Accessibility analysis of public services in rural areas under restructuring

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Abstract: Finland is currently undergoing a restructuring of the municipal and public service structure. This restructuring is an effort to react, in addition to tightening economy, to the changing circumstances with regard to the demographic structure, especially in rural areas. This paper examines the use of geographical information systems (GIS) to analyze the spatial accessibility of public services and unearth differences in the accessibility of different demographic subgroups in a rural municipality with a developed road transport network, but declining population and economy. The potential for applying GIS methods to future rural development and policies, in light of an increasing trend of municipal merges, is also discussed. This paper seeks to show that GIS driven demographic analysis are valuable in exposing equality issues and differences between possible locations when provision of public services is planned. Datasets used in this research are digital road network data covering the full extent of the Finnish road network and population grid data including the population of Finland in various demographic subgroups on a 1 km × 1 km grid cell size. Such datasets offer a unique insight into the spatial division of population and transport possibilities. Accessibility varies for different demographic groups and this can be projected and numerated by the use of two GIS methods: relative accessibility measures and average distance measures.

Introduction

Finland, with the majority of Europe, is in the final stages of demographic development, also facing a state of degeneration in peripheral populations with a strong trend of urbanization highlighting the struggle of maintaining affordable public services in rural and peripheral areas. Finland however has some characteristics that differ from the central areas of Europe. It is located in the north-eastern fringe of the European Union and is a large country in relation to its small, scattered

population (Tervo 2005). Thus, Finland's population centers are generally separated by long distances. Finland is very peripheral in the European context not only by geographic location, but also by different peripherality indexes (Schürmann & Talaat 2002). Also, it is noteworthy that areas that are peripheral on the Finnish national scale can be seen as extremely peripheral on the European scale (Spiekermann & Aalbu 2004). Generally this means, that while discussing European rural areas as a whole, Finnish rural areas are arguably different in terms of population density

and peripherality. This is to say, that while there are peripheral areas around Europe, those areas can be seen as more central if looked upon from the viewpoint of Finnish rural areas and periphery. Also it is to be noted that population and services are often clustered, and peripheral areas often have low population and relatively poor access to services (Cromley & McLafferty 2002). This results in challenges in maintaining an affordable public service structure in rural areas. Of course, the notion of access to services and every day possibilities being a challenge in rural areas is not a new one (see for example Moseley 1979). While the field has been visited before, the changes happening in the municipal structure and recent developments in geographical information systems (GIS) techniques and data available offer an interesting field to study. This paper also sets to utilize the chance of using spatially accurate demographic data as the population data input and more importantly the chance of analyzing spatial accessibility of services for different parts of the demographic: the youth, the working adults and the elderly.

As Tanser *et al.* (2010) put it: "*Optimal locations can be modeled to improve existing systems, while this is potentially useful, it might not lead to implementation because of the huge costs involved in changing expensive and entrenched health care systems.*" While the quote discusses health care, the issue is the same with other forms of services. This is why the primary aim of this paper is to analyze the accessibility of different public service locations already in place. This means that rather than trying to allocate and completely rearrange regional systems, this paper seeks to produce information for regional

policy makers, municipal decision makers and planners to make subtle shifts into the spatial formation of public services.

Periheral services and regional structure

Generally, municipalities in Northern, Eastern and Central Finland are large in terms of land area, which can be also seen in the map (Figure 1). In addition to this there are many municipalities with very small populations (Statistics Finland 2010). The municipal structure of Finland is however changing. The population is moving into centers while the rural areas are declining and facing a set of future challenges. Rural areas are declining in terms of total population and also the demographic structure is transforming in such a way that the number of the elderly is increasing while the number of children is declining. Demand for basic services is changing in different sectors, such as healthcare and education. The change is such that the need for some services is growing while others are declining. This is especially exemplified in areas with low number of children and high numbers of elderly citizens. Thus while the need for childcare might be declining, the need for care for the elderly might be crowing drastically. While Finland as nation is becoming increasingly urbanized, in the context of the European Union it has many areas that can be characterized as very rural and of a low population density. This means travel distances are most often long in the European context and there are vast uninhabited areas between population clusters. There are some 78,000 kilometers

Figure 1. Finnish municipal system and the study area of Siikalatva.

of public roads in Finland and most of the private transportation in Finland takes place via private car, even more so in rural areas where public transport possibilities are limited.

