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THE IMPACT OF ADVERSE GEOLOGICAL HAZARDS RISK ZONES ON CAR TRAVEL TIMES TO HOSPITALS: CASE STUDY OF THE KVEMO KARTLI REGION, GEORGIA

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Abstract: Timely access to healthcare facilities is essential, as it can have a decisive impact on the outcome of any disease. Travel time is significantly affected by various factors, including extreme natural events. The purpose of the study was to consider the impact of adverse geological events on highways on the car travel time to the nearest hospital, and on this basis to identify served and underserved areas in terms of medical services in the Kvemo Kartli region. The findings revealed that only 5% of the Kvemo Kartli population resides in underserved areas i.e., outside the 45-minute car travel time to a hospital. However, this figure significantly increases to 38% when the impact of extreme geological events on the roads is considered, highlighting the region's vulnerability. These results can be instrumental in guiding efforts to improve healthcare availability in the region.

Keywords: Isochrone map, GIS, Served and underserved areas, Road, Population

1. INTRODUCTION

Healthcare availability is a measure of human prosperity that is determined by many different factors (Fullman et al., 2016), of which one of the most important is time, which is needed for an individual to get to the appropriately equipped and adequately staffed medical facility. Timely access to a healthcare provider substantially impacts the outcome of any disease (Liu et al., 2022). Due to the inability to receive medical help in time, people's health may deteriorate significantly, or death of a person may occur (Manongi et al., 2014; Deeb et al., 2023). In addition, studies conducted in different countries of the world have shown that patients who need more time to reach a healthcare facility seldom go to these facilities in case of necessity (Maleki et al., 2024). Car travel time calculated in a geographic information system is used in several studies on access to healthcare services (Chien et al., 2020), that assess the impact of geographical availability on service use or health outcomes (Agbenyo et al., 2017); travel time is also used in studies that predict the impact of service reconfiguration on patients' flows (Barbieri & Jorm, 2019; Kara & Egresi, 2013). Such studies usually use GIS to find the shortest travel time along the road network from each location to reach healthcare facilities based on data on road length and average speed along subsequent road segments (Barbieri & Jorm, 2019).

Assessing the time required to reach a healthcare facility is essential in healthcare planning and resource allocation. This information will help us identify the areas or populations most in need of additional healthcare resources, including opening additional medical institutions and bringing in qualified doctors, subsidized transport, road infrastructure development, etc. Many studies in this direction have been conducted for different regions of the world (Salvacion, 2022; Zhang et al., 2020).

Travel time varies significantly in rural settlements, regions with heterogeneous road networks, weak transport infrastructure, physical barriers, and complex terrain (Higgs et al., 2017). Extreme geological events also affect travel times. Debris/mudflows, landslides, rockfalls, snow avalanches, etc., are common on roads in high mountainous regions. Such challenges require a quick response, although these events often cause traffic delays or even complete road closures for some time. At such times, the availability of medical services in villages is significantly limited. In this regard, the situation becomes even more complicated in the background of modern climate changes since the frequency and intensity of extreme weather and climate events under the conditions of global warming have significantly increased, which is likely to increase even more in the future (Elizbarashvili et al., 2024a). The increase in the frequency and intensity of extreme weather and climate events, including heavy rainfall, triggers dangerous geological events, activates landslide and mudflow processes, and increases their intensity, frequency, and scales (Lupp & Zingraff-Hamed, 2021; Ward et al., 2020). Geological hazards present significant challenges to accessibility, impacting transportation networks and infrastructure. These natural events can lead to substantial disruptions, posing risks to human life, economic stability, and societal functioning. Understanding the impact of geological hazards on accessibility is crucial for developing effective mitigation strategies and enhancing resilience (Bai et al., 2022; Ciurte et al., 2023). The impact of geological hazards on accessibility is a critical area of study that requires ongoing research and technological innovation. By leveraging advancements in GIS, remote sensing, and resilient infrastructure design, we can better understand and mitigate these impacts, enhancing the resilience of communities. Investment in early warning systems and infrastructure improvements will be essential in addressing the challenges posed by geological hazards to accessibility (Florath et al., 2024, Ajake et al., 2022).

The purpose of the study was to consider the impact of adverse geological events on highways on the car travel time to the nearest hospital and, on this basis, to identify served and underserved areas in terms of medical services in the Kvemo Kartli region. For this, first of all, 1) we compiled an isochrone map showing car travel time intervals to the nearest hospitals based on the maximum permissible speeds of the car on a separate section of the road and the length of this section of the road; 2) we studied the risk zones of geological hazards on the highways of Kvemo Kartli; 3) we compiled a map of geological hazard risk zones of roads; 4) we empirically evaluated how risk zones of different categories of geological hazards affect the maximum permissible speed of vehicle movement in this zone; 5) we compiled an isochrone map of car travel times to the nearest hospitals, considering the impact of the risk zones of different categories of geological hazards on the roads; 6) based on the isochrone maps, we identified served and underserved areas in terms of medical services in the region; 7) we estimated what percentage of the population lives in served and underserved areas. Such assessments are especially important for policymakers who manage staff and resources to improve health outcomes in the context of modern climate change.

2. STUDY AREA

Kvemo Kartli is one of the border regions of Georgia, to the north of which is the country's capital, Tbilisi; to the south-east it is bordered by the Republic of Azerbaijan, and to the south - by the Republic of Armenia. The region's area is 6528 km^2, which is 10% of the total area of Georgia. According to the National Statistics Office of Georgia, the population of Kvemo Kartli is 428,799, which is 11.42% of the population of Georgia. The administrative center of Kvemo Kartli is Rustavi. Apart from Rustavi, it includes the following municipalities: Bolnisi, Gardabani, Dmanisi, Tetritskaro, Marneuli, and Tsalka (Figure 1). Kvemo Kartli is distinguished by a high population density of 64.9 people/km^2; within the region, the population density varies extensively. Rustavi is the region's most highly populated area with the highest population density. It is followed by Marneuli municipality, where the population density is lower than that of Rustavi. The population density decreases in the Gardabani and Bolnisi municipalities and significantly decreases in the Tetritskaro, Tsalka, and Dmanisi municipalities (Figure 2). There are industrial centers such as Rustavi and Marneuli city and farmlands in the Kvemo Kartli region. 47.8% of the rural population of Kvemo Kartli is engaged in agricultural activities.

