

GEOGRAPHIC ACCESSIBILITY OF GENERAL PRACTITIONERS BY CAR AND PUBLIC TRANSPORT - A STUDY USING THE MINIMUM TRAVEL TIME METHOD IN A RURAL AREA IN THE NORTH-EAST OF GERMANY

Abstract

Basic medical care should be accessible to all people without restriction. However, the distribution of practices in rural areas is often limited to the centers, meaning that distances have to be covered. The Federal Joint Committee (G-BA), the highest decision-making body of the joint self-government of physicians, dentists, hospitals and health insurance funds in Germany, only states for cars that 95% of the population should be able to reach general practitioners (GPs) in less than 20 minutes on average. The aim of this study was to determine the geographic accessibility of GP practices by car and public transport.

A cross-sectional study was conducted in a rural area in the north-east of Germany called Neustrelitz Central Zone and reported according to the STROBE statement. Geographic data of OpenStreetMap and the Federal Agency for Cartography and Geodesy and GP practices data of the Associations of Statutory Health Insurance Physicians Mecklenburg-Western Pomerania and Brandenburg were used. Based on the method of minimum travel time, the required travel times by car and public transport from the local centers to the three nearest physician locations were determined using various online tools.

On average, inhabitants need 10.7 minutes to reach the three nearest GP practices by car, up to a maximum of 19 minutes. The average travel time by public transport for an appointment at 10 a.m. is four hours and twelve minutes. While it is possible for all municipalities (and their inhabitants) to reach the nearest GP practices in time for an appointment at 10 a.m. and to complete the return journey on the same day, this is no longer possible for 35% of municipalities (and their inhabitants) for an appointment at 3 p.m. and for 53% for an appointment at 5 p.m.

In the Neustrelitz Central Zone, the accessibility of GP practices by car is ensured in accordance with the G-BA statements. On the other hand, the accessibility of GP practices by public transport can be a problem for people who do not have their own car. This could be remedied, for example, by expanding eHealth or mobile medical practices.

Keywords: GIS, Primary care, Need related planning, Geographic accessibility, Minimum travel time method, Germany

1. Introduction

According to the Federal Institute for Research on Building, Urban Affairs and Spatial Development, services of general interest means providing the population with services and goods for daily needs in order to ensure equal living conditions for all (**BBSR 2022**). In Germany, the state's duty to provide services of general interest is set out in Section 2 of the Spatial Planning Act (ROG).

One aspect of services of general interest is the provision of comprehensive medical care for inhabitants. In Germany, medical care is divided into outpatient medical care, the hospital sector and outpatient and inpatient rehabilitation facilities (**IQWiG 2018a**). According to Section 39 of Book V of the Social Code (SGB V), however, inpatient care is subsidiary, which means that inpatient treatment should only be provided if outpatient treatment is not sufficient. Outpatient care in Germany is largely provided by office based physicians (**BÄK 2022**). Approximately 96% of outpatient physicians participate in the statutory health insurance (SHI) scheme as SHI-accredited physicians (**Klose/Rehbein 2017**). They are therefore allowed to provide services for people with SHI, who make up around 88% of the population in Germany (**IAQ 2023a**), at the expense of the SHI funds.

General practitioners (GP) care occupies a central place in the outpatient sector of the German healthcare system (**IAQ 2023b**). In the literature, GPs are often referred to as gatekeepers (**Fitzner 2021**) who (ideally) guide patients through the healthcare system (**Lübking 2020**). However, unlike many other countries, Germany does not have a gatekeeper model (**OECD 2013**), as it is also possible to visit a specialist practice without prior referral from a GP (**IQWiG 2018b**).

Need related planning forms the legal basis for the licensing of SHI-accredited physicians (**Rosenbrock/Gerlinger 2024**). This is intended to ensure

patient-oriented care that is equally accessible to all people with SHI, regardless of their place of residence or income (**KBV 2020**). Need related planning is divided into four levels of care. Depending on the level of care, need related planning relates to different geographical areas. The "general practitioner level of care" considers the small "central zones" (**KBV 2020**). Each central zone consists of a central location and its surrounding area (**KBV 2020**).

"Ratios" (**G-BA 2022**) are used to determine the need for SHI-accredited physicians in a region. These describe the desired "physicians-to-inhabitant ratios" (**G-BA 2022**) in the respective level of care, with adjustments being made with regard to changes in demographics and morbidity. This target level is compared with the actual level of the "physicians-to-inhabitant ratios" in order to determine the level of care (**KBV 2020**).

In addition to "physicians-to-inhabitant ratios", spatial access can also be measured by accessibility (**Sundmacher et al. 2018**). In this context, the Federal Joint Committee (G-BA), the highest decision-making body of the joint self-government of physicians, dentists, hospitals and health insurance funds in Germany, stipulates that 95% of the population should be able to reach GPs by car in less than 20 minutes on average (**G-BA 2022**), with accessibility being analyzed across federal state borders (**KBV 2020**). However, there are no corresponding figures for public transport. The consideration of both car travel times and public transport travel times appears necessary, as this is the only way to ensure accessibility analyses for the entire population (**Voigtländer/Deiters 2015**). For example, the older population is often not motorized and therefore particularly dependent on public transport (**Stentzel et al. 2016**). However, based on two different survey studies, it can be assumed that in Germany a maximum of 8% of patients in rural regions use public transport, whereas up to 92% of patients stated that they travel to the medical practice by car (**Baier et al. 2020, KBV 2013**).

Although Germany is a global leader in terms of physician density (**OECD 2021**) and access to physicians (**OECD 2019**), there are still differences in the level of care provided by GPs between urban and rural areas - despite need related planning (**KBV 2021**). In addition, in a German nationwide study based on billing data from statutory health insurance physicians, the average realized travel time for GP patients in rural areas was 21 minutes, almost twice as long as in urban areas at 11 minutes (**Schang et al. 2017**). Some regions in north-eastern Germany were particularly affected by long travel times (**Schang et al. 2017**) – despite an above-average physician density

compared to the rest of Germany (**KBV 2022**). However, the study can only be applied to the current situation to a limited extent. Firstly, it is based on billing data from April 2009 to March 2010. Secondly, since the beginning of 2013, GP care has been planned on a smaller scale than before on the basis of central zones (**Gerlinger 2017**). In addition, the travel times were calculated exclusively for the use of cars and not also for public transport.

A further study based on a grid approach came to the conclusion that GP care is "easily" accessible for the majority of people in Germany. However, there were differences in accessibility between different regions. For example, inhabitants in the German federal states of Mecklenburg-Western Pomerania, Brandenburg, Saxony-Anhalt and Rhineland-Palatinate are particularly affected by longer travel times. However, the study estimates that the proportion of people in Mecklenburg-Western Pomerania who have to travel more than 15 minutes by car to their nearest GP is very low at 7% (**Neumeier 2017**). Based on a similar approach, an expert opinion for the G-BA concluded that in sparsely populated rural areas of Germany, the nearest GP can be reached in an average of 4.1 minutes by car. The 10% of rural districts with the worst potential accessibility are largely located in Mecklenburg-Western Pomerania, although smaller-scale minute values were not reported (**Sundmacher et al. 2018**). A limitation for both studies is that no travel times for public transport were simulated.

The situation in the German federal state of Mecklenburg-Western Pomerania was examined in more detail in two further studies. Firstly, the accessibility of GP practices by car and public transport in the Western Pomerania-Greifswald district was analyzed on the basis of a network analysis and using data from 2012 (**Stentzel et al. 2016**). On the other hand, the 2018 monitoring of the Mecklenburg Lake regional planning association reported on the basis of a (not publicly accessible) small-scale expert opinion from 2013 on how GP practices in the Mecklenburg Lake District can be reached by car and public transport (**Mecklenburg Lake Regional Planning Association**). One limitation of both studies is that the study results are based on data that is more than 10 years old.

Due to a lack of current research, the aim of this study was to determine the accessibility of GP practices by car and public transport in a rural area in the German federal state of Mecklenburg-Western Pomerania.

