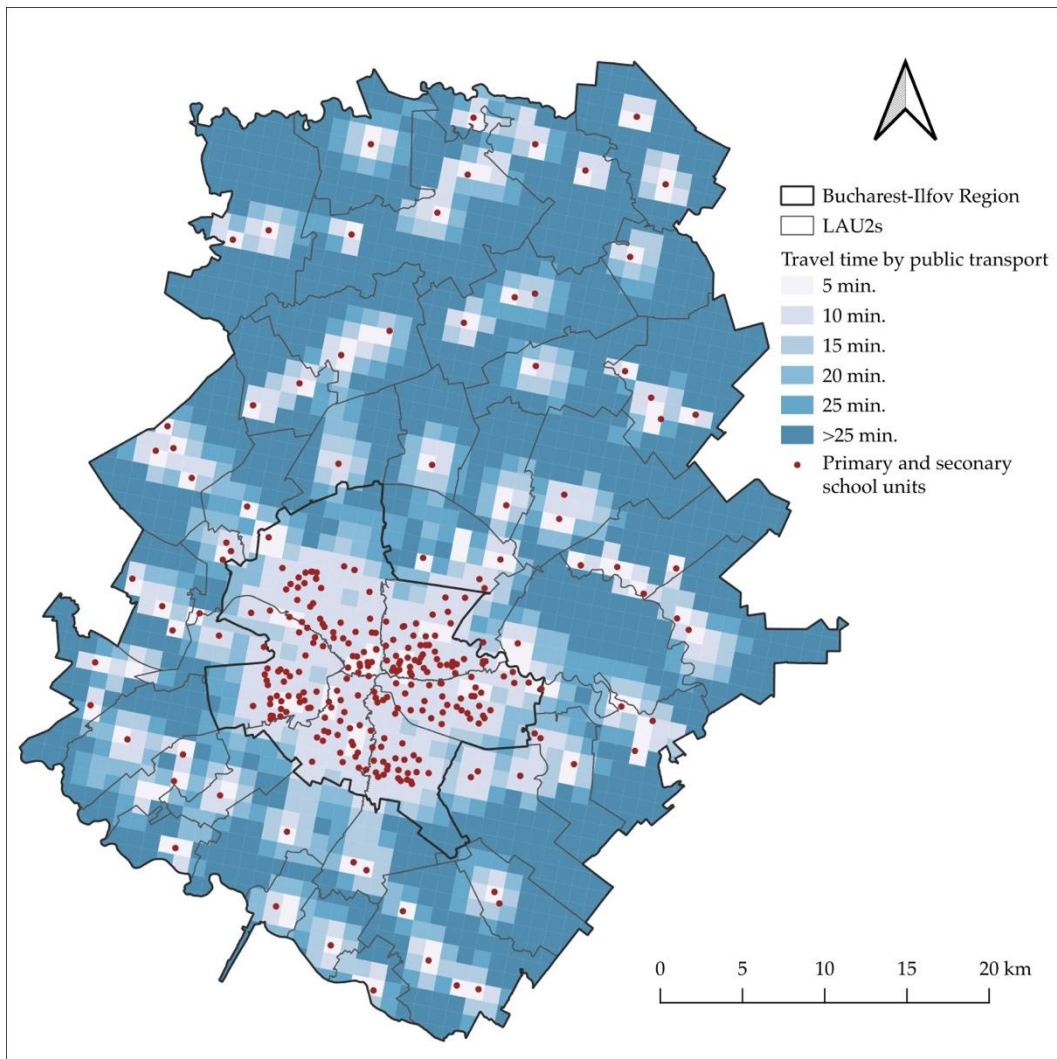


Figure 3. The spatial distribution of travel time by using public transportation cars as a mode of transportation.

Walking

Walking to school is the most common form of transportation, especially among younger children. Considering that all essential services should be located within a 15-minute threshold from the residency, the school should be no different. Students attending primary and secondary schools are usually enrolled in the closest education unit within each school's catchment area, according to the Romanian school catchment-area policy. However, results show that most of the LAU2s fall above the 25-minute threshold (Figure 4). This means the journey to school involves longer distances and longer travel times if public transportation or a private car is unavailable.

