JOURNAL
OF THE BULGARIAN GEOGRAPHICAL SOCIETY

GIS-based location analysis for hospital site selection: A case study on National Children's Hospital in Sofia, Bulgaria

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Key words:
geographic information systems, geospatial analysis, transport accessibility, service area, hospital location

ABSTRACT

The present research investigates the possibilities of the available online resources and GIS analytic tools to facilitate integrating the spatial context in urban and regional planning by testing a GIS-based location analysis that uses widely available data for identifying an appropriate site for National Children's hospital in Bulgaria. The elaborated methodology is easy to use, employs accessible online resources, and could be applied in different scales. The aim is to produce a comprehensible instrument that could be adopted by public authorities and used for informed political decision-making. A series of geospatial analyses are used to evaluate the potential location and its alternatives based on transport accessibility, population density in the service area, and public transport connectivity. The analyses are based on the online resources of Google Maps that are used to evaluate the transport accessibility to all the possible locations using different perspectives. The pedestrian access to public transport is also calculated to assess the different modes of transport available. To assess the locations according to the transport accessibility of the population, tools from ArcGIS Pro Network analyst are used. Accessibility is considered from the patient's perspective. The results are analyzed to make a supposition of the alternatives and to come up with a conclusion about whether the already chosen location is a sensible choice from a transport accessibility perspective. The outcomes of the research could help policymakers understand some of the spatial complexities associated with the demand and the accessibility dimensions of healthcare access. The article emphasizes the significance of integrating the spatial context in urban and regional planning and the possibilities of the new technologies to facilitate that task. This methodology for location analysis could be also used for other public services and urban-related matters.

Article processing
Submitted: 22 June 2023
Accepted: 05 August 2023
Published: 16 August 2023
Academic editor: Dimitar Simeonov

1. Introduction

Cities are dynamic geographic entities with complex spatial structure that provide a variety of functions generating constant movement and change in the population mobility patterns. One of these functions that are attracting points in city space is public services. The location of public services with spatial dimensions becomes a policy question that deserves careful attention (Thisse and Wildasin 1991). Therefore, the process of building new public service facilities in cities should be preceded by in-depth spatial analyses that consider all aspects of influence it will have in urban and regional development. Explanation and prediction of changes in the future over time should be part of that analysis (Horton and Raynolds 1971). A place is more attractive if it attracts visitors from various places in the city, such as universities and hospitals, which attract visitors from all over the city (Alhazzani et al. 2021). Consequently, when choosing a hospital location, many factors must be considered, including how it fits in the urban space, on the broader development concept, and what changes it will bring.

The present technologies suggest various ways to estimate the accessibility of a public service within urban space by using spatial context and selected factors (Halder et al. 2020; Silalahi et al. 2020; Tripathi et al. 2022). This paper focuses on elaboration and testing of a GIS-based location analysis that uses widely available data, is easy to apply and is flexible enough to be implemented for different public services worldwide. The aim is to produce a comprehensible instrument that could be adopted by public authorities and used for informed political decision-making.

The instrument is tested on a case in the capital of Bulgaria — Sofia, where a national hospital for children's health care is about to be built. The children's hospital is a facility of national importance that will provide health care services for the children of the whole country. This means the facility will be a destination attracting many visitors and be a factor in changing the mobility patterns in the city. Considering its importance as a healthcare facility with national significance, the accessibility of its location is of crucial importance. In 2022 the government decided to place the hospital in one of the districts on the periphery of Sofia city, near a specialized orthopedic hospital. This location was one of six alternatives the government discussed, all of them situated in the capital. Although there is a list of advantages attributed to the chosen site, the wide public is left with the impression that this decision was not based on expert analysis but was only taken regarding the available land. Therefore, the present article uses a series of geospatial analyses that evaluate the chosen location and its alternatives based on transport accessibility, population density in the service area, and public transport connectivity. The analysis is based on the online resources of Google Maps that are used to evaluate the transport accessibility to all the possible locations using different perspectives. The pedestrian access to public transport is also calculated to assess the different modes of transport available. To assess the locations according to the transport accessibility of the population, tools from ArcGIS Pro Network analyst are used. Accessibility is considered from the patient's perspective. The results are analyzed to make a supposition of the alternatives and to come up with a conclusion about whether the already chosen location is a sensible choice from a transport accessibility perspective. The results could help policymakers understand some of the spatial complexities associated with the demand and the accessibility dimensions of healthcare access.

To identify essential factors and ways to approach the problem, a review of the significance of public services in urban and regional planning was performed and completed with an analysis of the perceptions of accessibility and connectivity within urban space. Location analysis is one of the approaches modern planning has adopted in its attempt to include all the factors and interdependencies, forming the relations in the urban space into one single formula that answers the question "where". The complex interrelations in the city were put into the light back in 1961 by Jane Jacobs, that claims that the theorists of conventional modern city planning have consistently mistaken cities as problems of simplicity and of disorganized complexity and have tried to analyze and treat them thus. She argues that statistics and probability techniques should find their place in city planning. Since then, this notion has been deeply integrated into urban thinking and how cities are managed. Contemporary urbanists carefully explore the city environment before planning to create the best basis for developing urban liaisons. One of the principles of urban planning according to Gehl (2010) is carefully localizing the urban functions in order to shorten the distance between specific objects and to ensure a critical mass of people and events. With this regard, when deciding where to place a hospital within the city, many perspectives need to be considered. To make the whole system work, there should be a concept when organizing space, especially when this space is so intensely populated with people, services, and infrastructure. Optimal siting in healthcare is more important than in other fields, and decisions in this relation must be made systematically by taking into account the complete spatial context (Jausovec et al. 2021). Site selection for hospitals and centers should be based on criteria and standards and existing realities and take into account the urban context and the structure of the transportation network. This way, they can cover all urban areas with respect to standard spatial and temporal distance (Soltani et al. 2019). Apart from the strictly technical factors like available land and its parameters that correspond to the infrastructure requirements, one must consider how this location fits into the existing urban fabric and how it will influence the dynamics and structure of city life. Furthermore, when we elaborate on a facility that has national significance, we should broaden the horizon and reflect on its influence on a regional and national scale. The spatial distribution of opportunities across the urban territory is a meaningful explanatory factor in the reproduction of access disparities between transport users at different locations (Gusman et al. 2018). Usually, delay in the transfer of patients to medical centers for reasons such as traffic, poor access network, the unsuitability of many passages for emergency vehicle traffic, and low speed of vehicle traffic on the network cause irreparable damages to patients. Therefore, urban planning, especially in transportation network structure, should apply more sensitivity regarding the location of quick and convenient access to emergency centers and hospitals in accordance with standards and criteria, so that these facilities can be used as soon as possible and without facing barriers and limitations in the urban environment (Soltani et al. 2019). The siting of healthcare facilities is a process that must take into account several stakeholders: patients, who need access to facilities, physicians, who strive for attractive and easily accessible workplaces, taxpayers, who require good value for their contributions, and politicians, who aim to attain their goals (Jausovec et al. 2021). In this article, the focus is the accessibility of the facility from the patient's perspective. Hospital location is a multidimensional issue. Since healthcare facilities are part of social infrastructure, many studies are looking at the problem from a social perspective and assessing transport equity considering socioeconomic and demographic factors (Graham 2018; Lopes et al. 2019; Cheng et al. 2020). This article focuses on the spatial context and the accessibility in its broader sense, setting the frame for more detailed and specific analysis.