2. Materials and Methods

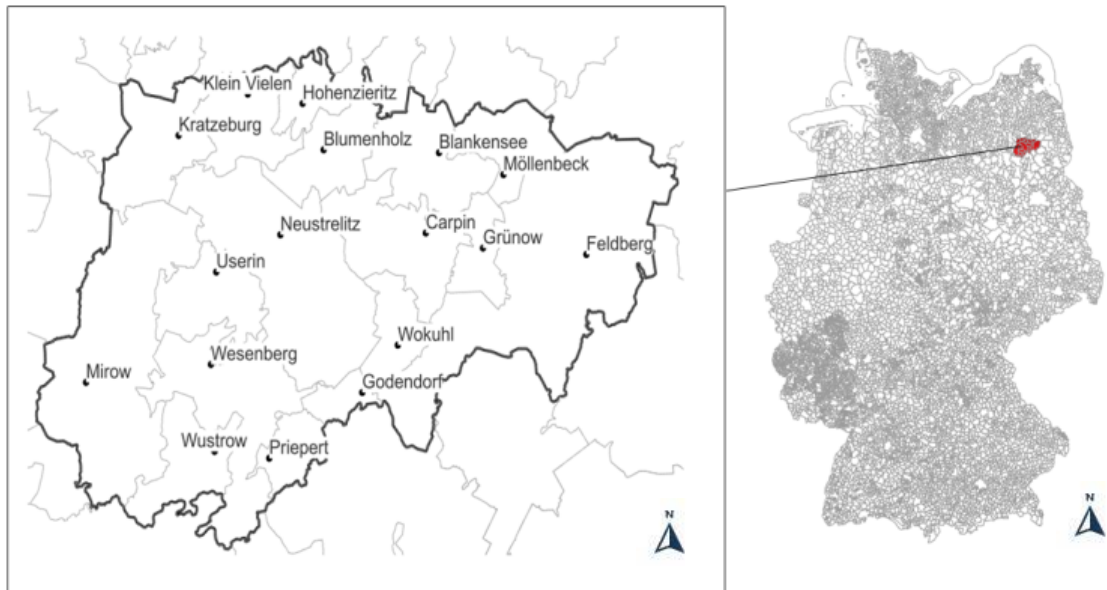
2.1 Design

This cross-sectional study was reported in accordance with the STROBE Statement [STROBE Statement 2022]. It was based on the "minimum travel time" method (Neutens 2015) to the nearest medical practices. A review showed that this method was the second most frequently used of all available methods in the health care setting (Neutens 2015). The method is easy to use and produces realistic results in rural regions, as the nearest doctors in the desired specialty are often the ones who are consulted (Pieper et al. 2019, Baier et al. 2020). In this regard, a somewhat older study from 2008 based on billing data from statutory health insurance physicians showed that 71.5% of German patients visit their nearest GP (Fülöp et al. 2011).

2.2 Setting

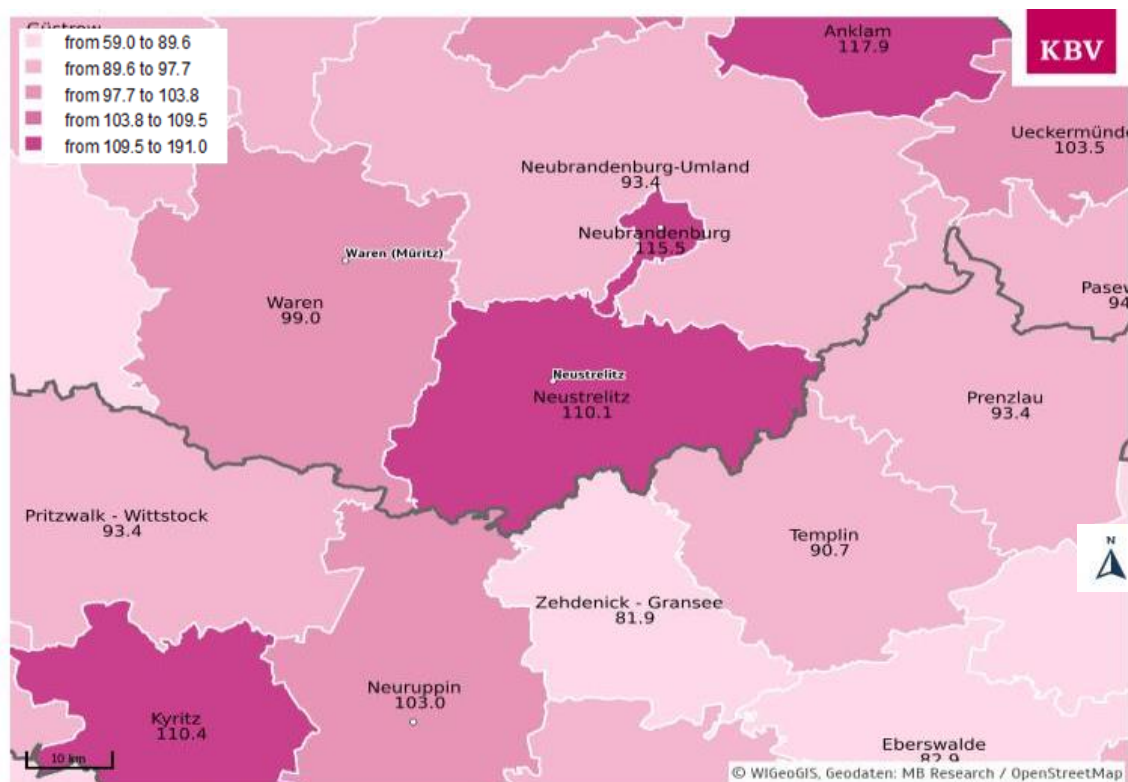
The study was conducted in a rural area called Neustrelitz Central Zone in the federal state of Mecklenburg-Western Pomerania in north-eastern Germany (Figure 1). This can be further subdivided into the city of Neustrelitz and the administrative areas of Neustrelitz-Land, Mecklenburg Small Lakeland and Feldberg Lakeland (Mecklenburg Lake District 2022). The administrative areas of Neustrelitz-Land and Mecklenburg Small Lakeland in turn consist of individual municipalities (for details see Figure 1 and Supplement 1) (KVMV 2020). As at 31 December 2020, the Neustrelitz Central Zone had a total of 39,949 inhabitants (Mecklenburg-Western Pomerania Statistical Office 2021). These are spread over an area of 1,104.93 km², which results in a below-average population density of 36.16 inhabitants per km² compared to the rest of Germany (Mecklenburg-Western Pomerania Statistical Office 2021).

Figure 1: Location of the Neustrelitz Central Zone in Germany



The Neustrelitz Central Zone is part of the Mecklenburg Lake District, which at approximately 5,500 km² is the largest district in Germany. It is located in the south of the district and is bordered to the north by the Neubrandenburg-Umland Central Zone and the Neubrandenburg Central Zone. The Waren Central Zone borders on the west of the Central Zone. To the east and south of the Central Zone are neighboring Central Zones of the German federal state of Brandenburg. The Neustrelitz Central Zone has an above-average GP level of care of 110.1% (**KBV 2021**) compared to the rest of Germany and the federal state (Figure 2).

Figure 2: Levels of care in the Neustrelitz Central Zone and in neighboring planning areas of the Associations of Statutory Health Insurance Physicians in Mecklenburg-Western Pomerania and Brandenburg



Quelle: BPL-Umfrage der KVen, 31.12.2021, KBV

The region's road, rail and bus route networks are shown in supplements 2, 3 and 4. The bus route network initially appears to be well developed. However, these are often school buses that only run early in the morning and usually three to four times in the afternoon. During school vacations, buses often only run to a limited extent (**MVVG 2022a**). However, the car density in the Mecklenburg Lake District is only 565.6 cars per 1,000 inhabitants, which is below the national average of 580.2 cars per 1,000 inhabitants (**Federal and state statistical offices 2022**). It can therefore be assumed that part of the population relies on public transport.

2.3 Data Collection

2.3.1 Geographic Data

Free map data from OpenStreetMap (**OpenStreetMap 2022**) was used to ensure a good overview of the region's population and transportation network. In addition, free map data from the Federal Agency for Cartography and Geodesy (**BKG 2021**) was used to determine the boundaries of the municipalities and the exact location of the local centers.

