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Potential Spatial Accessibility to Cardiovascular Hospitals in Romania

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Abstract: Cardiovascular diseases (CVDs) represent the leading cause of death globally. Romania recorded the highest mortality rate due to CVDs in the EU in 2022, with 162,984 deaths, while the number of registered patients with CVDs surpassed 4 million. This study aims to measure the population's potential spatial accessibility to cardiovascular hospitals in Romania, as timely access to such healthcare facilities is crucial to minimise avoidable mortality due to CVDs. Although distance is an essential parameter of spatial accessibility, time-based analysis is more reflective of real-world scenarios due to the unpredictability of travel. The potential spatial accessibility was measured using the Application Program Interface (API) offered through the Google Maps platform and a personal car as the transportation mode. The country's cardiovascular hospital network comprises 161 units, of which 84 can provide complex care. Because all of them are located in urban areas, three different time slots were considered to distinguish between high and low traffic congestion situations. We created hierarchies of ten-minute and five km intervals for travel time and distance, respectively, to emphasize the population percentages with better or low potential spatial accessibility. Results showed that only 15% of the population can reach the nearest cardiovascular hospital in less than 20 min, and 23% must travel for over 60 min, while 45.7% live farther than 20 km from a cardiovascular hospital. Inhabitants living in remote areas, especially rural ones, are the most vulnerable, having to travel for the longest time and distance. Actions like improving the existing transport infrastructure and upgrading healthcare facilities and equipment are needed to ensure better medical care and an adequate response to population needs. This study can support local authorities in optimising spatial accessibility to cardiovascular care by identifying the most burdened hospitals in the context of low medical specialised staff and large catchment areas.

Keywords: potential spatial accessibility; cardiovascular hospital; API; Romania

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1. Introduction

Cardiovascular diseases (CVDs) include a wide range of conditions such as ischemic heart disease (e.g., angina and myocardial infarction), diseases of the aorta and arteries (e.g., hypertension and peripheral vascular disease), congenital heart disease, rheumatic heart disease, cardiomyopathies, and cardiac arrhythmias. CVDs prevalence increases with age [1]. They are responsible for 3.9 million deaths yearly in Europe and over 1.8 million deaths in the European Union (EU) [2]. EU health statistics show that in 2020, 162,984 deaths were attributed to CVDs in Romania, representing 57.1% of all deaths. Eastern European countries have a higher prevalence of CVDs risk factors and are less effective in monitoring them [3]. In Romania, the death rate from ischemic heart disease was more than double the EU average, and mortality due to stroke was the second leading cause of death nationally in 2021, with the Organisation for Economic Co-operation and Development (OECD) listing 42,569 such deaths [4].

The high prevalence of CVDs has received increased attention at the governmental level in recent years. In hopes of improving policies that address CVDs and due to the lack

of data on this pathology, the Study for the Evaluation of Prevalence of Hypertension and Cardiovascular Risk in Romania (SEPHAR) project was implemented in 2005, 2012, and 2016. It aimed to assess awareness, prevalence, treatment, and control of CVDs among the Romanian adult population [5].

The National Programme for Cardiovascular Diseases, updated through Order No. 29/2023 and implemented by the National Health Insurance House [6], establishes the eligibility criteria and activities carried out in treating cardiovascular patients. The National Health Strategy 2023–2030, a document issued after consultation with representatives of all relevant institutions in the healthcare system, includes, among other objectives, to improve timely access to diversified, high-quality and efficient healthcare services provided by professional teams in primary health care. It warns that most potential years of life lost (YLL) can be attributed to premature deaths due to cerebrovascular and ischemic heart diseases [7]. A National Strategy for Preventing Cardiovascular and Cerebrovascular Diseases was launched in 2022, and one of its main objectives is to reduce avoidable mortality from cardiovascular and cerebrovascular diseases in Romania by 5% by 2030 [8].

Although Romania has a relatively large number of hospitals, urban areas and larger cities tend to be disproportionately favoured. This dispersal is the consequence of historical urban development decisions and policies on the territorial allocation of health services, which focused on aligning the hospital network with the country's urban development. To a lesser extent, this imbalance can be attributed to the population's selective use of some hospital services rather than other healthcare units [9].

The same pattern applies to the distribution of the healthcare workforce. While urban areas, particularly the capital city of Bucharest, are well-served with medical professionals, rural areas face a severe shortage of specialised healthcare providers, including cardiologists. The unequal distribution of physicians generates differences in service efficiency and the equitable access of the population [10].

Healthcare accessibility refers to how expeditiously residents in a given area can reach a particular healthcare facility, such as a hospital [11]. It is a complex concept that includes dimensions such as availability of services, affordability, and eligibility of patients according to a health unit's specialisation [12]. The term 'potential' when discussing accessibility means no real interaction between patients and healthcare providers has happened, and the analysis is purely hypothetical. On the other hand, realised accessibility reflects the actual use of the healthcare service, reflecting the supply and demand for services, including individual attributes such as preferences and information levels [13]. Spatial accessibility considers location relationships, travel time, and distance, while non-spatial accessibility focuses on socio-economic status and cultural background [14]. Unlike its non-spatial counterpart, spatial accessibility emphasises the role of geographic distance and time in interactions between health services and population demands.

Patients with acute cardiovascular conditions have higher mortality rates when care is delayed either because they need to travel long distances to reach emergency care facilities or because they are transferred to other units that are better equipped to provide proper treatment [15]. Travel distance and time to the nearest healthcare provider are the most commonly used parameters to assess accessibility to healthcare facilities and services [16–20]. Methods used to calculate hospital accessibility include the population-to-provider ratio [21], the kernel density method [22], the floating catchment area [23], the two-step floating catchment area [24], and the potential model or gravity model [25]. Numerous studies have concluded that travel time is more appropriate than travel distance for measuring travel effort, especially in regions with physical barriers such as major rivers, mountains, or an irregular coastline [19,26,27].

Time is a vital component when dealing with CVDs. It is critical that, in these cases, treatment is received as soon as symptoms are identified. Acute myocardial infarction (MI) is a cardiovascular disease that produces irreversible damage to the heart muscle due to a lack of oxygen [15]. Patients who receive treatment in the first hour after the onset of symptoms see the most benefits. Following American and European guidelines, in the case

of MI, cardiac catheterisation should be performed within 90 min of initial contact with a physician [28]. Many patients are excluded from treatment because of excessive delays, which were shown to vary between 4.6 to 24 h [29].