The fragmentation of production and consumption and the locational specificities of resources, labor, and markets generate a wide array of people, goods, and information flows. The structure of these flows in terms of origin, destination, and routing is closely related to spatial organization (Rodrigue et al. 2013). Therefore, to place a new concentration point in that complex structure in an intelligent way, one should be well aware of these relations. A national hospital is such an attractor that would influence the flow of people and would impose its demand on its surrounding infrastructure. According to Rahimi et al. (2017), hospitals are one of society's most important health facilities. Therefore, these facilities should be located in a rational manner. The results from their study revealed that 'proximity to the main roads' was the most crucial criterion amongst the whole applied criteria for selecting a hospital location. Another research from Jalil et al. (2018) listed the main criteria for children's hospital site selection, among them conformity to surrounding region, incremental operating costs, site purchase cost, travel time, proximity to public transport, traffic routes, site ownership, site shape, site gradient, ground conditions

(soils/rock), access, ease of patient flow and staff movement, existing infrastructure and availability of services, perimeter buffer zone, environmental considerations, future population.

Both the scientific research and the community perspective confirm that access is a significant criterion that determines the location of a hospital. The great demand for a children's hospital in Bulgaria and its impact on the configuration and distribution of health care services, in general, require a study of the spatial interdependencies that the case forms. Considering all these perspectives and factors, this article focuses on transport accessibility as the main channel for forming spatial relations. As Geurs and van Wee (2004) point out, accessibility, a concept used in a number of scientific fields such as transport planning, urban planning, and geography, plays an important role in policymaking. They also confirm that accessibility is a location factor and influences travel demand (transport component), people's economic and social opportunities (individual component), and the time needed for activities (temporal component). According to Popov (2012), the accessibility analysis has an important practical significance for the optimal localization and development of most economic activities and for clarifying the opportunities for the population to use social, administrative, cultural, and other services, which in most cases are unevenly distributed in space. Juliao (1999) considers that accessibility is a key variable for territorial development and planning because development and planning policies are concerned with equity and a better distribution of people and activities in the territory and also because nowadays, it is widely understood that one cannot promote development regardless of different territorial specifications that make the nation mosaic.

The concepts of accessibility and connectivity need to be clearly defined. Accessibility can be broadly defined as the degree to which relevant destinations can be reached given available transport means (Kompil et al. 2019). More specifically, accessibility is the measure of the capacity of a location to be reached from, or to be reached by different locations. The notion of accessibility relies on two core concepts – location with a set of referential attributes, such as its population or level of economic activity, and distance which is derived from the physical separation between locations (Rodrigue et al. 2013). Connectivity, on the other hand, is defined as the relative degree of connectedness within a transportation network (Abbas and Hashidu 2019). However, accessibility and connectivity measure different dimensions of location endowment, which respectively reflect how well a city is located or connected in the transport network. Therefore, it is significant to include both in the gauge of location endowment (Jiao et al. 2020). These concepts could be considered from different perspectives. For example, public transport connectivity has both spatial (routes coverage, stops locations, transfer availability, etc.), and temporal (waiting time, travel time, transfer time, etc.) components (Hadas et al. 2014). The elements time, costs and effort can describe the influence on the transport component on accessibility. The extent to which the land use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport modes (Geurs and van Eck 2001). Geertman and van Eck (1995) distinguish two types of accessibility – spatial and social and which of the two aspects is more important depends on the context.

The focus on the different components of accessibility has led to various indicators and methodologies for its measurement, which include infrastructure-based measures, location-based measures, and individual-based indicators as the dominant approaches, with more recent developments using mixed approaches to study the interrelations between different components (Geurs and van Wee 2013). The location analysis of medical service centers is often focused on accessibility and activity-based impacts (Soltani 2019). Researchers combine the concepts of distance and supply with examining spatial accessibility. Access to existing hospitals is quantified, taking into account factors such as distance to nearest hospital and road network density to estimate travel time (Varnakovida and Messina 2008). Another approach used is multi-criteria decision analysis using Analytic hierarchy process (AHP) method for identifying hospital site suitability area (Halder et al. 2020). Tripathi et al. (2022) also adopts AHP and compares it with Fuzzy AHP. The COVID-19 pandemic set the need for geospatial analysis to evaluate the demand in contrast to the capacity hospitals in order to support and organize an effective health service (Silalahi et al. 2020)

As the literature review reveals, transport accessibility is a main factor for hospital location. Therefore, this article elaborates on a comprehensible method to assess how accessible a possible location for a hospital is from a time-to-travel perspective, how connected it is from a public transport point of view, and how many people have fast access to its location, again from a travel-time perspective. The present study has adopted methods and techniques that are accessible for the wide public, but efficient as well. Therefore, the research is based on the following criteria: to be applicable in smaller and bigger scale; relies on realistic data; uses online resources that are easily available and require less effort for processing; gives a reliable information for the accessibility and connectivity that could be further elaborated with more specific analysis like social equity, specialized health services and so on.

2. Materials and Methods

The use of GIS analysis for assessing the accessibility of new facilities is widespread and the methods and approaches used are being constantly upgraded. Harris (2001) uses Network-Based Space-Time Prisms to analyze individuals' accessibility within the environment. This allows the accessibility measures to consider the locations and time-varying travel velocities dictated by the network. "Pathdistance" from ESRI Arc/Info was selected for the travel time methodology to quantify access to existing hospitals from Varnakovida and Messina (2008). Kara and Egresi (2013) used buffer zones around hospitals and a short distance analysis using GIS to measure the accessibility to healthcare institutions. Reckha et al. (2017) use a simple gravity-based accessibility model and floating catchment area method road network analysis to assess accessibility and availability to healthcare facilities in urban environment. Graham (2018) uses multinomial regression to examine the factors associated with GP coverage and the average travel distance to the nearest GP practice, again measured using network distance. Luqman and Kahn (2021) applied network analyst tools to the road network and health facilities to find accessibility and performed spatial overlay analysis to mask the residential areas and population count. Contemporary research relies on selecting important criteria for hospital by means of field survey, interviews and questionnaires (Youzi et al. 2017) or questionnaire, completed by experts based on analytic hierarchy process Rahimi et al. (2017); Halder et al. (2020) and Tripathi et al. (2022) apply multi-criteria decision analysis using AHP method for identifying hospital site suitability area. In Bulgaria, geospatial analyses for assessing accessibility to healthcare have not been done yet. They were applied in other spheres, in any case. In her dissertation, Manolova (2020) explores the dependency of the population on transport arteries in different parts of Bulgaria, confirming the significance of transport accessibility for the development of regions. Sarafova (2019) combines spatial analysis with business modeling to assess

Kyustendil Municipality's potential for ecotourism development. Accessibility modelling evolves over time with the development of the new technologies and software capabilities. The resources provided by Google Maps are implemented in the present research and demonstrate the opportunities of that this type of data that is easy access, detailed, accurate and up-to-date.