In Finland, local municipal authorities have the responsibility to provide basic services to citizens. Two consecutive Finnish governments have maintained a positive attitude towards restructuring of local governance and services since 2005 (see Virkkunen 2013). This has resulted in various municipal merges in yearly basis, which is arguably a very special set of events involving a large number of citizens. The number of municipalities has gone down

from 432 to 320 in the span of eight years. In the near future, even more municipal merges are very likely. Merges can lead to situations in which public services must be reorganized by cutting overlapping services and centralizing them, as economic issues are often a driving force behind the merging process. For the municipalities struggling with the economic issues following the decline of rural areas ensuring proper public services for its citizens can be a challenge. On this background, information on how accessible public services are for different parts of the demographic is very valuable for planners and decision makers.

In this paper, the municipality of Siikalatva is used as a case of a rural municipality with a recent municipal merge, which took place in 2009. Siikalatva is a municipality having a polycentric structure and Spiekermann and Aalbu (2004) consider it to be *extremely peripheral* in terms of accessibility in the European context. Siikalatva is a municipality of approximately 6300 inhabitants living in an area of 2230 square kilometers. This equates to a population density of 2.8 inhabitants per square kilometer. However, as is the case in most of Finland, the population is clustered in municipal centers and the municipality has a lot of unhabited land area. Siikalatva has four municipal centers: Rantsila, Pulkkila, Kestilä and Piippola, that each used to be separate municipalities but are now merged and form Siikalatva. The map of Siikalatva including the population data gives a good overview of the study area (Figure 2). The classification of populated areas is based on Rusanen *et al.* (2004), with adjustments to the class names by the authors to better display the

spatial distribution characteristics of the population in the Siikalatva area.

Reseach design

The aim of this paper is to examine GIS as a tool for analyzing the accessibility of public services in a rural municipality that has gone through a municipal merge and now consists of more than one roughly same-sized center. Access to public services is calculated for the municipal centers for the youth, the working aged and the elderly. GIS have been traditionally used in assistance of decision making in location allocation problems in the field of business facility planning (for example Clarke & Rowley 1995; Cheng *et al.* 2007; Yu *et al.* 2007; Church & Murray 2009) and there are some examples in which GIS have been used for service planning (for example Tanser *et al.* 2010).

There are several advantages in using GIS as a tool to analyze public service related issues, as listed by Richards *et al.* (1999), GIS data from various sources can be combined and linked; GIS provides several new types of data; new GIS methods can be added as tools to be used by the planners; maps produced using GIS can illustrate issues more efficiently than graphs and tables. While Richards *et al.* (1999) discuss GIS with a focus on healthcare; the same GIS approaches can be used for different forms of services.

