Spatially optimized health services – Effectiveness and equality of primary health care service network accessibility in Northern Ostrobothnia

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Summary

The Finnish healthcare system and service network are both under deep reorganization. Easy and equal access to services are key factors for good-quality health care, and legislation sets requirements for public authorities to ensure decent services to all. Thus, also unprofitable market segments and sites are needed to be served. Location-allocation analyses, such as p-median, are commonly applied to designing services network by travel cost (e.g. time). This paper applies location-allocation analysis in GIS, with aim is to find optimal spatial structure for primary health care services in Northern Ostrobothnia.

KEYWORDS: Accessibility, Health care, Location-allocation, Population, Public transports

1. Introduction

Healthcare systems and organizations are facing challenges through needed cost reductions and expected service improvements. Especially long distances in sparsely populated areas, changing age distribution and poor coverage of public transports set a challenge on the accessible healthcare system. One of the most important strategic approaches to these challenges is locating the service facilities (see e.g. Ahmani-Javid et al., 2017; Kotavaara and Pohjosenperä, 2018). These healthcare facility (HCF) location decisions, indeed, affect heavily on the effective and equal accessibility of health services and to costs associated with the provided service entity.

In Finland, the healthcare structure is going through a major reform. In the previous (and the current until further notice) system the hospital districts are in charge of arranging specialized health care in larger geographical areas, whereas municipalities organize public primary healthcare services. The reform will centralize all public healthcare into county level organizations. In addition, patients´ right to choose their health service providers increases that creates market opportunities for privately provided health services. Overall the reform process has opened discussions and planning of the content and the structures of the health services.

This paper focuses on health centre location scenarios in the Finnish county Northern Ostrobothnia (Figure 1). For successful reform information about present service network and its accessibility as well as strategical information about future service network scenarios are needed. Geographic information systems (GIS) is highly applicable framework in analysing accessibility by using spatial data of transport networks, supply and demand (Páez et al., 2012). Furthermore, accessibility in the context of health care has been analysed by as a spatial problem in many studies, also in Finland (see Huotari et

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al., 2017). GIS-based HCF location analysis enables to produce information to produce health services in new regional entities without relying on earlier service production or municipal and administrative borders. This gives new opportunities that affect service offering in the matter of quality, better accessibility to population, service and cost efficiency, equality in access, as well as promoting an environmentally friendly urban structure.

1.1. Research aim

In this study the aim is to seek the optimal spatial distribution of health centers (i.e. medical doctor and public health nurse services) in Northern Ostrobothnia. It is unclear, how well health centers are presently located, in what level new units would increase the accessibility and how strongly closures of units would decrease it. Thus, aim of this research is to produce scenarios to test service network changes in relation to accessibility. The optimal healthcare facility locations minimise the needed passenger car driving kilometres and thus support in achieving the goals in carbon emission reduction. Three research questions will be answered in this study:

1. What would the most optimal sites of primary health care service units in sight of accessibility, whit scenarios of increasing and decreasing service networks?
2. How different scenarios change service accessibility in relation to effectiveness and equality?
3. How the customer potential of service units varies in different scenarios?

2. Methods and data

In this study, p-median i.e. minimize impedance approach is used to optimize the spatial distribution of services, and spatial data used in the analysis consist of 1) routable road network with speed limit attributes, 2) population grid cells 3) commercial activity sites and 4) health centre location datasets.

The p-median type location-allocation is a common subtype of graph-based facility location problems (Rodrigue et al., 2013). P-median minimises the travel time sum of population reaching services, the analysis maximises the average accessibility of population, but does not take the spatial coverage into account. Method allocates predetermined number of facilities to set of candidate sites by travel cost and demand volume estimates (Cromley and McLafferty, 2002, Huotari et al. 2017).

Accessibility analyses are based on the Digiroad 2018 model of the Finnish road network. The data includes regional and local main streets, collector and feeder streets and private roads allowed for public use and walkways. In the road network, travel speed estimates were formulated on the basis of the speed limit data. 40 km/h was used for missing information and 4 km/h was applied for walking. Thus, travel time estimates are highly accurate in the mainly uncongested traffic of Northern Ostrobothnia.

