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GIS Served Car Travel Times to Maternity Hospitals in the Kvemo Kartli Region, Georgia

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Abstract

This study aimed to evaluate car travel times to maternity hospitals in the Kvemo Kartli region of Georgia, with the objective of identifying underserved areas and informing priority interventions to reduce spatial inequalities in access to maternal healthcare services. The isochrone map showing car travel times to the maternity hospitals was created using geographical information systems (GIS), taking into account the location of the maternity hospitals, the length of the roads, and data on the maximum allowed speeds of the vehicles. The research highlights discrepancies in women's access to maternity hospitals in the Kvemo Kartli region. All three maternity hospitals are located in the most densely populated areas, close to each other. Access to maternity hospitals is markedly constrained across large parts of the Kvemo Kartli region, particularly in areas characterised by lower population density. Overall, 51% of women aged 15–49 reside within adequately served zones (car travel time < 30 minutes), while the remaining 49% live in underserved zones (car travel time > 30 minutes). This spatial disparity underscores substantial risks to maternal and infant health, highlighting the urgent need for targeted interventions to improve healthcare accessibility. The most effective solution for reducing inequality in women's access to maternity hospitals is to either establish a new maternity hospital or relocate one of the three existing facilities to Bolnisi.

Keywords: isochrone, inequality, sustainable development

Introduction

Timely access to medical care during pregnancy, labour, and delivery is crucial to ensuring the mother's and baby's health and well-being (Pacagnella et al., 2014). International studies (Grzybowski et al., 2011; Ravelli et al., 2011b) have shown that travel time to the maternity ward is associated with increased intrapartum and neonatal mortality and morbidity risks. According to some authors (Blondel et al., 2011; Dietsch et al., 2010), travel time and unplanned out-of-hospital deliveries also have a positive association. Out-of-hospital deliveries are also associated with a higher risk of perinatal mortality than in-hospital births. According to Combier (2013), significant positive associations exist between travel time to the nearest maternity unit and critical risk factors for perinatal mortality, morbidity, and unexpected out-of-hospital deliveries.

A study carried out in the Netherlands showed that women who have 20 minutes or more of car travel to the nearest maternity hospital are at higher risks for harmful outcomes and mortality (Ravelli et al., 2011a). Similar results were reported in France (Blondel et al., 2011) and in other international studies (Grzybowski et al., 2011; Lisonkova et al., 2011; Tromp et al., 2009).

Research conducted in various countries worldwide indicates that patients who require longer travel times to reach a healthcare facility are less likely to seek care at these facilities when needed (Syed et al., 2013). Regular check-ups are vital for monitoring the health of the woman. Women may miss or delay these crucial appointments if the maternity hospital is far away, leading to potential health problems that go unnoticed. In recent years, driven by the impact of COVID-19, people have grown

increasingly concerned with the quality of hospitals in their living environment. As a result, hospital accessibility has become a key factor in determining housing prices (Chen et al., 2022).

Access to health services is a key indicator of sustainable development at both urban and regional levels and should be ensured for everyone equally and fairly (Soltani et al., 2019).

This study is linked to several Sustainable Development Goals (SDGs), primarily:

SDG 3: Good Health and Well-being: Improving access to maternity hospitals can reduce maternal mortality and guarantee access to reproductive healthcare services (https://sdgs.un.org/goals)

SDG 10: Reduced Inequalities: aims to reduce inequalities (https://sdgs.un.org/goals). By identifying "served" and "underserved" areas regarding access to maternity hospitals, interventions can be prioritized to reduce inequalities in healthcare access.

SDG 11: Sustainable Cities and Communities: https://sdgs.un.org/goals Improving access to healthcare facilities, including maternity hospitals, contributes to creating more inclusive and resilient communities.

SDG 17: Partnerships for the Goals: https://sdgs.un.org/goals. This goal emphasizes the importance of partnerships in achieving the SDGs. Collaborative efforts between governments, healthcare providers, and community stakeholders are essential to improving access to maternity hospitals and achieving the related SDG targets.

Achieving the SDGs is crucial because it represents a global commitment to creating a more sustainable, equitable, and prosperous world for all people, now and in the future.

Every individual is entitled to quality healthcare, so medical services must be strategically allocated. Prioritizing sufficiency and accessibility as key spatial dimensions of healthcare access will facilitate the effective distribution of health facilities to meet growing demand. Identifying areas with inadequate access to healthcare facilities can also support proactive hospital site selection. This data-driven approach could be integrated into regional healthcare planning, promoting both equity in access and sufficiency, ultimately contributing to greater health equity.

