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PEDESTRIAN ACCESSIBILITY TO EDUCATIONAL INSTITUTIONS IN THE MUNICIPALITY OF CRAIOVA: A SPATIAL ANALYSIS USING GIS METHODS

ACCESIBILITATEA PIETONALĂ CĂTRE INSTITUȚIILE DE ÎNVĂȚĂMÂNT DIN MUNICIPIUL CRAIOVA: O ANALIZĂ SPAȚIALĂ UTILIZÂND METODE GIS

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Abstract: This research illustrates the potential of Geographic Information Systems (GIS) in analyzing pedestrian accessibility to educational institutions in the Municipality of Craiova. By integrating spatial data from official and open-source platforms, thematic databases and digital street networks were created to model pedestrian service areas. The analysis allowed for the delineation of zones covered according to travel times and the identification of neighborhoods insufficiently served by educational infrastructure. Understanding accessibility is crucial not only for primary and secondary schools but also for high schools and universities, as distance and travel time significantly affect educational equity and institutional attractiveness. The scientific literature emphasizes the importance of accessibility in educational planning, while also pointing out methodological limitations and the scarcity of detailed urban-level analyses in Romania — gaps that this study aims to partially address. The results demonstrate the usefulness of GIS for local public administration, both in supporting urban planning decisions and in optimizing the transport network and the location of future educational units. The study thus underlines the role of modern digital tools in fostering sustainable urban development and improving equitable access to educational services.

Key-words: *educational institutions, accessibility, pedestrian, Service Area Analysis, Craiova*
Cuvinte cheie: *instituții de învățământ, accesibilitate, pieton, Service Area Analysis, Craiova*

1. INTRODUCTION

Pedestrian accessibility denotes the degree to which individuals can conveniently reach essential destinations, such as workplaces, educational

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facilities, commercial areas and recreational spaces, by walking. As a fundamental component of sustainable urban mobility, it exerts a significant influence on public health, social equity and environmental sustainability. Research on this topic spans multiple disciplines, including urban planning, transport engineering, public health and data science, reflecting its inherently interdisciplinary nature.

In academic literature, the term often refers to the ability of pedestrians (including those with reduced mobility) to reach destinations (e.g., shops, transit stops, services) easily, safely and comfortably. It differs somewhat from "walkability" which focuses more broadly on the attractiveness of walking and the walking environment (Vale et al., 2016; Haeffner et al., 2017; No et al., 2023; Cracu et al., 2024). Early studies defined accessibility as the ease of reaching opportunities (Hansen, 1959). Over time, this concept was adapted to pedestrian contexts, emphasizing walkability, street connectivity and the built environment's quality. Recent studies on pedestrian accessibility in European cities have highlighted the importance of urban design in promoting walkability and inclusivity (Table 1).

Table 1 Main features of state-of-the-art studies on pedestrian accessibility

Theme	Methodology	City/Country	Focus Area
Street Network & Urban Form	Network Analysis, Space Syntax	European Cities	Walking Frequencies
Pedestrian Flux Analysis	Wi-Fi Data, Entropy Measures	University Campus	Accessibility Robustness
Walkability Index Development	GIS, Remote Sensing	Europe-wide	High-Resolution Walkability
Urban Design & Walking	Street Connectivity, Streetscape	Santarém, Portugal	Utilitarian & Leisure Walking
Pedestrian Bridge Design	Accessibility Evaluation	Croatia	Bridge Design

