KTH ROYAL INSTITUTE
OF TECHNOLOGY

Licentiate Thesis in Planning and Decision Analysis

Planning for equitable emergency health care

Assessing the geography of ambulance supply and demand in Sweden

JACOB HASSLER

Stockholm, Sweden 2022

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The start of my PhD studies coincided with the shift from working in the office to working remotely due to the Covid-19 pandemic. As such, my time as a PhD student has been quite unusual. Now, two years later, as work has gradually returned to normal, I find myself greeting colleagues in person for the first time. Despite working from home for a large portion of the past two years, I have met many colleagues and friends through courses and seminars both at the institution and elsewhere. I would like to thank all the people who have helped me, both directly and indirectly, in my work thus far.

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Abstract

Providing high-quality health care to everyone who needs it is a central objective for the Swedish health care system. One way in which this goal is broadly pursued is by allocating resources that maximize the geographical coverage of ambulances, aiming at reducing ambulance response times as much as possible, for as many as possible. However, in reality, emergencies tend to be concentrated in space and time. They are more likely to occur at particular places and times, following people's routine activities. Likewise, some groups are more likely to require acute health care, implying that supply needs to be tailored to patient demand. This thesis investigates the nature of emergency health care (EHC) services by assessing the temporal and the geographical distribution of ambulance services from a supply and demand perspective using southern Sweden as a study area. Geographical information system (GIS), spatial analysis and regression models underpin the methodology of the study. Findings indicate that there currently exist disparities in access to EHC services in Sweden, both between urban and rural areas and between sociodemographic groups. Depending on how accessibility is measured, different spatial patterns emerge, suggesting that the current practice of measuring response times should be complemented by alternative measures of accessibility in an attempt to reduce inequities in access to ambulances between groups and places. Results also indicate that the demand for EHC services varies both spatially and temporally, and that demographic and land use differences can be helpful in explaining such variations. The thesis highlights that currently employed EHC policy goals may entail unexpected inequities in the access to and supply of ambulances and, consequently, of EHC. As such, the study opens up for a discussion on how useful quantitative measures can be in revealing group inequities in access to EHC.

Keywords: emergency health care, spatial analysis, equity, policy

Sammanfattning

Att erbjuda god tillgång till vård för hela befolkningen är ett centralt mål för det svenska vårdsystemet. Detta eftersträvas genom att resurser fördelas på ett sätt som maximerar den geografiska täckningen av ambulanser, där målet är att minska ambulansers responstider så mycket som möjligt, för så många som möjligt. I verkligheten är akuta situationer koncentrerade i både tid och rum. De uppstår på specifika platser, vid specifika tidpunkter och reflekterar till viss del människors rutinmässiga rörelsemönster. Samtidigt löper vissa grupper större risk att drabbas av akuta sjukdomar eller skador, vilket insinuerar att tillhandahållandet av resurser behöver skräddarsys efter behov, snarare än populationsmängd. Den här licentiatavhandlingen undersöker akutvården genom att analysera temporala och geografiska fördelningen av ambulansresurser utifrån ett tillgång- och efterfrågan-perspektiv i södra Sverige. Metoderna som studierna baserades på innefattade användandet av geografiska informationssystem (GIS), rumslig analys och regressionsmodeller. Resultaten indikerar att det finns skillnader i tillgång till akutvård i Sverige, både mellan stad och landsbygd och mellan sociodemografiska grupper. Beroende på hur tillgång mäts uppstår olika rumsliga mönster av skillnader i tillgång, vilket pekar på att nuvarande sätt att mäta responstid borde kompletteras med alternativa mått. Detta skulle kunna bidra till att minska ojämlikheter i tillgång till ambulansvård. Resultaten indikerar också att behov för akutvård varierar över tid och rum, och att både demografiska variabler och olika typer av markanvändning kan bidra till att förklara sådana variationer. Den här avhandlingen visar på att nuvarande policymål inom akutvård kan leda till oväntad ojämlikhet vad gäller tillgång och efterfrågan till ambulans och, som en konsekvens, till akutvård generellt. Studierna öppnar således upp för en diskussion om hur användbara kvantitativa mått kan vara vad gäller att belysa ojämlikheter i tillgång till akutvård.

Nyckelord: akutvård, rumslig analys, jämlikhet, policy

Contents

List of abbreviations

EHC – Emergency Health Care

GIS – Geographical Information System

ED – Emergency Department

GWR – Geographically Weighted Regression

ANOVA – Analysis of Variance

DeSO – Demographic Statistical Areas

OLS – Ordinary Least Square

MAUP – Modifiable Areal Unit Problem

List of figures and tables

Appended papers

Paper I

Hassler, J & Ceccato, V (2021). Socio-spatial disparities in access to emergency health care—A Scandinavian case study. PLoS ONE 16(12): e0261319. https://doi.org/10.1371/journal.pone.0261319

Paper II

Hassler, J & Ceccato, V (under review). Temporal variations in the demand for ambulances in urban and rural areas: Towards equitable ambulance services in Sweden.