It is understood that applied accessibility research can be used in planning when provisioning social services (Kwan *et al.* 2003). Quite often GIS methods for analyzing accessibility are used in
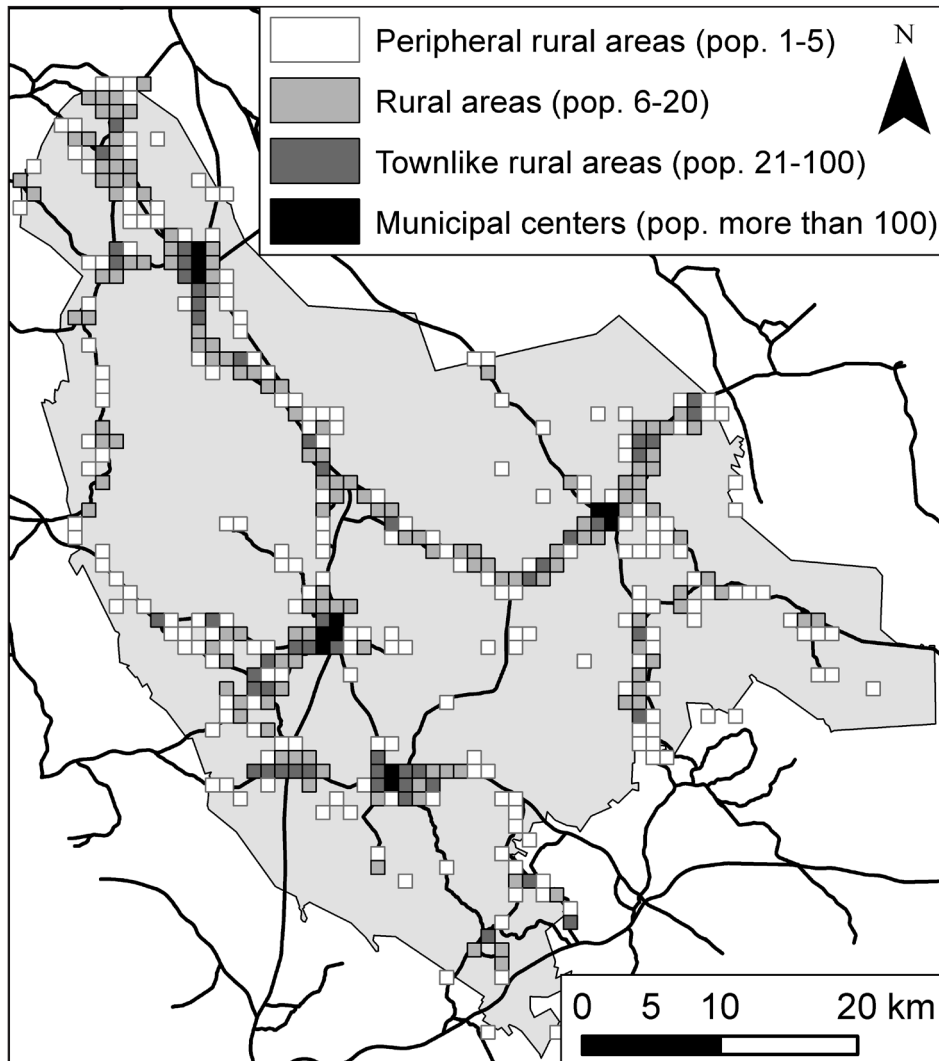
Figure 2. Demographic characteristics and the major roads of Siikalatva area.

urban planning (for example Liu & Zhu 2004) and often in rural areas without a developed transportation network, such as in developing countries. In this paper, however, while the area of focus is by all means rural, the road transport network is quite well developed and fulfills the role of a major means of transportation.

The aim of this paper is to touch on the set of intertwined issues of policies, political issues, demographic trends, regional development and change in municipal structure and public service (re-) organization with GIS and demographic analysis by seeking to answer two questions. The first question this paper seeks to answer

is, do the four municipal centers in Siikalatva differ in terms of network accessibility considering different age groups and if so, how? From there on, the second question is, are relative accessibility measures derived from potential accessibility measures and average distance measures useable in a rural setting in order to analyze accessibility to public services?

Data

The population database used in this paper consists of 1×1 km grid cells and includes a wide array of social and socioeconomic variables and most importantly considering this paper; the population is also classified into demographic groups. (Statistics Finland 2010) The data is constructed from various civil registers and is updated yearly. The population of each cell is derived from the actual number of residents in the addresses inside the cell area. This means the data is very accurate when it comes to spatial structure of the demographic and more reliable than datasets constructed from censuses or estimates. The data variables used in this paper are total population, youth (population under 20 years of age), working aged (population from 20 to 63 of age) and the elderly (population older than 63 years of age).

The digital road network data (DigiRoad) used in this research portrays the full extend of the Finnish road network in metric accuracy. The data is maintained by the Finnish Road Administration (2010). The dataset includes speed limits for each section of the road network and the length of the sections, which can be derived from

the spatial locations of each of the segments starting and ending points. Thus the dataset can be used to estimate travel times with the assumption that one travels at the highest legally possible speed when aspiring to reach public services. The road network used in the analysis involves Siikalatva area with a buffer of 20 kilometers outside the municipal boundaries to involve paths that might take place outside the municipal borders and return inside the municipal borders before reaching the destination.