The methodology combines the online resources of Google Maps for routing and evaluating the travel time from all city entrances and ArcGIS Pro Network Analyst for assessing the service area. Google Maps is very valuable source of information because the spatial data of the road network is enriched with the temporal data of the travel time in different traffic, which gives important insight for accessibility. Google Maps employs Graph data structures to calculate the shortest path from the source (point A) to the destination (point B) and A algorithm to find the shortest path between a given source and destination. Google Maps determines the approximate arrival time by considering factors like distance remaining, average speed due to real-time traffic conditions, historic data and officially recommended speed (Mehta et al. 2019). This paper relies on realistic data, and Google Maps algorithms reflect more factors than a transport GIS model that is based only on infrastructure data. Users' multiple forms of participation make a valuable contribution by powering this service with a constant feed of actual data. In fact, this platform has now attained a scale, reach, and social role similar to the existing infrastructures that typically organize cartographic knowledge in society (Plantin 2018). The implementation of this kind of data that is enriched with such powerful resources has the potential to change the common perception of accessibility analysis. Factors such as traffic congestion impose increasingly complex and severe constraints on individual travel and participation in activities (Wu and Miller 2001). Therefore, evaluations needed for traveling with no traffic and in rush hour were made to reveal the ratio between actual travel time / free flow travel time, using all scenarios. This gives an additional aspect of the availability of the location and contributes to reaching realistic results. The assessment of the accessibility was made in two ways: with starting point the main entrances to the city towards the hospitals and isochrones from the hospitals – driving time and walking time. The access time from the entrances of the city gives the regional context and gives ground to conclude whether the location of the hospital is of importance for the access of patients outside the city and which is the best choice in that case. The service area approach gives the urban context and shows the number of people directly served by its location and the urban transport connectivity of each of the six choices.

To collect the needed data, a request for routing from the nine main entrances of Sofia to the six alternative locations of the hospitals was made in Google Maps. The requests were made twice – once with parameters calculated with no traffic and once in rush hour (Monday, 8.30 am),

A table with the outcomes for the 54 alternatives is populated, containing the most and least favorable travel duration, the standard deviation, the distance in kilometers, and the deviation from the most favorable driving time per location.

To take into consideration the population living in the service area of the hospitals, again, from travel-time perspective, tools from ArcGIS Pro Network analyst are used. According to Popov (2012), this analysis is used to define an optimal route in a network structure based on specific rules for decision-making during moving through the network. The specific tool we use is the Service area analysis. Service areas are generated based on features such as road networks and base points representing selected objects or facilities. These tools are applied to solve transportation problems related to accessibility and the determination of service areas (Flisek and Lewandowicz 2019). This analysis was applied to calculate and draw isochrones for driving time toward the possible hospital locations and isochrones for walking time. The results were used to assess the following two criteria:

- the population within the different isochrones (driving time). For this analysis, were created isochrones with uneven steps - 5 minutes step for the isochrones from 0 to 30 minutes, 10 minutes step for those to 60 minutes, and one more 90-minute isochrone. Next, the population within each of the isochrones was calculated. The population data used for this analysis is very precise - geocoded data per building from the Vision for Sofia project (Sofia municipality 2020). The disadvantage of these data is that they are from the previous population census (2011) but nevertheless, it remains the only available for the moment. The most significant differences observed here are in the isochrones from 5 to 30 minutes, so they are more important for the analysis.
- the pedestrian accessibility to public transport - transport availability, concerning the number of public transport stops and lines within the walking time isochrones (5, 10, and 15 minutes). The stops and lines for this analysis are relevant to 10.12.2022, when they were last been edited. The source we used is the interactive map published by the Urban mobility center (Sofia municipality, Urban mobility center 2022).

A flow chart of the used Methodology is presented in Fig. 1.

2.1. Study area

Sofia is the capital and largest city of Bulgaria. It is situated in the western part of the country, at the foot of the Vitosha mountain. Sofia is a progressively developing city that has concentrated 25% of the country's population (National Statistical Institute, 2022). There are 59 hospitals that concentrate specialists from all fields of medicine (Plan for Integrated Urban Development, 2021). The need for a National Children's Hospital has been a burning issue in Bulgarian public space for years. Politicians, medics, experts, and society lead discussions on the form of property, the need for reform, the need to implement high-tech in pediatrics, the need for human resources in the sector, and, of course, where the future new hospital should be located. The National Healthcare Strategy 2021-2030 (Ministry of Healthcare 2020) recognizes the need for building a National Pediatric hospital that provides comprehensive medical services for children and brings together all specialists working with children and their health. This is of great importance for rendering adequate, timely, and highly qualified assistance to children. The six alternative hospital locations are situated in different parts of the capital. One of them is located in the southeastern part of Sofia, near the exit towards Trakya highway, connecting the capital with the central and eastern part of the country (St. Anna). One is in the central urban zone (Alexandrovska) and one is in its periphery (Lozenets). Other two are located in the southwest part of Sofia, near the exit that connects the capital with the southern part of Bulgaria, and one is in the suburbs of the city (Fig. 2).

Apart from being dispersed in space, the locations are situated in parts of the capital that are very heterogeneous in their structure – central urban spaces that accommodate a dense network of services and infrastructure, densely populated residential areas, urban periphery that offers free space but low density of surrounding services and also in the suburbs. These particularities are considered as they suggest different forms of access and would integrate such a facility in a different way. This aspect is be analyzed here from a transport accessibility perspective but could be also investigated from a development and planning point of view.