Another cardiovascular emergency that requires immediate care is stroke. The effectiveness of neuroprotective medications and thrombolytic treatment is distinctly time-dependent, with the best results showing within 3 h of the onset of symptoms and with some limitations of up to 4.5 h [30]. Furthermore, in the absence of highly specialised cardiac centres, a patient will survive if adequate care is provided no later than 30 min in a hospital setting [31]. Regardless of the type of treatment, the best-case scenario is obtaining the shortest delay between the onset of symptoms and treatment [32]. This highlights the need to get patients to an appropriate stroke centre quickly. A study conducted by Lorenzovici et al. (2020) underlines that 5.5% out of total patients who had a stroke diagnosis had been readmitted to a hospital within a 12-month period after the event [33]. Time was also identified as being vital when treating MI [34].

Spatial accessibility offers an image of existing inequalities in healthcare resource distribution and is influenced by the design of the healthcare network, traffic conditions, and geographic factors [35], which is why it has been a focus of the health geography literature for a long time. Only a few studies have approached the problem of population accessibility to hospitals in Romania [10,36,37], but fewer still have focused on a particular category of patients. One critical study explored the potential geographical access to different ranked public hospitals in Romania, concluding that over 80% of the population can reach the nearest hospital facility in less than 30 min of driving. In contrast, the maximum travel time by car to the nearest hospital was calculated at 117 min [36].

This study aims to measure the population's potential spatial accessibility, considering the travel time to reach the nearest cardiovascular hospital. Distance was also included in the analysis to provide a balanced approach. We considered three time slots reflecting different traffic conditions to obtain a more comprehensive view of the specificities in potential spatial accessibility to cardiovascular hospitals. This is the first study with a particular targeted approach at the national level.

2. Materials and Methods

2.1. Study Area

Romania is an Eastern European country with a population of 19 million at the last census in 2022 and a total land area of 230,170 km^2. The urban population represents 54% and is concentrated in 320 cities and towns. The rural population is relatively high, 46%, and is gathered in 2861 communes. Bucharest, the capital of Romania, is the largest city, with a population of 2,160,169 inhabitants. Administratively, there are 41 counties grouped into eight Development Regions established in 1998 [38]. These regions (corresponding to the NUTS-2 level of the EU) do not have a functional administrative board but provide a framework for the implementation and evaluation of regional development policies, as well as the collection of specific statistical data per the European regulations issued by EUROSTAT. The national road network includes 924 km of highways, 5697 km of European roads, 36,009 km of county roads, and 27,780 km of municipal roads. The coverage and quality of the road network can influence spatial accessibility to cardiovascular hospitals. The road quality in Romania is classified as very low, with a 2.7 score (on a value scale from 1 to 7) compared to other EU countries [39]. Only 48.2% of all roads are modernised, 1.6% (290 km) are 3-lane roads, 10.3% (1826 km) 4-lane roads, and 0.1% (22 km) 6-lane roads. Romania is ranked 17th at the EU level in terms of the number of built kilometres of highways. In 2022, there were only three completed highways, two in the advanced construction phases, three in the initial phase, and two in the design phase. Their distribution differs among regions, with the North-East region, for example, having only 20 km of highway [40].

Speed limitations can increase travel time. In Romania, the speed limit is 50 km/h on local roads inside a locality, 90 km/h on local roads outside a locality, 100 km/h on European, express, and national roads, and 130 km/h on highways [41].

2.2. Population and Cardiovascular Diseases Data

This study used 3186 Local Administrative Units (LAU2), consisting of communes, municipalities, and cities, as the starting points for assessing distance and travel time to the nearest hospital that can provide cardiovascular care. The data for the total population and those over 65 years at the LAU2 level in 2022 are available at http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (accessed on 27 January 2024). Data related to mortality due to CVDs were obtained for 2021 from the National Institute of Statistics (NIS) [42]. Data on the number of hospitalised patients diagnosed with CVDs per each hospital in 2021 was extracted from the Diagnosis Related Groups system database, managed by the National School of Public Health, Management and Professional Development [43].

2.3. Cardiovascular Hospitals and Cardiologist Data

Data on the number of hospitals and health facilities are available on the Romanian Ministry of Health website. In Romania, there are 544 hospitals, 357 of which are public [44]. There are 161 hospitals with at least a cardiology department, out of which 158 are public and 3 are private. A total of 84 of the 161 units can perform cardiovascular surgeries and are included in the National Programme for Cardiovascular Diseases (amounting to complex cardiovascular care). Out of the 161 hospitals, 41 are county hospitals located in a county capital, 49 are municipal hospitals located in cities with more than 20,000 inhabitants, 13 are in towns with a population of less than 20,000 inhabitants, and 4 are research institutes dedicated to cardiovascular diseases, also located in large cities. All cardiovascular hospitals are located in urban areas, especially in Bucharest (16) and cities with over 200,000 inhabitants, such as Iași, Cluj-Napoca, Timișoara, and Craiova. In this study, we considered all 161 public and private hospitals that can provide basic or complex cardiovascular care and have a framework contract with the National Insurance House, meaning that the general tax-paying population is able to target them without high extra payments.

In Romania, hospitals are categorised into five ranks by the level of competence and complexity of medical services provided. Category I includes hospitals that can provide complex medical care, while category V hospitals have a limited level of competence or can deliver a single type of medical services (have only one specialisation). At the country level, 137 hospitals belong to categories I–III, 229 to IV–V, and 9 hospitals are unclassified [45]. The cardiovascular hospitals in this study belong to categories I–III (91), while 70 are classified as IV–V.

According to NIS, in 2023, the healthcare workforce relied on 71,293 physicians, of whom only 2652 were cardiologists [46]. All medical staff (both public and private sectors), including personnel from administrative or scientific research units, are statistically catalogued as working in the medical field. This approach leads to overestimating the number of physicians and hinders ascertaining the actual number of practising staff. In this study, we considered only the practising cardiologists in each hospital, according to the nomenclature of the hospital's website. This investigation found that 991 cardiologists were practising in 161 hospitals, with one hospital unit having 1 to 79 cardiologists. Categories I–II hospitals generally have more cardiologists than III–V ones.

2.4. Travel Time and Distance

In the case of CVDs, time is crucial, and a late arrival at a hospital unit can be associated with other uncertainties such as lengthy waiting times, difficulties in reaching a physician, and a delayed diagnosis. Thus, studying travel time in peak and non-peak intervals and analysing the results is crucial. Terecoasă et al. (2022) [47] analysed the pre-hospital delay in acute ischemic stroke care for patients from the University Emergency Hospital

in Bucharest, Romania. Results indicated that out of the total sample, 70.8% reached the hospital within 24 h after the stroke onset. The patients who arrived after the 24 h window from the onset of a stroke were living in rural areas and travelled to the hospital using their own means and not an ambulance. This is a relevant detail, as many studies conducted so far that analysed the factors associated with hospital arrival after a stroke onset chose ambulances as the primary means of transport [48,49]. There is a positive relationship between mortality rate and the increase in travel time to the hospital; the mortality rate of patients suffering cardiovascular injuries decreases when the travel time is less than 10 min [50].