In Kvemo Kartli, there are seven hospitals with 1000 beds, nine emergency stations and 28 emergency medical service brigades, three maternity houses, 97 dental clinics, one endocrinological clinic, one dermatological clinic, one dermatological venereal clinic, 66 diagnostic and treatment facilities, five laboratories or Blood transfusion centers, and 163 pharmacies. The study focus is hospitals because the healthcare facilities encompass a set of basic actions to solve the most serious health problems in the community. Figure 3 shows the settlements, healthcare facilities - hospitals, and road network of Kvemo Kartli.

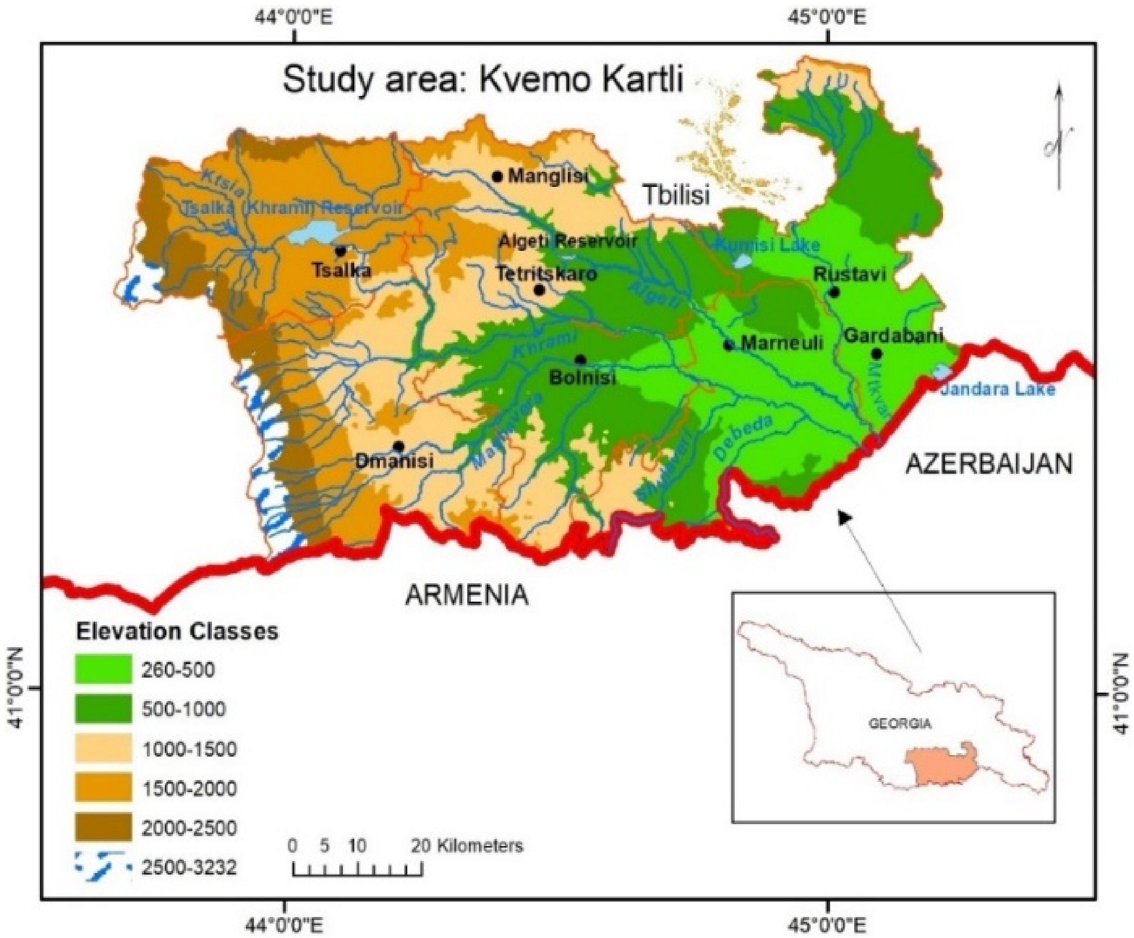

Figure 1. Location of the study area.

