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A Web-Application for Measuring Spatial Accessibility in Health Planning

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Abstract. The planning of health care facilities and the analysis of the medical care situation are complex topics that generally involve geographical and, specifically, settlement topographical, methodological, data-driven aspects. However, formal analyses and planning in the field of healthcare usually only touch on the aspects or do not fully include some of them. As a result, the complex situation is often not accurately. This paper addresses the multidimensional challenges planners and analysts face. Solutions to overcome these hurdles thanks to improved data availability and more advanced technical and methodological possibilities are presented. For this purpose, a Web-Application is proposed that enables planners without GIS knowledge to interact with method components via parameter adjustments. Subsequently, it is examined whether the technical prerequisites for the implementation of a Web-Application for health planning, in particular for outpatient demand planning and analysis, are given and make a proposal for implementation. Finally, the advantages, disadvantages and possible complications of using this Application in health planning and analysis, including critical points of implementation, will be addressed.

Keywords. Spatial Accessibility, Health-Planning, FCA, Spatial Decision Support Systems

1 Introduction

Analysis and planning are important elements of resource management in the health sector, as they enable the development of strategies to understand and solve various problems related to health care. In most developed countries, health planning is subject to strong legal regulations (Fülöp et al., 2011). In this paper we will discuss the importance of analysis and planning in the context of the outpatient sector in Germany. Specifically, we will look at the system of demand planning used, which aims to ensure comprehensive outpatient medical care close to the patient's home and to avoid or reduce deficits in care. The established planning system is currently limited by its dependence on prescribed rigid demand planning areas that may not adequately capture the situation and quality of patient care in individual sub-areas. Resulting from this, spillover effects in patient mobility are not accounted for and the centralisation effects of site locations at the sub-levels of the planning areas are not measured. In the paper, we discuss which analytical methods are suitable for solving these problems. At present, such methodologies and analyses are mainly used in the scientific field of health services research, but hardly available to a wider range of health planners. This can be explained by a rather high effort in data acquisition and integration (e.g. inhomogeneous small-scale datasets of population distribution, construction and adjustment of a network dataset) as well as by necessary GIS expert knowledge when performing accessibility analyses. To enable more realistic and accurate analytical results and support decisions in health planning a Web-Application is implemented.

2 Definitions and Preliminary Considerations

In this part, we will discuss important concepts of analysis and planning in the health sector, focusing on the situation in Germany. In particular, the methodological concepts of measuring the access to health services are described and the available Web tools to support analysis are discussed.

2.1 Current analysis and planning procedures in the ambulatory medical care

As an essential preliminary consideration and in order to differentiate the concepts the terms planning and analysis should be discussed. Planning is about developing a strategy or course of action to achieve a specific goal. The aim is to ensure that current and future finite resources are used as efficiently as possible (Green, 1995). In contrast, analysis is a systematic examination of data or information to understand a situation or problem. Accordingly, analysis precedes planning and is a precondition. Functionally, they are inseparable. However, they are different activities or tasks that require the use of different methods and different data.

In Germany, the main instrument for ensuring ambulatory medical care is a demand-planning system (in German: “Bedarfsplanung”, § 99 SGB V, 2022). The aim of the demand-planning system is to ensure that the population is provided with universal, locally available ambulatory medical care in a reasonable reachability from home, and to avoid and reduce supply deficiencies. Public-policy or regulatory approaches in the demand planning system determine the method of analysis for identifying demand. After an analysis of the situation, decisions can be made to release areas for further physician locations or to close them.

The main method of analysis is the determination of a ratio of the number of inhabitants per physician of a certain specialty within a sharply defined planning area. The size of the service area under consideration depends on the kind of specialisation of the physician. The general practitioner planning areas usually consist of several municipal areas (except for large cities, which then consist of only one municipal area). Separate specialists are organised in larger planning areas due to extensive specialisation. In special cases, the size of these areas can cover an entire federal state. The ratios were set by the lawmakers when they introduced the demand-planning system on the basis of a historical cut-off date. On this cut-off date, the level of care in Germany was assessed as adequate. The ratio is regularly modified on the basis of the number of inhabitants. In addition, since 2019 the quota has been adjusted every two years to regional demographic conditions with the help of correction factors. These correction factors take better account of regional additional expenditure in patient care due to area-dependent burden of disease and old age.

In summary, it can be said that the analysis or assessment of the medical care situation in the outpatient sector is currently carried out for special groups of physicians in sharply defined areas. Essentially, it refers to the conditions of number of inhabitants, proportion of elderly people and regional morbidity. The result is the determination of a ratio that is reflected in a care level expressed as a percentage. 100 to 110 percent can be considered as a target achievement value.