2.3.2 Data of GP practices

The online doctor search of the Association of Statutory Health Insurance Physicians Mecklenburg-Western Pomerania (**KVMV 2022**) was used to record the GPs in the Neustrelitz Central Zone. We were looking for GPs with a health insurance license, which according to Section 73 SGB V includes also medical practitioners and internists without a specialization who have their practice in the Neustrelitz Central Zone. Pediatricians and adolescent physicians, who also count as GPs according to Section 73 SGB V, were excluded, as the study was to be limited to the medical care of persons of legal age. As a result, 21 practice locations (with 33 doctors) could be included in the analysis.

People who live on the edge of the Central Zone may be able to reach a GP practice located outside the Central Zone more easily. To take this possibility into account, a buffer zone was created around the Neustrelitz Central Zone. GP practices located within the buffer zone were also included in the analysis. Speeds in rural areas range between 0 km/h (e.g. while waiting at traffic lights) and 100 km/h (legally permitted maximum speed on rural roads in Germany). An average speed of 50 km/h was assumed for the calculation of the buffer zone (**BBSR 2023**). Assuming the desired accessibility within 20 minutes (**G-BA 2022**), the range of a vehicle based on this assumption is limited to around 17 kilometers. However, it should be noted that the radius around the Central Zone is as the crow flies. Cars are dependent on the road network and can therefore only cover shorter distances in 20 minutes in most cases. For this reason, in terms of a conservative approach, it is not unrealistic to set the range of a car within 20 minutes and thus the extension of the buffer zone to a maximum of 15 kilometers (**Stentzel et al. 2016**).

In a next step, the buffer zone was systematically searched for GP practices using the map-based search functions of the Associations of Statutory Health Insurance Physicians in Mecklenburg-Western Pomerania (**KVMV 2022**) and Brandenburg (**KVBB 2022**). This enabled a further 69 practice locations (with 103 doctors) to be included in the analysis. A total of 90 practice locations (with a total of 136 doctors) were therefore included in the Neustrelitz Central Zone and the buffer zone.

2.4 Data Visualization and Analysis

The data was visualized using the QGIS program (**QGIS 2022**). First, a pre-installed background map from OpenStreetMap was loaded into QGIS. In order to be able to use the boundaries of the municipalities and the exact location of the local centers, the

map of the administrative areas of the Federal Agency for Cartography and Geodesy was added as a WMS layer. In the next step, the corresponding municipalities were merged into the Neustrelitz Central Zone by creating a shape layer.

The locations of the medical practices in the central zone and in the buffer zone were geocoded below using the QGIS tool MMQGIS. This makes it possible to identify which medical practice locations are located within the Neustrelitz Central Zone and where the exact boundary runs. Due to incorrect coordinate assignment, two locations had to be corrected manually.

The EPSG:25833 coordinate system was used in QGIS to analyze the distances, which works with the unit of measurement meter. The analysis of the distances was based on the local centers, the so-called local center points (**Stentzel et al. 2016**), which are specified in the map material of the Federal Agency for Cartography and Geodesy. These served as the starting point for determining the distance to the nearest medical practice. For this purpose, the three medical practices to which the direct distance - measured as the crow flies (**Fülöp et al. 2011**) - is the shortest were first recorded for each local center point in the central zone. The identical procedure was carried out again with the medical practices in the buffer zone in order to determine whether a GP practice in the central zone or in the buffer zone is more accessible for inhabitants in the local centers. Thus, inhabitants in the local centers may have different choices regarding the nearest GP practice in different central zones. Of the six medical practices identified, three within the central zone and three in the buffer zone, the three with the shortest distance to the starting point were selected in the next step.

The free online route planner from the provider OSRM (**OSRM 2022**) was then used to determine the car route and travel time. This calculates the car route and travel time using map data from OpenStreetMap. Delays caused by the current traffic volume or roadworks are not included in the calculation of the travel time (**OSRM 2022**). This means that the results are independent of the date and time of the calculation and can also be transferred to other days. In each case, the fastest route from the local center point to the respective medical practice was calculated and the estimated travel time in minutes and the length of the route in kilometers were noted. From the patient's point of view, the travel time is more important than the length of the route (**Voigtländer/Deiters 2015, Stentzel et al. 2016**).

To calculate the travel time when using local public transport, the timetable information of the Transport Company Mecklenburg-Western Pomerania (**VMV 2022**) or, for

destinations outside Mecklenburg-Western Pomerania, the navigator of the German Railways (**DB Vertrieb GmbH 2022**) was used. In order to generate a picture that is as suitable as possible for everyday use, three possible medical appointments were defined as a basis - analogous to the monitoring of the Mecklenburg Lake Regional Planning Association (**Mecklenburg Lake Regional Planning Association 2018**). One appointment at 10 a.m. in the morning and two appointments, at 3 p.m. and 5 p.m. respectively, in the afternoon. As with the monitoring, it was assumed that the medical appointment takes one hour and that the day of travel is a Thursday (20 October 2022) outside the school vacations (**Mecklenburg Lake Regional Planning Association 2018**). The fastest connections from a central bus stop or a central train station in the respective local centers to the three previously determined medical practices and back were determined. The total (minimum) travel time includes the journey to and from the medical practices and any walking and transfer times as well as the appointment duration of one hour and any waiting times at the medical practices between arrival and appointment. In addition, the condition was introduced that the walk between the individual stations or to the destination and back should not take longer than 15 minutes per appointment. If this condition was not met, an alternative route was sought. If this was not available, the appointment was deemed unavailable. This was to ensure that people with multiple illnesses or the elderly could also make the journey. If it was not possible to return by public transport by the end of the day, the appointment was also deemed unavailable.

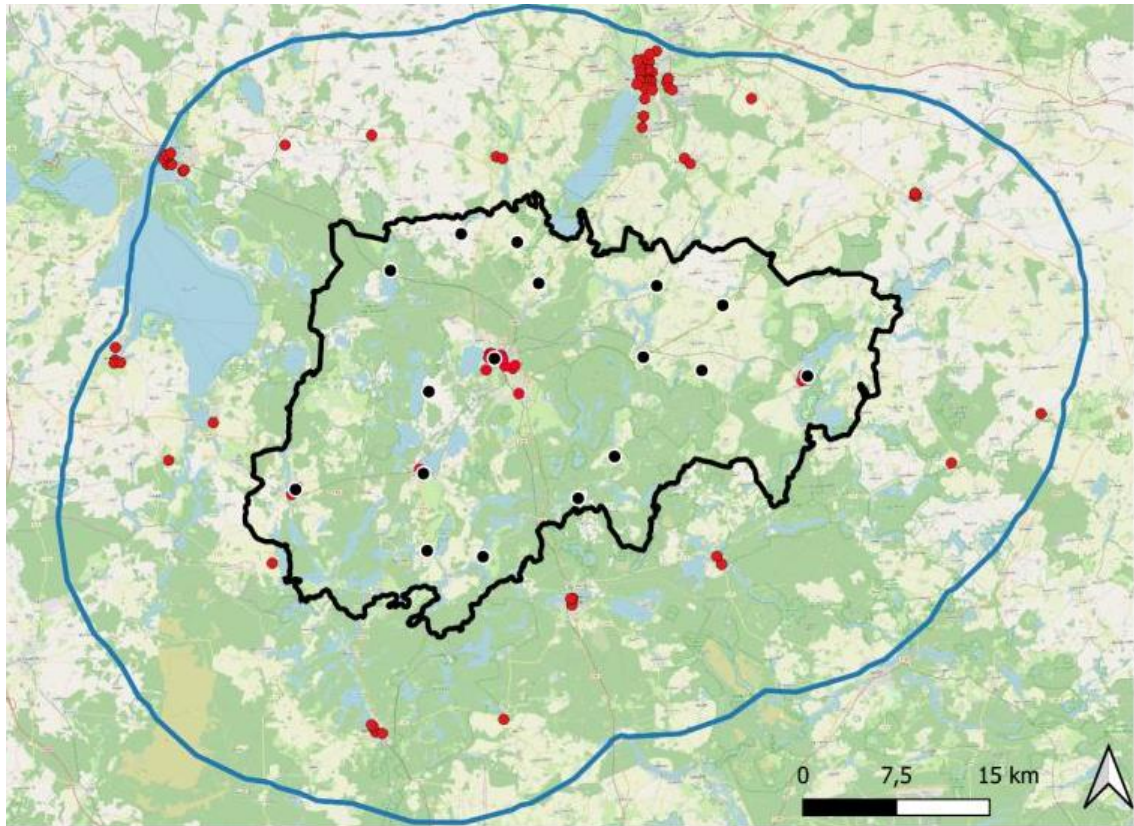
The arithmetic mean was then calculated from the three time values for car and public transport per local center, which describe the fastest travel time to the three nearest GP practices. This is to compensate for the fact that not all people in the respective town visit the same GP practice (**Sundmacher et al. 2018; Guagliardo 2004**). The locality of Wesenberg is an exception to this procedure. There are two GP practice locations in the immediate vicinity of the local center. The nearest practice outside the town is much further away and would therefore greatly distort the result.