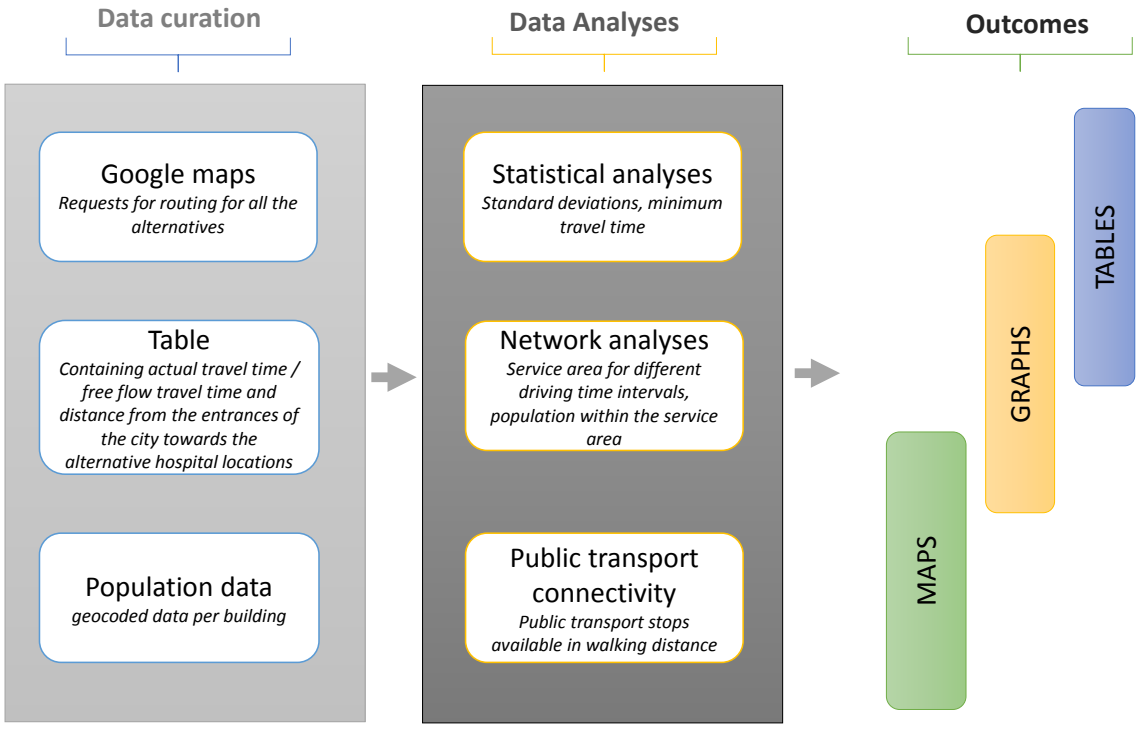

Figure 1. Flow chart of the used methodology.

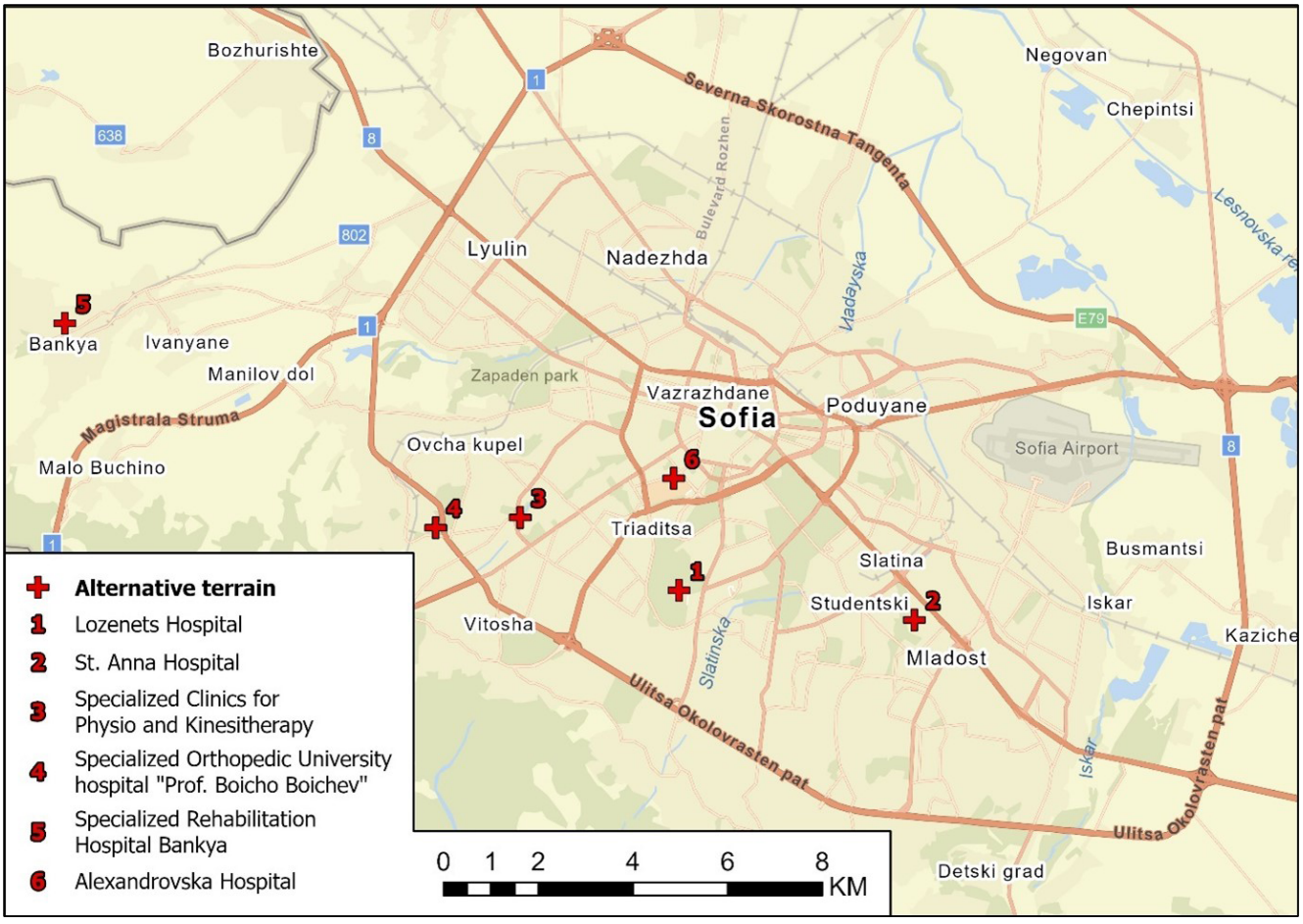

Figure 2. Location of the alternative terrains for children's hospital in Bulgaria. Source: basemap, Open Street Map (OSM).

3. Results

When looking into this issue three perspectives are considered, starting from the regional context, and narrowing the scale to service areas. Considering that this hospital will take care of children from the whole country, it is important first to analyze the access in a broader spatial context. To do that, we have calculated the driving time from the 9 main entrances of the city toward the 6 possible hospital locations, using the advantages of Google Maps. We have populated a table from each destination towards each option t considering the travel with heavy traffic and no traffic. This table was used as a source for a series of statistical and spatial analyses.

The table shows that when the city is entered from the north, the deviation in the travel time for reaching the six possible locations is smallest. This means that if one enters the city from the northeast, it is of no great importance which of the six locations is chosen. On the other hand, Alexandrovska Hospital is the one that is as easily reached from any entrance of the city. However, when traffic is added as a factor, the results are different (Table 2).