Three-quarters of the primary and secondary school-age population can reach the closest school unit within 5 minutes. However, in this scenario, for Bucharest, 243,359 (89.9%) are within 5 minutes of the destination, and 94.4% are within 10 minutes. Only about 2.8% and 1.5% fall in the 15- and 20-minute bands, and 1.3% exceed 20 minutes. In Ilfov, by contrast, just 38,459 youths (40.9%) are within 5 minutes and 60.7% within 10 minutes, with a much larger share located at 15 minutes (10.6%) and 20 minutes (11.7%). Long travel times are also far more common in Ilfov, where 3.9% of youths require 25 minutes and 13.1% more than 25 minutes to access the closest primary and secondary school unit.

Table 4. Travel time intervals for the youth population (0-15 years) using walking as a mode of transportation

Time interval	Bucharest		Ilfov	
	No.	%	No.	%
5 min.	243,359	89.9%	38,459	40.9%
10 min.	12,288	4.5%	18,583	19.8%
15 min.	7,561	2.8%	9,953	10.6%
20 min.	4,178	1.5%	11,045	11.7%
25 min	467	0.2%	3,693	3.9%
> 25 min	3,070	1.1%	12,311	13.1%

Discussions

Our findings show that most of the primary and secondary school-age population could reach the closest school within 10 minutes, either by private car, public transportation or walking. However, for a considerable share of students, the journey to the closest school unit may take more than 20 minutes. This relatively good accessibility is usually possible, as students attending primary and secondary school are selected based on their residency and are assigned to a school unit within their school catchment area if places are available. If not, students are assigned to other schools in the proximity. Thus, the journey to school can be lengthened by the unavailability of places in the closest school.

Bucharest serves as the centre of a larger Region, with many primary and secondary students travelling from surrounding towns in Ilfov County. The lack of convenient public transport options outside Bucharest's limits is a significant issue. The quality of transportation links significantly impacts these commutes. Research on towns near Bucharest indicates that when local schooling options are limited, students often need to travel to Bucharest, typically over distances of 30 to 40 kilometres. In these situations, walking or cycling is not feasible, and students rely on buses or mini-buses, resulting in travel times of over 50 minutes each way (Petre et al., 2024).