The time interval of the day becomes an essential element in measuring the travel time to the nearest hospital. As all hospitals in this study are located in urban areas, we started from the observation that morning and evening are peak intervals with heavy traffic when roads barely accommodate a high volume of vehicles, and midnight is a non-peak interval. Due to the fact that occurrences of heart attacks vary significantly across time of day, with a critical period being the first two hours after waking up [51], the time slots selected for this study were 7–9 a.m. (as a high stroke prevalence and peak traffic time slot), 7–9 p.m. (as another peak traffic time slot but with lower stroke prevalence) and 10–12 p.m. (as a time slot with the least traffic). For each time slot, six intervals of 10 minutes' difference were modelled, considering 10 min as the optimal travel time to reach appropriate cardiac care. This research approach was facilitated by the large amount of available data about traffic flows, which made it possible to select any interval/hour of the day.

As distance is present in spatial accessibility studies, we also measured quartiles of population located at distances of <5, 5–10, 10–15, 15–20, and >20 km. This approach was meant to strengthen our initial hypothesis that, given Romania's specificities in terms of geographical conditions and diverse transportation network, travel time is a better parameter of potential spatial accessibility since distance creates unrealistic premises.

2.5. Methods

The lack of accuracy and low reliability of health data, as well as fragmented geospatial data in Romania, limits the application of many validated accessibility calculation methods used in other countries. In the context of the rapid growth of technology, online mapping platforms have evolved. Online map navigation is a tool that can be used for traffic route planning and can also provide data about road networks, the number of vehicles, traffic situations, and real-time travel speed. Thus, spatial accessibility can be reliably measured using GIS technology. Various studies concluded that travel time can be accurately acquired by background high-performance platforms and precise geographical information, such as the Google Maps Application Program Interface (API) [52,53], which provides a simple and convenient way to apply online map navigation technology to spatial accessibility research [54]. One advantage of the API technology is its ability to integrate multiple traffic factors into the resulting travel time and distance, including fundamental traffic flow and historical traffic data. The web mapping API offered by the Google Maps platform includes navigation path planning and estimated arrival time [55]. These services are more accurate and realistic than Euclidian distance visualisation [56].

This study uses API to calculate travel time and distance from the centre of each LAU2 to the nearest hospital with a cardiology department (that can provide either basic or complex interventions in cardiac cases), starting from the premise that, in case of cardiovascular emergencies, time is directly related to high survival rates.

The main research steps were: identifying the hospitals to be included in the analysis; geocoding each hospital based on the address provided by Google Maps service, which was validated by the Romanian Ministry of Health database or the hospitals' websites (i.e., on multiple occasions, one was used to confirm the other); using API's TravelTime add-in to model 10 min travel time intervals for each hospital and using these categories for three chosen time slots. The following steps included calculating the number of potential patients according to six travel time intervals in each travel time slot as well as the number

of potential patients pertaining to five distance slots. This was carried out using the Extract tool from Romania's population grid available at https://www.efgs.info/data/national/ (accessed on 27 January 2024). When calculating travel time, the chosen means of transport was a personal car. Emergency vehicle lanes are lacking on most Romanian roads, making it difficult to navigate traffic. In 2022, the average intervention time of an ambulance was 56 min [57], which can be fatal for patients with CVDs. In some regions, mainly rural areas, ambulances may also encounter limiting factors such as geographical barriers, inadequate road networks, and insufficient healthcare infrastructure. Thus, due to the scarcity of ambulances (about 13/1,000,000 inhabitants) [58] and overcrowded roads without special emergency lanes, many patients and their families resort to their personal cars in case of a medical emergency. The same difficulties are also seen within cities at peak hours, as traffic congestions, narrow streets, and lack of emergency vehicle lanes make it difficult for ambulances to get through, even if Government Emergency Ordinance No. 195/2002 states that all traffic participants must prioritise emergency vehicles as quickly as possible [41].

ArcGIS Pro 2.5.0 software was used to geocode the hospitals and generate the time and distance hierarchies. The flowchart of the study methodology is presented in Figure 1.

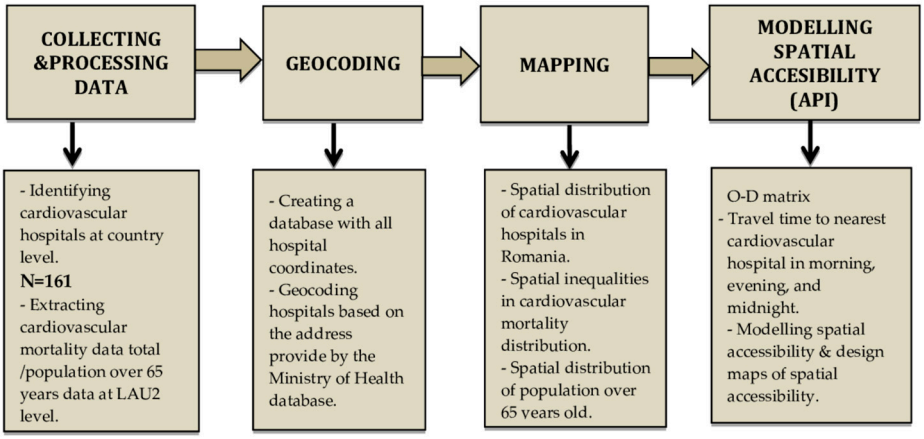

Figure 1. Methodology flowchart.

2.6. Study Limits

The lack of a more comprehensive national database regarding the number of practising physicians grouped by specialities and medical units made this research challenging. As a result, the study is based on fragmented data sources, which may have led to an incomplete and partially inaccurate representation of the territorial distribution of cardiologists.

In this study, we assumed that patients would go to the nearest hospital, but in reality, they may choose to go directly to the hospital that provides complex care or can be transferred there. Also, a patient's waiting time after reaching the hospital could not be considered. In real-life situations, the span of this waiting time can significantly influence the success of treating cardiovascular emergencies. Further in-depth studies at a smaller geographical level, possibly using the gravity model, need to analyse the differences between potential and realised access to identify discrepancies and understand the factors that affect overall access to healthcare services.

Traffic incidents are another element that can impact potential spatial accessibility to cardiovascular hospitals, especially in larger cities. Out of 27 EU countries, Romania has the highest fatalities per million inhabitants due to traffic accidents. The distribution of deaths by day of the week and time of the day is very similar to other cities from the EU, with most deaths occurring in the daytime during the working week [39]. While the API technology offered by the Google Maps platform presents an average travel time that considers historical events, this study may suffer from margins of error created by real-time specific events.