Planning measures that can be derived from this analysis are: If the value falls below 100 percent, activities can be undertaken to reach 100 percent again (opening of the planning area for physicians). If the value of 110 percent is exceeded, the planning areas are blocked for the settlement of further physicians. For our goal, the development of an analysis and planning tool for the outpatient health sector, the following becomes important: There are further special planning options that allow for the (monetary) promotion of new physician establishments in an underserved area. Or, in exceptional cases, to buy out practice locations in the case of extreme over-supply (degree of supply greater than 140 percent). Geoinformatics may be able to provide solutions to criticisms that focus on geographical aspects. According to Pieper et al. (2019), Fülöp et al. (2011) and Schuurman et al. (2007) these criticisms include issues related to: analysis and planning areas...

... are often too large to record and compare the situation and quality of patient care in individual villages.

... due to their clear demarcation, not suitable for taking into account the migration behaviour of patients and the spill over effects of practices in neighbouring areas.

...do not capture centralisation tendencies of physicians within an area.

Another point of criticism arises from the lack of small-scale analysis, which makes it difficult to decide objectively which sites should be bought up in the case of oversupply and which sites should be provided with new physicians in the case of undersupply. This is illustrated in Figure 1 is intended to illustrate this.. Map A shows the coverage rate of the general practitioner planning areas around the planning area "Jever". Non-geographical analysis instruments, as they are currently mostly used by measuring the ratio of inhabitants to physicians, cannot make any finely granulated statements within the planning area. Map B makes the mentioned points of criticism obvious. It shows the distribution of physicians (green) and the population densities (heatmap). Currently, the planning area of “Jever” does not suffer from undersupply, with a coverage rate of 107 percent (KV Niedersachsen, 2022). In sum, the planning area is close to overprovision of medical services. However, a detailed analysis shows that while the south is characterized by a good supply of medical services, the supply in the north is lower. Furthermore, this illustrates that the rigid area boundaries as a sharp analytical demarcation line do not sufficiently take into account patient migration behaviour and co-supply effects to surrounding districts (comparison with Wilhelmshaven). Better and more advancedanalytical methods could help to adress these criticisms.

2.2 Principles and related works

Ensuring, and therefore planning, access to health facilities and services is an important aspect of health systems around the world. This helps to ensure that people have the structures they need to maintain their health and well-being.

In the context of access to health facilities, the term "access" refers to the ability of individuals to obtain the health services they need. This includes both physical access to health facilities and access to the required health services once a person arrives at the facility (Gulliford et al, 2002).

There are a number of factors that can affect a person's access to health facilities, including geographic location, cost, transport and availability of services. For example, people living in rural areas may find it difficult to access health facilities because of a lack of nearby facilities or transport. Similarly, people who cannot afford the cost of health services may find it difficult to obtain the care they need.

Penchansky and Thomas (1981) proposed five dimensions to access: availability, accessibility, adaptation, affordability and acceptability (Five A's). Considering these Five A's of access has enabled health services research to understand access barriers in order to identify solutions (Sieck et al., 2021). In this paper, we use the term 'access'primarily to the geographical dimensions of access: availability and accessibility.

Serveral methods are available to measure accessibility. These include the Huff method, the gravity method, the cumulative opportunities method and the two-step floating catchment area (2SFCA) method group (Yang et al., 2006; Guagliardo, 2004). Over the past two decades, methodological offerings have emerged that can accurately determine access from demand locations to supply locations. In the context of this paper, the 2SFCA methodology, a group of spatial analysis techniques used to measure the accessibility of health services, should be given particular mention.

It was introduced by Luo and Wang (2003) based on the ideas of Radke and Mu (2000) and uses the achievements of Huff (1964). Increasingly in the last 10 years, there has been a wave of development in 2SFCA methods. The 2SFCA method is a special form of gravity-based modelling approaches and assumes that accessibility is not solely determinable by distance decay, but also by the interactions between supply and demand, the so-called complementarity (Haynes and Fotheringham, 1985). It overcomes the drawback of traditional location-based accessibility measures, which largely ignore the demand for services.

The 2SFCA method is widely used in public health and health services research, in particular for primary care, to identify and understand patterns of health service utilisation and to inform policy decisions about the allocation of health care resources. However, it is also suitable for many broader measures of spatial-physical access with strong demand dependence. For example, in retail (Dai and Wang, 2011; Chen, 2017; Chen 2019), education and labour markets (Dai et al., 2018) or urban planning (Xing et al., 2018).