1. Introduction

In emergency situations, every minute that passes may influence the health outcome of the patient. Delays may even mean the difference between life and death. The emergency health care (EHC) system is responsible for ensuring that timely medical interventions can be provided to patients, regardless of time or place. This is an important step towards reaching the United Nations' Sustainable Development Goals 2030, in particular to achieve "…access to quality essential health-care services…", i.e. goal 3.8 (United Nations, 2022). In practice, this is a challenging task. Resources are limited and need to be distributed in a way that facilitates quick supply of EHC to anyone, when they need it. For planning, this is particularly challenging in sparsely populated rural areas where geographical distances are long. How, then, should limited resources be allocated?

EHC systems generally aim at increasing equality of access to EHC resources by reducing ambulance response times as much as possible, for as many as possible. This is achieved by situating ambulances stations in a way that maximizes coverage of the population. The supply of ambulance services are organized to serve the majority and tends to be informed by GIS-based network analyses that model travel times between ambulance stations and the population (e.g. Leknes et al., 2017; Uncu and Erol, 2010). Travel times between ambulance stations and the population is usually referred to as a measure of accessibility, where shorter travel times indicate higher levels of accessibility. As such, the organization of the supply directly determines the levels of accessibility. This way of planning assumes that demand, i.e. emergencies where patients require EHC, is a function of the population size. However, in reality this is not the case, as some groups are more likely to suffer emergencies at certain times and places. To assure that resources are available when and where they are needed, i.e. to assure resources are more equitably distributed, it is therefore crucial that populations or places that run a higher risk of requiring EHC are in some way prioritized. Assuming that levels of demand are solely dictated by population numbers may lead to a disproportionate concentration of EHC resources in urban areas, where more people, in absolute numbers, can benefit from e.g. an ambulance station compared to rural areas (Siegel et al., 2016).

In this thesis, it is argued that equitable planning of ambulance stations and Emergency Departments (EDs) posits that resources are distributed not only according to population size, but also to heterogeneous levels of demand between populations across space. The current principles of Swedish EHC planning are questioned by investigating alternative measures of accessibility and demand to EHC, and by comparing how different places and groups may be at a greater risk of requiring an ambulance than others. Through two case studies, it is illustrated that definitions and conceptualizations of measures that underpin planning of EHC supply may obscure the perspectives and challenges faced by some groups in the population. The findings have important implications for practical planning in Sweden, but also open up an international discussion on how the existing quantitative measures that currently underpin planning may entail unintended outcomes.

This thesis is part of a larger research project entitled "*Blue Light in Green Surroundings: Challenges and Opportunities for Emergency and Rescue Services in Sweden*" that aims to identify and investigate challenges and opportunities related to emergency and rescue services in Swedish rural areas. The project is funded by FORMAS, Grant number 2016-01424, and executed by researchers at KTH Royal Institute of Technology (Vania Ceccato, the principal investigator) in collaboration with Uppsala University (Susanne Stenbacka) and Linköping University (Tobias Andersson Granberg).

1.1 Aim

This thesis aims to investigate the nature of EHC services by assessing their temporal and geographical distributions from both the supply and demand perspectives. More specifically, the objectives are to reveal potential urban-rural and group-level disparities in accessibility to EHC services, and to identify covariates of disparities in the demand for such services. Thus, the following overarching research questions are asked;

- What are the spatial patterns of EHC accessibility, and demand, in southern Sweden, and which are the underlying factors?
- How does ambulance demand vary spatially and temporally, and how can variations in demand be explained at different times of the day?
- Which are the main urban-rural and group-level disparities in accessibility to EHC, and how can inequities in accessibility be tackled?

The outline of the thesis is as follows. First, the key concepts and theoretical perspectives that underpin the analyses are presented, followed by a section introducing previous studies on EHC supply and demand. Then, the Swedish health care system and the policy goals in Swedish EHC planning are briefly described, followed by an outline of the conceptual framework that underpins the analyses. This is followed by a presentation of the study area and a section on the methodologies of the papers and their limitations. Summaries of Paper I and Paper II are then presented, before the thesis concludes with a discussion of the broader implications for policy and research.

2. Key concepts and theoretical perspectives in EHC

2.1 Supply and demand

Supply, in this thesis, refers to all EHC resources which can be spatially organized to facilitate a rapid response to emergencies, such as ED's and ambulance stations. Meanwhile, demand is defined as emergency situations where the patient requires EHC. Demand is heterogeneous across space and time as some individuals are more likely to suffer an emergency illness or injury. For example, older individuals are more prone to have underlying diseases (Prückner et al., 2008) and to suffer falling injuries that call for EHC, especially in densely populated areas in the daytime (Ceccato and Willems, 2019). Moreover, physical violence may be more likely to occur in alcohol-selling districts in the evening and nighttime (Cusimano et al., 2010).

2.2 Equity, equality and social justice

The importance of increasing equity in EHC planning was recognized already in the 1970s and 1980s (Savas, 1978; Humphreys, 1988). To conceptualize equity in EHC access and supply, this thesis draws on Rawls theory of justice and fairness. The objective of social justice, according to Rawls, is "… in the first instance [to provide] a standard whereby the distributive aspects of the basic structure of society are to be assessed." (Rawls, 2005: 10). According to Lucy (1981), a Rawlsian view on social justice is that equity is an issue of distributive justice. The focus of the theory is thus on the principles or structures that should guide the allocation of resources in order to achieve a just distribution. Thus, inequalities are not just or unjust in themselves, but the way that inequalities are handled by institutions may be unjust (Parfit, 1997). Social inequalities, such as unequal distribution of welfare service resources, are justified only if everyone benefits from them. This theory explicitly opposes a long standing doctrine of utilitarianism in Western society that has failed to satisfy the basic rights and liberties of citizens (Rawls, 2005).