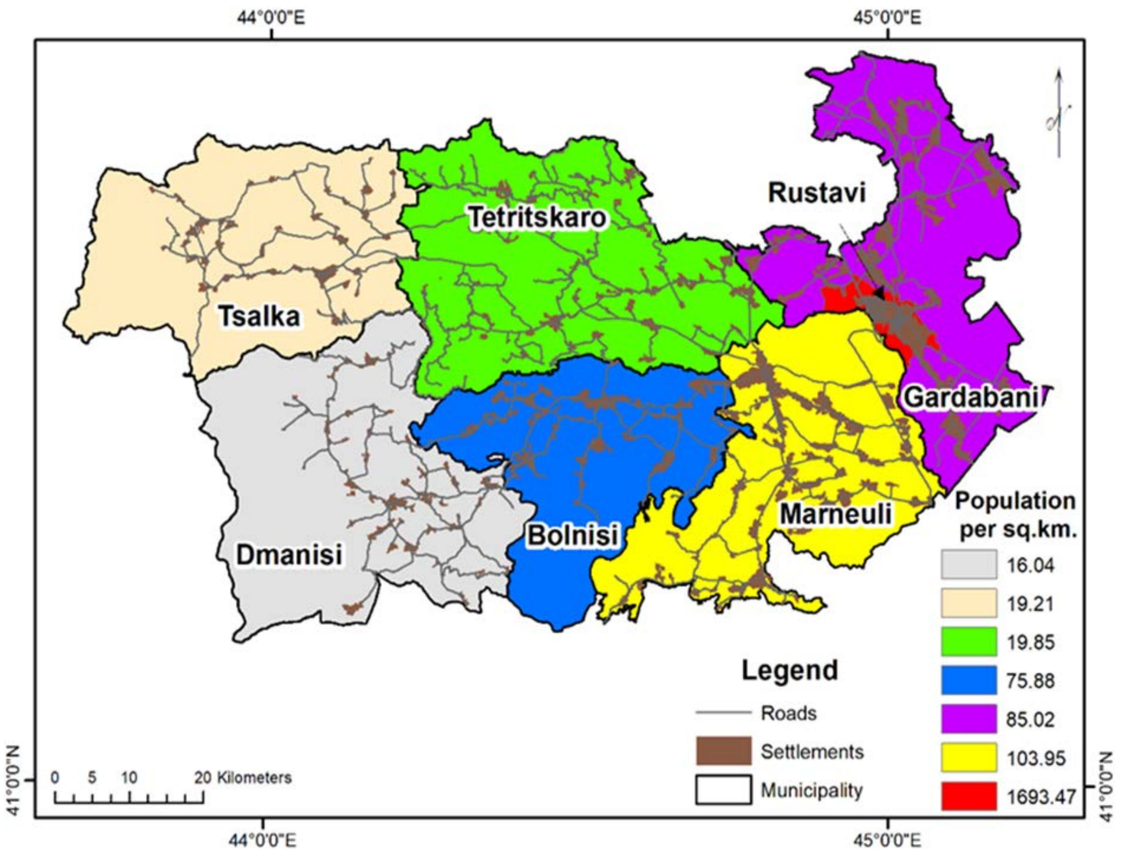

Figure 2. The population density according to municipalities in the Kvemo Kartli Region.

The total length of highways in the Kvemo Kartli region (including internal roads of settlements) is 3, 036 km. Three roads of international importance pass through the territory of Kvemo Kartli: one to the border of Azerbaijan, and two to the border of Armenia. The total length of roads of international importance is 229.2 km. A large part of the internal state roads of lesser and local importance (including roads connecting municipal centers and relevant settlements) is not covered with asphalt or concrete pavement.

In the Kvemo Kartli region, almost all kinds of dangerous geological processes are common: landslides, mudflow/debris flow, erosion (lateral and deep), inundation-accumulation, rock avalanches and rockfalls, inundation, and swamping caused by seasonal fluctuations in the vertical level of groundwater (Tsereteli et al., 2021). The development of geological processes in the territory of Kvemo Kartli and their periodic activation are determined by the following natural and anthropogenic factors: complex geological and tectonic structure, the division of the crystalline massifs developed here by deep faults - upward neotectonic movements and their accompanying seismic events - location in the zone of high seismic activity, which is characterized by a significant probability of recurrence of high-energy earthquakes; natural landscape conditions; pronounced vertical contrast of relief, in which almost all geomorphological districts are distinguished; wide distribution of mountainous terrain (up to 60% of the territory), whose hypsometric values exceed 1000 m; Intensive surface fragmentation with deeply incised canyons and "V"- shaped valleys; Slope of surfaces – high energy potential and tension; frequency of hydrographic network; hydrological conditions; Spatial-zonal changes of climatic conditions; Impact on the environment caused by human economic activity - unsystematic mass cutting of forest massifs, incorrect irrigation; salinization of significant areas (Gaprindashvili et al., 2021).

Kvemo Kartli is distinguished by a rather harsh winter and diverse landscapes, where such meteorological events as fog, hail, heavy rainfall, blizzard, high temperatures, and drought are observed quite often (Elizbarashvili, 2017; Elizbarashvili et al., 2024). Based on all these features, the Kvemo Kartli region is a representative geographic area for the case study.