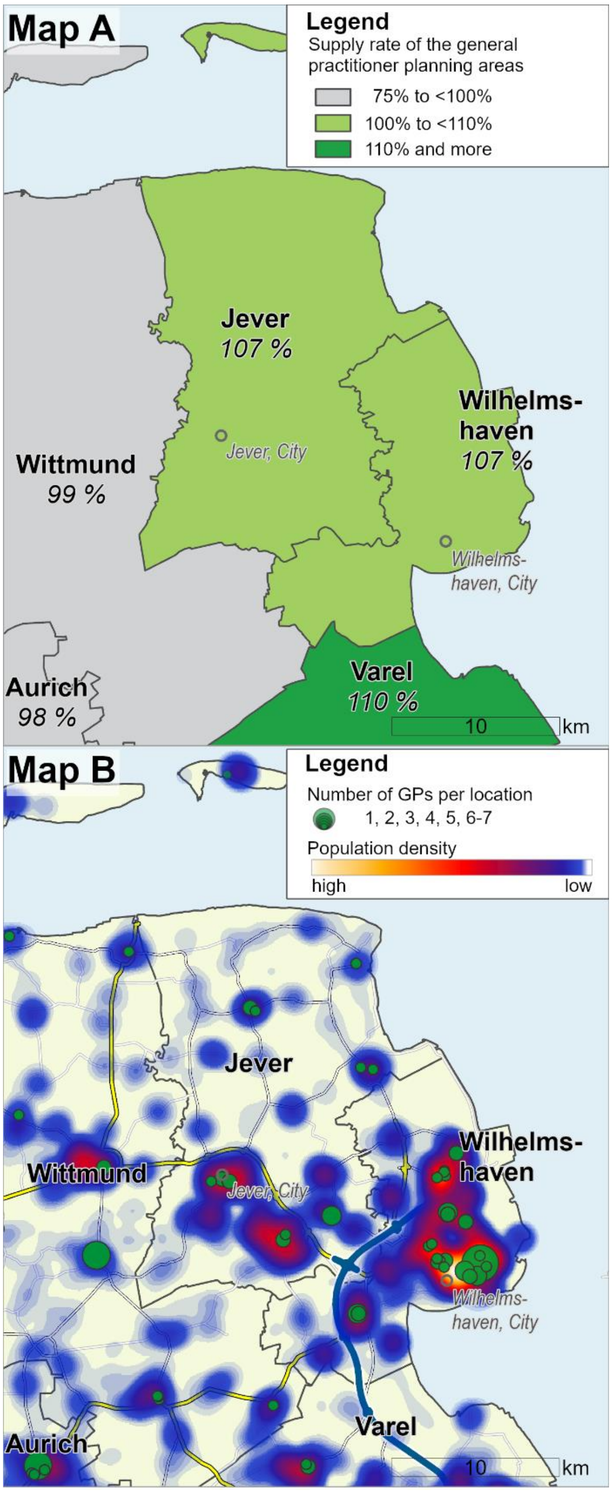

Figure 1. Map A shows the coverage of the general practitioner planning area "Jever" and its neighbouring areas according to current formalised planning. Fine-scale differences and gaps in supply are not visible. Map B shows the distribution of general practitioner (GPs) and the population distribution**.**

2.3 Measurement of Access to Health Services

The 2SFCA method works in two steps: First, the supply-demand ratio is determined (R_j), by dividing the capacity of a facility S_j (the supply) by the population P_k (the demand) within a certain distance d_0 (the catchment size). This step determines the facility's ability to meet the health care needs of the population within its service radius as shown in equation (1).

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} P_k} \quad (1)$$

In the second step, the accessibility index A_i for demand point i is calculated as the sum of R_j derived from the first step, as shown in equation (2).

$$A_i = \sum_{j \in \{d_{ij} \le d_0\}} R_j = \sum_{j \in \{d_{ij} \le d_0\}} \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} P_k} \quad (2)$$

The summation is based on all service providers within the catchment area, which represents the activity space of the population living at location i. The resulting indicator is the accessibility index A_i. It is a supply-demand ratio adjusted by the travel time and distance function. This method is unique in that it considers both the supply and demand sides of spatial interaction. Previous place-based accessibility measurements have considered only the supply side.

By establishing distance decay functions that adjust the spatial supply and demand situation, the method becomes even more realistic. This takes into account that a supply close to home is better than a supply far from home when evaluating the supply performance. To make the complexity easier to represent, the function f(d) (i.e. $f(d_{ij})$ and $f(d_{kj})$) is added to R_j (equation 3) and A_i (equation 4).