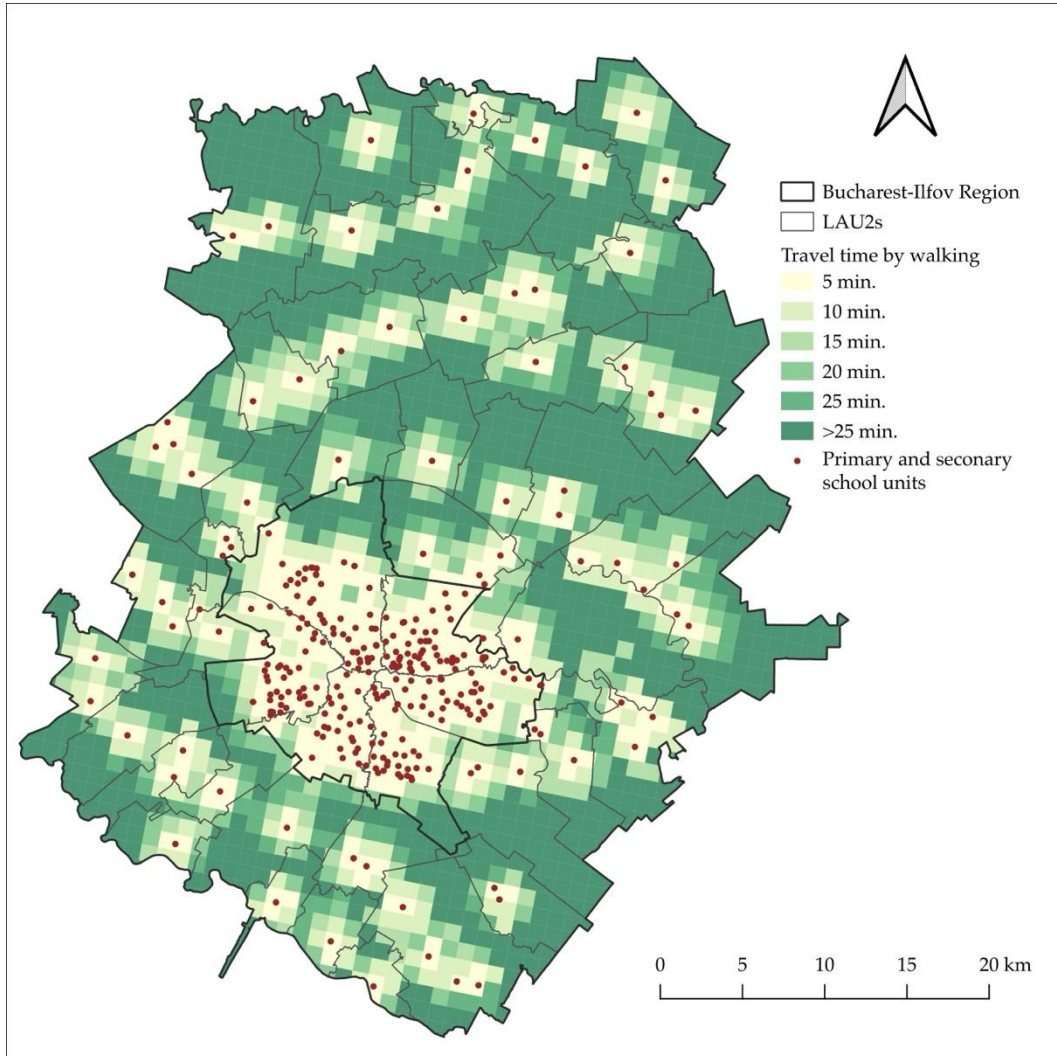


Figure 4. The spatial distribution of travel time by using walking as a mode of transportation.

Interestingly, some peri-urban areas reported no dropout cases despite long travel times because those communities offered supportive measures, such as special school buses or boarding arrangements. One viable solution for Bucharest's suburbs is to integrate these areas into the capital's transport network, using ring roads and rail systems. In 2023, the Government mandated free transportation for all students to address these access challenges (Law 198/2023).

A "child-friendly mobility" ranking of 36 European cities in 2025 placed Bucharest at 34th, noting poor conditions for walking or cycling and unsafe traffic conditions (Clean Cities, 2025). In contrast, cities like Stockholm, Vienna, and Paris scored highly, having safer school streets, lower speed limits, and comprehensive public transit for students. These comparisons highlight that Bucharest's long school travel times are not an inevitable consequence of the city's size; they also result from policy choices around urban planning,

transport, and education. European best practices suggest that coordinating these domains (for example, aligning school locations with residential patterns and improving pedestrian/cyclist safety) can significantly reduce travel times and improve students' daily commuting experience. Also, walking in big cities in Romania, such as Bucharest, could represent a real challenge. Parking on sidewalks in Bucharest has become a real issue, and cars parked in pedestrian areas pose a serious hazard (Popescu, 2022). Therefore, the decision to walk to school is strongly influenced by safety considerations.

Also, the Bucharest-Ilfov Region is among the most active in residential construction and demographic change. Urban sprawl has affected most of the settlements surrounding Bucharest, with new urban neighbourhoods appearing on the outskirts of the city, promoting residential mobility and, therefore, population growth of above 25% in several LAU2 between 1991 and 2007 (Suditu, 2009). This continuous process of suburbanization and residential mobility has changed spatial accessibility patterns. Most residential planning did not take into account accessibility to daily services, creating socio-spatial inequities (Nae & Dumitrache, 2019). This has led to the growth of the private school sector, with most settlements surrounding Bucharest home to numerous private institutions authorised to offer primary and secondary education. Unfortunately, tuition fees for private education exceed average incomes, so private units are available only to high-income families. Over time, the continuous urban-rural outmigration will need to be addressed, considering the accessibility of daily services and the reorganisation of service locations.