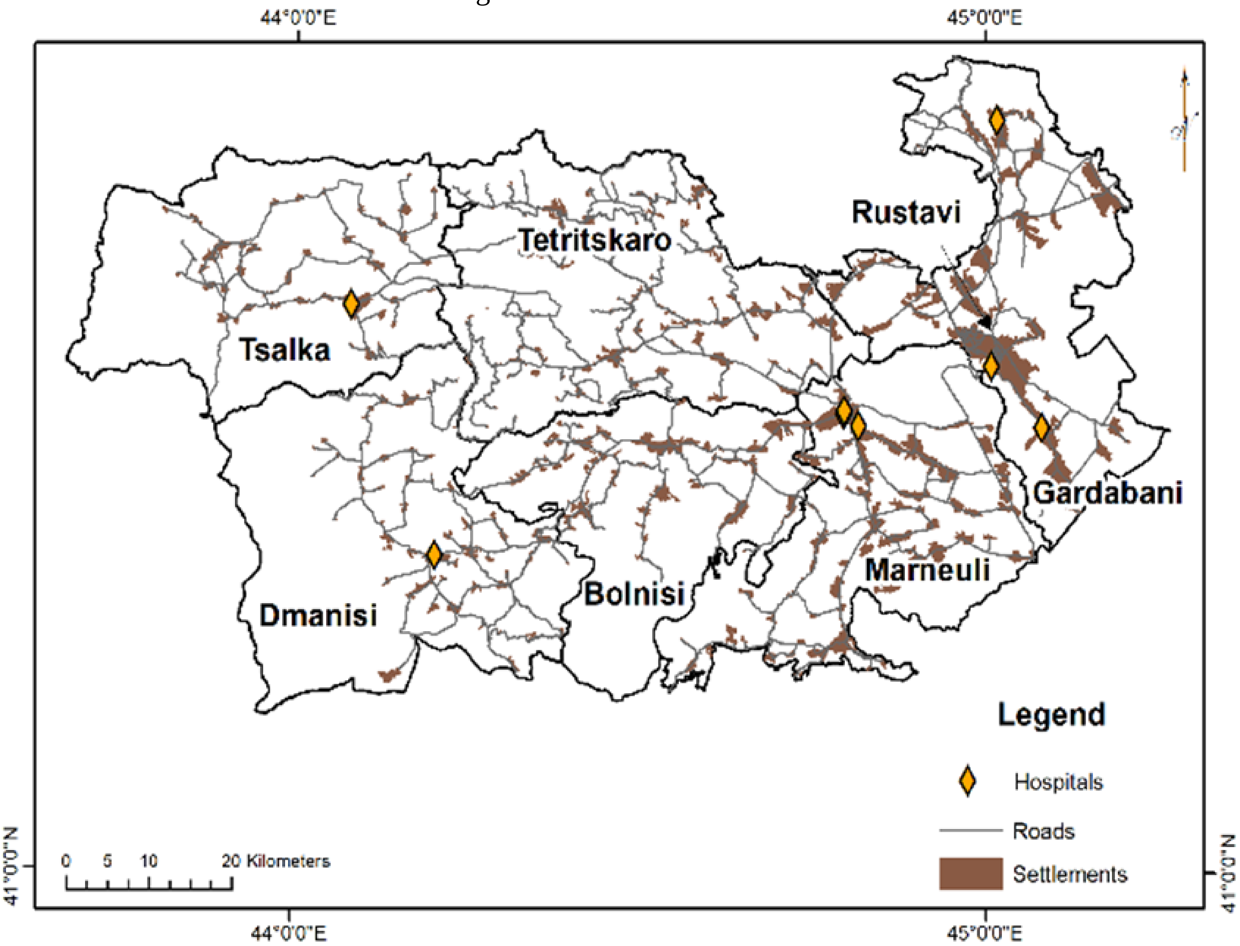

Figure 3. A map of settlements, hospitals, and road network in Kvemo Kartli.
Note: The black bold lines on the map represent the municipal boundary.

3. MATERIALS AND METHODS

3.1. Creating the isochrone map showing the car travel time intervals to the nearest hospitals for Kvemo Kartli, Georgia

In the research, we used the 1:10000-scale geographic information system of the healthcare infrastructure of the Kvemo Kartli region, which we had developed based on field and desk work. Our previous study (Elizbarashvili et al., 2021) describes the development of this GIS. Specifically, the cartographic base was created by digitizing orthophotos, space imagery, and cartographic maps from 2000 to 2017 using ArcGIS 10.8.1. program (Elizbarashvili et al., 2024b). Data on settlements, roads, healthcare facilities (hospitals, emergency medical care, pharmacy network, dental clinics, diagnostic centers, and others), and data on the maximum allowed vehicle speeds on each road segment were obtained from official government sources: the Ministry of Internally Displaced Persons from the Occupied Territories of Georgia, Labor, Health, and Social Protection, the Ministry of Internal Affairs of Georgia, and direct fieldwork, including visits to healthcare facilities in the Kvemo Kartli region and collecting the coordinates of the points where the maximum permitted speed signs were located on the roads using the GPS. In the presented study, the Arc GIS 10.8.1 geoinformation platform was used, to process information and data obtained in previous studies to generate an isochrone map (Figure 4) showing the car travel times to the nearest hospitals. Isochrone maps are valuable tools for visualizing and analyzing travel times or distances from a specific location, for understanding accessibility patterns, and for making informed decisions.

3.2. Zoning of the roads of the Kvemo Kartli region according to the risks of extreme geological events

Since our goal was to take into account the impact of the risks of dangerous geological events on the roads on the time needed to reach the medical facility, at this stage of the research, we studied the extreme geological events on the roads of the Kvemo Kartli region. Based on hazard type, movement mechanism, velocity, volume, geological structure, morphology, and different triggering factors and parameters we identified different categories of danger zones on the roads (Figure 5).

Geological hazard assessment is an essential step towards hazard and risk management. There are several methods for hazard zoning, with heuristic, semi-quantitative, quantitative, probabilistic, and multi-criteria decision-making processes (Gaprindashvili et al., 2021).

In the first stage of the compilation of zoning maps, we obtained and processed all available historical materials regarding assessments of natural hazards, including landslides and disasters, known to affect the study area. Geological (scale: 1:50 000, 1:200 000, 1:500 000), topographic (scale: 1:25000 and 1:50000), hydrographic, aerial, and remote sensing data (2010 and 2020 years) were mainly used during this study. Using theoretical and cartographic information (Annual "Geological Bulletin," 2021, 2022) about the locations, types, hazard risks, and categories of dangerous geological events on the roads of the region and in its vicinity, a field research route was selected and planned to validate the current state of each geological event.

Geological hazard information and mapping of the study area are obtained through the field-based investigation. Activities were conducted using different field equipment: geological compass-clinometer, GPS, digital camera, etc. The assessment of geological hazards includes filling out pre-made Forms/Sheets, where the basic parameters of the hazards were given, including the type of hazard, exact location, area, geological structure, hydrogeological conditions, elements at risk, etc. Filling of the mentioned forms was done both in the field and in the office conditions. These parameters are essential to prepare hazard zoning maps.

The GIS database and inventory map were created based on historical data and field studies. As it is known, the main triggering factors for geological hazards are geology, tectonics, morphology, climate, hydrology, seismicity, and human activities, different parameter maps were used for susceptibility and hazard assessment, such as elevation, slope, aspect, curvature, geology, faults, hydrography, etc.

The main methodology used to create the map was the application that assists and guides users in doing multi-criteria evaluation spatially. The input is a set of maps that are spatial representations of the criteria. They are grouped, standardized, and weighted in a „criteria tree”. The output is one or more composite index maps, which indicates the realization of the model implemented. The theoretical background for the multi-criteria evaluation is based on the analytical hierarchical process. To make spatial multi-criteria analysis possible, the input layers (triggering factors) need to be standardized from their original values to the value range of 0–1. The next step is to decide for each indicator whether it is favorable or unfavorable regarding the intermediate or overall objective (Gaprindashvili, 2021).