The time to access the hospitals rises several times when traffic is added, the patients using the northwestern entrances, travel 4 four times more than when there is no traffic. Traffic influences least the access to Specialized Orthopedic University hospital "Prof. Boicho Boichev" (4).

The hospital that is easy to reach when coming from the east is St. Anna, and when coming from the west - Specialized Rehabilitation Hospital Bankya and Specialized Orthopedic University hospital "Prof. Boicho Boichev" and are the slowest alternatives to reach when coming from the east. It is important to pay attention that the eastern entrances (SE and NE) give access to a significant part of the population in Bulgaria. The location of the hospital matters the most for all the locations coming from the east, from Trakia highway. St. Anna hospital is located at that entrance, and it is much easier to reach than any other possible location. Here the bypass roads play an important role because they allow avoiding heavy traffic. This circumstance gives precedent to all the locations situated on the city's periphery. The statistics analysis revealed that traffic plays an important role in access to the locations and influences accessibility

Table 1. Access time from the city entrance to the six possible hospital locations with no traffic (min.): 1- Lozenets Hospital; 2- St. Anna Hospital; 3- Specialised Clinics for Physio and Kinesitherapy; 4- Specialized Orthopedic University hospital "Prof. Boicho Boichev", 5- Specialized Rehabilitation Hospital Bankya; 6- Alexandrovska Hospital, Source: Google Maps.

Entrance	Direction	1	2	3	4	5	6	Deviation (min)
A1	SE	18	10	19	18	30	17	20.00
A2/I-1/I-6 (Dolni Bogrov)	NE	20	16	25	24	24	20	9.00
A3	W	20	23	12	8	11	15	15.00
II-82 (Pancharevo)	SE	14	11	16	15	30	16	19.00
III-181 (Bistritsa)	S	11	13	13	12	27	13	16.00
I-1/I-6 (Knyazhevo)	SW	13	18	7	4	19	9	15.00
I-8 (to Kalotina)	W	28	23	15	11	9	16	19.00
II-81 (to Petrohan)	NW	23	23	16	12	12	18	11.00
II-16 (Iskar gorge)	NW	27	26	20	17	16	21	11.00
Difference between the minimum and maximum travel time (min)		17.00	16.00	18.00	20.00	21.00	12.00	

Table 2. Deviation in access time for the six possible hospital locations with heavy traffic (min.): 1 - Lozenets Hospital; 2-St. Anna Hospital; 3-Specialised Clinics for Physio and Kinesitherapy; 4-Specialized Orthopedic University hospital "Prof. Boicho Boichev", 5- Specialized Rehabilitation Hospital Bankya; 6-Alexandrovska Hospital, Source: Google Maps.

Entrance	Direction	1	2	3	4	5	6	Deviation (min)
A1	SE	30	20	35	35	45	45	25.00
A2/I-1/I-6 (Dolni Bogrov)	NE	40	30	40	40	35	45	15.00
A3	W	60	65	45	35	16	45	49.00
II-82 (Pancharevo)	SE	26	26	28	30	60	45	34.00
III-181 (Bistritsa)	S	22	30	24	26	55	28	33.00
I-1/I-6 (Knyazhevo)	SW	30	45	12	10	40	26	35.00
I-8 (to Kalotina)	W	60	65	50	40	12	45	53.00
II-81 (to Petrohan)	NW	60	45	50	40	16	50	44.00
II-16 (Iskar gorge)	NW	70	50	55	45	22	55	48.00
Difference between minimum and maximum access time (min)		48.00	45.00	43.00	35.00	48.00	29.00	

Table 3. Summary on the access to the alternative hospital locations: 1- Lozenets Hospital; 2-St. Anna Hospital; 3-Specialised Clinics for Physio and Kinesitherapy; 4-Specialized Orthopedic University hospital "Prof. Boicho Boichev", 5- Specialized Rehabilitation Hospital Bankya; 6-Alexandrovska Hospital, Source: National Statistical Institute.

Entrance	Type	Districts	Population	Children	Direction	Fastest (no traffic)	Fastest (heavy traffic)	Slowest (no traffic)	Slowest (heavy traffic)
A1	Highway	parts of Sofia district, Pazardzhik, Plovdiv, Stara Zagora, Sliven, Yambol, Smolyan, Kardzhali, Haskovo, Burgas	2 328 324	429 808	SE	2	2	5	5 and 6
A2/I-1/I-6 (Dolni Bogrov)	Highway	Lovech, Vratsa, Pleven, Gabrovo, Veliko Tarnovo, Ruse, Targovishte, Razgrad, Shumen, Silistra, Dobrich, Varna, parts of Sofia district, parts of Pazardzhik, Plovdiv, Stara Zagora, Sliven, Burgas	2 126 691	361 211	NE	2	2	3	6
A3	Highway	Pernik, Kuystendil, Blagoevgrad, parts of Sofia-town district	518 125	90 034	W	4	5	2	2
II-82 (Pancharevo)	Class 2	parts of Sofia district	34 864	6 555	SE	2	1 and 2	5	5
III-181 (Bistritsa)	Class 3	parts of Sofia district	34 864	6 555	S	1	1	5	5
I-1/I-6 (Knyazhevo)	Class 1	Pernik, Kuystendil, Blagoevgrad,parts of Sofia-town district	518 125	90 034	SW	4	4	5	2
I-8 (to Kalotina)	Class 1	parts of Sofia district	45 814	7 222	W	5	5	1	2
II-81 (to Petrohan)	Class 2	Montana, Vidin, Vratsa	348 171	58 135	NW	4 and 5	5	1 and 2	1
II-16 (Iskar gorge)	Class 2	parts of Sofia district, Vratsa	172 240	29 788	NW	5	5	1	1

when it refers to time. The central locations, like Aleksandrovska hospital, are not easy to reach from destinations outside the capital during rush hours.

Specialized Clinics for Physio and Kinesitherapy and Specialized Orthopedic University Hospital "Prof. Boicho Boichev" have a very balanced location, and it makes almost no difference from which part of Bulgaria you are coming from.

The hospital is in the territory of the capital, the city with the greatest concentration of population. Therefore, accessibility within Sofia is also an important accent of the research, again with a focus on the driving time to reach the six alternative locations. A network analysis was done to distinguish the service area of the hospitals in terms of the population that falls within driving time intervals from 5 to 40 minutes.

Fig. 3 shows the service area for the possible terrains. The red zone illustrates the service area within a 5 minutes' drive of the location, while the dark green territories are 40 minutes away. We observe that the eastern and southern locations pull away the accessibility, leaving a bigger part of the territory in the 25 – 30-minute interval. The location in the suburbs (Specialized Rehabilitation Hospital Bankya) leaves most of the capital in 30–40-minute intervals. Most central locations, like Alexandrovska Hospital and Lozenets Hospital (terrains 1 and 6) provide evenly distributed access that is core centered. However, this does not mean it is directly proportional to population density. Furthermore, having in mind that in the capital city live 1 274 000 people (according to the census 2021), which is 19.5% of the country's population, it is important to estimate how the locations reflect the distribution of people in the capital. We calculated the population that lives in that service area using the census from 2011 and outlined the number of children up to 18 years.