In short, utilitarianism posits that a society is justly ordered when major institutions are arranged to achieve "…the greatest net balance of satisfaction summed over all the individuals belonging to it" (Rawls, 2005: 21). The best possible outcome for the majority, in this view, should take precedence over individual- or group-level claims. The greatest sum of benefits, the maximum 'utility', should thus be strived for even if that comes at the expense of a few being worse off (Parfit, 1997). In other words, equality is strived for, regardless of whether it comes at the expense of a minority of the population that is worse off as a result. In contrast, from an egalitarian perspective, a distribution of resources that benefits many at the expense of a minority that is worse off is not considered just – a smaller sum of benefits may be preferable, for example by giving priority to those who are worse off (Parfit, 1997). In other words, egalitarian principles prescribe the unequal treatment of unequals while utilitarian principles prescribe the equal treatment of everyone regardless of differences or similarities (Lucy, 1981). Conceptually, the difference between equality and equity is thus that the former asserts that all persons are fundamentally equal, while the latter takes into account individual circumstances (Espinoza, 2007). In practice, achieving an equitable distribution of resources requires some form of moral or ethical judgment to determine who has a greater claim to resources, while increasing equality "involves only a quantitative assessment" (Espinoza, 2007).

The performance of public services is monitored through various indicators to determine how, for example, the spatial distribution of resources can be improved. Traditionally, these measures relate to efficiency and effectiveness, e.g. the utility in economic terms or the area that is covered within a certain time threshold. However, according to (Savas, 1978), such measures are insufficient on their own. Public services are funded publicly and should serve all of society. Thus, he argues, equity needs to be measured as an indicator of performance as well. How, then, can the utility of resources be maximized while also prioritizing those that need care the most? According to Lucy (1981) and Neutens (2015), in order to operationalize 'need' in quantitative analysis, it is crucial that the factors that influence the need for EHC are defined and quantified. Similarly, Humphreys (1988: 336) argues that "… [It is] imperative to identify the patterns of need for health care services within the population, and how these needs are distributed. This has major implications for what types of services are provided, and whether policies to distribute them should be geared to social or spatial (area-based) delivery."

3. Spatial methods in EHC analysis: An overview of previous research

3.1 Accessibility and spatial distribution of EHC resources

Research on the spatial aspects of EHC supply and demand can be divided into two strands – one that investigates how the distribution of resources can be optimized to best serve the population, and one that investigates how the demand for EHC varies spatiotemporally. Allocation of resources often relies on some form of network analysis. In one such example, the theoretical travel times of ambulances are first calculated in a GIS. Then, based on chosen thresholds of response times, accessibility is calculated by summarizing the share of population that falls within the thresholds, versus the share that does not. This provides the population-level access to EHC (Branas et al., 2005; Carr et al., 2009; Tansley et al., 2016) and can be used to illuminate spatial and sociodemographic disparities in accessibility (Lilley et al., 2019). Network analysis has been employed to calculate accessibility in terms of both ambulance response times by ambulances and transportation times to hospitals (Freyssenge et al., 2018). Variations in access to EHC has also been compared between different types of areas by running a network analysis to calculate travel times between areas and suppliers of EHC, and then running an analysis of variance (ANOVA) test on the resulting travel times split by the different types of areas (Silva and Padeiro, 2020)

Another type of technique, clustering, is typically employed to detect spatial and temporal clusters of demand for EHC. For example, the popular Getis-Ord Gi* hotspot analysis technique calculates a measure of spatial clustering that incorporates neighboring areas, i.e. spatial context, in the analysis. This has been employed to analyze, for example, spatial clusters of traffic incidents (Songchitruksa and Zeng, 2010; Ulak et al., 2017) and to find clusters of municipalities with poor access to EHC services (Rocha et al., 2017). Network analysis and clustering methods have also been used in combination. For example, Ulak et al. (2017) investigated the intersection of road segments with poor levels of accessibility to EHC and those with high frequencies of road crashes by employing hotspot analysis and network analysis simultaneously.

3.2 Modelling EHC services

Alongside increased technical capabilities, a convergence between fields such as mathematics, statistics and geography has taken place. Regression modelling is commonly employed to quantify, and explain, EHC demand. These models often rely on spatially aggregated, historical records of ambulance utilization and census tract data. Examples of such studies were carried out already in the 1970s, when Siler (1975) explained variations in rising ambulance utilization by modelling ambulance utilization data against census-level, socio-spatial factors. Similar techniques were used by Kamenetzky et al. (1982) to explain both the demand and need for ambulance transportation in the 1980s. Later studies have employed various types of models. For example, Ramos et al. (2021) and Hsia et al. (2018) employed negative binominal regression models to assess whether socioeconomic status was related to longer ambulance response times for patients suffering cardiac arrests.