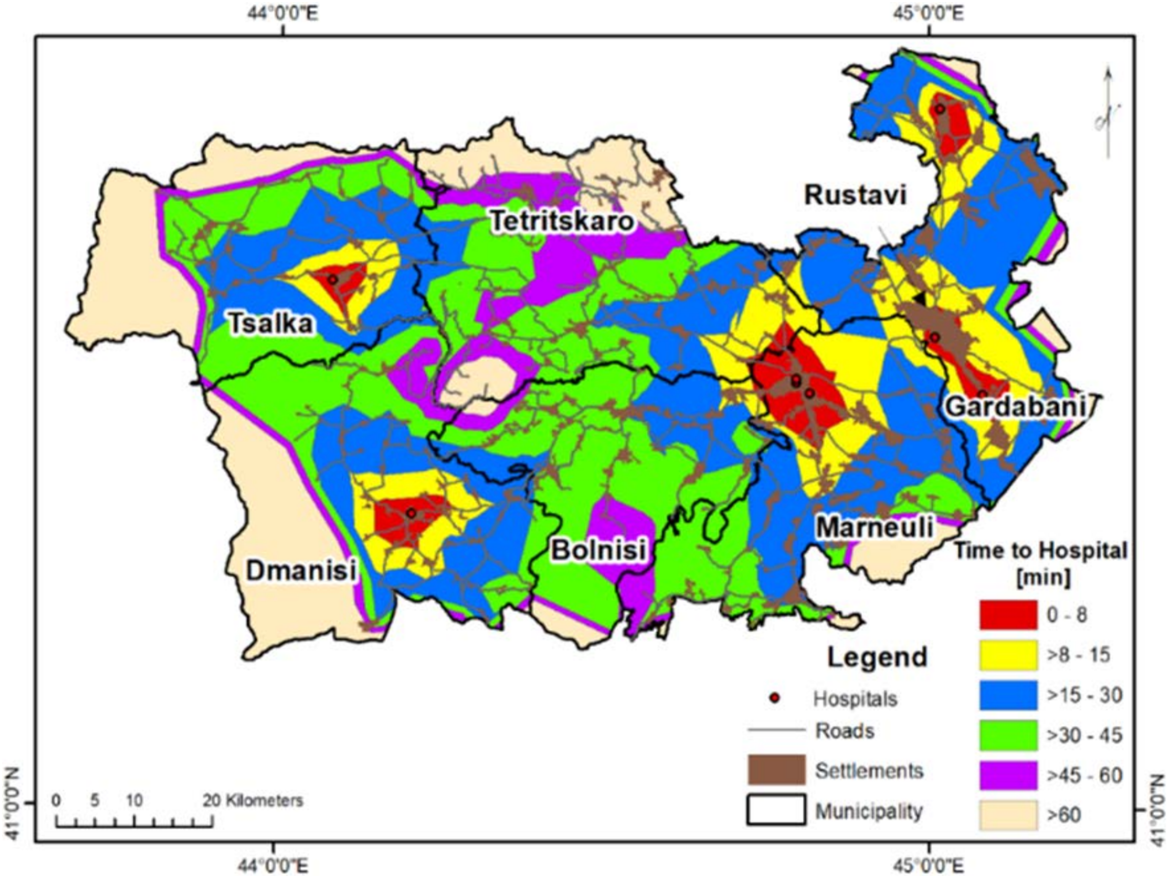

Figure 4. An isochrone map showing the car travel-time interval to the nearest hospital when the impact of extreme geological events risks to the car's movement speed is not considered.

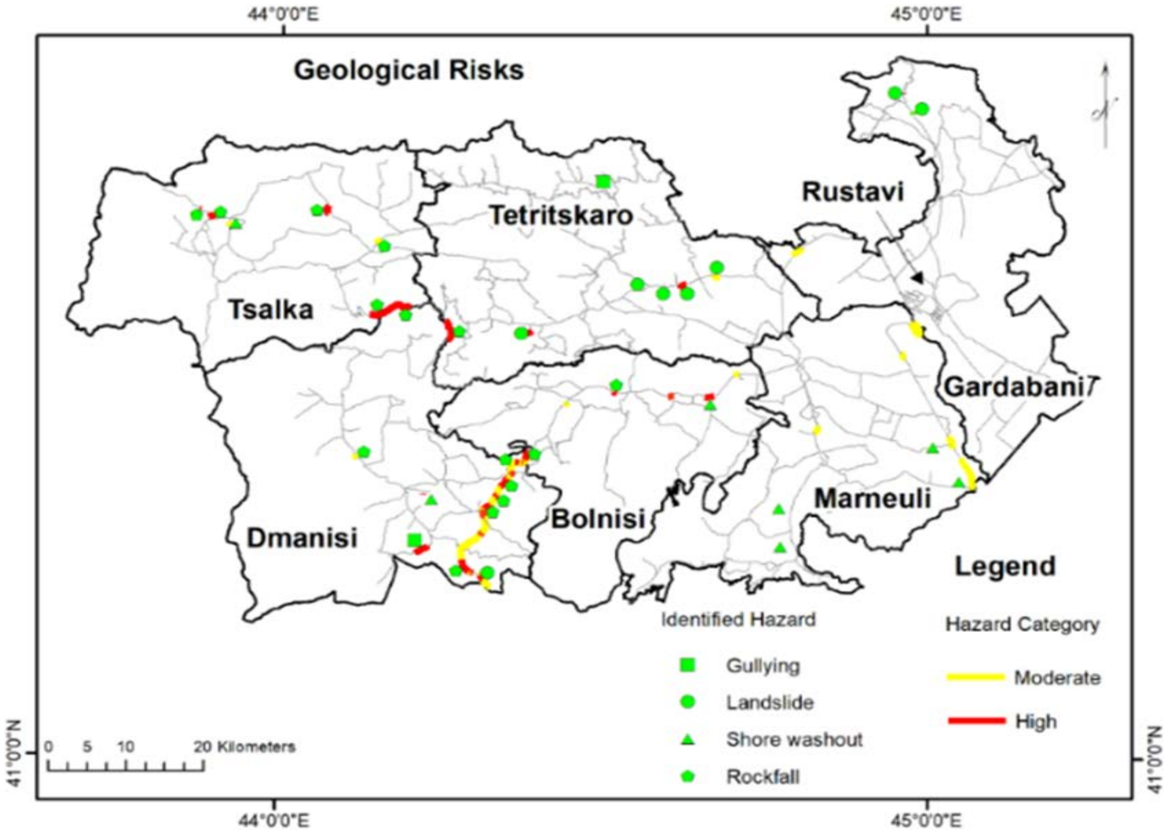

Figure 5. Zoning of roads in the Kvemo Kartli region according to the risks of extreme geological events (bold black lines in the map represent municipal boundaries).

After selecting the appropriate indicators, defining their standardization, and the hierarchical structure weights were assigned to each criterion and intermediate result. For weighting, 3 main methods can be used: direct method, pairwise comparison, and rank order methods. In this study, the map was created by the direct method.

As we were interested in studying the high-risk zones concerning roads only, we identified only high and medium-danger zones on the roads based on the analyzed information.