While it is a known fact, and some Romanian studies have established a correlation between CVDs and education level within population samples [59,60], such analysis could not be conducted in this study due to restrictions imposed by the General Data Protection Regulation (GDPR). The socio-economic profiles of patients, which typically include education level, are considered sensitive personal data and are protected under GDPR. Thus, hospitals were unable to provide this information for research purposes. Additionally, considering the differences in the population's education levels is not viable at a national scale. This limitation underscores researchers' complexities and challenges when navigating healthcare data analysis.

3. Results

The distribution of mortality rates due to CVDs reveals many inequalities at the national level (Figure 2). High mortality areas are extensive in the South-West, West, and South-East regions, where mortality rates exceed 2056–4583/100,000 inhabitants. These are densely populated, predominantly rural areas, with a large share of the population aged over 65 (Figure 3). Large cities, namely Bucharest, Timișoara, Iași, Constanța, and their surrounding territories registered the lowest mortality due to CVDs in 2020, with values between 39 and 732/100,000 inhabitants.

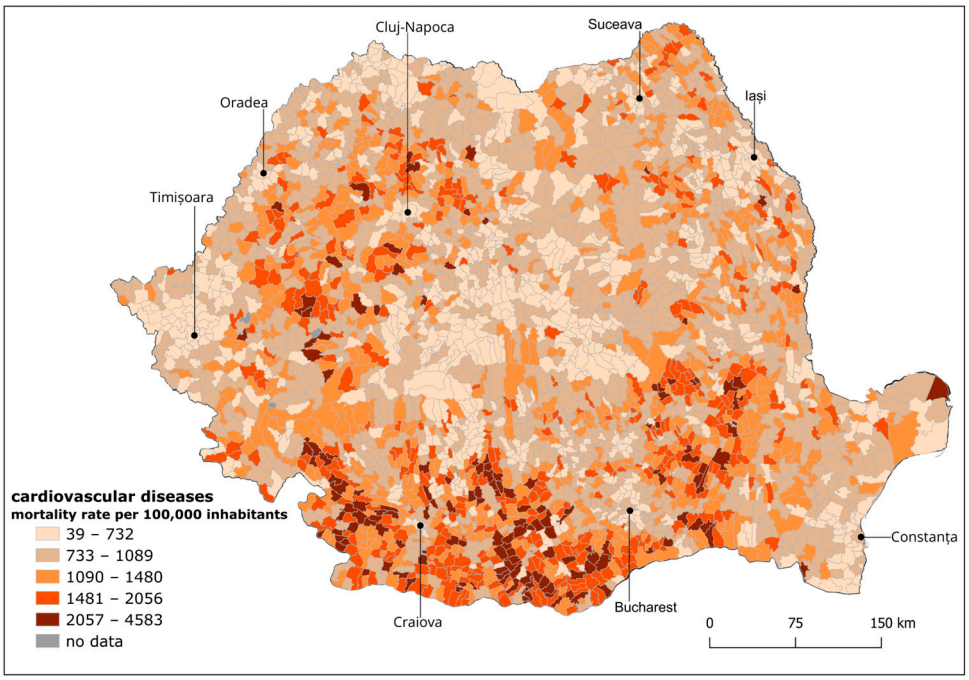

Figure 2. Mortality rate per 100,000 inhabitants due to cardiovascular disease in 2020.

Demographic ageing is highly visible in the South-West, South, and West regions, which contain extensive rural areas where the population over 65 surpasses 30% (Figure 3). Most areas shown to be affected by demographic ageing also overlap with those with a high mortality rate due to CVDs, suggesting a high prevalence of cardiovascular morbidity thus, a greater need for timely cardiac care.

The distribution of cardiovascular hospitals is uneven across the country, with most of them located in large or medium-sized cities and one always in the county capital city (Figure 4). All 41 counties in Romania have at least one general hospital with a cardiology department. Bucharest concentrates most units (16), followed by Cluj-Napoca (6), Timișoara (5) and Iași (5).

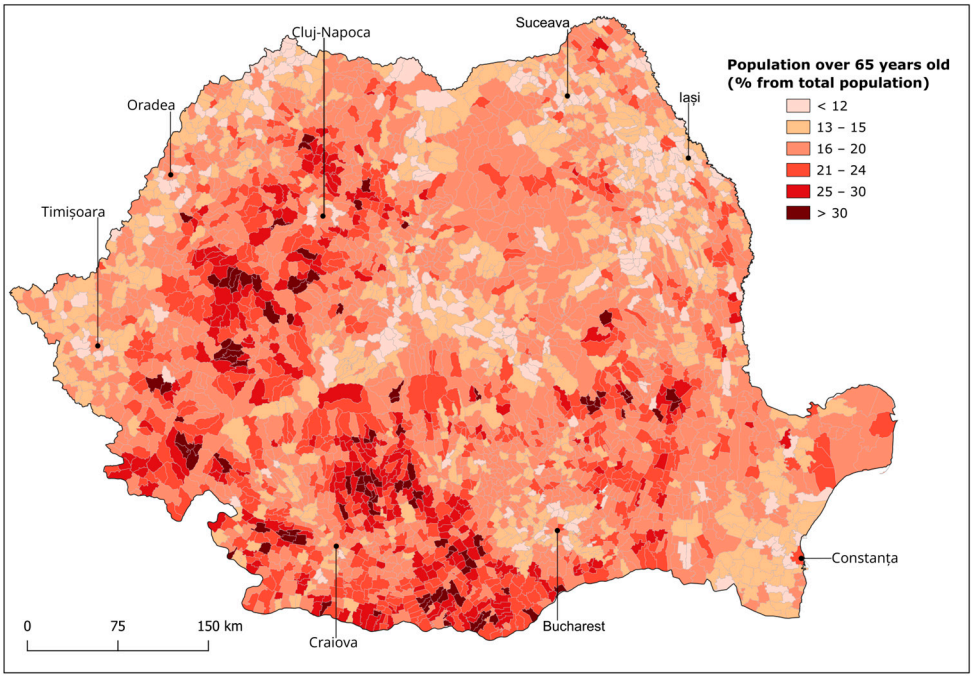

Figure 3. Distribution of the population aged over 65 years (2022).