Active mobility is beneficial for students' health (Janssen & LeBlanc, 2010); however, it is more common when distances to school are shorter. A case study conducted in five cities in the Netherlands showed that the average walking distance a student takes to elementary school is 4.2 minutes and 288 meters, while the average distance by motorised transportation is 1176 meters and 7.4 minutes (Dessing et al., 2014). In Poland, 82% of responding middle school students reported that the journey to school takes less than 20 minutes, while only 65% of high school students reported this (Wojtyła-Buciora et al., 2017). The mode of transportation to school varies significantly between communities. Studies on the prevalence of active school transportation show that the most common mode of transportation is walking in the Czech Republic, Scotland, Wales, and Norway. No study has addressed this issue in Romania; therefore, it is difficult to determine which mode of transportation is most preferred among the primary and secondary school-age population and their families. The journey to school depends on whether the family owns a private car, on public transportation availability and schedule, or on each family member's schedule and eventual availability to take students to school. Thus, the journey to school could become a burden to family members.

In Romania, to provide equitable access to education, under Law 198/2023, all primary and secondary students have free public transportation. In this case, public transportation becomes the most viable option. However, for most students, the journey to primary and secondary school takes more than 15 minutes, and in fact, if waiting times or changing buses are factored in, it could double. A study using semi-structured interviews found that increased travel time to school was the most common reason for absenteeism and school dropout in several settlements in Ilfov County (Petre et al., 2024).

The overall good accessibility results indicate that a vast majority of the population has relatively good access to the primary and secondary school network. However, the incidence of long school travel times across all modes of transportation is usually concentrated in areas that are already disadvantaged or vulnerable, such as rural settlements with low incomes.

Finally, the present situation shows that primary and secondary school education options are spread across the region accordingly to the specific school-age population. The

issue is that after completing gymnasium education, the options for pursuing studies with high school education narrow, as fewer upper secondary school units are available (Petre et al., 2025). In the context of the restructuring of the education system in Romania, under Law 141/2025, classrooms with fewer than 12 pupils enrolled would automatically be merged with other classes from the same school or with other schools in the immediate vicinity. Thus, this issue will mean closing schools and increasing the distance and travel times to schools, posing constraints on spatial accessibility to primary and secondary education. No official data on this restructuring is available, but its effects are yet to be seen. Spatial accessibility to education facilities remains an important issue for the Romanian authorities (Ministry of Education, 2015).

It is essential to analyse the spatial accessibility to all levels of education, as it could play an important role in public policy planning for educational attainment. Thus, attention to school transportation buses as well as enhanced school mobility would represent real solutions to the accessibility issue. Further studies should focus on real travel-to-school solutions and the optimisation of the school network, as well as on the effects of spatial accessibility on the socio-economic characteristics of the population.

Conclusions

The present paper provides the first multimodal assessment of travel times to the primary and lower secondary school network in the Bucharest-Ilfov Region. By combining geocoded school locations, 1 km² youth population grids and network-based isochrones for three different modes of transportation: walking, private transportation and private car, it offers an integrated picture of the accessibility patterns in the area. The results reveal that, in the Bucharest-Ilfov region, the public-school network broadly matches the distribution of the school-age population.

The analysis reveals intra-regional spatial inequalities. In Bucharest, under all three scenarios, the majority of the youth population live within 10 minutes from school, and very few experience travel times above 20 minutes. However, in Ilfov, the spatial dispersion of housing and schools, combined with less-dense transport infrastructure, creates a peripheral ring where long school journeys are more common. In the car-based scenario, accessibility remains relatively good, but for public transport and walking, a considerable share of Ilfov's youth must travel more than 20, and even 25, minutes to reach the nearest school unit.

From a policy perspective, these results call for better coordination between school network planning, housing development, and transport provision. In the rapidly suburbanising areas of Ilfov County, new residential projects should consider increasing the local school capacity. Targeted improvements to public transport, such as dedicated school buses, could substantially reduce travel time for residents in peripheral areas.

Finally, the methodological framework developed here can be replicated and extended. Future research could incorporate dynamic congestion data and expand the analysis to upper secondary education. By systematically monitoring spatial accessibility across all education cycles and other services, authorities can better align infrastructure investment and social policy to achieve equitable mobility.

Acknowledgement: The research was presented at the 17th International Asian Urbanisation Conference (IAUC), organised by the Centre for Southeast Asian Social Studies (CESASS), in Bali on 14-16 January 2025.

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