The closest area that falls within 5 minutes driving time away services directly most people around Specialized Clinics for Physio and Kinesitherapy — 47 384 people live 5 minutes away from the hospital (7 661 children). That hospital is in a densely populated residential area and provides direct fast access to most people. If we widen the interval, we get Alexandrovska Hospital at the top list. Because of the specifics of the residential area, still, the Specialized Clinics for Physio and Kinesitherapy hold the top place for the number of children in the service area that is 10 minutes away. The more we widen the interval the more Alexandrovska Hospital stands out as a location that ensures fast access to health services for many people. Nevertheless, the analysis shows that 5 out of the 6 hospitals are 30 minutes away from most of Sofia, which is still acceptable and again does not serve as a criterion to drastically differentiate the advantages of any location. It is important to mention that

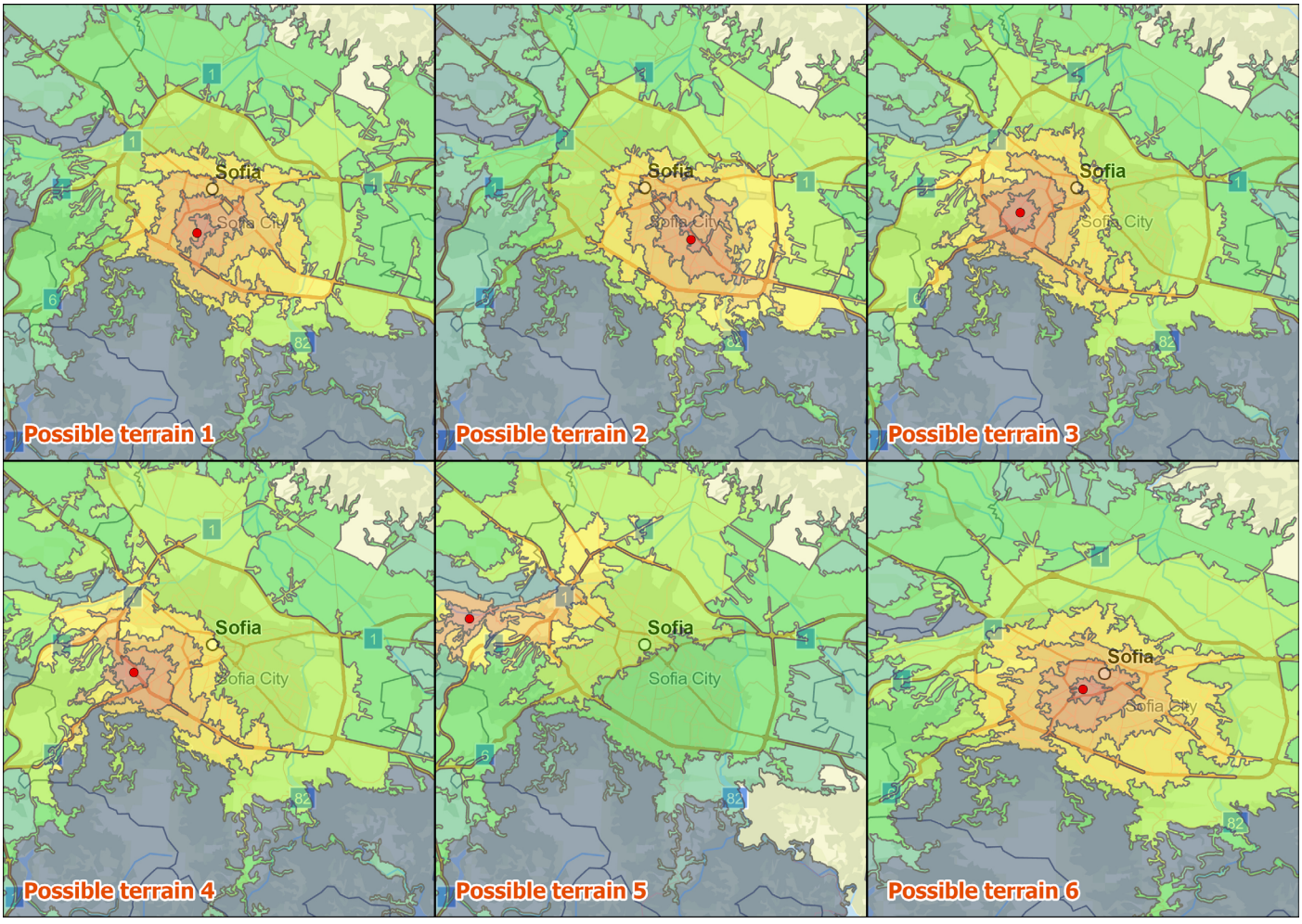

Figure 3. Service area for the possible terrains: 1 - Lozenets Hospital; 2 - St. Anna Hospital; 3 - Specialized Clinics for Physio and Kinesitherapy; 4 - Specialized Orthopedic University hospital "Prof. Boicho Boichev"; 5 - Specialized Rehabilitation Hospital Bankya; 6 - Alexandrovska Hospital. Source: basemap, OSM.

Specialized Clinics for Physio and Kinesitherapy and Specialized Orthopedic University Hospital "Prof. Boicho Boichev" are about 30 minutes away from Pernik which has 71 504 residents in 2020 and they should also be included in this calculation. The Specialized Rehabilitation Hospital Bankya is the outlier that includes the least people in its service area.

To open the analysis to access beyond the car dependency, the public transport available to the 6 possible locations was estimated. Following the tendencies and intentions for a city with fewer cars and diversion of transport means, it is important to include this analysis as a criterion. Planners should always have a broader view for the development of urban space and investigate the long-

Table 4. Population within the services area of the 5 possible locations, Source: National Statistical Institute (2011).