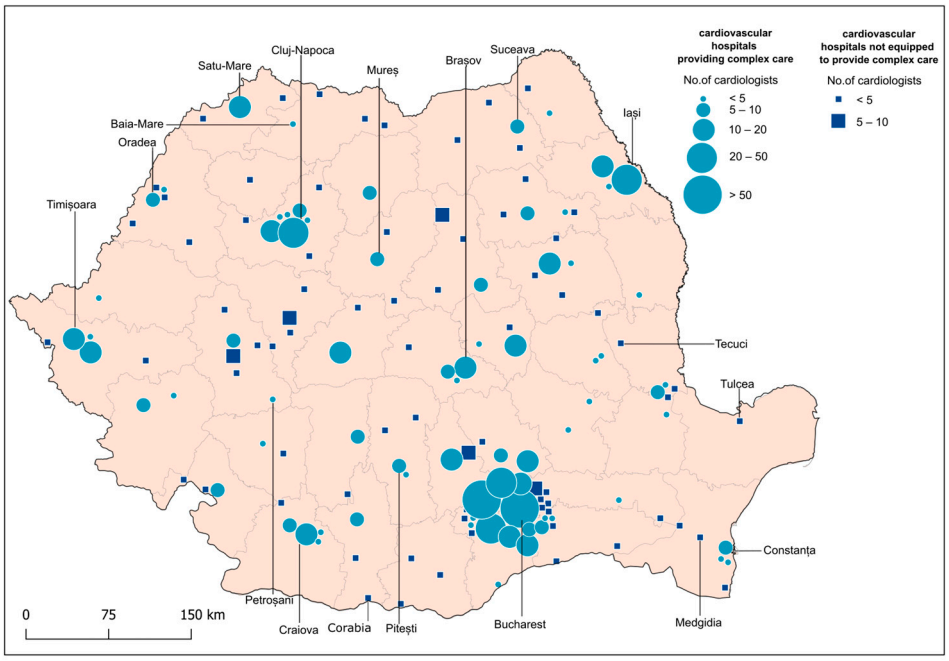

Figure 4. Distribution of cardiovascular hospitals and number of cardiologists.

The potential spatial accessibility to cardiovascular hospitals in Romania showed that during the morning time slot (7–9 a.m.), 38.8% of the population has to drive more than 60 min to reach the nearest hospital, and only 13.7% has relatively fast access, meaning 10–20 min (Figure 5).

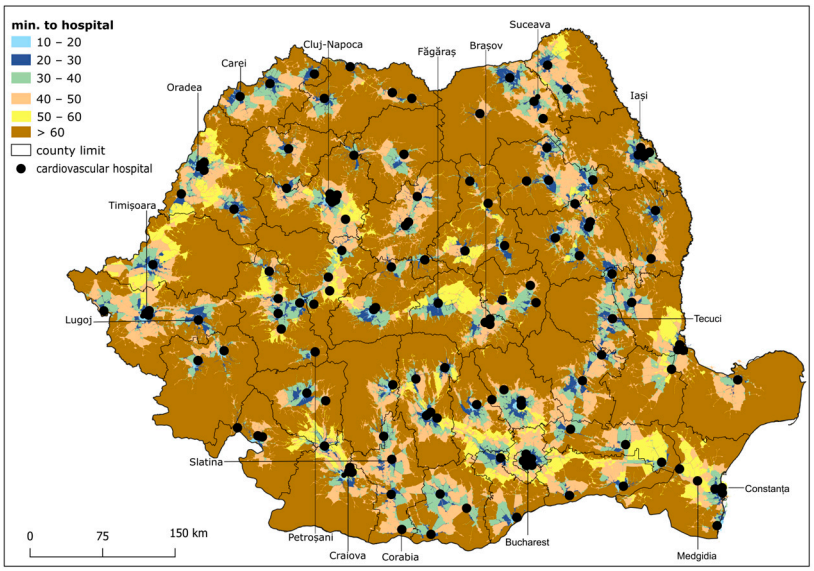

Figure 5. Travel time to the nearest cardiovascular hospital during the 7–9 a.m. time slot.

In the evening (7–9 p.m.), travel time to the nearest cardiovascular hospital exceeded 60 min for 41.4% of the Romanian population, with only 12.8% reaching the closest hospital with a cardiology department in a 10–20 min drive (Figure 6).

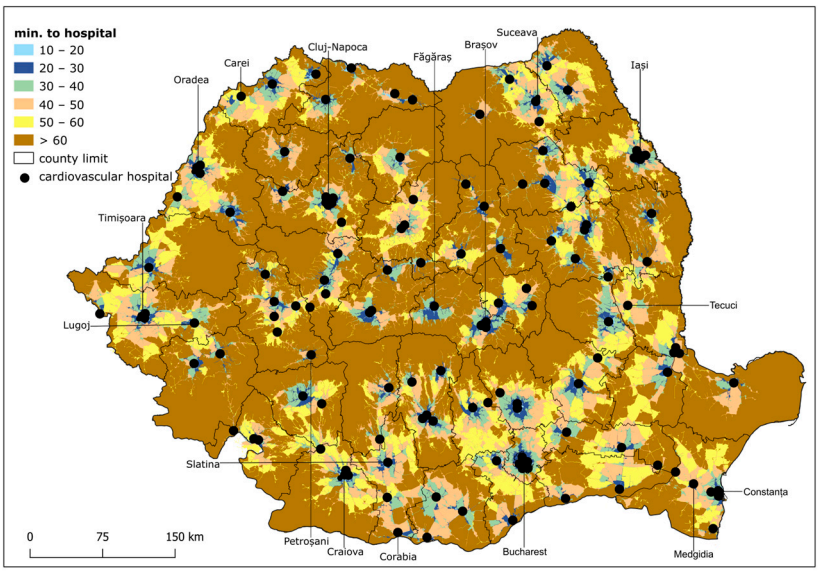

Figure 6. Travel time to the nearest cardiovascular hospital during the 7–9 p.m. time slot.

The potential spatial accessibility measured using travel time is slightly better at midnight (10–12 p.m.). The percentage of the population travelling for more than 60 min to the nearest cardiovascular hospital has dropped from 38.8% during the 7–9 a.m. time slot to 38.4% during the 7–9 p.m. time slot and to 35.9% during the 10–12 p.m. time slot (Figure 7).

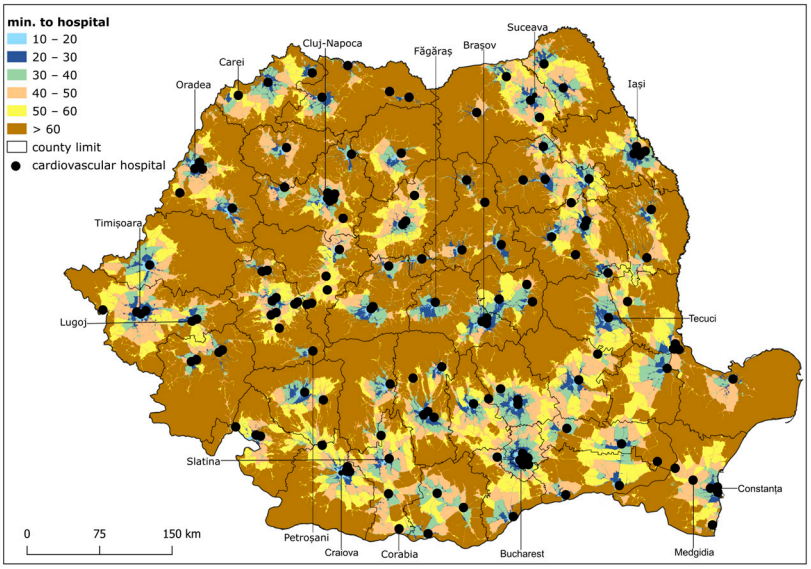

Figure 7. Travel time to the nearest cardiovascular hospital during the 10–12 p.m. time slot.