A key to effectively planning EHC resources is to accurately forecast the future demand for ambulances using historical records of ambulance dispatches (Aringhieri et al., 2017). Forecasting ambulance demand has also become increasingly technical, influenced by mathematical and statistical modelling. It is often a challenge that spatiotemporal datasets of ambulance utilization are large and at many points in time no event is recorded in areas, which makes analysis difficult because there are many zeroes in the dataset. This has been overcome by running zero-infalted Poission regression models (Steins et al., 2019) and by adding spatio-temporal weights (Zhou and Matteson, 2015). Both these studies found that these methods resulted in greater forecasting accuracy compared to the models currently employed in practice.

Furthermore, in spatial analysis, one cannot assume that the relationships between variables remain constant across space. Relationships may change between regions, and explanatory factors may differ from place to place. Therefore, spatial regression models have been developed to control for local contexts. Including spatial effects in modelling is usually motivated either on theoretical grounds or due to peculiarities of the data (Anselin, 2002). For example, Comber et al. (2011) identified geographical variations in the relationship between some predictor variables and perceived accessibility to health care by modelling local relationships using Geographically Weighted Regression (GWR) models. Other spatial models include spatial lag and spatial error models, both of which control for different types of spatial autocorrelation – the former for spatial effects where events or values in one area predict that neighboring areas will have similar values, and the latter for omitted explanatory variables that could explain the spatial patterns observed in the data (for more information, see e.g. Anselin, 2002; Anselin, 2003).

Moreover, there are several examples of studies that incorporate equity and need in quantitative measures. For example, Jagtenberg et al. (2020) and Jagtenberg et al. (2021) assessed optimal locations for ambulance bases in Norway while prioritizing the reduction of response times for those with the longest wait times rather than maximizing overall coverage of the population. Including aspects of fairness or equity when localizing EHC resources may, however, come at the expense of traditional measures of performance such as response times and coverage rates (Enayati et al., 2019). Thus, it is ultimately a question of balancing effectiveness (or utility) and equality (Parfit, 1997; Enayati et al., 2019). Or, as Humphreys (1988: 332) put it, when planning EHC services, "[the benefits of] propinquity to services have to be balanced against the effectiveness".

4. The Swedish health care system

The Swedish health care system is a decentralized system. Overall goals and policies are set at the national level, but the responsibility to provide health care services is split between three levels of administrative bodies – the state, regions and municipalities (The Swedish Research Council, 2021). The system is primarily publicly funded by taxes and is based on three fundamental principles: the equal right to health care regardless of socioeconomic status; the principle of 'need and solidarity', meaning that those who need health care more are prioritized over those who do not; and the principle of cost effectiveness which states that there should be "… a reasonable relationship between the costs and the effect…" (WHO, 2005). The overarching objective of the health care system is to ensure the supply of adequate, high-quality health care to everyone who needs it (Regeringen, 2022). While containing market-oriented elements (The Swedish Research Council, 2021), the Swedish health care system differs from e.g. the US system, which relies primarily on private actors, market-oriented forces, and individuals' insurance levels; for more comparisons between countries, see e.g. Böhm et al. (2013).

Within the broad framework set up by the national principles outlined above, Sweden's administrative regions and municipalities are relatively autonomous in organizing the EHC system. For example, regions may choose to outsource parts of the system, e.g. the ambulance services, to private companies or to operate the supply on their own. Regions set benchmarks in policy goals that are used to evaluate how well the system performs. In 2012, all regions had policy goals of ambulance accessibility that included two components – reaching a certain share of the total population of the region within certain time thresholds. These varied between reaching 80% of the population within 10 minutes to reaching 100 % of the population within 30 minutes (The Swedish National Audit Office, 2012: 53).

5. Assessing the geography of ambulance supply and demand in Sweden: A conceptual framework

In Sweden, policy goals that inform planning decisions aim at improving accessibility for as many as possible. They are underpinned by utilitarian principles, where population counts are viewed as a proxy of demand. Distributing resources to benefit as many as possible, without regards to the heterogeneous needs for EHC, is from a Rawlsian perspective arguably not only unjust (Rawls, 2005), as, for some, more than being of moral importance, inequitable distributions of EHC resources can mean the difference between life and death. Therefore, it is crucial that supply is more equitably tailored to demand. To achieve this, the heterogeneous nature of health care needs should be taken into account.

A first step towards this end is to understand how spatial patterns of accessibility to EHC vary, as well as how spatial and temporal patterns of demand vary and what factors drive demand. Therefore, two separate studies were carried out – one investigating spatial and sociodemographic variations in accessibility, and one investigating the spatiotemporal patterns of demand. These studies provide a basis for discussing how striving towards maximizing the utility of resources can simultaneously achieve equitable access to EHC. Because the heterogeneity of demand is not reflected in the policy goals, there is a risk that planning that aim at maximizing the utility of resources, i.e. to serve larger shares of the population, prioritizes urban populations over rural populations. In such a planning process, groups with great demand may be neglected and obscured. Potentially, current planning may succeed in reaching policy goals while failing to ensure the supply of EHC to patients that have greater needs. The conceptual principles applied in each of the two papers are presented in Table 1 below.

Table 1: Theoretical and conceptual principles applied and discussed in the two papers.