Population data includes year 2017 population structure at 1km×1km grid cells. Commercial activity sites, which are applied as candidate locations for HCF, were available at 250m×250m. Both datasets are obtained from the Monitoring System of Spatial Structure and Urban Form (YKR) produced by the Finnish Environment institute. Commercial activity sites including 2933 retail units in 1561 grid cells produced to 196 candidate unit sites for location-allocation, by first smoothing local variation with focal sum using 400 m buffer, and then selecting local maximum points iteratively with 1400 m buffer.

Health centre data is based on the HILMO and TOPI registers of the National Institute for Health and Welfare (see Lankila et al., 2016) and data updated for the end of year 2018. For surveying new unit sites by allocation analysis, commercial activity sites were applied as candidates. The Monitoring System of Spatial Structure and Urban Form (YKR) includes the amount of retail units at 250m×250m grid cells. The local maximum of the cells with 1200 m range was selected to candidate sites (N=78). Thus, the most-dense agglomeration of retail units in centres and a single retail unit in periphery areas represent candidate unit sites with suitable density and coverage.

3. Results

Accessibility to health centres is widely in a high level, as the majority of the population (90 %) reaches health services in 15.1 minutes by car, as shown in Table 1. In practice, majority of small population densities comparable to small municipality or large village have their own health centres. In areas having longer than 20 minutes travel time to health centres (see figure 1), population numbers are very low, which is visible in figure 2. Again, densely available services within sparsely populated areas have relatively small customer potentials.

Table 1 Health centre accessibility in location-allocation scenarios

Service location-allocation scenario			Accessibility (minutes) of population (quartiles and last decile)					Service unit customer amount	
N	(%)	Description	25%	50%	75%	90%	100%	min	max
32	-30	Major decrease	4.7	6.8	10.5	17.5	93.3	959	46908
39	-15	Minor Decrease	4.5	6.4	9.7	15.2	75.3	959	46908
46		Present locations	5.2	7.8	11.0	15.1	86.1	887	54355
46		Present relocated	4.2	6.0	8.8	13.8	75.3	959	44470
53	+15	Minor increase	4.1	5.8	8.7	13.3	75.3	959	44482
60	+30	Major increase	3.9	5.5	7.6	12.4	75.3	959	32874