Our objective was to create an isochrone map illustrating car travel times to the nearest maternity hospitals to identify underserved areas, prioritize interventions to address inequalities, and contribute to achieving multiple health and SDGs.

Methods and Materials

Case Study

According to Yin, case studies are a valuable and valid research approach, particularly for examining complex real-world phenomena (Yin, 2014). Research using case studies on travel time to maternity hospitals allows for an in-depth exploration of specific cases, offering detailed and insightful findings that may be difficult to achieve with other research methods. This thorough analysis can enhance our understanding and provide a valuable means of gaining deep insights into the complexity of this issue, informing policies and interventions aimed at improving access to maternity care.

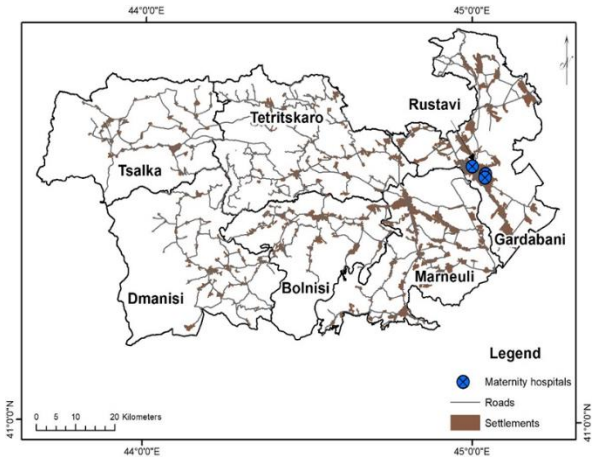

Figure 1. A map of settlements, maternity hospitals, and the road network in Kvemo Kartli
Note: The bold black lines on the map represent the municipal boundary

For the case study, we selected one of the border regions of Georgia - Kvemo Kartli (Elizbarashvili et al., 2024a). To the north of the country's capital, Tbilisi, to the southeast, it is bordered by the Republic

of Azerbaijan, and to the south, by the Republic of Armenia. The administrative center of Kvemo Kartli is Rustavi. Apart from Rustavi, it includes the following municipalities: Bolnisi, Gardabani, Dmanisi, Tetritskaro, Marneuli, and Tsalka. The region's area is 6,528 km2, 10% of Georgia's total area. According to the Georgian National Statistics Office, the population of Kvemo Kartli is 428,799, which is 11.42% of the population of Georgia. The Kvemo Kartli region features industrial centers and farmlands. The industrial cities in the area are Rustavi and Marneuli. Within Kvemo Kartli, the population density varies extensively (Elizbarashvili et al., 2024b). There are three maternity hospitals in the Kvemo Kartli region, all located close to each other in the key industrial city of the region – Rustavi. Figure 1 shows the settlements, maternity hospitals, and the road network of Kvemo Kartli. Based on all these features, the Kvemo Kartli region is a representative geographic area for the case study. The research will give us a broad idea of how access to maternity hospitals changes for women living in different areas in Kvemo Kartli, what contextual factors affect this, and what measures need to be taken to reduce inequalities and contribute to achieving multiple SDGs related to health and sustainable development.

By studying car travel time to maternity hospitals and identifying underserved areas, interventions can be targeted to improve healthcare access, reduce inequalities, and contribute to achieving SDGs related to health and sustainable development.

Data collection

Data for medical stations were obtained from both official government sources: "Ministry of Internally Displaced Persons from the Occupied Territories of Georgia, Labor, Health, and Social Protection", web pages of medical institutions, and direct fieldwork, including visits to medical institutions in the Kvemo Kartli region (Elizbarashvili et al., 2024a, Elizbarashvili et al., 2024b).

Mapping and calculations

In this study, we used the 1:10000 scale geographic information system of the healthcare infrastructure of the Kvemo Kartli region, which includes information on settlements, population, roads, bridges, healthcare facilities (hospital, emergency medical care, pharmacy network, dental clinics, diagnostic centers, etc.), data on the maximum allowed vehicle speeds on each road segment (Elizbarashvili et al., 2024a). Based on this GIS, the isochrone map showing the car travel times to the nearest maternity hospital was compiled, and the percentage of women aged 15- 49 years living within different travel-time intervals to the maternity hospitals was calculated.