	Paper I	Paper II
Supply	x	
Demand		x
Distributive justice and utilitarianism	x	
Social equality and equity	x	x
Spatial perspectives	x	x
Temporal perspectives		x

6. The study area

The study area in both case studies was delimited to southern Sweden. This area contains a population of roughly 4.3 million people, about 40 % of the total Swedish population (SCB, 2020a). Delimiting the study area to southern Sweden was motivated primarily by two factors – data availability and the context. First, the locations of ambulance stations, which underpinned the analysis in Paper I, were gathered from individual administrative regions because no registry of these currently exists. As some Swedish regions did not respond or were unwilling to provide these locations, a smaller study area than the national level was chosen. Second, there are significant geographical and demographic differences between northern and southern Sweden. Northern Sweden is characterized by large, sparsely populated areas and mountainous regions presenting unique challenges for EHC supply. Southern Sweden is more similar to many other European countries in terms of population density and geographical context, thus, results presented in this thesis may thus be more applicable to other countries. Sweden also constitutes an interesting case because welfare functions are often perceived as being well-functioning here. However, ongoing reforms and reorganization of health care services, including centralization of ED's (Vårdanalys, 2018) affect the potential of supplying EHC. Thus, assessing accessibility to EHC in the Swedish context is important because reorganization has likely changed the spatial patterns of accessibility over the previous decades. The study area – showing the administrative regions (A) and the spatial divisions used in the studies as well as the rural and densely populated urban areas (B) – is presented in Figure 1.

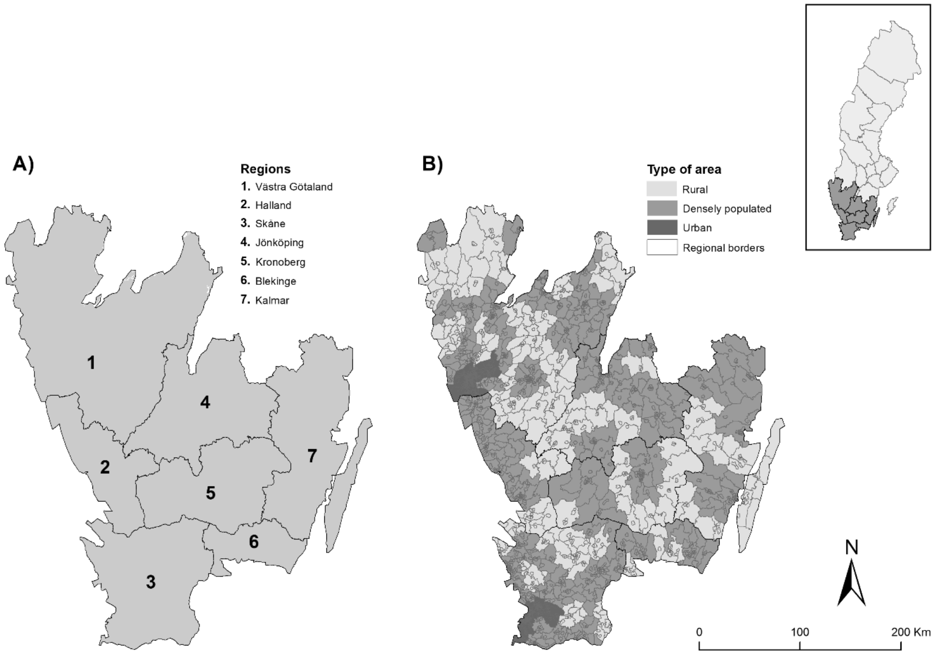

Figure 1: Map showing the study area: A) Regions and B) Type of area.

7. Data and methodology

In both Paper I and Paper II, Demographic Statistical Areas (DeSO), a Swedish, nation-wide system of spatial division that utilize population size (SCB, 2021), was employed as the unit of analysis. Each DeSO area contains around 2000 individuals and sociodemographic information of the population, and the areas share borders with other administrative units, e.g. regions and municipalities. This was important because regression analysis was run with some covariates aggregated to other geographical areas, e.g. municipal and regional. An official road network (The Swedish Transport Administration, 2020) underpinned the analysis in Paper I, together with the location of ED's (N=22) and ambulance stations (N=118), which were manually gathered from Google Earth. In Paper II, ambulance dispatch data from 2018 delimited by night (00:00 – 08:00), day (08:00 – 16:00) and evenings (16:00 – 00:00) were supplied by SOS

Alarm, a publicly funded body for handling emergency calls. The dispatches (N=577,404) were spatially aggregated by DeSO areas. The regression analysis in Paper II included covariates related to land use variables gathered from Open Street Map and sociodemographic data from Statistics Sweden.

Spatial and statistical methods underpinned the analyses presented in this thesis. Visualizing the spatial patterns in maps of accessibility (Paper I) and demand (Paper II) was a key part of the results. The road network and DeSO areas were imported to a GIS to run a network analysis, where travel times between supply points (ambulance stations and ED's) and the DeSO areas were calculated. The centroid of the DeSO areas were used a proxies of the population's location, and were weighted by another dataset on population with higher spatial resolution. Instead of calculating buffer zones based on travel times and summarizing the population within different zones (Branas et al., 2005; Carr et al., 2009; Tansley et al., 2016), separate routes were calculated for each individual area and the closest supply point in Paper 1. The areas were then visualized in separate maps for each measure of accessibility, using manually set thresholds that were suitable to compare levels of accessibility.