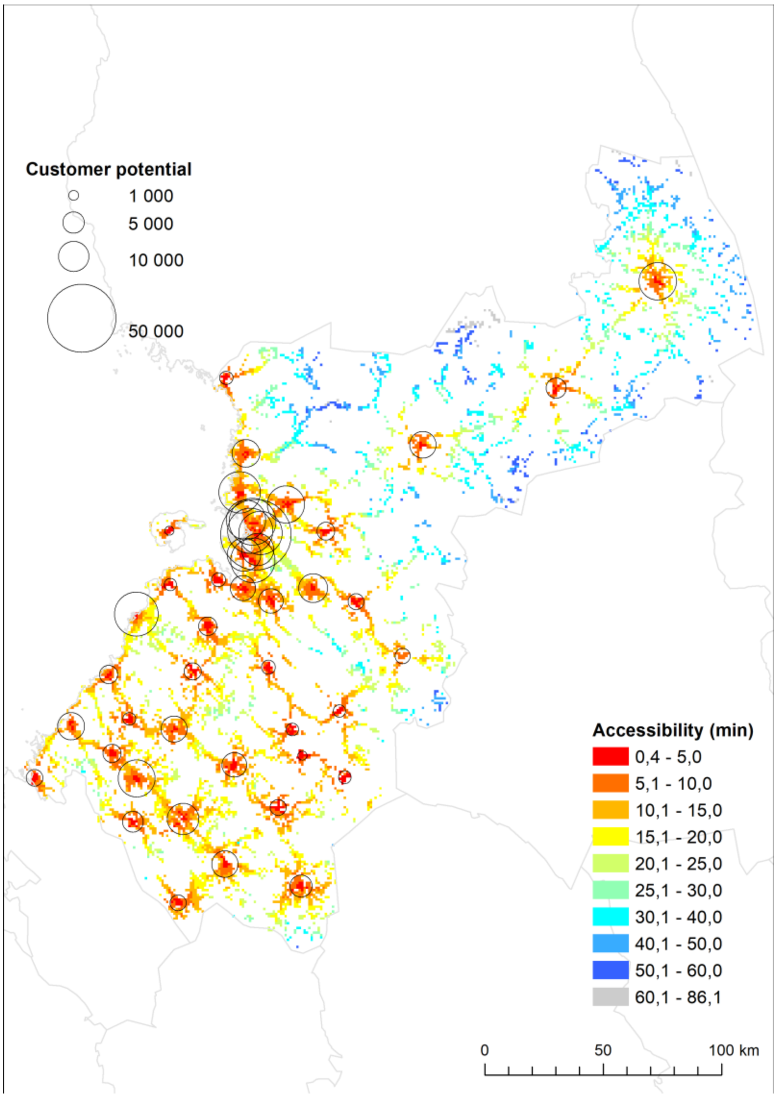

Figure 1 Health centres, their accessibility by car and customer potentials in Northern Ostrobothnia.

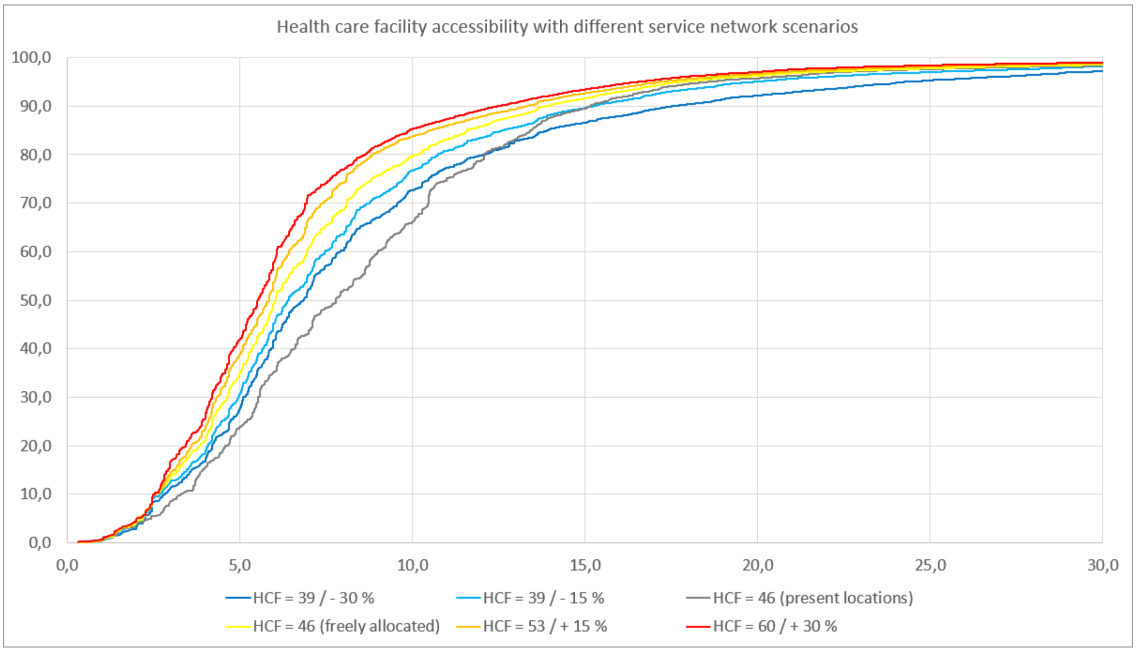

Figure 2 Location-allocation scenarios and health centre accessibility of population by car.

Reducing services with 15 % or 30 % does not affect remarkably to accessibility in general when service sites are optimally located. However, if the number of service units are reduced, in southern parts of the study area, some smaller municipal centres having low population will have certain weakening in accessibility, if services are allocated in sight of the region´s whole population. In majority of the areas, a slight increase in accessibility is achieved, by relocating services. However, the effect to accessibility is inside 5 minutes increase or decrease, which may be considered as a marginal change.