Results

The isochrone map showing the car travel times to the nearest maternity hospital

The isochrone map presented in Figure 2 shows the spatial distribution of (red, yellow, blue, green, purple, and light brown) areas, which correspond to the following car travel time intervals: 0-8 min, >8-15min, >15-30 min, >30-45 min, >45-60 min, >60 min.

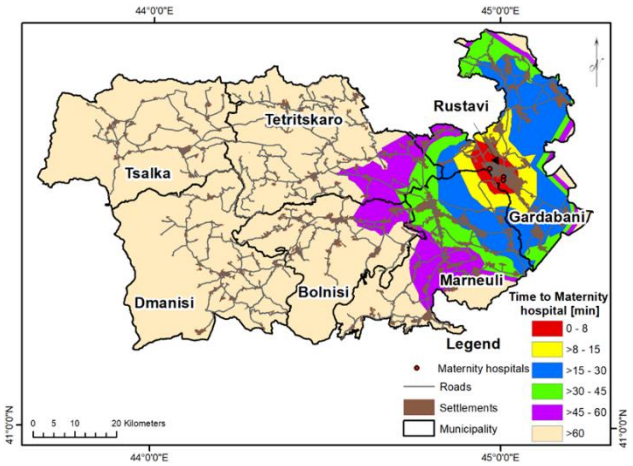

Figure 2. An isochrone map showing the car travel times to the nearest maternity hospital

People living in the red area will reach the nearest maternity hospital by car within 8 minutes, it will take 8 to 15 minutes for people living in the yellow area to reach the nearest maternity hospital by car,

15 to 30 minutes for people living in the blue area, 30 to 45 minutes for people living in the green area, 45 to 60 minutes for people living in the purple area. People who live in the brown area will need more than 1 hour to get to the nearest maternity hospital by car. The brown area covers a large part of the Kvemo Kartli region.

Women of reproductive age living within the different travel time intervals

Women of reproductive age are usually considered to be in the age range of approximately 15 to 49 years old. This age range is chosen because it encompasses the years during which women typically experience menstruation, ovulation, and the potential for pregnancy. According to data from the "National Statistical Service of Georgia," 103,758 women of this age live in the Kvemo Kartli region, which is slightly more than 24% of the total population of Kvemo Kartli.

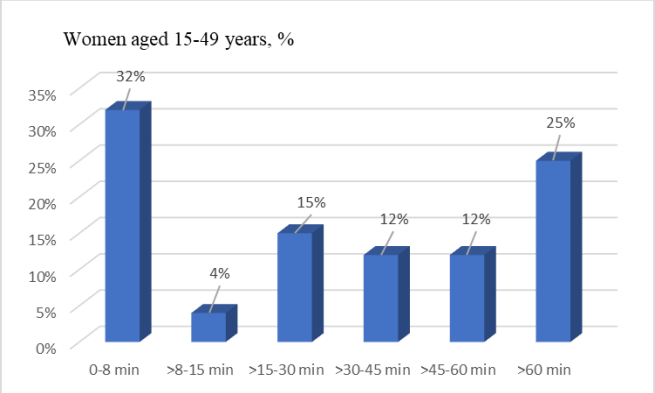

Figure 3. Distribution of the percentage of women aged 15- 49 years in the Kvemo Kartli region according to the different travel time intervals to the nearest maternity hospital

Based on GIS analyses, it was assessed that about 32 % of women aged 15-49 years of Kvemo Kartli live within the 8 min car travel time to the nearest maternity hospital, about 4 % live within > 8-15 min car travel time, about 15% live within the >15-30 min car travel time, 12 % within the >30-45 min car travel time, 12 % within the >45-60 min car travel time and almost 25% life outside the 60 min car travel time (Figure 3). Such a percentage distribution is determined by the location of maternity hospitals and the region's population density change.

Table 1. The density of women aged 15-49 years

Municipality	The density of women aged 15-49 years, people/km²
Rustavi	448.82
Marneuli	24.86
Gardabani	20.58
Bolnisi	16.99
Tsalka	4.54
Tetritskaro	4.24
Dmanisi	3.28

There are three maternity hospitals in the Kvemo Kartli region. However, all of them are located in Rustavi, the most highly populated area where the density of women aged 15-49 years is the highest in the region. Rustavi is followed by Marneuli municipality, where the density of women aged 15- 49 years is nearly 20 times lower than that of Rustavi. The density decreases in the Gardabani and Bolnisi municipalities and significantly decreases in the Tsalka, Tetritskaro, and Dmanisi municipalities (Table 1).