Similar to Silva and Padeiro (2020), an ANOVA test was employed to analyze if levels of accessibility, i.e. the travel times calculated in the network analysis, varied across urban and rural areas. Then, regression analysis was employed to explain variations in accessibility. The separate measures calculated in the network analyses were included as dependent variables. All measures exhibited a strong, right-tail skew and problems with overdispersion, i.e greater variability in the data than would be expected. Thus, like similar studies by Ramos et al. (2021) and Hsia et al. (2018), following standard procedure with this type of data (see e.g. Jarman et al., 2019; Ver Hoef and Boveng, 2007), Negative Binominal regression was utilized (instead of Ordinary Least Square (OLS) that assumes a normal data distribution).

The same spatial units were employed in the analysis in Paper II. To identify areas running a greater risk of requiring an ambulance, standardized ambulance demand ratios were calculated as a function of ambulance dispatch rates and population sizes. These indicated whether an area, relative to the rest of the study area, ran a higher or lower risk than expected to require an ambulance dispatch. Ratios were calculated for each different area, at day and night time and were visualized in maps divided by areas that had lower, or higher, than expected risk of requiring an ambulance dispatch. Then, similar to the analysis in Paper I, an ANOVA test was run to compare ratios between urban and rural areas. As the ratios had a non-parametric distribution, a Kruskal Wallis ANOVA test, which does not assume parametric data, was run. Then, a Getis-Ord Gi* hotspot analysis was carried out to identify clusters of areas with greater, or lower, than expected demand in Paper II. This is a common method used to identify statistically significant spatial clustering of high or low values (see e.g. Songchitruksa and Zeng, 2010; Ulak et al., 2017; Rocha et al., 2017). The hot- and cold spots that were generated indicated clusters of areas with ambulance demand that was higher or lower than expected. A hotspot analysis was not suitable in Paper I because areas located in close proximity generally had the same closest supply point (ambulance station or ED) – and thus had similar travel times.

Lastly, regression analysis was employed to identify covariates that explained the ratios calculated in Paper II. The modelling strategy started out with standard OLS models. However, as spatial autocorrelation was present in the data, indicated by a statistically significant Moran's I value on the residual values, spatial lag and spatial error models were employed to control for unaccounted spatial effects. Both were included because the type of spatial autocorrelation was unknown. Also, the independent variables were spatially aggregated on different levels. Table 2 shows the methods and techniques employed in each of the two papers.

Table 2: Methods and techniques employed in the two papers.

	Paper I	Paper II
Visualization	x	x
Network analysis (GIS)	x	
Hotspot analysis (GIS)		x
Statistical tests of variance	x	x
OLS regression models		x
Spatial regression models		x
Negative binominal regression models	x	

7.1 Limitations

Several limitations were related to the data type and quality. Because data on population movement, i.e. the location of population's on an hour to hour basis, was lacking, the impact of population movement on evening ambulance demand could not be analyzed in Paper II despite having ambulance dispatch data for evenings. Place of residence and workplace data were used as proxies for the population's locations during the night and day, respectively, which is a common approach to analyze spatiotemporal changes in people's location (Siler, 1975). However, no such assumptions could be made about the population's location in the evening.

Modelling ambulance travel times through network analysis has previously been shown to produce underestimated travel times compared to real world trips (Patel et al., 2012). Lacking data on actual ambulance trips led to not being able to confirm if our calculations underestimated ambulance travel times or not. However, factors that influence travel times are inevitably omitted in any network analysis. The impacts of bad weather, seasons, sudden events affecting driving speed (e.g. traffic jams or accidents), or ambulance drivers driving faster than legally allowed all likely influence travel times. Moreover, there are more dimensions to accessibility than the spatial dimension. Social factors, such as language barriers or a lack of trust, may make an individual more or less hesitant to call for an ambulance or go to an ED at all. In this thesis, accessibility has been measured with the underlying assumption that such obstacles or problems have been overcome a priori. Also, as in all studies including spatial analysis, it is important to mention the Modifiable Areal Unit Problem (MAUP). In its simplest definition, the MAUP can be defined as referring to "… the cartographic representation of data whose attributes are significantly influenced by the spatial scale used." (Buzzelli, 2020). As the same system of spatial division, i.e. DeSO areas, was utilized in both papers, this is not necessarily a limitation. However, it is worth pointing out as future studies with different divisions may yield different results.

8. Summary of the articles

Paper I: Socio-spatial disparities in access to emergency health care – A Scandinavian case study

In the light of ageing populations and changing population structures in urban and rural areas, and an ongoing centralization of ED's, the objective of Paper I was to investigate, and explain, potential disparities in access to EHC. Currently employed Swedish policy goals consider ambulance response times as an indicator of EHC accessibility. As patients sometimes need to be transported to hospitals to receive medical interventions, we calculated response times and two additional measures of accessibility – transportation time to the closest ED and the total time elapsed from when a patient calls the ambulance to when he or she arrives at the ED. These measures were then analyzed to assess potential disparities in EHC access between urban and rural areas, and between population groups. The analysis was based on a network analysis which was carried out to calculate the separate measures of accessibility. Then, socio-spatial disparities in accessibility were investigated through regression modelling and statistical testing.