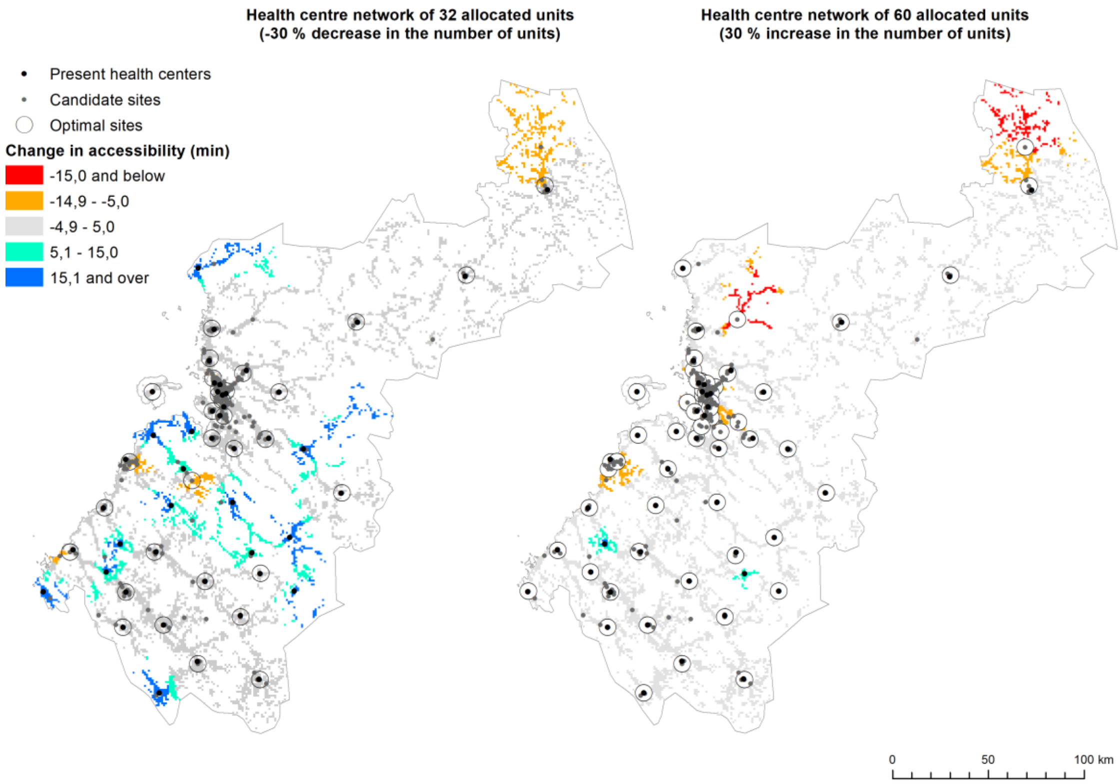

Figure 3 Accessibility effects in -30 % and + 30 % unit change based location-allocations.

4. Conclusive discussion

Optimising effectiveness of service accessibility is easier than measuring spatial equality, as some part of population will always have longer distances to services. Thus, decent service level for majority of the population is a useful target for allocation. However, the equality in service accessibility is rather a high-level, when equality measures such as Lorenz curve and Gini coefficient, which were tested during the preliminary analyses, were unable to indicate the minor differences in accessibility, as the worst inequalities cover such a small share of population. As a slight improvement of good accessibility may not matter so much than guaranteeing decent accessibility for the great majority of population, updating the p-median analysis distance decay with more specific functions would be needed. Common linear, power or exponential functions cannot ignore e.g. travels shorter than e.g. 5 minutes, which would balance the optimisation process much.

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Biographies

Ossi Kotavaara is postdoctoral researcher in the field geoinformatics and GIScience with focus on accessibility and geospatial analytic. More precisely the research focuses to transport accessibility analysis of population and freight, analysing spatial patterns and dynamics in population or society, and applying statistical methodology in spatial context with empirical-explorative perspective.

Timo Pohjosenperä is managing multidisciplinary healthcare logistics research projects in Oulu Business School. Close themes in qualitatively oriented research are logistics value, value co-creation, resilience and service modularity. In these studies, accessibility and location-based questions are analysed with the researchers in the field of geoinformatics.