	Service area 5 min			**Service area 10 min**			**Service area 15 min**		
Hospital	Pop.	% of the total pop.	Children (up to 18)	Pop.	% of the total pop.	Children (up to 18)	Pop.	% of the total pop.	Children (up to 18)
Terrain 1 Lozenets Hopsital	24 754	2.1%	3 830	167 508	13.9%	24 261	552 676	46.0%	86 399
Terrain 2 St. Anna Hospital	25 568	2.1%	3 782	246 710	20.5%	38 106	469 914	39.1%	74 289
Terrain 3 Physio and Kinesitherapy	47 384	3.9%	7 661	260 927	21.7%	43 073	456 321	37.9%	71 338
Terrain 4 "Prof. Boicho Boichev"	19 748	1.6%	3 515	112 425	9.3%	18 359	297 386	24.7%	49 469
Terrain 5 Bankya	6 728	0.6%	1 071	11 137	0.9%	1 835	67 402	5.6%	11 534
Terrain 5 Alexandrovska Hospital	35 200	2.9%	4 483	261 701	21.8%	37 708	596 212	49.6%	92 431
	Service area 20 min			**Service area 30 min**			**Service area 40 min**		
Hospital	Pop.	% of the total pop.	Children (up to 18)	Pop.	% of the total pop.	Children (up to 18)	Pop.	% of the total pop.	Children (up to 18)
Terrain 1 Lozenets Hopsital	887 454	73.8%	142 284	1 127 112	93.7%	182 240	1 172 298	97%	189 865
Terrain 2 St. Anna Hospital	720 119	59.9%	113 744	1 125 227	93.6%	181 866	1 168 415	97%	189 239
Terrain 3 Physio and Kinesitherapy	796 492	66.2%	128 212	1 137 336	94.6%	183 741	1 173 851	98%	190 132
Terrain 4 "Prof. Boicho Boichev"	626 021	52.0%	102 362	1 145 832	95.3%	185 160	1 171 016	97%	189 563
Terrain 5 Bankya	167 590	13.9%	28 430	659 185	54.8%	105 022	1 158 891	96%	187 687
Terrain 5 Alexandrovska Hospital	1 033 257	85.9%	165 921	1 136 036	94.5%	183 693	1 175 107	98%	190 313

term trends and perspectives for the territory. The contemporary concept of the 10-minute city is a worldwide trend that consolidates urban planners and gives a new perspective for urban territory management centered around living locally. It is basically all about the ability that people to meet their everyday needs within a 10-minute walk, cycle, or public transport. The ability of urban neighborhoods to meet these requirements is often unequally distributed across cities, predicated upon both existing urban morphology and extant patterns of spatial inequalities. However, it is often presented as an equitable force for enhancing all citizens' well-being, ignoring, or at best, hopefully re-imagining, the impact of planning for new services and active travel support on existing spatial inequalities (Calafiore et al. 2021).

Three possible intervals considered: 5-10-15 minutes walking distance and summarized the number of stops for these three isochrones, the number of public transport lines passing by, as well as the available metro stations and helipads. We considered these intervals to reflect the general public attitude towards city walking and are based on general observations of pedestrian movement. This factor, however could also be a matter of individual research as pedestrian movement is a complex matter, difficult to interpret. Key features to be incorporated are the agenda of the individual (purpose of journey) and interaction with the built and demographic environment — road traffic, urban layout, and crowd size. Two elements present difficulty. Pedestrians do not always follow simple logic or "stimulus-and-response"-based behavior and, unlike other road users (such as motorized vehicles or bicycles), do not need to, and indeed do not, follow preset movement lines. This freedom in choice and execution of movement means that any model must allow for randomness, treating individual behavior as unique to some extent (Bezbradica and Ruskin 2019). For the purpose of this study, we used a very general model with short time intervals.

Table 5 presents the total number of stops within 15 minutes of walking time (calculated for both directions). Public transportation is available for all locations, which is good. Alexandrovska hospital is best supplied with public transport. There are 41 public transport stops in the vicinity, 3 of which are 5 minutes away. There are 15 lines passing by that connect different parts of the city. Moreover, the metro station is 15 minutes away, making access more diverse. This is one of the advantages of being in the central part of the city – good connectivity in terms of public transport. However, this location is related to congestion and lack of parking space when accessed by car.

The Specialized Clinics for Physio and Kinesitherapy is also well supplied with public transport, with 5 stops within 5 minutes of walking time.

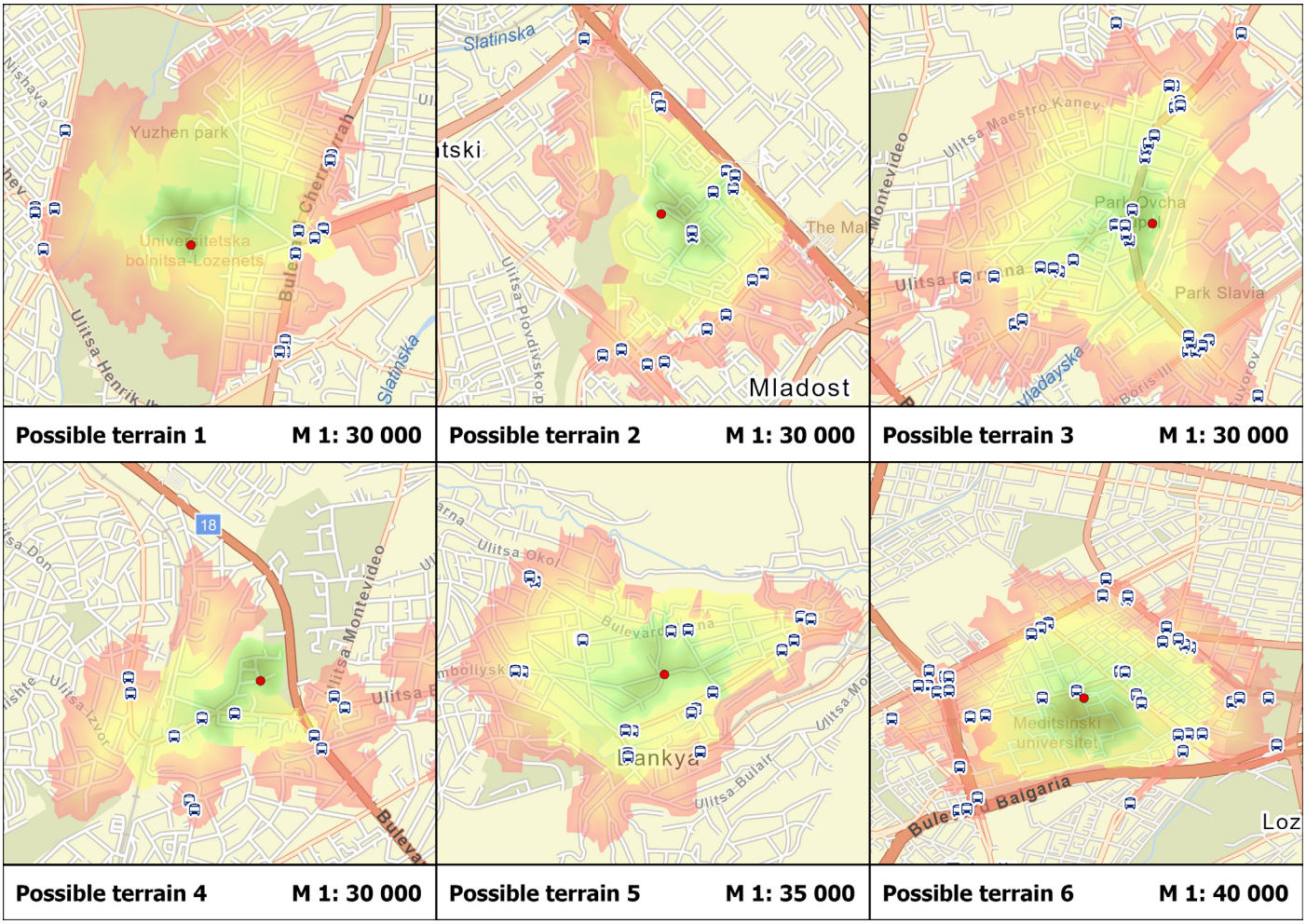

Figure 4. Public transport connectivity to the six possible locations, 1 - Lozenets Hospital; 2 - St. Anna Hospital; 3 - Specialized Clinics for Physio and Kinesitherapy; 4 - Specialized Orthopedic University hospital "Prof. Boicho Boichev"; 5 - Specialized Rehabilitation Hospital Bankya; 6 - Alexandrovska Hospital. Source: basemap, OSM.