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} P_k \mathrm{f}(d_{kj})} \quad (3)$$

$$A_i = \sum_{j \in \{d_{ij} \le d_0\}} R_j \mathrm{f}(d_{ij}) = \sum_{j \in \{d_{ij} \le d_0\}} \frac{S_j \mathrm{f}(d_{ij})}{\sum_{k \in \{d_{kj} \le d_0\}} P_k \mathrm{f}(d_{kj})} \quad (4)$$

The way distance weighting is applied depends on the specific use. These methodological aspects will be discussed in Section 3.

Sundmacher et al. (2018) consider the use of 2SFCA methods as the most appropriate toolkit to measure spatial access. This is because it incorporates cross-border co-supply from neighbouring planning areas and allows to consider the percentage-based coverage levels established in demand planning. However, they also recognise that the calculations require a great deal of technical effort and professionals with great expertise in spatial analysis methods.

For this reason, access analyses have so far been conducted mainly in a scientific context. Planners have almost no access to the method portfolio. In the following, the difficulties that accompany a planner in the implementation of analyses are addressed.

2.4 Current Web Applications in the health sector

Apart from the COVID dashboards developed in the recent years (Global: Dong et al., 2020 and Kamel and Geraghty 2020; Ghana: Safro and Karuppannan, 2020; Mexico: Ghilardi et al., 2020; Germany: Blätgen and Milbert, 2021), cartographic web-solutions, and especially web-analysis tools, are comparatively underrepresented in the health sector. Analysis results are mostly presented with the help of traditional map products that do not allow for interaction and further processing (Khashoggi, 2020; Augstein et al., 2018). The situation in Germany is described in a study by Augstein et al. (2018): With the exception of the Versorgungsatlas (Health Care Atlas) of the Zentralinstitut für die Kassenärztliche Versorgung (Central Institute for Statutory Health Insurance), no web systems are in use, at least for reporting (it should be noted here that health atlases are being studied as reporting instruments - here the technical implementation barriers are actually lower than for analysis and planning instruments). Koller et al. (2018), who examine geographical approaches in health reporting, also attest that reporting in Germany could benefit from health geographical methods and concepts. They summarise that the technical possibilities have not yet been exhausted (for example, through the use of accessibility and network analyses as well as spatial statistics).

The expert report on the further development of demand planning, which deals with proposals for analytical improvements in the health sector, concludes: The technical hurdles for the introduction of 2SFCA are too high and the necessary know-how is not yet available in the planning departments and will not be for the foreseeable future (Sundmacher et al., 2018). Following this execution, there do not seem to be any analysis offers or methods used that are eligible for planners in health systems to evaluate access to outpatient health facilities with gravity-based methods. As far as we are aware, Desktop-GIS-Applications to perform detailed spatial analyses have not yet been established in all regional Associations of Statutory Health Insurance Physicians in Germany. However, the data situation and the actual technical possibilities allow the integration of such systems for the analysis of health care provision, as will be shown in the following.

3 Multidimensional Challenges

A planner, who has the task of evaluating access to primary care facilities, (e.g. general practitioners), mapping the supply and presenting a recommendation to a decision-maker has to overcome a number of difficulties. In the following, we address a selection of aspects that the planner has to take into account.

3.1 Methodological aspects

Even though it was previously stated that the use of the 2SFCA method group is the most suitable, parameterisations are still required to represent a realistic model. These include in particular the size of the catchment area and the distance decrease function.

The former is a threshold distance beyond which the interaction between demand and supply cannot occur. It has to be realistically chosen, as it depicts at what point the transport costs exceed the benefits of the take-up. Chen and Jia (2019) determined in a comparative statistical analysis of 24 different 2SFCA methods that changes in threshold adjustment significantly affect the outcome. The latter, the distance decay function, reflects how the take-up of an offer decreases with increasing distance from home. Figure 2 illustrates possible weighting functions. They can be distinguished into binary decay, hybrid decays and some functional decays and are suitable for different analysis areas, use cases and settlement structures (Bauer and Groneberg 2016; Chen and Jia, 2019). For example, assessing place-based accessibility refers to the travel environment in which the service is provided. This consideration stems from the distinction between urban and rural areas.