The results showed that roughly 90% of the population in southern Sweden had access to EHC at the ED within one hour of calling an ambulance, i.e. within the 'golden hour'. Internationally, this indicates comparatively high levels of accessibility. Although ambulance response times were relatively low for all areas and groups, there existed geographical variations in accessibility where accessibility tended to be lower in rural areas. Nearly one-third of all rural populations had more than one hour wait time to reach the ED when calling an ambulance. Moreover, despite having relatively equal response times, rural areas tended to have increased transportation times to ED's compared to urban areas. Furthermore, the regression modelling indicated that population groups that may have greater health care needs, e.g. older adults, had statistically significant longer wait times for all three accessibility measures. Meanwhile, higher income levels and higher education levels explained shorter wait times for some accessibility measures, but not others. An interaction effect between rurality and shares of older adults came out as statistically significant too, suggesting that rural areas with high shares of older adults may have particularly low levels of accessibility. For planning purposes, these results highlight the importance of critically evaluating measures of performance and of incorporating various measures of accessibility. Focusing solely on ambulance response times risks obscuring poor accessibility in areas that may have low response times, but high transportation times to emergency departments.

In Paper I, the conceptualization (definition of aims and objectives) and the structuring of the paper, the writing and the interpretation of the results were carried out as a collaborative process. The author of this thesis was responsible for the literature review, data collection and curation, and executing the analysis, as well as for establishing analytical links between findings from this research and those found in the literature, and for drawing conclusions.

Paper II: Temporal variations in the demand for ambulances in urban and rural areas: Towards equitable ambulance services in Sweden.

Paper II investigated how ambulance demand varied spatiotemporally, and where and when ambulance demand was disproportionally high. We hypothesized that land use factors, such as schools and factories, i.e. work places, dictated routine population movements due to work commutes, and that spatiotemporal variations in ambulance demand could therefore be partly explained by land use factors. To carry out the analysis, a standardized ambulance demand ratio was first calculated, where ambulance demand was defined as a function of the number of ambulance dispatches and the population size, controlling for daytime and nighttime populations. The standardized ambulance demand ratio thus indicated the risk of a population requiring an ambulance in one area relative to other areas, taking into account the overall distribution of both the number of dispatches and the population for the whole study area.

Findings showed that although the total number of ambulance dispatches was higher in urban areas due to larger population numbers, demand was higher in rural areas when the number of dispatches was considered relative to population size. Moreover, clusters of high ambulance demand were observed in rural areas, while clusters of low demand were observed in urban areas. These clusters furthermore expanded spatially in the daytime, suggesting that urban-rural variations in demand may be exacerbated in the daytime.

Then, spatial regression models were employed to assess which factors could explain spatiotemporal variations in ambulance demand. While sociodemographic variables came out as statistically significant predictors of ambulance demand regardless of time or place, land use factors explained higher demand in the night and lower demand in the day, indicating that population reshuffling influences the proportionality between ambulance dispatches and population numbers. When the working age population commute away from their areas of residence for work, more ‘vulnerable’ population groups, e.g. older adults, make up a larger share of those who remain. As a result, ambulance dispatches become more numerous than the smaller population counts would predict in areas that commuters move away from during the day. Concurrently, the daytime increases in population numbers in e.g. industrial areas consist largely of working age individuals who are less likely to require an ambulance. These results suggest that the absolute number of calls for ambulances may be a poor indicator of health care need. Planning emergency services based on population numbers, rather than on their needs, may thus be detrimental for those that need the services the most.

In Paper II, the conceptualization (definition of aims and objectives) and the structuring of the paper, the writing and the interpretation of the results were carried out as a collaborative process. The author of this thesis was responsible for the literature review, data collection and curation, and executing the analysis, as well as for establishing analytical links between findings from this research and those found in the literature, and for drawing conclusions.

9. Discussion of the results

9.1 Planning EHC supply – pursuing equity or equality?

Assuring the supply of adequate, high-quality health care to anyone who needs it is a core objective of the Swedish health care system (Regeringen, 2022). The EHC system is expected to adhere to principles of need and solidarity where those that need health care should, ideally, be prioritized over those who do not (WHO, 2005). However, in reality there are limited resources and thus there needs to be a “…reasonable relationship” (WHO, 2005) between the costs and the utility of resources. This entails a process of weighing needs and cost-effectiveness in the planning process, and a limit to the extent that striving towards equity can be financially motivated. Striking a balance in this process of weighing between need and cost-effectiveness has been argued to be a key for equitable planning of EHC resources (Humphreys, 1988: 332).

Swedish EHC planning strives towards reducing ambulance response times as much as possible, for as many as possible. This is evident in the regional policy goals, which stipulate that certain shares of the population should be reachable by an ambulance within certain time frames. To achieve these goals, ambulance stations are allocated in way that covers as large shares of the population as possible within the stipulated response time thresholds. As was illustrated in Paper I, this way of planning entails a risk that even if policy goals related to accessibility are achieved, some parts of the population may still be underserviced; a situation that is, in some sense, obscured by the currently employed policy goals. Achieving the policy goals may generate perceptions of the system as being well-functioning, despite inequities in access being present. That is problematic considering that the underserviced minority comprise populations that live in rural areas and that may have greater health care needs, such as older adults, as was highlighted in Paper I. Drawing on Rawls theory of social justice, one could critique current planning for not weighing the health care needs of various groups. In current EHC planning in Sweden, the few are in some sense sacrificed for the many.