Table 5. Public transport connectivity to the six possible locations, Source: Urban Mobility Centre.

Terrain	Number of stops in total	Number of stops 5 minutes away	Number of stops 5 minutes away	Number of stops 10 minutes away	Number of stops 10 minutes away	Metro stations 5 minutes away	Metro stations 10 minutes away	Metro stations 15 minutes away	Helipad
Terrain 1 Lozenets Hopsital	14	0	4	4	4	0	0	1	yes
Terrain 2 St. Anna Hospital	17	2	3	14	2	0	0	1	yes
Terrain 3 Physio and Kinesitherapy	32	5	0	0	6	0	0	1	no
Terrain 4 "Prof. Boicho Boichev"	14	2	1	1	2	0	0	0	no
Terrain 5 Bankya	22	1	4	3	0	0	0	0	no
Terrain 5 Alexandrovska Hospital	41	1	3	8	7	1	0	3 (2 lines)	no

Although in the periphery of the city's center, Lozenets Hospital has no public transport that goes nearby. The closest stops are about 10 minutes away, and 6 more if one is determined to walk 15 minutes.

Specialized Rehabilitation Hospital Bankya is the most peripheral location, 4 public transport lines connect it, but it is hardly accessible via public transport.

This public transport analysis gives just a short glimpse of the situation and gives an overall picture of the alternatives to accessibility by car. Therefore, it is important when deciding where to place the hospital to analyze the lines and the connections they make with the rest of the city. This is vital information that would help improve the public transport connectivity of the future pediatric hospital and make it easier to reach.

4. Discussion

Analyzing and estimating the long-term consequences of interventions in the urban environment should be the core of urban planning. The dynamics of the city require a broad vision of possibilities and different angles of looking into the problem. The National Children's Hospital is an interesting example of introducing a component into the urban environment that may lead to a wide range of socio-economic and transport impacts. That is why the spatial organization of this public service should be a factor of importance. The lack of an urban and regional planning perspective in health care is not local and has already been the focus of research (Humer and Granqvist 2020). The selection of a hospital location can be considered a multicriteria decision-making problem that includes existing hospitals, roads, industries, educational institutions, water bodies, demographic structure, investment costs, travel time and travel costs, environmental factors, infrastructure, compatibility, population density and many more (Gul and Guneri 2021). The present research is narrowed down to the transport perspective, investigating the travel time variations due to traffic and the significance of the bypass roads for easy access. The paper demonstrates the possibility to use online sources to analyze the spatial context of locating the healthcare facility and interpret the results from urban and regional planning perspectives. The elaborated methodology is simple to use, employs accessible online resources, and could be applied in different scales. The presented results are easy to comprehend by the wide public and could be adopted by public authorities and used for informed political decision-making. The case study is of local importance but also aims to display the significance of the preliminary analyses and spatial planning and highlight the importance of such decisions for the direction of urban development.

A perspective that the article does not concern is the railway transport – there is a station near the chosen location, which might be an option for people coming from Pernik. However, the decreasing interest in railway transport and its poor connecting possibilities make railways an unattractive option for the moment. The option for fast access that the helipad gives is of crucial importance for a hospital like this and is another important aspect that needs attention.

The research confirms that the adopted methodology shows good results and demonstrated that the chosen location is a good option for transport accessibility. The article emphasizes the significance of integrating the spatial context in urban and regional planning and the possibilities of the new technologies to facilitate that task. This methodology for location analysis could be also used for other public services and urban-related matters.

These conclusions might be a part of a location analysis for such a facility, but more assessments should be done to complete it. The matter should also be addressed from the perspective of urban development. The development of a city is more than just property management. We cannot manage a city by thinking in terms of a product or the market share. Due to the revolution of communications, a city is nowadays a space for relationships, very often virtual. Urbanism is more than management paper and should seek an increase in the sense of belonging in citizens and their

involvement in the development process of a city (González 2017). As a National Children's Hospital, the analysis should be also elevated to the spatial planning concepts on regional and national levels. The expected social impact of the location of the hospital is significant. This might also raise questions in the context of the intensifying processes of increasing the differences in region's development in the Republic of Bulgaria, raised by Ivanov (2021). That is why the choice of the location of such a facility with national significance should be a matter of expert planning that includes analysis of spatial, socio-economical, healthcare, and political nature.

5. Conclusions

The present study investigates the accessibility of the possible locations for national children's hospital by testing a flexible GIS-based location analysis that uses widely available data and is easy to apply. The study presents comprehensive results on a particular location issue that are easy to implement in the urban and regional planning mechanisms.

The conclusions from the case study show that the terrain near the Specialized Orthopedic University hospital "Prof. Boicho Boichev", which was the government's choice, is actually a very balanced option and it makes almost no difference from which part of Bulgaria you are coming from. An advantage that should not be ignored is that you pass by the big congestion of the city that could slow you down within an hour if you aim for a destination in the city center. The location is not situated in the most densely populated parts of the capital, but it is 30 minutes' driving time away from most of Sofia and moreover – it is half an hour away from Pernik. The public transport connectivity for this location is not good. The locations in the central parts of Sofia are way better served by public transport. Metro station "Gorna banya" is a good connection to the rest of the city but is more than 15 minutes away from walking time. However, this is an issue that should be addressed when planning the transport connectivity of the city and could be easily solved. A very important accent from the analysis is the role of the bypass roads and the alternatives they give. The conclusions made demonstrate the importance of the knowledge that the analysis provides. Planners and policymakers could benefit from addressing the issues with public transport connectivity and traffic in advance to make access to the hospital smarter and easier.

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Author contributions (CRediT roles)

LT: Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing - review and editing; ET: Conceptualization, Methodology, Writing - original draft.

Conflict of interest

The author have declared that no competing interests exist.

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Supplementary material

Suppl. material 1. Input data: Travel time and distance
Author: Todorov, L
Data type: Table, .xlsx
Size: 16 KB
DOI: https://doi.org/10.3897/jbgs.e108502.suppl1