3 Results

3.1 Distribution of GP practices in the central zone

The distribution of GP practices and the geographical dimensions of the central zone and the 15-kilometer buffer zone are shown in Figure 3.

Figure 3: Distribution of GP practices in the Neustrelitz Central Zone and in the 15-kilometer buffer zone

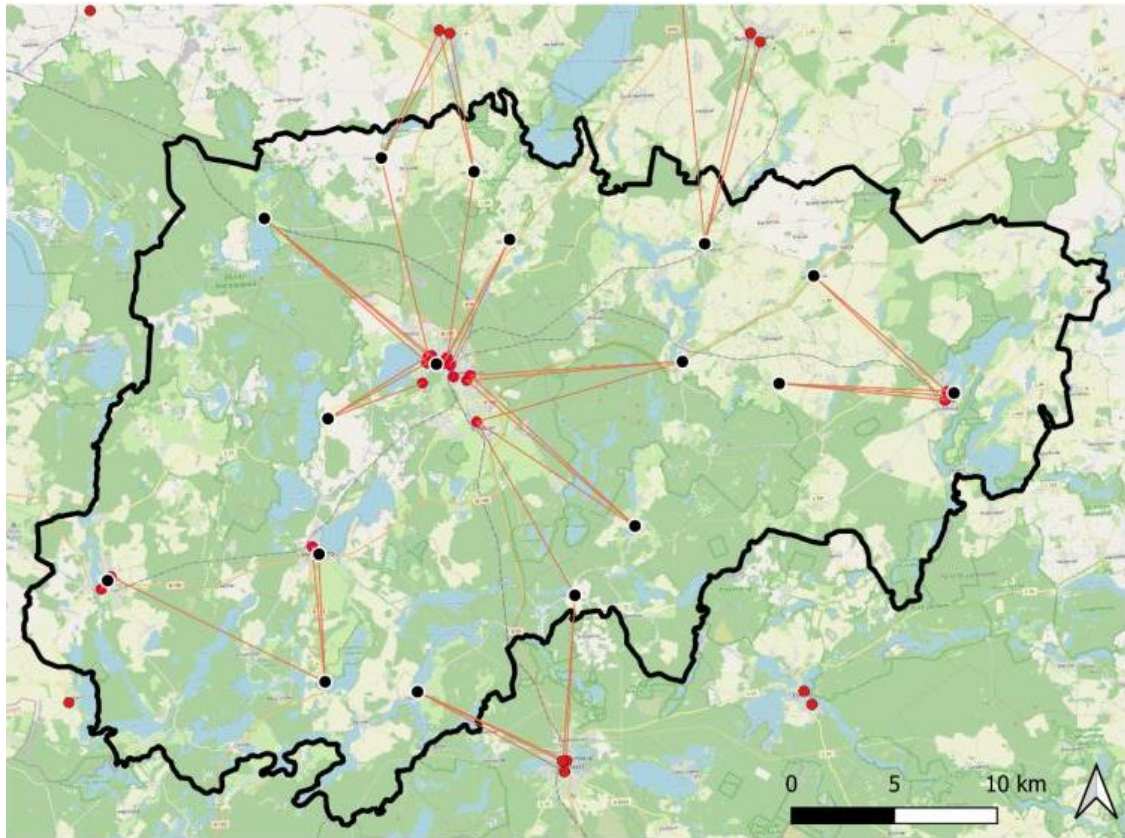


map legend

- General practitioners' practices
- Local centers
- Buffer zone
- Neustrelitz Central Zone

There are 33 general practitioners in the central zone, whose practices are located in Neustrelitz (20), Mirow (7), Wesenberg (2) and the Feldberg Lakeland (4). This means that only 24% of the municipalities in the central zone have at least one GP practice. The practice locations are therefore mainly in the southwest, east and center of the central zone, which already suggests gaps in the north, south and southeast. In the buffer zone, the practices are mainly located in the centers of Neubrandenburg, Waren, Röbel, Rheinsberg, Fürstenberg and Lychen. However, unlike in the Neustrelitz Central Zone, there are also a few GP practices in smaller localities (e.g. in Groß Dratow).

Figure 4: Allocation of the local centers to the three nearest GP practices



map legend

- General practitioners' practices
- Local centers
- Allocation of the general practitioners
- Neustrelitz Central Zone

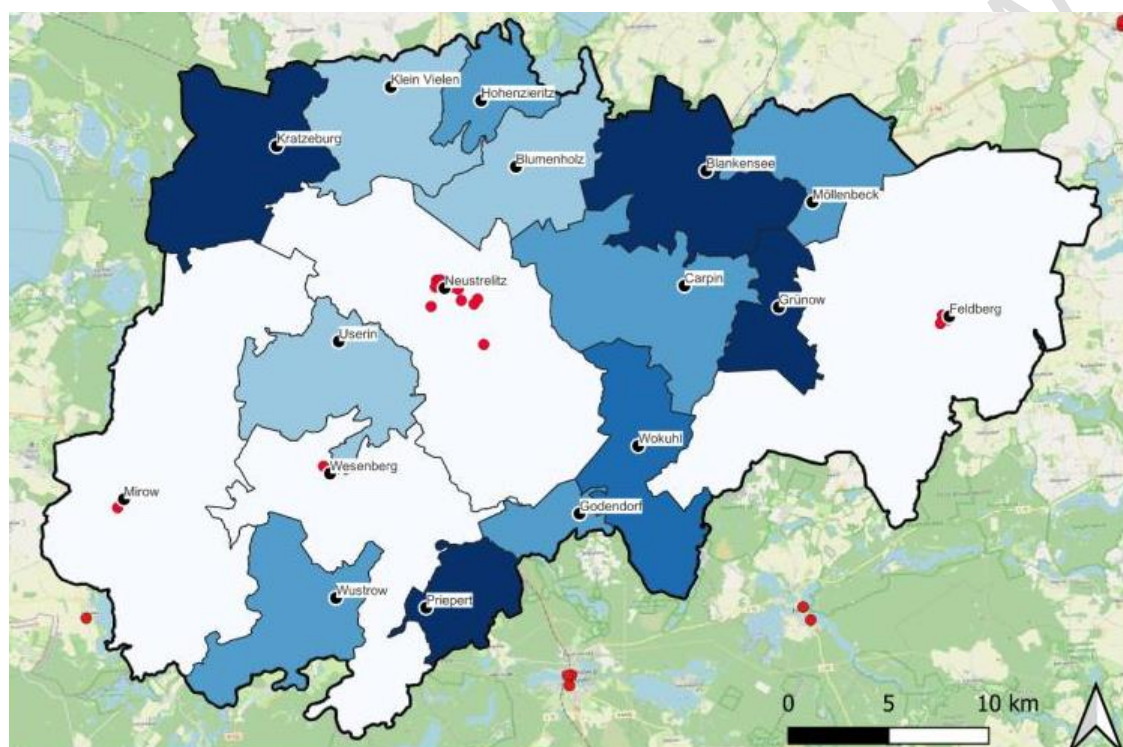
Figure 4 shows the allocation of the nearest GP practices to the respective local centers. It can be seen that the inhabitants of the local centers Kratzeburg, Blumenholz, Carpin, Wokuhl-Dabelow and Userin are likely to visit the doctors in Neustrelitz, as these are closest to their home town. For Grünow and Möllenbeck, the practices in the Feldberg Lakeland are the easiest to reach. In most cases, the three closest GP practices are located in the same locality, so it is likely that inhabitants will also visit a GP in this locality. Only for the local centers of Klein Vielen, Hohenzieritz, Godendorf and Wustrow are these GP practices spread over two locations. For Klein Vielen and Hohenzieritz, the GP practices in Neustrelitz or Penzlin and for Wustrow Mirow or Wesenberg are the closest. The map already shows that the nearest GP practice location for some municipalities is outside the central zone in the buffer zone. This applies to inhabitants of the municipalities of Priepert, who are likely to consult a GP in Fürstenberg, and Blankensee, who are likely to travel to Burg Stargard or

Neubrandenburg to see a GP. In addition, some inhabitants of the municipalities of Klein Vielen, Hohenzieritz and Godendorf visit a GP practice in the buffer zone.