Discussion

Travel time to maternity hospitals

According to this study, many women in the Kvemo Kartli region face challenges in reaching the nearest maternity hospitals on time. Specifically, 68% of women aged 15 to 49 cannot reach the nearest maternity hospital within 8 minutes, a critical time frame for emergencies. 64% of women aged 15 to

49 cannot access the nearest maternity hospital within 15 minutes, 49 % of women aged 15-49 cannot access the nearest maternity hospitals within 30 minutes, 37 % of women within 45 minutes, and 25% - within 60 minutes. Figure 4 shows the distribution of the percentage of women aged 15- 49 years in the Kvemo Kartli region according to the reaching not reaching the nearest maternity hospital within different travel time intervals. Logically, more women face challenges when reaching maternity hospitals without a car, as public transport is not developed in Kvemo Karli.

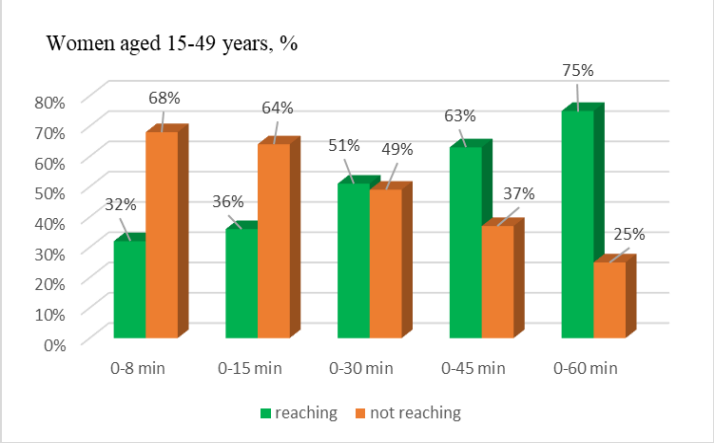

Figure 4. Distribution of the percentage of women aged 15- 49 years in the Kvemo Kartli region according to the reaching not reaching the nearest maternity hospital within different travel time intervals

For pregnant women, it is essential to have convenient access to healthcare facilities. Delays in accessing care can lead to birth complications and hurt both maternal and neonatal outcomes (Pacagnella et al., 2018). Longer travel times may contribute to delays in receiving necessary medical attention, which can be critical during childbirth, particularly in emergencies. The labor process can sometimes progress rapidly and can lead to accidental out-of-hospital births. Without appropriate medical assistance, it can pose risks to both the mother and child (Blondel et al., 2011). Quick access to healthcare can help prevent complications and ensure safe deliveries.

The study conducted in the rural region of France in Burgundy showed that a travel time of 30 min or more to maternity units could delay the delivery of the baby, increasing risks of fetal heart rate anomalies, out-of-hospital births, and pregnancy hospitalization (Combier et al., 2013). The finding related to travel time from home to the hospital in the Netherlands and its association with adverse outcomes in pregnant women suggests that a longer travel time, specifically 20 minutes or more by car, is linked to an increased risk of mortality and other negative outcomes (Ravelli et al., 2011a).

According to the Belgian National Geographic Institute, over 99% of women aged 15 to 49 can reach one or more maternity services within a 30-minute drive under typical traffic conditions. Additionally, 92.3% of women in the same age group can access maternity services within a 15-minute drive (Lefèvre et al., 2019).

In the Kvemo Kartli region, only 36% of women aged 15 to 49 can access maternity services within a 15-minute drive. Approximately 51% of women aged 15 to 49 can access maternity services within 30 minutes by car.

Research conducted in Northern Sweden shows that 40% of women need more than 20 minutes to reach maternity hospitals. The same study shows that in 2013, approximately 90% of women could reach their nearest maternity hospital in Northern Sweden within one hour, compared to around 80% in 2019 (Elin, 2019). In the Kvemo Kartli Region, about 75 % of women can reach the nearest maternity hospital by car within one hour.

On the map presented in Figure 3, the red, yellow, and blue areas where it takes 30 minutes to reach the maternity hospital by car were evaluated as "served"; approximately 51% of women aged 15 to 49 live there. Green, purple, and light brown areas, where it takes more than 30 minutes to reach the maternity hospital by car, are classified as "underserved;" 49% of women aged 15 to 49 live there.