Modelling potential spatial accessibility according to the chosen time slots and intervals uncovered the population quartile most vulnerable (Table 1).

Table 1. Population potential spatial accessibility to cardiovascular hospitals.

	Morning (7–9 a.m.)		Evening (7–9 p.m.)		Midnight (10–12 p.m.)	
	Population	**% Total Population**	**Population**	**% Total Population**	**Population**	**% Total Population**
<20 min.	3,290,237	13.7	3,022,325	12.8	3,760,219	17.5
20–60 min.	11,367,425	47.5	11,769,221	48.9	11,292,814	46.6
>60 min.	9,252,478	38.8	9,766,711	38.4	9,154,202	35.9

In terms of distance, the most significant percentage of the population (34.5%) resides within less than 5 km of a cardiovascular hospital. As the distance increases, the percentage of the population gradually decreases, with smaller percentages residing within 5–10 km, 10–15 km, and >20 km from cardiovascular hospitals, each representing approximately 6–7% of the total population (Table 2).

Table 2. Population distribution by distance to cardiovascular hospital.

Distance (km)	Population	% Total Population
<5	8,490,304	34.5
5–10	1,620,979	6.6
10–15	1,643,385	6.7
15–20	1,602,023	6.5
>20	11,201,666	45.7

4. Discussions

4.1. Cardiovascular Diseases in Romania

In Romania, inconsistent policies and underfunding of cardiovascular surgical procedures have led to a failure to address the issue of CVDs effectively. This has resulted in an avoidable mortality rate of 345 deaths per 100,000 inhabitants in 2021, one of the highest rates in the EU [61].

CVDs risk factors mainly include smoking, hypertension, elevated cholesterol, obesity, diabetes, and physical inactivity. In 2020, 21.7% of the total Romanian population smoked, 26.3% were obese, and 4.21% had diabetes, which had a higher incidence among males

than females [62]. The prevalence of elevated cholesterol levels is high among Romanians, similar to other European countries like Ukraine, Bulgaria, Hungary, and Lithuania [63]. While numerous studies have addressed CVDs risk behaviours at the national or regional level, there are no databases for such information at LAU2 level, consistent with our research. According to the SEPHAR study from 2016, the prevalence of hypertension in Romania was 45.1%, regardless of sex and area of residence [64].

Despite some advancements in medical care and prevention strategies, CVDs continue to have a high incidence nationwide, at 1465 per 100,000 people [2]. The number of deaths due to CVDs was higher in 2020 (162,984) compared to 2019 (150,427). Also, the number of patients suffering from CVDs has increased from 102,618 in 2020 to 193,079 in 2021, making Romania one of the EU countries with high cardiovascular risk, according to data from the latest European Society of Cardiology guideline for preventing CVDs [65].

Previous research in Romania revealed that in 2008, 64,465 patients were hospitalised with a stroke diagnosis. Out of total stroke cases, 54% were strokes without catastrophic or severe prognosis, 30% of cases had complications and severe prognosis, 11% had complications and catastrophic prognosis, and 5% of patients died. Most hospitalisations happened in Bucharest, Mureş, Braşov, Hunedoara and Dolj counties, which are the Central, West, and South-West regions [66]. In terms of cardiovascular interventions, only 937 Percutaneous Coronary Interventions and 2.3 Transcatheter Aortic Valve Implantations per million people were performed in 2020, a relatively small number given the high incidence of cardiovascular cases [67].

In 2021, the total number of inpatients due to CVDs registered in the hospital selected for this study was 102,511, with most of them in Bucharest (18,847), Cluj County (7506), Iași County (5265) and Mureș County (3361). Out of the hospitals in these regions, only three are research institutes able to perform highly specialised interventions: Fundeni Clinical Institute in Bucharest (3344), Nicolae Stancioiu Heart Institute in Cluj-Napoca (2716) and Cardiovascular and Transplant Emergency Institute in Târgu Mureș (2172). Other hospitals, most of which are county emergency units in Constanța, Satu Mare, Baia Mare, and Pitești, registered between 1000 and 2000 cardiac inpatients. Hospitals in towns of 10,000 to 50,000 inhabitants, such as Tecuci, Medgidia, and Corabia, had less than 100 inpatients. There is a positive relationship between a low number of cardiac inpatients and a high mortality rate due to CVDs (Figure 2).

Ageing is also associated with an increased risk of CVDs. The elderly population is more susceptible to developing CVDs due to age-related impairments in cardiovascular function. Like many Eastern European countries, Romania is facing demographic ageing (Figure 3). Massive emigration after its EU accession, merged with a continuous decline in birth rates after 1990, has led to an increased share of the elderly population, from 10.1% in 1990 to 19.1% in 2021 [68]. Studying the overall potential spatial accessibility to cardiovascular care is vital because CVDs have a high prevalence within the under 65 age group (114.6 per 100,000 people) and especially among those over 65 (140.4 per 10,000) [69].

According to the National Public Pension House, in 2023, there were 3,815,430 pensioners, and the average pension was RON 2006 (about EUR 400), while 10% of them had a pension under EUR 200. With many Romanian seniors relying on low pensions, the cost of CVD treatment can be daunting. Not all medications and therapies needed are paid through health insurance, which limits access to necessary cardiovascular care. The average pension varies geographically, with lower brackets being registered in the North-East and South-East regions of RON 1966 (EUR 395) and, respectively, RON 1950 (EUR 392) [70].

Socio-economic status has been linked with an increased risk of developing premature CVDs [71]. The South-West and North-East regions, which registered a high number of deaths due to CVDs (Figure 2), reflecting high CVD morbidity, are among the NUTS-2 regions with the highest shares of the population living at risk of poverty in the EU [72]. These population groups tend to have poorer nutrition and higher rates of smoking [63], making them vulnerable groups who seek healthcare services less frequently, soliciting

medical care only in emergencies, which reinforces their need to access proper care in a timely manner.