Recent research has addressed pedestrian accessibility and walkability from multiple analytical perspectives, emphasizing the role of the spatial determinants such as street network configuration, environmental design and urban form in shaping walking behavior. Using network analysis and space syntax methods, Schön et al. (2025) demonstrated that the structural characteristics of street networks – such as higher centrality, street continuity and connectivity within European street networks are associated with greater walking frequencies, underscoring the significance of urban form in supporting pedestrian mobility. Similar approaches have been used to explore how urban design and street network configuration influence both utilitarian and leisure walking (Pereira et al., 2024; Gálvez-Pérez et al., 2024). Thus, Gálvez-Pérez et al. (2024) found that both network connectivity and streetscape characteristics influence walking behavior: connectivity plays a dominant role in utilitarian walking, while aesthetic and environmental qualities are more relevant for leisure-oriented movement. Beyond

structural metrics, researchers have explored how network configuration interacts with environmental and design features to influence pedestrian movement. Gálvez-Pérez et al. (2024) emphasize that while connectivity is a key driver of functional, utilitarian walking, streetscape attributes – such as green spaces, shading and aesthetic quality - tend to foster leisure walking.

Complementing these findings, Cerioli et al. (2025) utilized Wi-Fi tracking data and entropy measures to analyze pedestrian movement within a university campus. Their results highlight the influence of network structure on pedestrian flow and identify critical nodes that would benefit from infrastructural improvements. Patel et al. (2025) advanced this line of inquiry by developing a standardized, high-resolution walkability index for Europe that integrates street length, intersection density, green spaces and access to public transport - providing a comprehensive comparative tool for assessing walkability across cities. In a similar direction, Vale & Lopes (2023) examined pedestrian accessibility within a 15-minute walking threshold across different European cities, revealing notable disparities and suggesting that expanding the diversity of opportunities reachable on foot can enhance urban equity.

Other studies have broadened the accessibility discourse toward inclusivity and methodological innovation. Štimac Grandić et al. (2024) discussed accessible design principles for pedestrian bridges, focusing on physical parameters such as width, slope and surface material to accommodate users with mobility impairments. Several methodological frameworks have been proposed to evaluate pedestrian accessibility using GIS and composite indicators (Maghelal & Capp, 2011; Morar et al., 2014), focusing on aspects such as land-use diversity, street connectivity, and proximity to green or public spaces. In Romania, GIS-based analyses of pedestrian accessibility remain limited, with a few recent applications focusing on urban parks or green space accessibility (Cracu et al., 2024; Vîlcea & Șoșea, 2020). On a global scale, Liu et al. (2022) introduced an open-source framework for measuring pedestrian accessibility using open data, enabling large-scale comparative assessments of accessibility conditions worldwide.

The social dimension of pedestrian accessibility has also been explored, highlighting issues such as safety, gendered experiences, and perceived mobility justice (Lubitow et al., 2020).

Advances in GIS have enabled detailed network-based accessibility models (Erath et al., 2017; D'Orso & Migliore, 2020), which account for real walking routes, crossings, and environmental barriers.

Overall, these studies confirm that accessibility is a multidimensional concept integrating land use, transport and social equity dimensions (Moura et al., 2017; Vîlcea & Șoșea, 2020; Stoia et al., 2022; Gaglione et al., 2021, 2022; Ferrer-Ortiz et al., 2022). Over time, it has been studied and applied across various fields, including urban and regional planning, geographic information systems and public administration, reflecting its growing importance as a cross-disciplinary framework for understanding spatial and social dynamics in cities.

Within this framework, accessibility reflects the ease with which people can

reach essential urban amenities such as educational institutions, which constitute the focus of the present study. Moreover, Geographic Information System (GIS) tools provide a robust methodological basis for quantifying and visualizing spatial accessibility. The main goal of this research is to assess pedestrian accessibility to educational institutions in the municipality of Craiova. For the GIS analysis, we propose relevant data sources and set up a procedure for calculating an indicator for educational accessibility, which is subsequently represented cartographically. The selected time intervals (5, 10 and 15 minutes) are intended to facilitate further discussions regarding the accessibility of educational institutions at the neighborhood level. The ultimate objective of this study is to support various stakeholders in identifying and removing barriers to accessibility thereby contributing to improved territorial planning and management.