Addressing Pregnant Women's Healthcare Access in Rural Kvemo Kartli: Limitations of Maternity Waiting Homes and the Need for Localized Solutions

To address the challenge of long distances to healthcare facilities for pregnant women, many countries have established maternity waiting homes (MWHs) near maternity units. These facilities (Stekelenburg et al., 2006, Sialubanje et al., 2015) are designed for women living in remote rural areas. MWHs allow these women to stay close to a hospital during the final weeks before delivery, ensuring timely access to care when labor begins. Additionally, in rural areas, MWHs can provide a respite from strenuous fieldwork, which may otherwise contribute to pregnancy and childbirth-related complications (Agbla et al., 2006). However, we believe that MWHs cannot work in the Kvemo Kartli region due to the cultural characteristics and mentality of the population. The opening of MWHs also fails to ensure regular visits of pregnant women to Maternity hospitals for prenatal check-ups, which are essential for monitoring the health of both the mother and the baby. Therefore, we consider it most optimal to create a new maternity hospital or move one of the three existing maternity hospitals to Bolnisi, which is in the "underserved" area and where the density of women aged 15- 49 years is the highest after Rustavi, Marneuli, and Gardabani. Such a change will improve the current situation to some extent. Bolnisi borders Marneuli municipality and is also close to Rustavi, where the population density is highest; on the other hand, Bolnisi municipality borders Dmanisi and Tetritskaro municipalities, which are also in the "underserved" area. It is essential to develop roads and public transport in the Kvemo Kartli region, which will help women to go to maternity hospitals for regular check-ups and examinations.

Limitations and strengths of the study

This study has important limitations. Firstly, we have made all discussions and conclusions considering all 15- to 49-year-old women who live in the Kvemo Kartli region. However, the level of accessibility to maternity hospitals can be more crucial in some situations than in others, one of which is childbirth.

Secondly, isochrone maps are a valuable tool in planning as they visually represent accessibility within a certain time frame. However, isochrone maps have limitations, as they simplify travel time calculations and do not consider real-world factors such as traffic conditions, road closures, or weather.

However, the strength of our research lies in the use of GIS with the road layer created at a larger scale of 1:1,000 and the maximum permissible car travel speeds in each segment along the road between two places. The advantage of using the maximum permissible car travel speed is that it already considers road surface conditions, terrain, steep bends, or other real-world difficulties that may affect real-time travel (Elizbarashvili et al., 2024a, Elizbarashvili et al., 2024b).

Conclusion

The research underlines disparities in women's access to maternity hospitals in the Kvemo Kartli region. It helps us understand what contextual factors affect this situation and how to address it.

- All three maternity hospitals are located in the most densely populated areas close to each other, which means that access is significantly limited in a large part of the Kvemo Kartli region, where the population density is significantly lower.
- This study identifies key regions in Kvemo Kartli where maternity hospitals are lacking, based on driving travel time distance assessments. 51% of women aged 15 to 49 live in the served area (car travel time < 30 min), while 49% (50,332 women) live in the underserved area (car travel time >30 min). The mapped findings could have policy implications and be valuable for future decision-making and analysis.
- The most optimal solution to reduce inequality in women's access to maternity hospitals is to create a new maternity hospital or move one of the three existing maternity hospitals to Bolnisi.
- Regarding population density, Kvemo Kartli is slightly behind only one region of Georgia and much higher than the population density of the rest of Georgia. This makes it clear that the accessibility problem will be even more acute in the other regions, where the population is much more sparsely distributed than in the Kvemo Kartli region. Low population density areas may have fewer hospitals or healthcare facilities due to lower demand, leaving residents underserved. Therefore, creating an isochrone map illustrating car travel times to the nearest maternity hospitals in other regions of Georgia is crucial. This map can help identify underserved areas and support the development of targeted interventions to improve healthcare access, reduce inequalities, and contribute to achieving various SDGs related to health, equality, and sustainable development in Georgia.

The information obtained from the study can serve as a basis for policy recommendations and interventions aimed at improving access to maternity care in the Kvemo Kartli region. Policymakers,

healthcare professionals, and other stakeholders can use these data to develop targeted strategies that address specific challenges and improve the general well-being of mothers and babies in the region.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

M.E. conceptualization, methodology, writing- original draft preparation supervision. B.K. data curation, writing - original draft preparation. Sh.E. software, investigation. N.Ch. and E.E. writing - reviewing and editing. T.K. visualization, software, validation. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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