4.2. Cardiovascular Care

Despite many reforms and restructuring efforts, the Romanian healthcare system is still hospital-centred, with the population directly addressing hospitals even for minor health issues [36]. Cardiovascular hospitals are the only medical units with the equipment and expertise for diagnosing and treating CVDs. As they are concentrated in cities, many areas remain underserved. Hospitals in the South-East (18), South-West (15), Central (23) and North-East (22) regions carry out medical assistance for extensive and densely populated areas. The South-East region is serviced by 10 hospitals able to provide complex cardiovascular care and 8 hospitals that can offer basic care or have a low number of cardiologists (less than 35). The South-West and Central regions have 15 hospitals that can offer basic care, with 23 hospitals equipped for complex care. Similarly, the most populous region, the North-East, comprises six counties and a population of 588,800 inhabitants and is served by 10 hospitals that can provide complex cardiovascular care.

The geographic location of cardiovascular hospitals plays a vital role in shaping disparities in healthcare access and generates contrasting health outcomes. The distribution of cardiovascular mortality across the country suggests a strong association between areas with higher mortality rates and regions underserved by hospital units (Figures 2 and 4). This correlation underscores disparities between potential spatial accessibility to healthcare services and existing resources. It also strengthens the conclusions of other studies that highlight the need to address healthcare accessibility and resource allocation [69]. This also creates increased pressure on the medical staff, particularly in larger hospitals that become overcrowded with patients from large catchment areas. Moreover, the variability in cardiovascular hospital distribution exacerbates this challenge. Hospitals serve as critical hubs for healthcare services for rural areas, where distances between communities can be considerable and transportation infrastructure is limited [73].

Hospital capacity, represented by the number of beds, varies nationwide. The number of hospital beds provides a measure of resources available for delivering services to inpatients, making it an indicator of health service capacity. The number of hospital beds at the national level is subject to government approval every three years and is mentioned in the National Hospital Bed Plan 2023–2025. It includes 117,248 hospital beds for 2023, meaning 56.9 beds per 1000 inhabitants. Most hospital beds are concentrated in large medical centres in Bucharest (20,100), Iași (6373), and Cluj-Napoca (6168). Data on the number of hospital beds allocated for cardiology are displayed on each hospital's website, with the highest number also registered in Bucharest (847), Cluj-Napoca (412), and Iași (348) [74]. The distribution of cardiovascular hospital beds also displays territorial inequalities, with the South-West and West regions placing lowest in this hierarchy.

The distribution of cardiologists practising in cardiovascular hospitals mirrors the discrepancies between large medical centres and hospitals in medium-sized cities or small towns, with the latter ones facing cardiologist shortages. Specialists and physicians generally prefer to practice in large hospitals because of their better infrastructure and modern equipment. Cardiovascular hospitals in larger cities are more attractive due to better career and training opportunities. The reduced number of cardiologists in certain regions resulted from the emigration of health professionals after 2007 but is also a consequence of the lack of planning and strategies to retain the healthcare workforce. A study from 2017 showed that out of the total number of physicians who received a Current Professional Certificate, which allows them to work abroad, 3.1% were cardiologists [75].

The country reported 63 cardiologists per million inhabitants in 2022, respectively, one of the lowest rates in the EU [76]. Almost half of the hospitals in our study have a shortage of cardiologists; 44 hospitals have only one cardiologist, and 33 hospitals have two cardiologists. This low number makes it impossible to ensure the constant presence of a specialist, leaving cardiology emergencies to internal medicine physicians (if the hospital

has an internal medicine physician on-call) or to other medical professionals. Almost 15% of cardiologists are practising in the capital city. At the county level, a significant number practice in Cluj (54), Timiș (46), and Iași (33) counties. Their number per hospital varies between 1 and 79 (Figure 4). Hospitals that can provide only basic cardiovascular care have less than 10 cardiologists and are most frequent in the Central, South-East, and South-West regions, and overlap with areas of high cardiovascular mortality rates (Figure 2) and prolonged travel time (Figures 5–7). This finding strengthens a study conducted by Simionescu et al. (2019), which suggests that the need for cardiologists in Romania is more urgent than the necessity to build hospitals caring for patients with CVDs [69]. It is worth mentioning that Romania overall is confronted with a physician shortage [36].

An effective way to improve the outcomes of out-of-hospital cardiac arrest survivors is to ensure effective remote cardiac recovery care. As this practice is lacking in Romania [77], it falls to GPs to guarantee proper follow-up. GPs, especially in small towns or remote rural areas, have to oversee a high number of patients scattered over large territories, making it difficult for them to prioritise cardiovascular patients. Authorities have fallen short of solving the shortage of general physicians and specialists [10].

4.3. Potential Spatial Accessibility to Cardiovascular Hospitals

In the case of spatial accessibility for patients suffering from CVDs, the time from the onset of symptoms to receiving medical care is vital for their survival. A study by Kai et al. (1992) suggests that geographic proximity, which is the immediate vicinity of a hospital, encourages the population to go to the nearest health unit in case of a stroke [78].

Our study showed that potential spatial accessibility to cardiovascular hospitals is low for the population from the North-East, North-West, and South-West regions (Figures 5–7). Many of these areas are also characterised by geographical remoteness, a high share of the population over 65 years (Figure 3), and limited healthcare infrastructure (Figure 4), exacerbating disparities in cardiovascular outcomes.

However, at peak time slots, 5% of the population living 10–15 km from a hospital equipped to treat CVDs still have to travel for more than 60 min due to traffic conditions. This is the case for people inhabiting the metropolitan areas of Bucharest, Cluj-Napoca, and Iași. In these cities, traffic has become increasingly congested, resulting in an extensive loss of time [79]. The population living in Bucharest and surrounding areas has better potential spatial accessibility due to the high number of hospitals and the vast road network that connects the capital with its neighbouring towns. Unfortunately, in 2023, Bucharest had an average congestion level of 50%, 8% higher than in 2021. The same data source mentions that in Bucharest, the busiest day is Tuesday evening, when driving 10 km takes, on average, 39 min and 50 s, which, in the context of a stroke, is a very long time [80]. The Sustainable Urban Mobility Plan 2016–2030 for the Bucharest–Ilfov region notes that the average congestion index during evening peak hours is 82%, and the busiest evening is Friday when many residents choose to leave the city [81].

Compared to the 7–9 p.m. time slot, those who can reach a hospital within 20 min in Bucharest increased by 19% during the 7–9 a.m. time slot and by 17% during the 10–12 p.m. time slot. In the case of one of the largest hospitals in the country that can provide cardiovascular care, the University Emergency Hospital in Bucharest can be reached in 50 min during the 7–9 a.m. time slot, 60 min during the 7–9 p.m. time slot, and 20 min during the 10–12 p.m. time slot by someone who lives 20 km away.