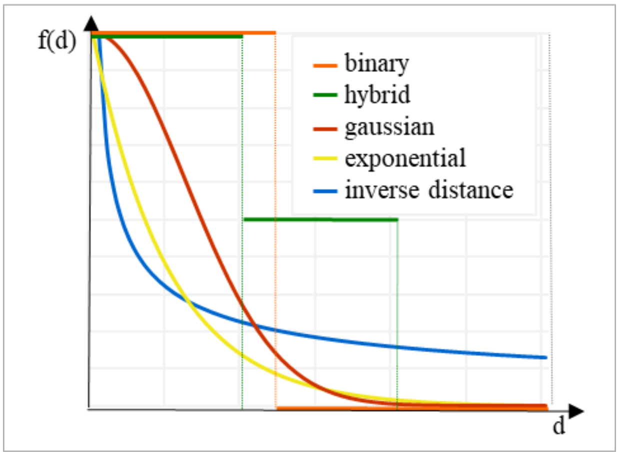

Figure 2. Selected examples of distance weighting of supply or demand locations.

Because health-related service facilities are limited in both number and density in rural areas, rural residents have a higher tolerance for long journeys (McGrail et al., 2012).

3.2 Settlement topographical aspects

As already addressed in Section 2.2 with Figure 1, residents (but also physicians) can be concentrated in one particular region of the planning area and / or be shaped by co-supply effects of neighbouring areas. Even if health planners have instruments such as the "additional local supply requirement" at their disposal, it is difficult to make detailed statements on the supply situation due to the size and topographical differences of the analysis areas. Settlement topographical aspects such as rural and sparsely populated areas alternating with urban, densely populated areas make it difficult to select and define analysis parameters. This shows how difficult it is to assess access to health care in the case of inhomogeneous population and physician distributions.

In informal healthcare analyses, the planner is faced with the choice of considering only the physicians and residents of the planning area and disregarding the co-serviced areas. Or to extend the scope of analysis beyond the planning area to include the co-supply effects of surrounding primary care sites. And whether or how to map the centralisation trends within a planning area.

3.3 Input-Data Aspects

Another aspect is the availability of data. In order to make a statement about the accessibility of a population group in a small area, diverse and small-scale data are needed. For a health planner, the least effort is the collection of doctor locations and their utilisation parameters. More difficult is the collection of small-scale, often heterogeneous, population data from different sources. As well as the construction of a network data set to complete the routing for the catchment areas. In addition, the routing data, the small-scale population data and the municipal areas have to be updated regularly.

3.5 Interaction of all Aspects

In summary: A health planner has the statutory mandate to implement planning decisions on the state of medical care in a region. The legally prescribed analysis parameter is a population/physician ratio adjusted for demographic factors for a given area.

However, to examine an area in more detail, a more in-depth analysis may be desired to evaluate access to medical services within a planning area. Doing this is (currently) not part of the legal mandate and requires a lot of time and expertise: Source data must be kept up-to-date, must be built and parameterised using the scientific methods presented, analysis decisions must be made for the specifics of the study area, the output product (map, table) must be designed and meet cartographic standards. In the following we present an approach that can bring relief and improve the quality of the analysis.

4 Proposed solutions to tackle the constraints

This Section examines to what extent the challenges mentioned in Section 3 can be overcome with the help of Web-Applications. They can offer a pre-configured set of data and methods as well as computational (geo)operations and allow the essential parameter settings to be made by the user. They can help to reduce the repetitive effort of data collection and updating, modelling and analysis before implementing a planning decision, while improving the informative value and realism of the analyses.

4.1 Data-Source

Analyses in geographic health services research that deal with the topic of "access" are particularly dependent on data that depict the supply structure (location of primary care), the demand side (patient residences or residents in general) and the route relationships between the supply location and the demand location. The supply locations and their utilisation parameters (for example, number of physicians at a location or patient base served) are well known. For the Web-Application, we work with the position data at the primary care location. This data is made available by the Ministry of Building and European Affairs and the Association of Statutory Health Insurance Physicians of Lower Saxony. However, utilisation parameters cannot be implemented because we cannot obtain information on this.

With regard to the availability of population data, there is now also sufficient small-scale data that depict both the number of inhabitants and the age structure available (e.g. in a 100x100m grid).

Route relations between the supply location and the demand location can be carried out with pre-calculated distance matrices both by car, public transport or pedestrian or one resorts to commercial or freely available modelling of the road networks. In our application case, the use of OSM data is absolutely appropriate, whereby we initially work with car travel times and distances. Even if the quality differs between densely populated and rural areas, the realism of the road network for the determination of catchment areas is considered sufficiently good in our prototypical use case (Neis et al 2012).