3.3. Creating a combined map of the risks of extreme geological events and car travel time to the hospitals, using the Kvemo Kartli region, Georgia, as an example

Finally, our goal was to compile an isochrone map of car travel time intervals to the nearest healthcare facilities when considering the impact of the risks of extreme geological events on the roads on the car travel speed. We used the road zoning map of the Kvemo Kartli region according to extreme geological events, and we evaluated the real car travel speeds while driving through the risk zone of different categories depicted on the map in Figure 5. Our task was not to discuss the cases when this or that geological event was activated and as a result, the road was completely or partially blocked. If the road is blocked, it is natural, that the car speed will be zero. Our task was to study, how the risk zones themselves affect and how they change the maximum permissible speed of the vehicle based on the current situation and, accordingly, how they affect the time to get to the nearest hospital. Zones of high and medium geological risks are distinguished by their complex terrain, hydrographic network, existing permanent landslides, stones, etc. that force the driver to slow down We tried to empirically evaluate and generalize how the speed of vehicle movement decreases in the geological risk zone of the high and medium categories. For this purpose, on each section of the different geological risk zones on the roads in the Kvemo Kartli region, it was observed what time the vehicle took to pass in each direction. For this, the movement of vehicles was observed and time was set by a person standing at the beginning and end of the risk zone. On average, 50 different vehicle movements were observed in each section in each direction. After calculating the average time for passing a specific section of each risk zone, we estimated how much the maximum permissible speed decreased for each specific section When we sorted the data according to the risk zone categories of the roads of the region, we found that in the high-risk zone, the maximum permissible speed of the vehicle was reduced to 50%, and in most of the medium-risk zones - to almost 30%. The fact that we have observed completely different randomly selected cars, that naturally were driven by drivers of various ages and experiences, adds reliability to the results of our experiment and thus we can conclude that the reduction in the estimated speed is due to the presence of geological risk zones.

Thus, according to our assessment, the maximum permissible traffic speed on the corresponding section of the road in the high-risk zone is reduced by 50% and in the medium-risk zone by 30%. These new values of the speeds were used to create an isochrone map of the car-travel time interval to the nearest hospital.

4. RESULTS AND DISCUSSION

4.1. Isochrone maps

The isochrone map presented in figure 4 shows the spatial distribution of red, yellow, blue, green, purple, and light brown areas, corresponding to the following car travel time intervals: 0-8 min, >8-15min, >15-30 min, >30-45 min, >45-60 min, >60 min. These areas' spatial distribution and layout are changed when considering the impact of the risks of extreme geological events on car travel speed (Figure 6).

Based on GIS analysis, it was assessed what percentage of the population lived within 8 minutes, >8-15 minutes, >15-30 minutes, >30-45 minutes, >45-60 minutes, and more than 60 minutes of car travel time to the nearest hospital and how the population changes in each of these travel time intervals when the delays caused by extreme geological events risks zones on the roads are taken into account. About 32% of the Kvemo Kartli population live within the 8-minute car travel time to the nearest hospital, 21% live within the >8-5-minute car travel time, 9 % live within the >15-30-minute car travel time, 33 % live within the >30-45-minute car travel time, 3 % live within the >45-60-minute car travel time, and almost 2 % live outside the 60-minute car travel time (Figure 7).

4.2. Discussion

In the Kvemo Kartli region, out of 7 hospitals, 5 hospitals are located in the city of Rustavi and in the municipalities of Marneuli and Gardabani, where the population density is the highest. In Rustavi, where there are 2 hospitals, the population density is 160 times higher than in Marneuli. In Gardabani, the population density is decreasing even more.