Similarly, in Iași, the largest city in the North-East region, those who can reach a cardiovascular hospital in less than 20 min increased by 12% during the 10–12 p.m. time slot compared to the 7–9 p.m. time slot and by 10% compared to the 7–9 a.m. time slot. The population living 20 km away from the "Saint Spiridon" County Emergency Hospital in Iași will need 60 min in the 7–9 a.m. time slot, 50 min in the 7–9 p.m. time slot, and 25 min in the 10–12 p.m. time slot to reach it.

Roads tend to be more crowded in the evening (Figure 6). Analysing the potential spatial accessibility to hospitals between 7 and 9 p.m. and comparing it with 7–9 a.m.,

this study showcased a decrease in the percentage of the population with better potential spatial accessibility to cardiovascular care services (Figure 6). For example, due to the poor road quality connecting rural areas to cities and the lack of highway infrastructure, in the North-East region, 40% of the population has to travel more than 30 min to reach the nearest hospital in all analysed time slots.

The best time slots to access cardiovascular hospitals differ from city to city, depending on the quality and density of the transport infrastructure and traffic flow. For large cities, both 7–9 a.m. and 7–9 p.m. are peak time slots and travel time often takes more than 30 min compared to travel time during 10–12 p.m. For smaller cities such as Lugoj, Carei, Corabia, and Slatina, the difference between the three chosen time slots was no more than 10 min.

With 87% of the country's surface being rural and 31% covered by mountains, improving population potential spatial accessibility to cardiovascular hospitals is a real challenge. The spatial distribution of cardiovascular hospitals affects people's ability to seek timely and adequate treatment. Hospitals located in the mountainous regions of Romania (such as Făgăraș Municipal Hospital, Brașov Emergency Hospital, and Petroșani Municipal Hospital), especially in the south Carpathians, face the challenge of serving highly scattered communities. The narrow, winding mountain roads can significantly impede patients' transportation, particularly during harsh weather conditions or in the winter when heavy snowfall is frequent. Patients living in these areas face longer travel times compared with the ones from plain areas, and this can be fatal in emergency cardiac situations (Figures 5–7). Incidentally, these regions require more cardiovascular care, as suggested by extensive areas of high mortality due to CVDs (Figure 2), mirroring high CVDs morbidity and a significant share of the population aged over 65 years (Figure 3).

Remote rural areas also see low potential spatial accessibility due to topographical barriers and poor road infrastructure (Figures 5–7). Because rurality is associated with lower socio-economic status and the unlikelihood of health insurance coverage, the rural population from these areas depends entirely on urban services for complex cardiovascular care, which overburdens hospital capacity and medical staff, leading to long waiting times.

People living in the Danube Delta are in an even worse situation. This remote area from the South-East region, characterised by a labyrinth of waterways, islands, and wetlands, poses specific difficulties for the population living here when medical assistance is urgent. The closest hospital is the Emergency Hospital in Tulcea. Unfortunately, it can provide only basic cardiovascular care, has three cardiologists and serves 185,654 inhabitants (the population of the Danube Delta area plus those from its own surroundings) (Figure 4).

Also, the scarcity of GPs in these vulnerable areas makes it difficult for seniors to receive continuous monitoring and regular check-ups close to home. Consequently, many are forced to travel to specialised hospitals in urban areas for routine appointments, further straining their health and financial resources. Alternatively, they postpone or ignore regular visits, making it even more critical that they are able to reach the cardiovascular centre in a timely manner in case of an emergency. Studies, including Romanian ones, have already proved that rural residents see fewer medical specialists than their urban counterparts [82,83].

As previous studies have shown [69], increasing the number of hospitals is not viable. This study strengthens the idea that, in order to improve potential spatial accessibility to cardiovascular care, governmental policies should focus on improving the existing road infrastructure in metropolitan areas of larger cities and designing special lanes for emergency vehicles. Additionally, it is essential to improve the quality and time response of care in the existing cardiovascular units. This can be achieved by ensuring a more balanced spatial distribution of cardiologists, especially in units that cannot ensure the continuous presence of at least one specialist, and equipping cardiovascular units with the necessary technologies to reduce avoidable mortality rates due to CVDs. Such tailored healthcare services have become increasingly imperative in the current demographic landscape, with an increased share of the ageing population and a high mortality rate due to CVDs (Figures 2 and 3).

Given the high mortality rate due to CVDs in Romania, public health campaigns and community engagement are also helpful in raising awareness and promoting preventive measures. Collaborative efforts between government bodies, healthcare professionals, and advocacy groups are indispensable in developing comprehensive and sustainable strategies to mitigate CVDs effects.

5. Conclusions

Improved access to cardiovascular hospitals and policies that promote cardiovascular health and well-being among the elderly, as well as the general population, are necessary to reduce mortality rates due to CVDs. This study aimed to measure the potential spatial accessibility to cardiovascular hospitals in Romania using API provided by the Google Maps platform. The data were acquired for 7–9 a.m., 7–9 p.m., and 10–12 p.m. time slots to capture intervals that consider the high prevalence of stroke incidents combined with different traffic situations. The findings proved that urban areas and those from the metropolitan surroundings of the capital city have the best potential spatial accessibility, with 40% of the population reaching a cardiovascular hospital in less than 30 min regardless of the time slot, while mountainous, rural and deltaic regions remain the most disadvantaged. The 7–9 a.m. (when most strokes occur) and 7–9 p.m. time slots are intervals in which approximately 14% and 12%, respectively, of the country's population can reach a cardiovascular hospital in less than 20 min. Overall, 38% of the total population has to travel more than 60 min to receive cardiovascular care in any of the selected time slots. The low number of inpatients in some hospitals is frequently the combined result of patients seeking treatment at larger units, a lack of cardiologists and/or limited medical equipment, burdening these more prominent cardiovascular hospitals.

This study's results can be used by decision makers in order to improve the population's spatial accessibility to cardiovascular care, emphasising the need to prioritise improvements to the existing road infrastructure while also upgrading cardiovascular hospitals from being able to offer only basic care, especially those that cater to a high number of population (i.e., the Emergency Hospital in Tulcea—185,654 inhabitants). The approach of this study is pertinent because while numerous investigations analyse distance when discussing spatial accessibility, in the current context of traffic and the level of congestion, travel time is, in fact, able to act as a more accurate parameter for spatial accessibility. For example, although 34.5% of people live fewer than 5 km from a cardiovascular hospital, only a maximum of 17.5% can reach one in less than 20 min.

Future studies could focus on analyses at a regional or local scale, where road infrastructure, traffic flows, specific means of transportation, patients' socio-demographic characteristics and geographic landscape create particular scenarios.

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