2. DATA AND METHODS

2.1. Study area

Craiova is a major urban center located in southwestern Romania, with a population of about 235,000 inhabitants, according to the official results of the 2022 census. The city has a complex urban structure characterized by a densely built-up central area with mixed residential and institutional functions, surrounded by peripheral neighborhoods that have expanded rapidly over the past two decades. This spatial contrast has generated visible differences in accessibility and connectivity, particularly between the compact historic core and the newer suburban developments.

Craiova's street network combines a radial-concentric pattern in the central districts with more fragmented, irregular structures in peripheral zones, influencing both mobility and service accessibility. Public transport includes bus and tram lines, but pedestrian infrastructure varies considerably across the city, with better facilities in central and educational areas and limited walkability in newer residential sectors.

The spatial distribution of educational institutions (Fig. 1) reflects this urban heterogeneity, as most schools and universities are concentrated in central and semi-central districts, while peripheral areas remain less well-served. This uneven configuration makes Craiova a relevant case study for analyzing pedestrian accessibility to educational facilities in a medium-sized European city undergoing dynamic spatial transformation.

According to *the Report of the Mayor of Craiova on the Economic, Social and Environmental Status of Craiova*, 2024, the local education network for the 2023-2024 academic year comprised 98 educational institutions, including 35 kindergartens, 24 primary and secondary schools, 29 high schools, 8 specialized post-secondary schools and 2 higher education institutions.

The education system employed 4,897 teachers, distributed as follows: 46 in early childhood education, 612 in preschool, 1,645 in primary and secondary education, 1,281 in high schools, 60 in vocational and post-secondary education and 1,253 in higher education.

Enrollment data indicate a total of 7,540 children in kindergartens and nurseries, 22,591 pupils in primary and secondary education, 14,850 in high school, 1,242 in vocational education, 4,632 in post-secondary and vocational programs and 22,735 students in higher education.

The municipality hosts two major universities - the University of Craiova and the University of Medicine and Pharmacy of Craiova - which serve as regional centers of higher education. Non-formal education is also represented through the Children's Palace of Craiova, an extracurricular institution offering cultural, artistic, and technical programs for pupils aged 4 to 19 across Craiova and Dolj County.