4.2 Workflow for large-scale and small-scale analysis

Our developments are based on the MasterPortal Hamburg which is a open source Geoportal software and is published under MIT licence (MasterPortal Hamburg, 2022). It already holds some useful functionalities and the OpenLayers JavaScript library is integrated. The MasterPortal is a responsive and modular application based on Vue.js. It contains mainly functionalities for map users but add-on components for more complex own implementations are possible.. Another big advantage is that the MasterPortal is becoming more and more established in German administrations at federal, state and local level (for example Schlüter et al., 2021). Therefore, it could be more easily established in public health planning departments. On the backend side, we operate with two virtual servers. One server holds the geodata in the map server application GeoServer. On the second server, the open route service (ORS) of the Heidelberg Institute for Geoinformation Technology is implemented (HeiGIT, 2022). We have separated the two servers because this allows us to allocate resources to the servers separately in the course of the computationally intensive method implementation (Capture 4.4) for determining access and to carry out performance tests. Through data transfer contracts, the application, including its data and infrastructure, is only available via VPN.

As a requirement analysis with potential user showed, it is relevant for almost of the users surveyed that even complex calculations can be displayed in the application in less than 30 seconds. Therefore, it is our goal to implement the calculation in less than 30 seconds for the two use cases in health planning within the web application. Figure 3 presents the two cases, large-scale and small-scale analysis. They require different technical solution strategies.

In the first case (in figure 3 green elements), a large-scale analysis is to be realised, in our case for the federal state of Lower Saxony. It can help to identify priority regions for a more detailed and small-scale analysis. This requires pre-processing of the potential analysis results, as we have to deal with 445,796 demand locations (population) in a 100 m x 100 m grid with 14,484 supply locations (potential physician locations), for each of which 11 catchment area polygons are to be calculated. For case 1, only a limited selection of parameters is available to the user via the user interface (1). This is because all potentially possible parameter adjustments cannot be calculated in advance. After complete input by the user, the parameters are transferred (2). The ORS catchment areas determined via a REST API in GeoJSON format (3) and the accessibility indices pre-processed in ArcGIS (4) can be transferred to the master portal via WebFeatureService and WebMapSerice (5).

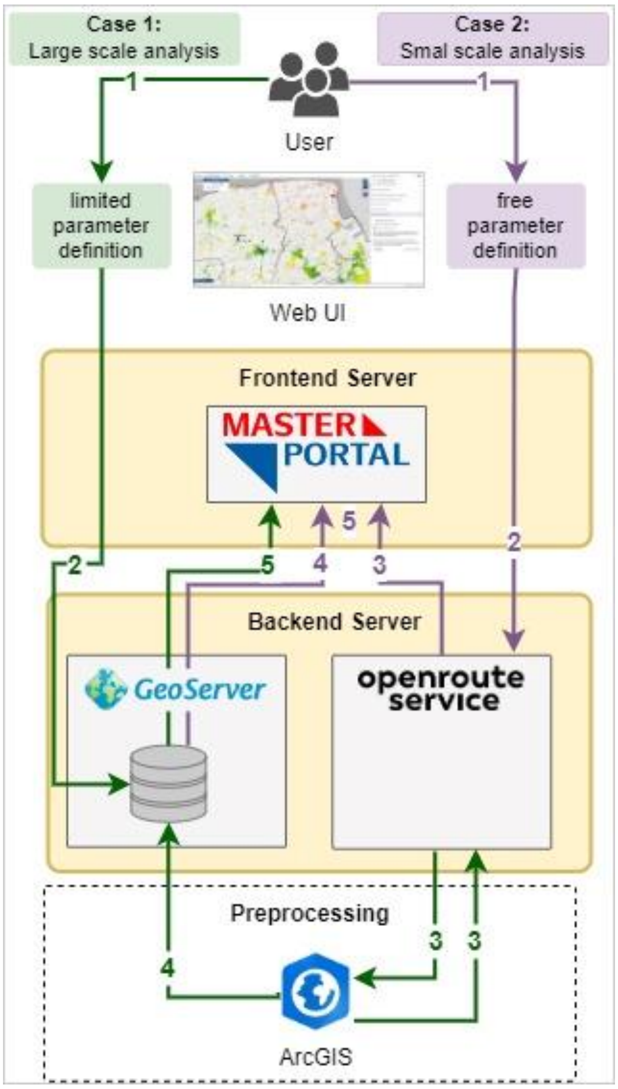

Figure 3. Simplified representation of the two different technical workflows for large-scale and small-scale analyses.