Theory and calculation

Accessibility in a rural setting

For *access*, there are arguably a plethora of indicators and definitions. Ricketts (2010) has listed some concerning healthcare, defining *accessibility* is somewhat of an easier task. Accessibility is simply put, the ease by which a place can be reached from another place (Liu & Zhu 2003). To be more precise, accessibility is the measure of the capacity of a location to be reached by, or to reach different locations (Rodriguez *et al.* 2009). In this research accessibility is seen as the extent to which the land-use system enables individuals to reach their destinations, which are in this case public services (see Geurs & Ritsema van Eck 2001). In this case the form of access measured is in its essence *spatial access*, meaning that the focus is on spatial distance variables (length or time), rather than for example social issues (see Lou & Wang 2003 for more), which could (and by all means should) be a field studied elsewhere. However, we argue that GIS works very well as a methodology

for evaluating spatial access using a more numeric approach.

As a basis and an enabling factor on which the analyses are made, an assumption concerning public service is made. It is assumed that in a rural setting the vast majority of services are located in municipal centers. Therefore, the destinations used in the GIS analyses are located in the municipal centers, which were identified by the researcher by viewing the population grid data and the road network data. The destinations were selected from the grid cell of the highest population and from the basis of the network topology. The factual center (or the 'main street') was identified as the assumed location of public services. While identifying the actual center or assumed public service locations might be difficult or impossible in an urban setting, it can be done quite reliably in very sparsely populated rural areas, where the municipal centers stand out from the spatial demographic surroundings and the road network thickens in a very noticeable way, as seen on the map displaying the road network topology of the Siikalatva area (Figure 3).
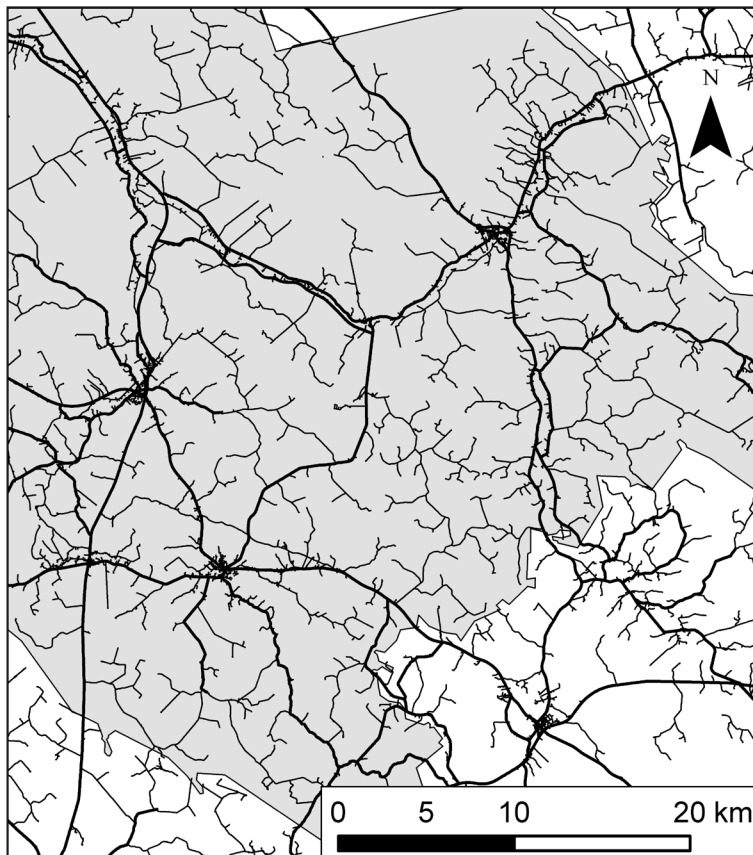

Figure 3. Excerpt of the road network shows that the centers are easily indentified.