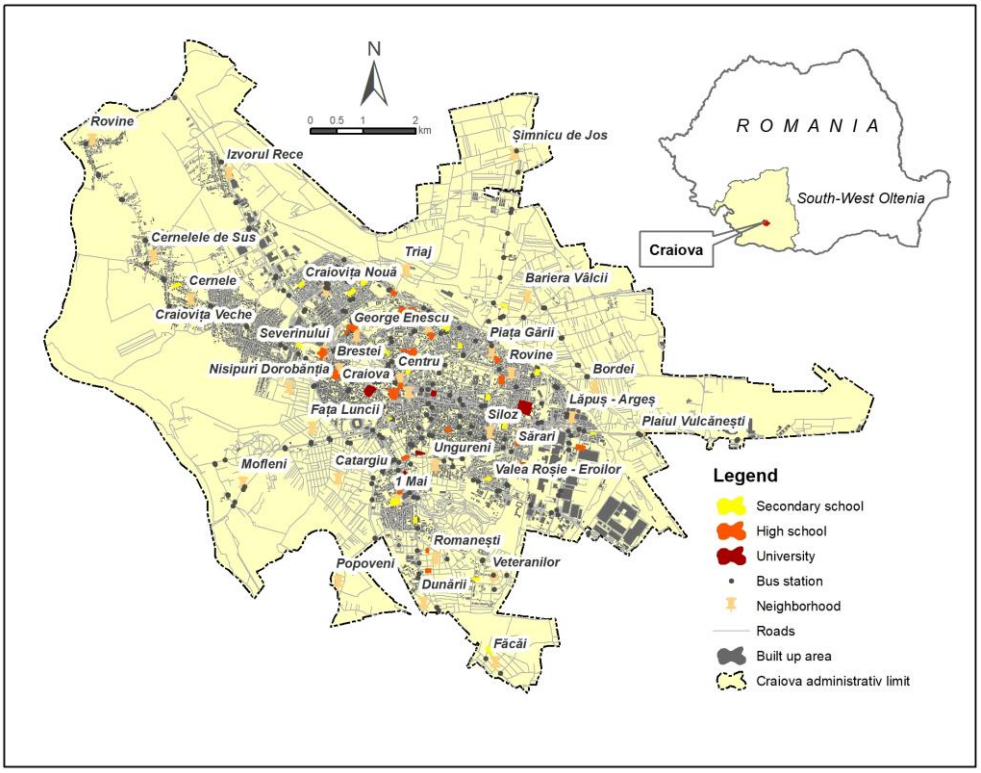

Fig. 1 Craiova Municipality – distribution and classification of educational institutions
Sources: processed after Open Street Map datasets

The municipality's educational documents emphasise the importance of accessible infrastructure and equal access in education, training and lifelong learning (www.primariacraiova.ro).

The municipality has initiated projects to increase access to education through improving infrastructure of schools and kindergartens. For example:

- At the start of a school year, the municipality opened a new daycare centre in the Popoveni district with modern facilities (rooms, kitchen, play space) and

modernised nine other educational units (https://www.primariacraiova.ro/);

- At the tertiary level, the University of Medicine and Pharmacy of Craiova is implementing a project (EGALMEDU) to support students with disabilities: procuring assistive IT, training staff, adapting materials, etc. (https://www.umfcv.ro).

2.2. Methodological framework

Technology advancements such as GIS tools and available geospatial data facilitated access studies by providing easier ways to measure distance to urban amenities (Erath et al., 2017; D'Orso & Migliore, 2020) (Fig. 2).

Advances in GIS enabled detailed network-based accessibility models, accounting for real walking routes, crossings, and barriers (Geurs & van Wee, 2004). Indices such as Walk Score (Duncan, 2011) and local walkability models integrate land-use diversity, street connectivity, and pedestrian infrastructure (Maghelal & Capp, 2011; Morar et al., 2014).

Recent studies use GPS traces, smartphone data, LiDAR, and street-view imagery to capture actual pedestrian behavior and micro-scale environmental features (e.g., shade, benches, noise) (Lubitow et al., 2020).

ArcGIS Pro is a powerful GIS platform that can be used for facility accessibility analysis helping researchers and territorial analysts understand how easily people can reach a facility (like hospitals, schools, parks or stores) based on distance, travel time, or network connectivity (Bilașco et al., 2017).