In Paper I, findings indicate that in cases where patients needs to be transported to the ED to acquire adequate health care, there are even greater disparities in accessibility than for ambulance response times. This, too, is in some sense obscured by the focus on ambulance response times in the policy goals. It is an important finding because disparities in accessibility to EHC located at the ED's have been exacerbated by an ongoing, long-term process of centralization of specialist services which has led to a closure of around 40 % of Swedish ED's since the 1970s (Vårdanalys, 2018). The centralization process has been driven by dwindling population numbers in rural areas and, relatedly, financial difficulties in upholding levels of service as well as problems with maintaining expertise. ED's have been relocated to larger population centers which provide a 'better' basis for offering health care. In other words, the centralization of Swedish EDs in the past decades is an indirect effect of changes in the primary care sector, where reforms and reorganization in other parts of the health care system have hampered the ability to provide EHC services. While such problems are often pointed out when reforms are implemented in specific parts of the health care system (e.g. Vårdanalys, 2018: 36), their magnitude and importance are seldom recognized. This is problematic because the lack of a holistic perspective in health care planning entails that solutions to problems in one part of the system may come at the expense of generating new problems in other parts of the system. It is important to recognize that the health care system consists of many interconnected systems that are not isolated from each other – they affect, and are affected by, reforms in other parts of the health care system.

This discussion then turns to a central question – are utilitarian ideals, i.e. covering as large a share of the population as possible with as short ambulance response times as possible, commensurable with notions of equity? Ultimately, resources are limited and they need to be distributed in some way. Any decision of distribution will in the end entail that somewhere, at some time, resources are not available that could have been (Hynninen et al., 2021). To assure that those who have the greatest medical needs and runs the highest risk of requiring EHC, some form of prioritization needs to be made when resources are distributed. As Espinoza (2007) points out, this requires ethical and moral judgments of what factors should be used to determine who has the greatest claim to resources, which is arguably more complicated and subjective than utilitarian planning that aims at maximizing the coverage of as many as possible.

One way to assess how risk for requiring EHC was presented in Paper II, where ambulance dispatches were found to be more numerous in urban areas. However, when controlling for population size, the risk of requiring an ambulance was higher in rural areas than in urban areas. In other words, although larger populations in urban areas entail more ambulance dispatches, the risk of an individual requiring an ambulance is generally greater in rural areas. Population size may thus be considered an inaccurate indicator of ambulance demand, or medical needs. Despite a large majority experiencing high levels of EHC accessibility, as was shown in Paper I, it seems that the minority that experience lower levels of EHC accessibility are also those with the greatest needs, e.g. older adults. Although reaching a point of completely equitable supply of EHC services would, in theory, require everyone to be located at a single geographical point at all times and to have the exact same needs, which is clearly unrealistic, it is still important to recognize that current planning may exclude groups that may need EHC services the most. More than being a question moral or ethics, increasing equity of access to EHC has a tangible and important value when it comes to planning an emergency response.

9.2 Planning EHC supply – a way forward

Based on the findings presented in this thesis, some suggestions for planning practices that could contribute to increasing equity in EHC supply have been identified. First, travel time to the closest ED and the total time elapsed from calling an ambulance until arriving at the ED should be implemented as standard measures of accessibility alongside ambulance response times. Policy goals that incorporate these two measures could be implemented on a regional basis to ensure that patients can acquire EHC in a timely manner.

Second, the spatial and temporal heterogeneity of health care needs should to be recognized so that prioritization of resources can be made. This could be done, for example, by calculating a measure of need based on sociodemographic variables that are known to be correlated to an increased risk of suffering an acute illness or an emergency. Such a measure could help identify areas or population groups that needs to be prioritized in EHC planning.

10 Conclusions and suggestions for future research

Both the supply of, and demand for, EHC resources vary across space and between population groups. Accessibility to EHC tends to be lower in rural areas compared to urban areas, especially the accessibility of EDs, which is problematic as health care needs may be higher in rural areas. As population counts do not necessarily reflect EHC need, planning and supply-related decisions should therefore not be made in isolation from need and demand. As people go about their daily routines, the spatial patterns of demand change throughout the day and planning should incorporate such knowledge to ensure a more equitable supply of EHC services. Current Swedish policy goals may be insufficient in the sense that both spatial and population-level inequities in accessibility may persist even if the goals are reached. As such, the findings of this thesis provides a basis for critiquing the way in which the performance of the EHC system is currently measured, and ultimately of how planning is currently carried out. It contributes to a growing body of literature that investigates how equity can be conceptualized in and incorporated into EHC planning – knowledge that is internationally viable, and not restricted to the Swedish context.

Building on the spatiotemporal analysis of ambulance demand presented here (Paper II), future research could further explore the use of higher resolution spatio-temporal data. Mobile phone data, for example, could be utilized to analyze how different places are more or less likely to generate demand at certain times, and to what degree population numbers drive demand. Several questions could be investigated – What factors explain ambulance demand over the course of the day? Do the explanatory factors differ between weekdays and weekends? Furthermore, Paper I focused on static measures of accessibility. Rather than being static, the accessibility levels of populations change as individuals move around in space and time, performing routine activities. A ‘dynamic’ measure of accessibility at different times in the day, where the travel times between places and the populations at the places are measured, could underpin a different planning of ambulance locations. Comparing accessibility levels at certain times to standard, static accessibility measures would also help evaluate the accuracy of common accessibility measures. Such a study could inform planning of the EHC system to distribute resources to where and when they are needed.

11. References

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