Relative accessibility measures

Relative accessibility (also referred as potential accessibility or market potential) is arguably one of the most important practices of analyzing accessibility and has its roots in the history of spatial science (see for example Harris 1954). The accessibility analytical perspective of this study is, *how accessible is the select destination from all of the possible origins?* rather than asking, h*ow accessible are all the possible destinations of a system in relation to each other?*

The accessibility values are standardized into such a form, that the most accessible location gains the value one and the less accessible destinations gain values smaller than one and are theoretically asymptotical to zero. Generally, different destinations can be easily and unambiguously compared, because relative accessibility values do not tend to fall very close to zero in practice. It is to be noted however, that in this approach, accessibility values can only be compared for each of the destinations between the set demographic group, meaning that the values that can be compared against are on the horizontal rows of the table, in which the results are presented.

As relative accessibility has its core in potential accessibility, understanding how potential accessibility analysis works is crucial in order to fully understand the relative accessibility values produced in the analysis. Potential accessibility is a measure to describe how the population of other locations can be accessed from each location involved in the analysis by the transport network. By the analysis the centrality and peripherality of locations can be related numerically. The benefit of the potential accessibility analysis is the ability to differentiate between the clustered population concentrations and isolated concentrations, as well as peripheries (Geertman & Ritsema Van Eck 1995; Rodriguez 2006; Spiekermann & Wegener 2007). Potential accessibility of the population for each location can be calculated by dividing the population count of another location by the distance attribute such as travel time between the locations, and summarizing these values. The calculated value indicates how each location can reach an attracting attribute in other locations related to a transport friction. Hence, the clustered population concentrations as well as isolated concentrations and peripheries can be differentiated. The equation for this in the simplest form can be presented as:

$$\mathbf{A(P)} = \sum_{j=1}^{n} \frac{p_j}{d_{ij}^{\alpha}}$$

where $\mathbf{A(P)}$ is the potential accessibility matrix, d_{ij} is the distance between the location i and j, p_j is the attribute of the related destination location, n is the number of origins, and α is the parameter for the transport friction indicating the efficiency of the transport system and the interest to move. An increase of α will lead to a greater distinction between nearby and distant destinations. Ideally, α should be estimated empirically, but usually, like in the case of Siikalatva, there is no adequate survey information available to do this. The value is highly dependent on scale and the type of activity modeled. At a local level, higher values of α are typically used, but in national and international scale analyses α is assumed to be 1 (see for example Gutiérrez

2001; Holl 2007). In this case, values 1 and 2 were used for α which were applied also by Kotavaara *et al.* (2012). The former was used to denote linear friction increase involving "wider" potential accessibility, while the latter was used to estimate more locally focused potential accessibility with quadratic friction increase.

The potential accessibility analysis is often considered as one of the most essential accessibility analyses in theoretical terms, but it is used quite rarely in practice, which arguably is due to the requirements related to the GIS techniques. To the best of our knowledge there is no commercial software available for carrying out potential accessibility analyses. This being the case, in this study a Python script was applied in ArcGIS in order to compute needed calculations.

Average distance measures

The second measure used is average distance. The idea is to measure the average distance one person has to travel via road network to reach services. In this calculation the population weight in different habited grid cells is taken into account. Thus, the calculation is not merely of the average distance to habited areas, but for a single person. The average distance a citizen has to travel to a select location can be calculated with the following formula:

$$S_i = \sum_{j=1}^{n} \frac{p_j s_{ij}}{P}$$

Where the average distance S_i to location i is the sum of all destination's population p times distance s from origin j to location i divided by the total population P (or in the case of different demographic groups, the total of the population of the demographic groups in question). Empirically calculated network distance values are applied to the distance value to control the movement connecting the grid cells into the actual road network. As with relative accessibility, average distance values are also presented as actual length of travel in kilometers and also in standardized form. Average distance values are also standardized as such that the location of the longest average distance gains the value 1.

Results and discussion

Relative accessibility and average distance values

These analyses show that Pulkkila is the most accessible municipal center in the Siikalatva area (Table 1). There are however some variations and interesting differences in the accessibilities of the other three centers, especially when different age groups are involved in the analysis. This means putting the municipal centers into an order from the most accessible to the least accessible is a task in which careful consideration is needed.