3.2 Accessibility of GP practices by private transport

The average car travel times determined for the individual municipalities are shown in Figure 5.

Figure 5: Average travel times by car from the local centers to the nearest GP practices in minutes



map legend

- General practitioners' practices
- Local centers
- Neustrelitz Central Zone

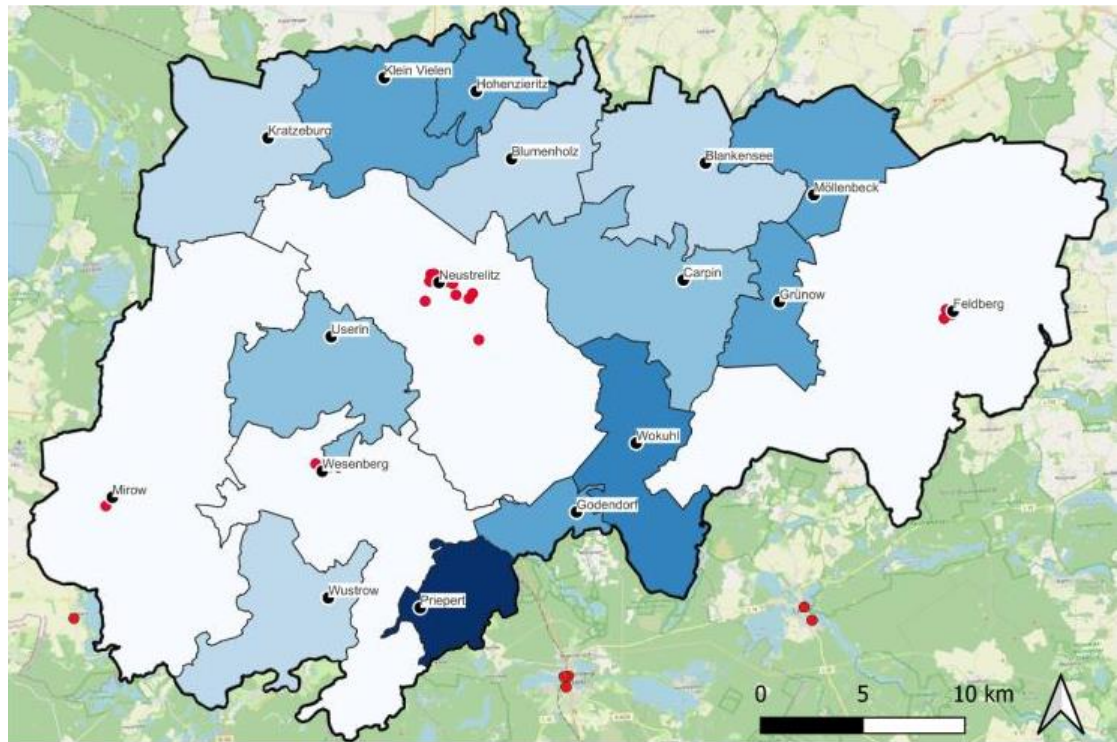
On average, inhabitants of the local centers in the Neustrelitz Central Zone need 10.7 minutes to reach the nearest GP practices, which corresponds to a travel distance of 8.9 kilometers. As already shown in the distribution of medical practices within the central zone, the travel time is above average in some northern municipalities and partly in the south and southeast. Inhabitants of Kratzeburg and Blankensee, for

example, need an average of 19 minutes to reach their GP, as they have to travel 14.4 and 15.9 kilometers respectively. Inhabitants of PriePERT and Grünow also have an above-average travel time of 18 minutes and 17 minutes respectively. The distance by car to the respective GP practices is 14 kilometers from PriePERT and 13 kilometers from Grünow. This is followed by Wokuhl-Dabelow with a travel time of 15 minutes and a distance of 12 kilometers. From the municipalities of Wustrow and Möllenbeck, the travel time is 11 minutes each, covering a distance of around 10 kilometers. Inhabitants of the local centers of Carpin and Godendorf have slightly longer journeys of 13 and 12 kilometers respectively, which takes an average of 13 minutes, and Hohenzieritz with 11 kilometers and 12 minutes respectively. Inhabitants of the municipalities of Klein Vielen and Blumenholz have a below-average travel time. Here, a visit to the GP only requires a journey of less than 10 kilometers, which corresponds to a travel time of around 10 minutes. Inhabitants of Userin only have to travel 8 minutes to their GP practice. In this time, they have to cover a distance of 7 kilometers. Inhabitants of Mirow, Wesenberg, Feldberg Lakeland and Neustrelitz have the shortest travel time. Here, the GP practices are located within the localities, which results in a significantly below-average travel time of one to three minutes (for details see Supplement 5).

3.3 Accessibility of GP practices by public transport

The extent to which it is possible to make appointments with a GP using public transport varies greatly depending on the starting point and time of the appointment. The different travel times, which include the journey there, a one-hour stay at the GP practice and the return journey to the starting point, are shown in Figures 6 to 8.

Figure 6: Accessibility of GP practices by public transport for an appointment at 10 a.m.

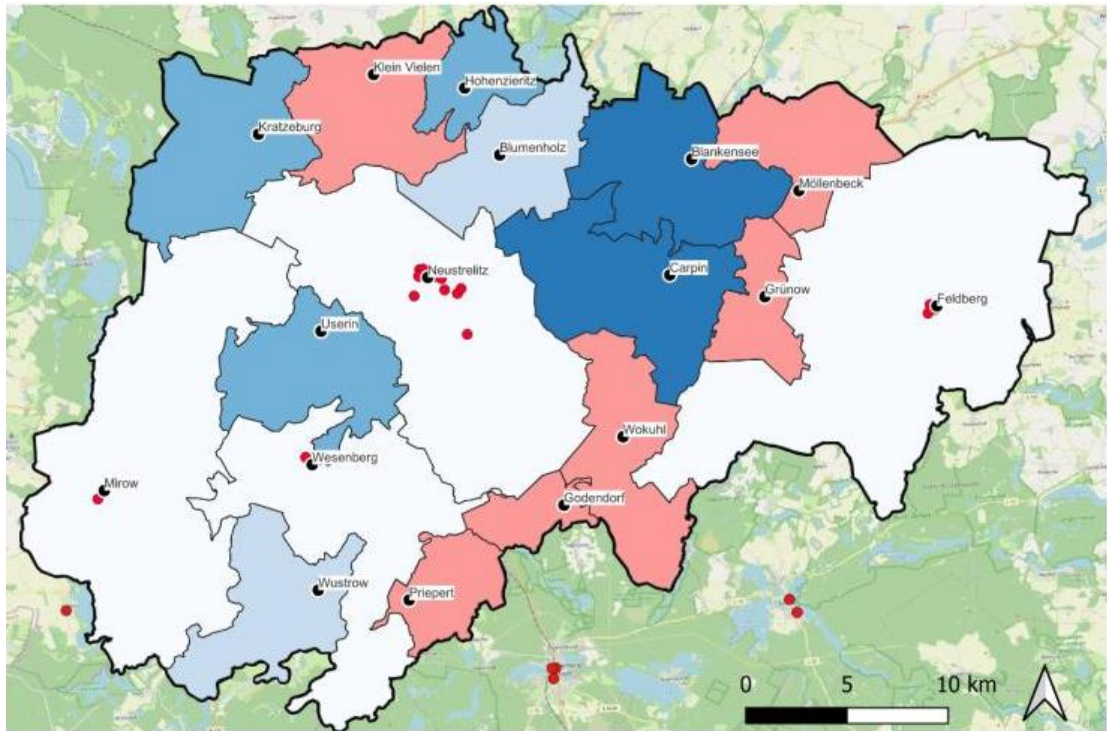


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Figure 7: Accessibility of GP practices by public transport for an appointment at 3 p.m.