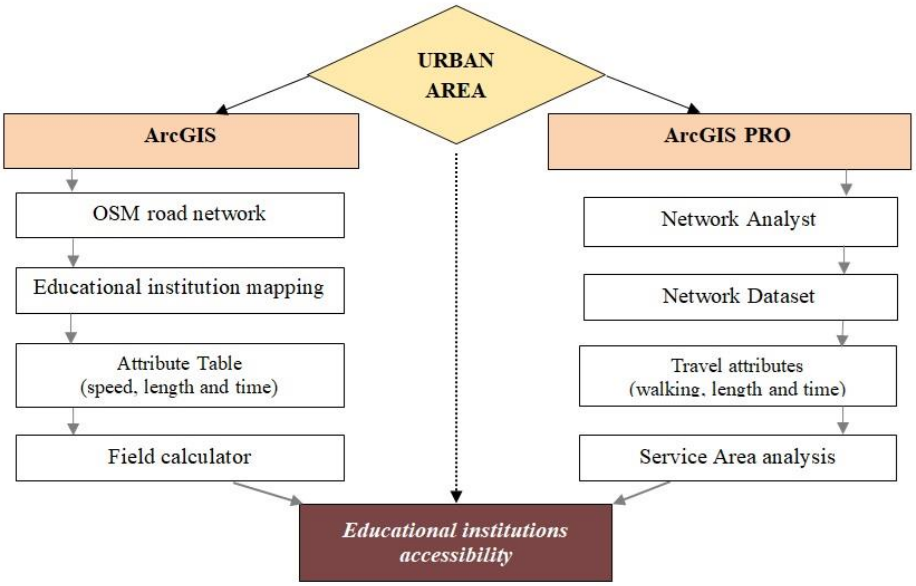

Fig. 2 Methodology flowchart

By using GIS (ArcGIS 10.7) and open geospatial data (available on Geofabrik) we managed to build the network dataset for Craiova Municipality. With the help of ArcToolbox features we created vector layers for neighborhoods, bus stations, built up areas, education facilities and transport networks (pedestrian roads). The transport network layer was updated with information regarding length, speed and travel time. Next, we used ArcGIS Pro Network Analyst tool in order to create the network dataset for Craiova. The Service Area function, incorporated into the Network Analyst extension, allows the assessment of territorial accessibility taking into account two main components embodied in vector spatial databases: the areas for which accessibility is calculated and the infrastructure on which accessibility is made, depending on a variable considered cost (time or distance) (Table 2). Accessing the Service Area function conducted to the final model for educational institutions, taking into account the speed of travel (pedestrian) by road categories, generating accessibility zones (centroids).

Table 2 Service Area Database structure

Database name	Structure	Type	Atribut
Network Dataset	Vector	Line Point	Length (m) Travel speed (km/h) Travel time (minutes) Unique travel ways
Points of interest	Vector	Point	Point of interest name (educational institutions)

3. RESULTS AND DISCUSSIONS

The map resulted has a color gradient to represent walking time (in minutes) to the nearest educational institution. The results reveal a clear accessibility gradient between the compact, well-connected central area and the more fragmented peripheral neighborhoods, reflecting the dual urban structure of Craiova. Central and densely built-up areas (shown in lighter shades of green) have the best accessibility - typically within 2 to 10 minutes of walking, while peripheral and suburban zones (brownish areas) show reduced accessibility, with walking times extending up to 73 minutes (Fig. 3). Educational institutions (marked with red dots) are concentrated in the central and southern parts of Craiova. The northwestern and eastern peripheries are less well-served, indicating potential accessibility gaps.

Central areas enjoy high spatial equity, while peripheral zones show educational access disparities. The municipality central area concentrates most of the city's schools and universities, showing the highest density of educational institutions and excellent pedestrian accessibility. In contrast, Rovine neighborhood has a mixed urban structure, with several schools located along secondary streets that still offer good accessibility. In Craiovița Nouă and George Enescu, the landscape is dominated by large residential blocks, and accessibility is ensured

mainly through the major boulevards. The 1 Mai neighborhood includes mostly secondary schools and one high school, surrounded by low-rise housing areas with easy access to the main streets. Peripheral neighborhoods such as Mofleni or Izvorul Rece show lower accessibility, primarily due to discontinuous street networks and limited pedestrian infrastructure. These areas could be prioritized for urban improvement projects aimed at reducing spatial inequalities and improving safety for schoolchildren.

Figure 3 illustrates the 5-, 10-, and 15-minutes pedestrian service areas, highlighting these spatial differences across the city.