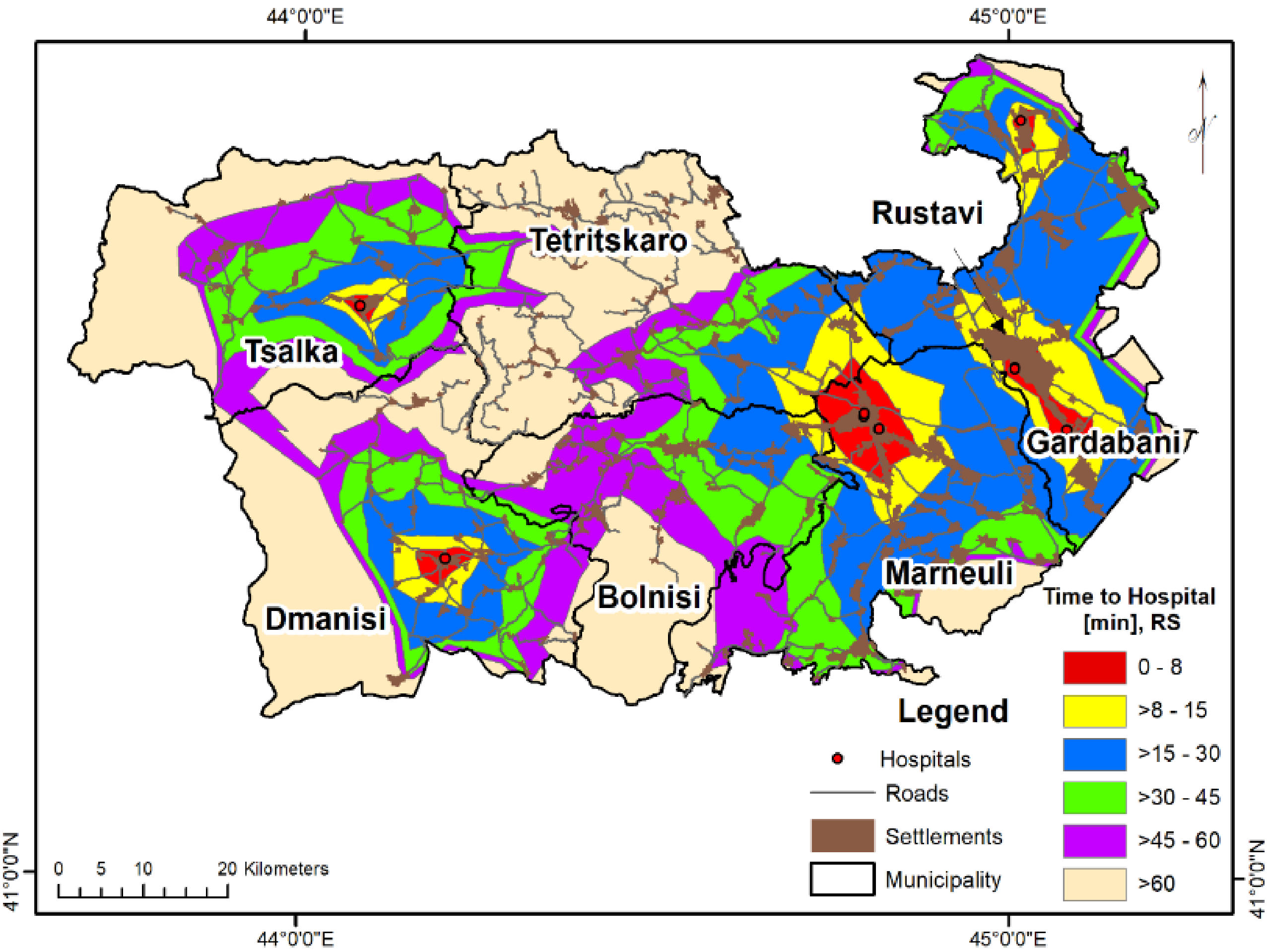

Figure 6. An isochrone map showing the car travel time interval to the nearest hospital, when the impact of risks of extreme geological events on the car movement speed is taken into account.

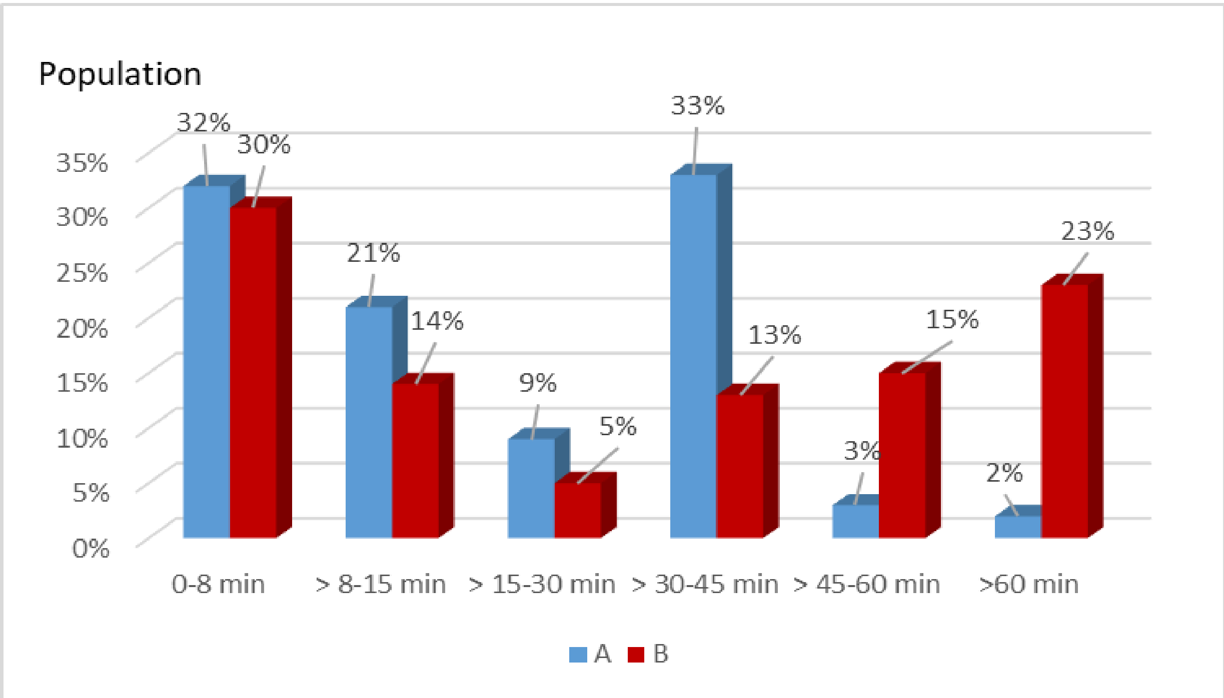

Figure 7. Percentage distribution of the population of Kvemo Kartli according to the different ravel-time intervals.
A - the impact of the geological hazards risk zones on car travel times is not considered.
B - the impact of the geological hazards risk zones on the car travel speeds is considered.

That is why almost a third of the population of Kvemo Kartli is concentrated in the 8-minute reachable area to the hospital, which decreases with the increase of the travel time interval and, therefore, with the distance from the hospital. However, in the area corresponding to the 30-45 min time interval, the percentage of the population increases, since a significant area of the region corresponds to this time range (green color) and then it significantly decreases again, because the interval zone (>45-60, >60 min) corresponding to the subsequent time covers tiny areas distinguished with a lower density of population.

Vehicle speeds are affected by the risk zones of various geological events on the roads. In the Kvemo Kartli region landslides, and rockfalls are the primary road hazards, although there are individual cases of gullying and shore washout. Figure 6 presents an isochrone map showing the car travel time interval to the nearest hospital when the impact of risk zones of geological events on the car movement speed is considered. When the delays due to extreme geological events risks are taken into account, about 30% of the Kvemo Kartli population live within the 8-minute car travel time to the nearest hospital, 14% − live within the >8-15-minute car travel time, 5 % − live within the >15-30-minute car travel time, 13 % − live within the >30-45-minute car travel time, 15 % − live within the >45-60-minute car travel time, and almost 23 % of population live outside the 60-minute car travel time.

Compared with the no geological events scenario, the travel time areas, determined while a geological hazard takes place, reveal that the red zone (0-8 minutes time interval) is reduced at the expense of the expansion of the yellow zone (corresponding to the >8-15 min time interval); however, the yellow zone is also reduced at the expense of the expansion of the blue zone (corresponding to the >15-30 min time interval); The blue zone is reduced at the expense of the expansion of the green zone (corresponding to the >30-45 min time interval), which in turn is significantly reduced at the expense of the significant expansion of the light brown zone (corresponding to the >60 min time interval) and the purple zone (corresponding to the >45-60 min time interval). Accordingly, the percentage of the population in the red zone decreased by 2%, since it fell into the yellow zone, i.e. in the range of >8-15 min. The percentage of the population living in the yellow zone has increased at the expense of the addition of the population in the red zone; however, it ultimately decreased as a certain part of the population living in the yellow zone moved into the blue zone, which in turn, increased the population of the blue zone, but ultimately decreased as a certain part of the population from the blue zone moved into the green zone, i.e. in the spatial zone corresponding to the >30-45 min time interval.