UNDEK



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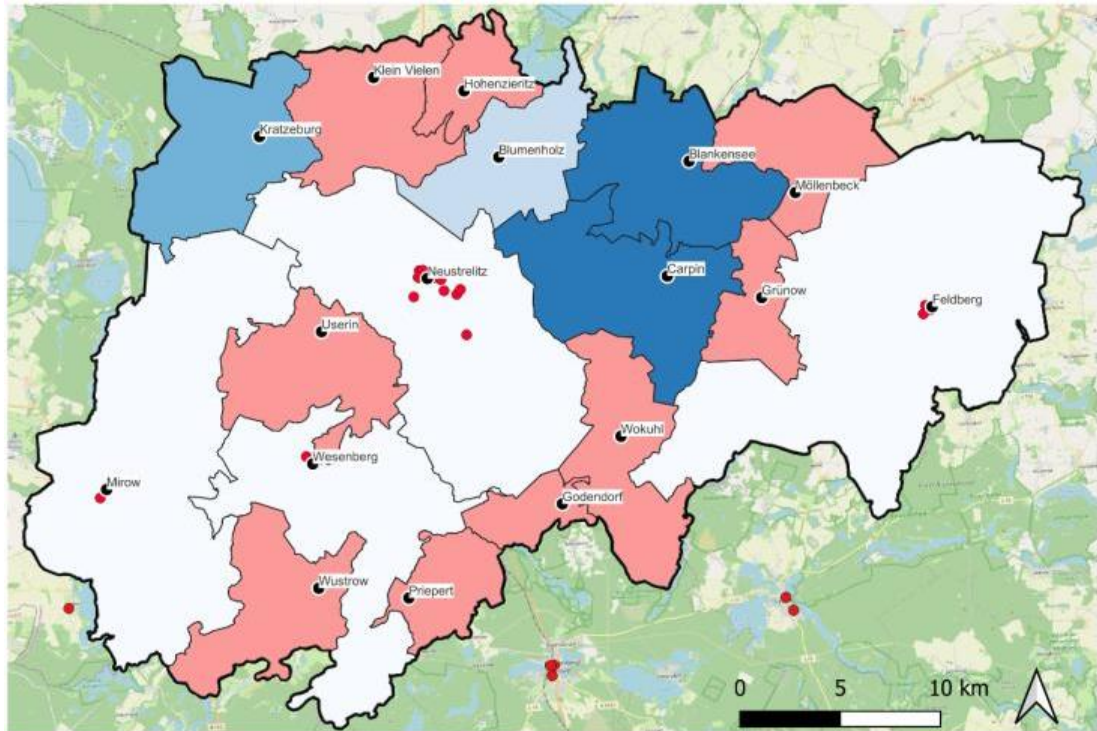
- General practitioners' practices
- Local centers
- ▭ Neustrelitz Central Zone

Travel time incl. appointment in minutes

- >60 - 120
- >120 - 180
- >180 - 240
- >240 - 300
- not possible

Figure 8: Accessibility of GP practices by public transport for an appointment at 5 p.m.

UNDERREVIEW



map legend

- General practitioners' practices
 - Local centers
 - Neustrelitz Central Zone
- | Travel time incl. appointment in minutes | |
|--|--------------|
| □ | >60 - 120 |
| □ | >120 - 180 |
| □ | >180 - 240 |
| □ | >240 - 300 |
| □ | not possible |

While it is possible for all inhabitants of the local centers to reach the GP practice in time for an appointment at 10 a.m. and to complete the return journey on the same day, this is no longer possible for the inhabitants of 35% of the local centers for an appointment at 3 p.m. and for over half (53%) for an appointment at 5 p.m. Mirow, Wesenberg, Feldberg Lakeland and Neustrelitz are again the most easily accessible. The average travel time for the entire central zone for an appointment at 10 a.m. is four hours and twelve minutes. The inhabitants of Priepert have the longest travel time at this time. They are away from home for a total of eight hours and 17 minutes for an appointment at 10 a.m., while they cannot attend appointments at 3 p.m. or 5 p.m. Even with an appointment at 3 p.m., it is no longer possible for inhabitants of some local centers to keep it if they are dependent on public transport. It is often no longer possible to return to the starting point by public transport after 4 pm. This applies to the municipalities of Klein Vielen, Möllenbeck, Grünow, Wokuhl-Dabelow, Godendorf and Priepert. In the case of an appointment at 5 p.m., which would result in a return journey from 6 p.m., it is also no longer possible for inhabitants of the local centers of

Hohenzieritz, Wustrow and Userin to attend the appointment and return to the starting point on the same day (for details see Supplement 6).

4 Discussion

4.1 Accessibility of GP practices

For inhabitants of Neustrelitz, Mirow, Wesenberg and the Feldberg Lakeland, it is possible to reach a GP practice within a few minutes by car, as GP practices are located in these localities. The further away the local centers in the surrounding area are from these centers, the worse the connection. However, the accessibility of GP care within 20 minutes by car, as required by the G-BA, is also ensured in the remaining municipalities. In the study of the regional planning association, which however refers to the entire Mecklenburg Lake District, the accessibility of GP practices by motorized private transport is also classified as assured, albeit somewhat vaguely described as "predominantly accessible within a travel time of 15 to 30 minutes" (**Mecklenburg Lake Regional Planning Association 2018**). The nationwide study based on billing data showed - albeit also in relation to the entire district of Mecklenburg Lake - a far below-average proportion of GP billing cases with a car travel time of more than 30 minutes compared to the rest of Germany (**Schang et al. 2017**). The accessibility analysis by **Stentzel et al. (2016)** for the district of Western Pomerania - Greifswald (neighboring district to the district of Mecklenburg Lake) also showed a car travel time of more than 20 minutes to the nearest GP practice in only one of 464 areas. On average, a GP practice could be reached there in as little as 6 minutes.

In Neustrelitz, Mirow, Wesenberg and the Feldberg Lakeland, it is possible to reach GP practices within a few minutes on foot from the city center, meaning that inhabitants here are not dependent on public transport. However, there are gaps in GP care in terms of accessibility by public transport in the other municipalities in the central zone. Accordingly, our study is in line with the statements of the Regional Mecklenburg Lake Planning Association (**Mecklenburg Lake Regional Planning Association 2018**). As with the planning association's monitoring, accessibility decreases the later the doctor's appointment is scheduled (**Mecklenburg Lake Regional Planning Association 2018**). Accessibility problems with public transport are also evident for GP care in the study by Stentzel et al. for the district of Western Pomerania - Greifswald (**Stentzel et al. 2016**), although the results are not directly comparable due to different assumptions

(e.g. different times of doctor's appointments). The poor accessibility, especially in the afternoon and early evening, shows that public transport in the area surrounding the city of Neustrelitz is primarily focused on school transport and was not designed for the general population. This can be seen, for example, in the fact that connections are often thinned out during school vacations (**MVVG 2022b-d**). Future analyses should be supplemented with a population reference in order to determine the number of inhabitants affected by poor accessibility in the respective municipalities (**Sundmacher et al. 2018**).

It is striking that an above-average travel time by car does not necessarily result in a comparatively long travel time by public transport. The municipalities of Kratzeburg and Blankensee, which have above-average travel times by car, score below average when it comes to accessibility by public transport. A connection to the rail network, as is the case in the municipalities of Kratzeburg and Blankensee, therefore significantly improves accessibility.

4.2 Possible instruments for improving accessibility

In order to be able to offer everyone the same level of medical care, work should be done to improve accessibility and to design the system in such a way that disadvantaged people also have access to GP care at all times.

Based on the results described above, the most obvious way to improve accessibility is to expand public transport. This is the only way to ensure that inhabitants in rural areas who do not have access to a private car have access to social infrastructure. This includes not only medical care, but also access to everyday necessities.

Another important point is the expansion of eHealth and telemedicine. The term "eHealth" covers applications that use the possibilities offered by modern information and communication technologies to support the treatment and care of patients (**BMG 2022**). For example, patients can receive medical advice over the phone or via a video call to save them a trip to the doctor (**Lübking 2020**). Another possibility offered by digitalization in the healthcare sector is, for example, the monitoring of medical parameters (**Hoffmann et al. 2020**). This allows patients to monitor various values and parameters independently at home and share the results with doctors. However, Lübking also sees problems in telemedicine, as nationwide broadband coverage must first be established in Germany in order to successfully establish this tool (**Lübking 2020**).