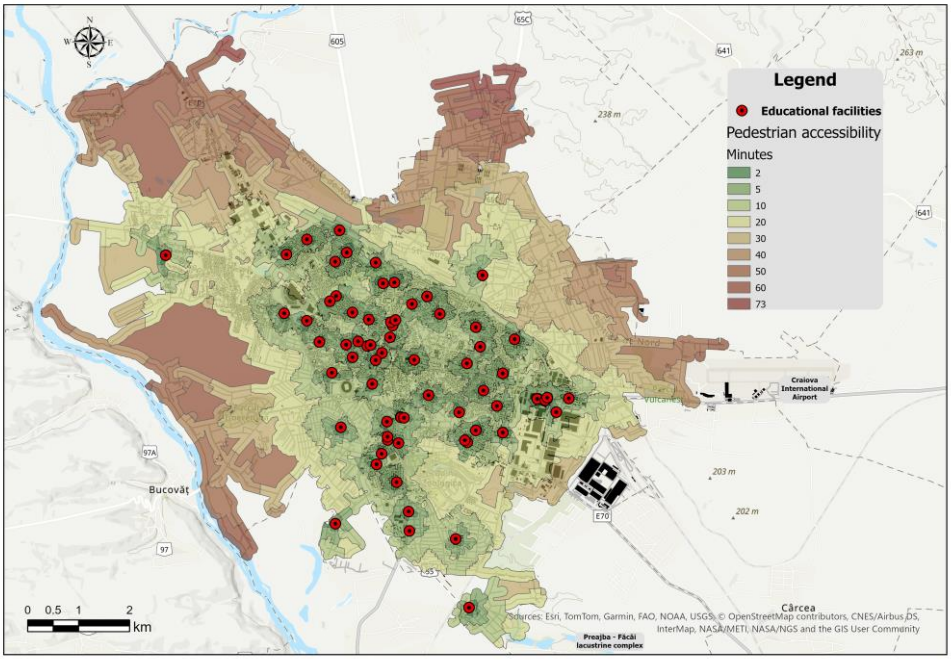

Fig. 3 Pedestrian accessibility to educational institutions in Craiova municipality

The spatial analysis by GIS methods demonstrates that pedestrian access to education in Craiova is generally good in central areas but decreases significantly toward the outskirts, highlighting areas that may benefit from improved school placement or transportation planning. The Service Area model proved effective in delineating walkable catchments and identifying accessibility gaps. Nevertheless, future analyses could integrate additional parameters such as slope, land-use patterns or sidewalk quality to refine the spatial accuracy of results.

The GIS spatial analysis highlights the potential for establishing new educational institutions in densely populated areas of the city that are not currently served by public transport. Improving accessibility in these zones would not only facilitate faster, more affordable and more comfortable access for pupils and students to their educational institutions, but could also stimulate further urban

development and reduce spatial inequalities within the municipality. Enhancing pedestrian accessibility to educational institutions not only supports sustainable mobility but also promotes social inclusion and public health by encouraging active travel among students.

Actions that can be taken based on the analysis include: development of new public transport routes in the peripheral areas of Craiova Municipality to enable and facilitate faster, at a lower cost and more comfortable access for pupils and students to their educational institutions. Overall, the spatial analysis underscores the need for integrated planning approaches that balance urban growth with equitable access to educational opportunities across all neighbourhoods of Craiova.

4. CONCLUSIONS

The integration of GIS tools in the analysis of territorial accessibility contributes to a more effective spatial management and enhances the geographical understanding of Craiova Municipality, a city currently undergoing continuous development and expansion. From a methodological standpoint, the Service Area model incorporates two essential vector components: the spatial units for which accessibility is computed and the road network employed for travel-time estimation. The combination of ArcGIS and ArcGIS Pro tools enabled the refinement of the transport network and the execution of detailed spatial analyses.

Beyond supporting spatial analysis, the resulting databases can be incorporated into the digital platforms used by local public administration, serving both informational and analytical purposes. Such integration is essential for evidence-based decision-making and for improving the efficiency of urban planning processes.

Moreover, the establishment of geoportals for managing and disseminating spatial data within local administrations is recommended, as these systems allow the creation of interactive maps that visualize buildings, available land, infrastructure, natural hazards and other relevant datasets. Looking forward, the future of pedestrian accessibility depends on the adoption of dynamic, inclusive and human-centered planning frameworks that promote public health, safety and environmental sustainability.

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