For more detailed consideration, the relative accessibility values in table 1 are shown following a pattern of each demographic group being listed first with α having the value of 1 and then with α having value of 2. Standardized values are listed after the non standardized ones. As can be seen from the table, when α has a value of 2, the differences in accessibility

Table 1. the results of the calculations made in this study.

Accessibility index	Pulkkila	Piippola	Kestilä	Rantsila
Total population relative accessibility 1	23,45	19,62	15,77	20,12
Total population relative accessibility 2	0,36	0,26	0,17	0,27
Youth relative accessibility 1	5,18	4,50	3,71	4,28
Youth relative accessibility 2	0,078	0,057	0,037	0,049
Working aged relative accessibility 1	12,61	10,62	7,71	10,34
Working aged relative accessibility 2	0,18	0,14	0,076	0,13
Elders relative accessibility 1	5,61	4,50	4,35	5,50
Elders relative accessibility 2	0,096	0,061	0,054	0,083
Total population relative accessibility 1 standardized	1*	0,84	0,67**	0,86 ****
Total population relative accessibility 2 standardized	1*	0,72	0,47**	0,74 ****
Youth relative accessibility 1 standardized	1*	0,87 ****	0,72**	0,83
Youth relative accessibility 2 standardized	1*	0,74 ****	0,48**	0,63
Working aged relative accessibility 1 standardized	1*	0,84 ****	0,61**	0,82
Working aged relative accessibility 2 standardized	1*	0,75 ****	0,41**	0,73
Elders relative accessibility 1 standardized	1*	0,80	0,77**	0,98 ****
Elders relative accessibility 2 standardized	1*	0,64	0,56**	0,86 ****
Total population average distance	22.48 km	25.83 km	29.86 km	29.79 km
Youth average distance	23.37 km	26.62 km	30.15 km	29.56 km
Working aged average distance	21.92 km	25.34 km	30.10 km	30.04 km
Elders average distance	22.87 km	26.16 km	29.06 km	29.44 km
Total population average distance standardized	0,75 *	0,86 *****	1***	0,99 ***
Youth average distance standardized	0,76 *	0,88 *****	1***	0,98 ***
Working aged average distance standardized	0,73 *	0,84 *****	1***	0,99 ***
Elders average distance standardized	0,78 *	0,89 *****	0,99 ***	1***

* Pulkkila is the most accessible by all measures.
** Kestilä is the least accessible by relative accessibility measures.
*** Kestilä and Rantsila have essentially no difference in average distance values.
**** By relative accessibility measures, Rantsila is more accessible for the older population, while Piippola is more accessible for younger population.
***** Piippola is the second most accessible by average distance measures.

are more extreme. This is a result of the cost of moving along the road network and the will to make the trips modeled in the calculation have a stronger effect. To put otherwise, values with α being 2 seek to model the accessibility in a situation in which movement along a network is costly, difficult or undesired. Average distance values are presented in the same manner in table 1, below relative accessibility values.

As can be seen by scrutinizing all the measures, Pulkkila is the most accessible of the four municipal centers. This leaves little room for speculation, since the difference in accessibility is quite large in Pulkkilas's favour against the other three centers. This goes in such extremes, that with α value of 2, the accessibility of Pulkkila is more than double the accessibility value of the least accessible center (for example, the youth of Kestilä). On the other hand, some differences are not very large, for example accessibility values with α of 2, and there is hardly any difference between the elders of Pulkkila and Rantsila. The general superiority of Pulkkila can of course be explained by the central location of Pulkkila in the Siikalatva area. The other three centers however, offer many interesting points to address.

Kestilä is the least accessible of the four centers by the relative accessibility measures even though Kestilä and Rantsila have essentially no difference in average distance measures. However, the difference in relative accessibility values between Kestilä and Rantsila is remarkable. Spatially both are located in their respective corners of the Siikalatva area, which might be an explanation for the similarities in average distance values.