Another way to improve accessibility is to create more medical practices in rural areas. Mobile practices could also be used for this. One example of this is the "DB Medibus" (**Deutsche Bahn AG 2020**), which is used in the area of the Hesse Association of Statutory Health Insurance Physicians to support GP care in rural areas (**Deutsche Bahn AG 2020**). The Medibus travels to locations in five different localities in the districts of Werra-Meißner-Kreis and Hersfeld-Rotenburg every week. Inhabitants can receive diagnostic examinations and treatment there just like in a GP practice (**KVH 2022**).

4.3 Limitations

The results of this study only apply to one central zone in one federal state. There is a need for further research with regard to other rural central zones in the same federal state or in other federal states and also with regard to urban central zones. Other methods (e.g. 2FSCA and 3FSCA method) are recommended for the latter (**Baier et al. 2020, Shah et al. 2016**). In addition, the analysis is limited to the local centers as a starting point. These are often centrally located and, compared to the other areas of the municipalities, have good connections to the nearest local centers. It can therefore be assumed that inhabitants outside the local centers have to accept longer than the calculated travel times for car and public transport. A grid analysis could be carried out to find out how many inhabitants outside the local centers are affected by poor accessibility. Furthermore, it is not always the case that inhabitants go to the nearest GP practices. Other factors, such as reputation, likeability, opening hours or even the location of one's own workplace, can play a role when deciding on a GP. In addition, good accessibility is only useful if the GPs are also accepting new patients and there are enough appointments available for everyone. There is therefore a need for further research to investigate the utilization of individual GP practices in order to generate a more accurate picture of GP care in the central zone.

The study results may be different for other groups of doctors (**Neumeier 2017, Stentzel et al. 2016**). In addition, the study relates exclusively to SHI-accredited physicians providing GP care. Private GP practices were not taken into account, but are unlikely to play a role in the rural, structurally weak (**Bauer 2022**) study region, not least due to the lack of privately insured patients (**Sundmacher & Ozegowski 2016**).

When selecting the three nearest GP practices, the assumption was made that the practices with the shortest direct distance, i.e. as the crow flies, to the local centers are also the ones with the shortest travel distance by car. In reality, this may not always be the case, as a car connection to a GP practice may prove to be less favorable compared to the linear distance. It is also possible, for example, that in some municipalities there are better public transport connections to GP practices other than those included. It should also be noted that the calculated car and public transport travel times to the practices often do not reflect the actual duration of the journey and can vary, for example, due to selected speed profiles and road conditions (e.g. rush hour traffic or construction work). In the case of public transport accessibility, it is also possible that the times may vary depending on the choice of bus stop. In this study, a central bus stop or, if available, a train station was chosen as the starting point. Some practices may be easier to reach from a different starting point.

In addition to distance and time, another important factor for accessibility is the cost of the journey, for example for fuel, parking costs or bus or train tickets. Especially in the context of old-age poverty, excessive costs could mean that people cannot afford to travel to the doctor and therefore receive inadequate medical care. A future study could address this aspect, especially as travel costs for outpatient treatment are generally not reimbursed by SHI scheme. For a long journey to really be a problem, it must also be perceived as disruptive by those affected. There is therefore a need for further research with regard to the consideration of perceived access and possible differences compared to geographical access (**Baier et al. 2020**).

5 Conclusion

In the Neustrelitz Central Zone, the accessibility of GP practices by car is ensured in accordance with the statements of the G-BA. However, there is a need for action in terms of accessibility by public transport, so that the possibilities of reaching a GP practice without a private car should be further expanded. Additional relief could be provided by the expansion of eHealth or mobile medical practices. Furthermore, the G-BA should develop realistic recommendations on the accessibility of GP practices by public transport.

DATA AVAILABILITY

The datasets are available from the corresponding author upon reasonable request

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UNDER PEER REVIEW

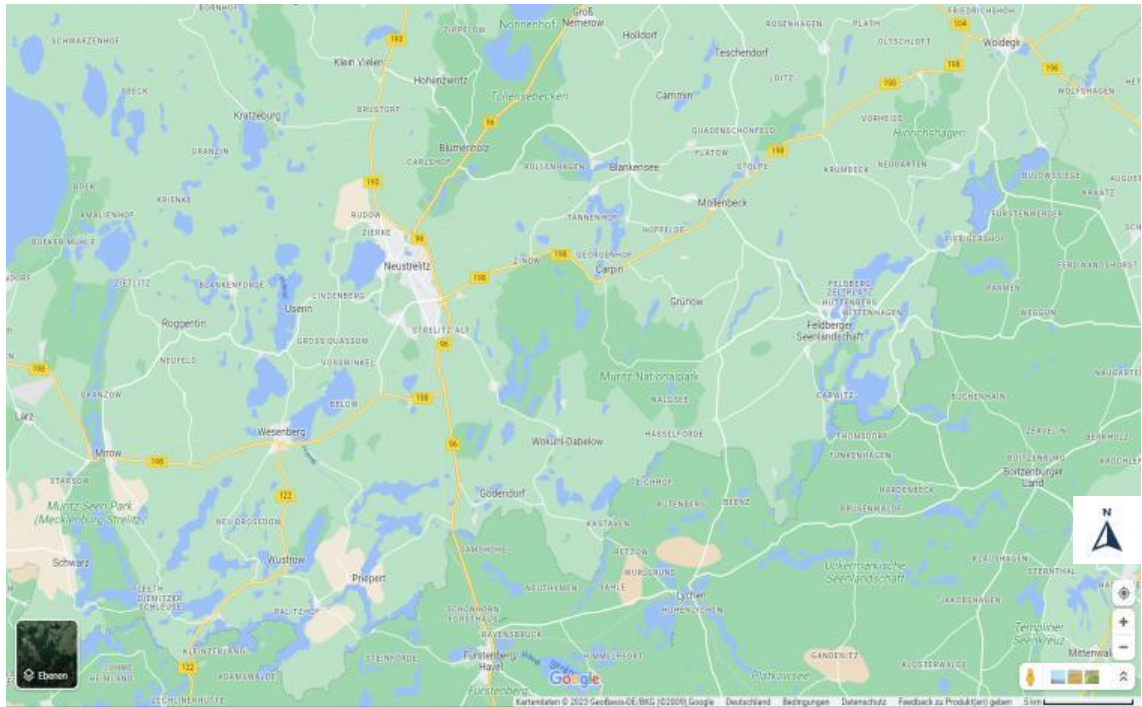
UNDER PEER REVIEW

Supplements

Supplement 1: Population figures and surface area of the municipalities in the Neustrelitz Central Zone

Municipalities	Inhabitants	Surface area	Inhabitants per km ²
Neustrelitz-Land			
Blankensee	1,636	56.14 km ²	29.14
Blumenholz	773	41.84 km ²	18.47
Carpin	844	64.11 km ²	13.16
Godendorf	226	13.93 km ²	16.22
Grünow	287	23.22 km ²	12.36
Hohenzieritz	451	20.54 km ²	21.95
Klein Vielen	620	45.64 km ²	13.58
Kratzeburg	526	55.50 km ²	9.48
Möllenbeck	721	36.32 km ²	19.85
Userin	688	46.61 km ²	14.76
Wokuhl-Dabelow	590	46.30 km ²	12.74
Total	7,362	450.14 km ²	16.35
Mecklenburg Small Lakeland			
Mirow	3,883	158.28 km ²	24.53
Priepert	317	22.58 km ²	14.04
Wesenberg	3,057	89.65 km ²	34.10
Wustrow	735	43.29 km ²	16.99
Total	7,992	313.80 km ²	25.47
Feldberg Lakeland			
Feldberg Lakeland	4,444	201.10 km ²	22.10
Neustrelitz			
Neustrelitz	20,151	139.89 km ²	144.05
Total			
Total	39,949	1,104.93 km ²	36.16