Case 2 (in figure 3 violet elements) is the implementation of a small-scale analysis. It includes one or more municipalities or a general practitioner planning area including its neighbouring catchment or planning areas. In contrast to case 1, the user has much more degrees of freedom after deciding on a small-scale analysis area (1). This is of particular importance in this case. In contrast to the federal state-wide analysis, where it is sufficient to identify accessibility or supply deficits only on a rough spatial basis, direct planning decisions can emerge from the small-scale analysis. The increased freedom is compensated by the fact that the user can select the utilisation parameters of the physicians. The user can include certain population groups in the analysis on the basis of age, select the means of transport and determine the weighting function himself. Once all entries have been made, the required isochrones are calculated by the ORS (2), the 2SFCA methods are executed with the help of the previously determined catchment areas, population and physician data (4) and transferred as a response with GeoJSON (5).

4.3 Individual distance decay and simulation

In the second use case mentioned above, the increased degrees of freedom in parameter adjustment make it possible to realise the user's individual analysis and planning needs. Without going into all of them, the user can parameterise whether he wants to use a weighting actually measured on patient behaviour in the form of a hydride decay, a complex-reduced linear weighting or even store his own parameters for the desired analysis range. Table 1 shows the weighting values for the respective isochrones with the distance. Here, d can be used for time or distance metrics. However, the measured weighting values correspond to the distance metrics given in $1d \triangleq 1$ km (last column of the table). Another interesting aspect of this approach is that it is possible to simulate the future supply situation by adding or removing sites before starting the calculation.

Table 1. User parameter selection in the distance decay function in live processing.

Distance *d*	Modifiable weights/ decays		
	Linear	User-based	measured
0-1 d	1	↑	1
> 1-2 d	0.9		0,603
> 2-3 d	0.8		0,345
> 3-4 d	0.7		0,251
> 4-5 d	0.6		0,183
> 5-6 d	0.5	individual	0,135
> 6-7 d	0.4		0,103
> 7-8 d	0.3		0,084
> 8-9 d	0.2		0,059
> 9-10 d	0.1	↓	0,046
> 10-11 d	0		0,031

5 Result and Discussion

Figure 4 shows a possible calculation result of case 2 for the planning area "Jever" in the user interface of the Web-Health-Application. In addition to the planning area boundaries, the spatial accessibility at each potential demand location of the analysis area can be seen. With the help of the ordinally scaled classification, the reddish colouring indicates rather low spatial accessibility values compared to the rest of the analysis area. The greenish colouring indicates good accessibility values at the potential demand locations. When interpreting this, it should be taken into account that this is not an adaptation of the legal and formal level of coverage at a smaller area level. Thus, there is no indication of over- or under-supply within the region. Rather, the result is to be understood spatially on a comparative basis. As mentioned in Section

2.2, the planning area "Jever" is close to oversupply with a supply level of 107 percent. However, this exemplary analysis shows how inhomogeneous the supply situation can be for some regions within the planning area. This analysis, which is much more detailed than the legal requirements, allows the derivation of much more concrete planning measures: Planning areas with imminent or actual undersupply can be specifically analysed for particularly critical areas in order to explicitly take stabilisation actions in these areas. In this way, practices can be identified that are most likely to be suitable for buying up due to very good spatial accessibility of an area. Another advantage is that the simulation can be used to model the impact of site closure. This also helps to evaluate and support the potential planning decision.

Due to its simple interface with the prepared data and provided methods, the web-based approach has the potential, on the one hand, to reduce the analysis effort for planners of the health care system. On the other hand, since these methods have not been applied outside research groups so far, this approach can be used to make previous analysis results of practical planners more precise.

It has to be mentioned that although the presented solution can sharpen the analysis and support the decision, this analysis is not embedded in any legal framework. However, with reference to Section 2.1, it should be pointed out that the improvement of an analysis before the planning can also lead to a change in the way of planning in the long run.

In a first step, it could be possible that this form of analysis provides a basis for argumentation in order to determine a small-scale supply need in an area that is actually well supplied. The example of the Jever planning area makes this clear.