The percentage of the population living in the corresponding zone of the >30-45-minute time range (33%) decreases significantly (to 13%), while the percentage of the population (3% and 2%) living in the corresponding zones of the >45-60 and >60-minute time range, increases significantly (15% and 23%) when we consider the dangers of geological events on the roads. The obtained isochronous maps allow detailed analysis of such changes.

The World Health Organization (WHO) recommends using travel time to service to assess geographical availability (Dos Anjos Luis & Cabral, 2016). Different standards for assessing geographical availability have been introduced in many countries. For example, there is an opinion that if it takes more than 30 minutes for a patient to reach the hospital, then the access to services for this patient is limited (Rooväli & Kiivet, 2006). According to other authors, the patient's access to medical services is limited, if it takes more than 45 minutes to reach the medical facility (Kara & Egresi, 2013). Indeed, there is a need for different time standards, which are defined by the situation. For example, the patient needs urgent emergency medical care or current service. We have classified the areas of the Kvemo Kartli region from which it takes less than 45 minutes (red, yellow, blue, and green zones) to get to the hospital by car as served areas, and the areas, from which it takes more than 45 minutes (purple and light brown zones) to get to the hospital or hospital by car were classified as underserved areas.

It was assessed that about 95% of the population of Kvemo Kartli lives in served areas (< 45-min car travel time or red, yellow, blue, and green zones), and 5% of Kvemo Kartli's population lives in the underserved areas (> 45-min car travel time or purple and light brown zones). The above figure in served areas decreases to 62 % (<45 min car travel time) and the figure in the underserved areas increase to 38% (> 45 min car travel time) when we consider the risks of extreme geological events on the roads.

5. LIMITATIONS AND STRENGTH OF THE STUDY

This study has significant limitations. Firstly, we assume the patient always goes to the nearest medical facility. This means that taking into account the maximum permissible speeds of the car in the individual segment of the road, the patient identifies in advance which medical facility he will reach in the shortest time and chooses a medical facility based on this, which is not the case in reality; the patient may choose another medical facility or choose a different way from the beginning.

The use of the isochrone map has its limitations in general. Isochrone maps provide a simplified representation of travel times, which may not account for factors like traffic congestion, weather conditions, or changes in terrain. Isochrone maps do not allow for the reflection of real-time population density changes during the day and night. They are typically generated from a single point, which may not fully capture the complexity of travel patterns in a region, such as if people commute for work or shopping during the day, etc. It is also important to note that 47.8% of the rural population of the Kvemo Kartli region is engaged in agricultural activities, so they mostly do not commute to Tbilisi or Rustavi for work. In the isochrone maps we created, settlements are presented as one object. The map scale does not allow individual buildings to be mapped. Accordingly, the population percentages are calculated according to settlements. Although the capital city borders the study area – the Kvemo Kartli region, the created isochrone maps do not consider hospitals in Tbilisi. The inclusion of Tbilisi hospitals in these isochrone maps is irrelevant since the problem of medical services in the Kvemo Kartli region is in the municipalities of Bolnisi and Tetritskaro, that is, in the areas that are colored purple and light brown and are far from Tbilisi. Geological events mainly affect the same municipalities, and adding Tbilisi hospitals cannot change the situation in these areas. In the Kvemo Kartli region, near Tbilisi, there is no problem with the availability of hospitals; it is also important that when adding Tbilisi hospitals, it is necessary to consider the traffic jams on the Tbilisi roads, which will significantly increase the travel time, the traffic jams are not typical for the Kvemo Kartli highways.

The importance of the isochrone maps is because a map itself presents areas from which a person can reach the nearest hospital by car in a certain period of time. In these maps, we can also identify served and underserved areas. It doesn't matter if a person lives or works in this area; this area is a served and underserved areas from the point of view of medical services, and this result should be considered for the further development of the region.

The accuracy of isochrone maps depends on the quality and availability of underlying data, such as transportation networks and travel speeds. The strength of the research lies in the fact that in the 1:10,000 scale geographic information system, even each tiny section of the road network of the study region is assigned the maximum permissible traffic speed in this section. We assess travel times considering these speeds by modeling the movement of vehicles along the road network, which allows for a reasonably accurate assessment compared to the straight-line distance model. Isochrone maps provide a clear and intuitive visual representation of travel times, making it easy to understand the accessibility of different areas. They can aid in decision-making processes, such as determining optimal hospital locations based on accessibility. Isochrone maps are useful for urban and transportation planning, helping policymakers understand the impact of infrastructure changes or public transport improvements on accessibility. They help analyze accessibility for various modes of transportation, including walking, cycling, driving, or public transport.

6. CONCLUSION

The main result of our research is the identified served (red, yellow, blue, and green zones) and underserved (purple and light brown zones) areas in terms of medical services within the Kvemo Kartli region by two approaches: 1) the effects of extreme geological events are not considered when the car is driving on the road; 2) the corresponding scenario of slowing down the speed of car movement on the individual section of the road network due to the impact of extreme geological events risks is provided. The percentage of the population living in these areas was also assessed.

The results of this study can help policymakers design effective measures to improve healthcare accessibility in the Kvemo Kartli Region. These can include opening an additional hospital, replacing the existing location, developing road infrastructure etc.

Isochrone map showing the car travel-time intervals to the nearest hospital, in which the impact of extreme geological events risks is considered, is a combined map of the risks of extreme geological events and travel time to the health care facilities. This map allows us to assess the geographical accessibility of medical services in Kvemo Kartli, taking into account extreme geological events, which allows for detailed modeling of fundamental problems in the conditions of modern climate change and their use in the development plan of the health care system, which can bring significant social and economic benefits to the Kvemo Kartli region and the country as a whole. This approach can be used in other regions of the country to identify areas where extreme natural events risks overlap with limited access to healthcare facilities.

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