Supplement 2: Section of the road map



UNDER PEER REVIEW

Supplement 3: Section of the German Railways regional transport network



UNTER PE

Supplement 4: Section of the MVVG bus route network



UNDER PEEK

Supplement 5: Car travel times

Local centers	Location ID	As the crow flies in km	Travel distance in km	Travel time in min
Blankensee	81	10.5	12.1	16
	62	10.2	17.5	17
	80	12.8	18.1	23
	Average:		15.9	18.7
Blumenholz	3	6.5	7.2	9
	2	6.7	7.2	10
	6	7.6	7.6	10
	Average:		7.3	9.7
Carpin	5	10.3	12.5	12
	20	10.4	13.1	13
	10	10.5	12.5	13
	Average:		12.7	12.7
Godendorf	20	9.7	11.7	12
	26	8.0	12.4	14
	78	8.1	12.3	13
	Average:		12.1	13
Grünow	7	8.1	12.4	16
	19	8.2	13.0	18
	15	8.5	12.4	16
	Average:		12.6	16.7
Hohenzieritz	3	9.2	11.7	14
	70	7.1	10.4	11
	36	6.9	9.6	10
	Average:		10.6	11.7
Klein Vielen	21	9.9	10.7	11
	70	6.8	9.6	10
	36	6.8	10.4	10
	Average:		10.2	10.3
Kratzeburg	21	10.4	14.2	18
	14	10.5	14.4	19
	1	10.6	14.6	19
	Average:		14.4	18.7
Möllenbeck	15	9	9.8	11
	19	8.6	10.4	12

	7	8.8	9.8	10
		Average:	10	11
Priepert	78	7.8	13.8	17
	26	8.0	13.8	17
	68	8.1	14.4	20
		Average:	14	18
Wokuhl-Dabelow	10	10.8	12.9	16
	5	10.9	12.9	16
	20	9.2	10.3	13
		Average:	12	15
Userin	16	4.9	5.9	7
	1	5.5	7.0	8
	21	5.8	7.2	9
		Average:	6.7	8
Wustrow	9	11.6	16.6	17
	12	6.2	7.3	9
	11	6.6	7.1	8
		Average:	10.3	11.3
Mirow	17	0.2	0	0
	18	0.5	0.8	2
	9	0.3	0.3	1
		Average:	0.4	1
Wesenberg	12	0.1	0.1	0.5
	11	0.5	0.5	1.5
	16	9.7	13.3	17
		Average:	0.3	1
Feldberg Lakeland	15	0.2	0.6	2
	19	0.4	0.7	2.5
	7	0.6	1	3
		Average:	0.8	2.5
Neustrelitz	13	0.1	0.6	2
	1	0.5	1	3
	4	0.3	0.7	2
		Average:	0.8	2.3

Supplement 6: Public transport travel times

Local centers	Location ID	Appointment 10 a.m. -> Return journey from 11 a.m.			Appointment 3 p.m. -> Return journey from 4 p.m.			Appointment 5 p.m. -> Return journey from 6 p.m.		
		Travel time	Departure	Arrival	Travel time	Departure	Arrival	Travel time	Departure	Arrival
Blankensee	81	03:37:00	09:11:00	12:48:00	03:37:00	13:11:00	16:48:00	03:37:00	15:11:00	18:48:00
	62	03:37:00	09:11:00	12:48:00	03:37:00	13:11:00	16:48:00	03:37:00	15:11:00	18:48:00
	80	03:37:00	09:11:00	12:48:00	05:37:00	13:11:00	18:48:00	05:37:00	15:11:00	20:48:00
Average:		03:37:00			04:17:00			04:17:00		
Blumenholz	3	03:41:00	09:02:00	12:43:00	02:26:00	14:17:00	16:43:00	02:31:00	16:12:00	18:43:00
	2	03:41:00	09:02:00	12:43:00	02:26:00	14:17:00	16:43:00	02:31:00	16:12:00	18:43:00
	6	03:41:00	09:02:00	12:43:00	02:26:00	14:17:00	16:43:00	02:31:00	16:12:00	18:43:00
Average:		03:41:00			02:26:00			02:31:00		
Carpin	5	04:11:00	08:32:00	12:43:00	04:34:00	13:53:00	18:27:00	04:56:00	15:27:00	20:23:00
	20	04:11:00	08:32:00	12:43:00	04:00:00	14:27:00	18:27:00	04:03:00	16:20:00	20:23:00
	10	04:11:00	08:32:00	12:43:00	04:00:00	14:27:00	18:27:00	03:51:00	16:32:00	20:23:00
Average:		04:11:00			04:11:20			04:36:40		
Godendorf	20	04:38:00	08:30:00	13:08:00		Not possible			Not possible	
	26	06:39:00	06:29:00	13:08:00		Not possible			Not possible	
	78	06:39:00	06:29:00	13:08:00		Not possible			Not possible	
Average:		05:58:40								
Grünow	7	05:52:00	08:19:00	14:11:00		Not possible			Not possible	
	19	05:52:00	08:19:00	14:11:00		Not possible			Not possible	
	15	05:52:00	08:19:00	14:11:00		Not possible			Not possible	
Average:		05:52:00								
Hohenzieritz	3	05:34:00	07:31:00	13:05:00	03:20:00	14:10:00	17:30:00		Not possible	
	70	04:52:00	07:31:00	12:23:00	03:55:00	12:23:00	16:18:00		Not possible	
	36	04:52:00	07:31:00	12:23:00	03:55:00	12:23:00	16:18:00		Not possible	
Average:		05:06:00			03:43:20					
Klein Vielen	21	05:14:00	07:20:00	12:34:00		Not possible			Not possible	
	70	05:14:00	07:20:00	12:34:00		Not possible			Not possible	
	36	05:14:00	07:20:00	12:34:00		Not possible			Not possible	
Average:		05:14:00								
Kratzeburg	21	03:59:00	08:17:00	12:16:00	02:42:00	14:40:00	17:22:00	03:08:00	16:34:00	19:42:00
	14	03:59:00	08:17:00	12:16:00	03:39:00	13:43:00	17:22:00	03:08:00	16:34:00	19:42:00
	1	03:59:00	08:17:00	12:16:00	03:39:00	13:43:00	17:22:00	03:08:00	16:34:00	19:42:00
Average:		03:59:00			03:20:00			03:08:00		
Möllenbeck	15	05:31:00	08:35:00	14:06:00		Not possible			Not possible	
	19	05:31:00	08:35:00	14:06:00		Not possible			Not possible	
	7	05:31:00	08:35:00	14:06:00		Not possible			Not possible	

Average:		05:31:00						
Priepert	78	08:17:00	06:21:00	14:38:00				Not possible
	26	08:17:00	06:21:00	14:38:00				Not possible
	68	08:17:00	06:21:00	14:38:00				Not possible
Average:		08:17:00						
Wokuhl-Dabelow	10	06:30:00	06:32:00	13:02:00				Not possible
	5	06:30:00	06:32:00	13:02:00				Not possible
	20	06:30:00	06:32:00	13:02:00				Not possible
Average:		06:30:00						
Userin	16	04:52:00	08:07:00	12:59:00	02:53:00	14:43:00	17:36:00	Not possible
	1	04:52:00	08:07:00	12:59:00	03:20:00	14:16:00	17:36:00	Not possible
	21	04:52:00	08:07:00	12:59:00	03:20:00	14:16:00	17:36:00	Not possible
Average:		04:52:00			03:11:00			
Wustrow	9	03:57:00	08:21:00	12:18:00				Not possible
	12	03:57:00	08:21:00	12:18:00	02:40:00	13:43:00	16:23:00	Not possible
	11	03:57:00	08:21:00	12:18:00	02:40:00	13:43:00	16:23:00	Not possible
Average:		03:57:00			02:40:00			
Mirow	17	01:00:00			01:00:00		01:00:00	
	18	01:28:00			01:28:00		01:28:00	
	9	01:04:00			01:04:00		01:04:00	
Average:		01:10:40			01:10:40		01:10:40	
Wesenberg	12	01:16:00			01:16:00		01:16:00	
	11	01:12:00			01:12:00		01:12:00	
Average:		01:14:00			01:14:00		01:14:00	
Feldberg Lakeland	15	01:02:00			01:02:00		01:02:00	
	19	01:08:00			01:08:00		01:08:00	
	7	01:14:00			01:14:00		01:14:00	
Average:		01:08:00			01:08:00		01:08:00	
Neustrelitz	13	01:04:00			01:04:00		01:04:00	
	1	01:18:00			01:18:00		01:18:00	
	4	01:16:00			01:16:00		01:16:00	
Average:		01:12:40			01:12:00		01:12:00	