6 Conclusion and Outlook

In summary, analysis and planning are crucial components of health care systems, where analysis involves the study of data to understand a situation or problem, and planning involves the development of strategies to achieve specific goals. In Germany, the most important instrument for ensuring ambulatory medical care is a demand planning system, which aims to ensure comprehensive outpatient medical care close to the patient's home and to avoid or reduce deficits in care. This requires a prior analysis of the current situation. We explained that the analysis in the outpatient sector is based on a ratio of inhabitants per physician in a defined area and that a supply ratio is set as a percentage target - with further influencing components being mentioned. The analysis results in planning measures that can lead to the promotion of physicians allocations in under-supplied areas or the purchase of practices in cases of extreme over-supply. However, the current system has its limitations, including the use of large planning areas that are not sensitive to small-scale statements. In addition, this application is able to account for patient migration and spillover effects outside the planning area, and it can capture the centralisation or decentralisation of health care locations. Since an analysis and planning tool that takes these factors into account could improve the effectiveness of care in the outpatient sector, we address the complexities that planners face in a healthcare

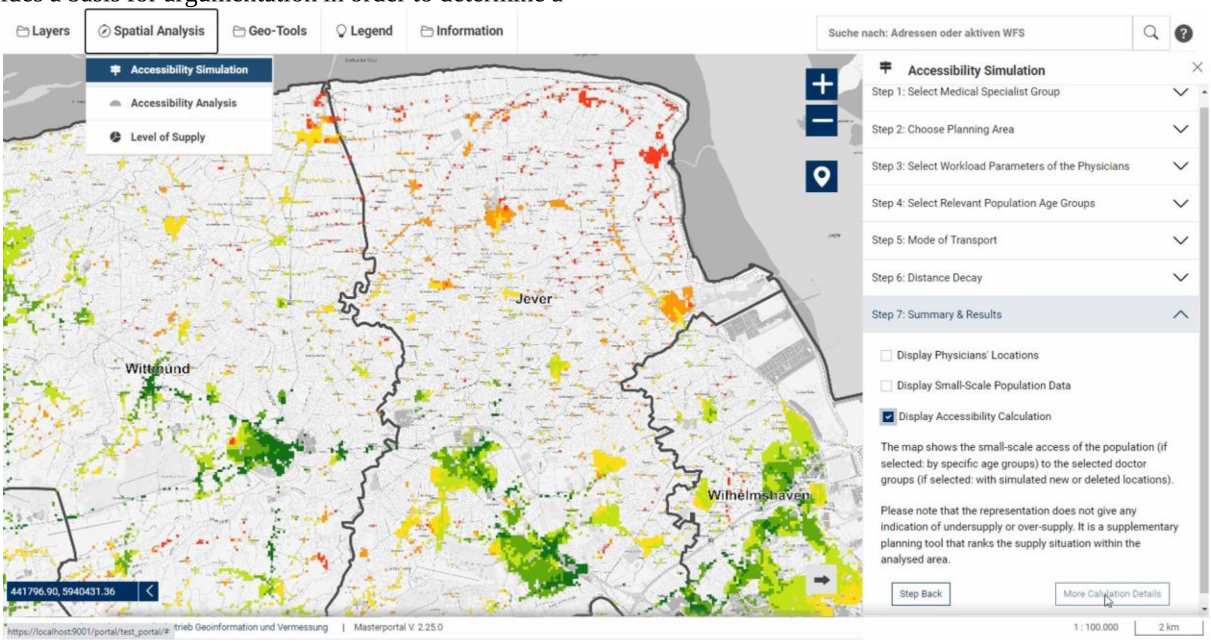

Figure 4. User interface of our Application proposal with a view to spatial accessibility analysis.

analysis. In doing so, it becomes clear that a methodological upgrading of an unsatisfactory legally obligatory analysis and evaluation method has not been possible so far: Despite the elaborated analysis concepts by science, the implementation failed on the one hand on account of the technical complexity of more sophisticated analysis methods. On the other hand, there is a lack of specialists for the comprehensive implementation of the concepts in all regional Associations of Statutory Health Insurance Physicians.

We propose a technical analysis system that provides relevant demand and supply locations (data), the network analysis (catchment areas) and the technical methodology (2SFCA) as well as a sufficient parameter influence via an interface. With this proposed solution, we hope to make a contribution to increasing the possibilities of analysis for health planners. For this we will evaluate the development and especially the interface from the perspective of expert planners in the coming months and make adjustments if necessary.

In the long term, more powerful and spatially more accurate analysis systems can enable improved planning. Technical innovations and finer analysis systems can contribute to the transformation on the long run the established regulations the planning system. In this way, the basic principle of equality of living conditions in all parts of Germany can be fulfilled even better in the future and health services can be allocated equally and nationwide.

Data and Software Availability

As part of the research and development contract, we are obliged to hand over the developed modules and the source code for unrestricted and sole use and exploitation. The small-scale population data used and updated by population registration offices as well as the data sets of general practitioners used are subject to data protection and are not our property.

The input data used in the work were provided by the Federal State of Lower Saxony within the framework of a data use agreement.

The software used is described in the text and figures.

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