The division of data into three demographic subgroups unearths an interesting difference between Piippola and Rantsila. By relative accessibility measures, with both α values, Rantsila is more accessible for the elderly population, while Piippola is more accessible for the youth and the working adult segment of the population. Also, the advantage Rantsila has towards the elderly tilts the total population accessibility values in Rantsila's direction even though Piippola has much shorter average distance values for all the demographic subgroups. If the analyses would have been done only for the total population, this would not have been noticed.

Using GIS for accessibility analysis in a rural setting

Based on these empirical results, we argue that relative accessibility measures can be used to present differences in accessibility in a very simple form and the comparison of various locations is easy when this method is used. However, relative accessibility measures are somewhat abstract by nature and a few of the possible caveats should be mentioned. Firstly, in the method there is a step in which calculating how many people can be reached in a second takes place, which can be seen as being somewhat abstract. Secondly, any accessibility value does not carry any information when it is cut off from the other values of the relative accessibility matrix. Thirdly, potential accessibility measures used in the background are somewhat theoretical and a valuable question is: Do they even work

on a smaller scale, such as on the scale of a rural municipality? Caveats aside, we believe that as a method for aiding local knowledge based decision making in combination with other methods, such as average distance measures, relative accessibility is a sound method.

Average distance is of course in its very definition an average, a rough estimate of what the reality of a resident of the municipality in question is like. For a person living in a municipal center, the average distance values might seem outrageously high and on the other hand, for the residents living in the extreme periphery the values might be something to dream of. Nevertheless, average distance measures do provide a useable estimate of what the travel distances in the municipality are like, especially for the interest of making comparisons. However, average distance as a method of analyzing accessibility is best used in unison with other analyses and its usability lies in the practical nature of the values and easy comparisons, as travel costs, be they measured in distance or time used, are quite easily understood.

It is curious, that in some cases, like Pulkkila for example, relative accessibility values and average distance values are clearly in unison: Pulkkila is relatively the most accessible center and offers the shortest average distances. In some other cases, however, the two analyses might give different outcomes: Average distances for Kestilä and Rantsila are essentially the same, but corresponding relative accessibility values are strongly in Rantsila's favor. This is the result of nuances in the topology of the road network manifested in the accurately modeled data, spatial demographic structure

and the different locations of the municipal centers in relation to the network and the population.

Conclusions

We argue that by use of relative accessibility and average distance calculation with well modeled road network and accurate demographic data in GIS environment, this study has succeeded in proving its usability in analyzing public service accessibility and unearthing differences in the accessibility of municipal key locations for different parts of the demographic in a heavily road transport dependant rural setting. On this basis, we argue that these kind of measures should be taken into account in situations much like Siikalatva's merge that are taking place in Finland as part of the municipal restructuring, or in any similar processes wherever they might be taking place (and we are of the belief that such reorganizations have been and will be taking place around Europe with similar processes of outmigration and urbanization), be that the necessary data is available. Our notion here is that the methods built for analyzing large-scale economic behavior have to be applied carefully and with consideration when operating in on local and rural scale and variables must be selected carefully, as was done in this study.

It is to be noted, that while Farrington and Farrington (2005) do give credit to empirical measurements of accessibility as a way of gaining some general vision on the (rural) accessibility, they deem them as normative and imbued with value judgment. However, we feel that in this paper we have

managed to take this into account and view accessibility as a relative and an abstract measure rather than voicing opinions how public services in rural areas should or need to be accessed, while still maintaining functionality in decision making processes taking place outside the academic world.

However, as far as decision making processes go, we argue that there is generally not enough spatial and demographic information on spatial accessibility available to decision makers. We firmly state that GIS analysis should be taken into account more often when making large- scale reformations in services. However, accurate georeferenced demographic information is not always available to decision makers. Also, the role of quantitative information may be avoided in politics, due to its technical and revealing nature. Spatial accessibility is however not always a straightforward phenomenon that can be grasped without diving into demographic analysis in order to reveal possible unseen factors. This can be seen very clearly from the differences in accessibility for the different parts of the demographic. We are of course certain that accessibility has many forms and measures with spatial network accessibility being only one side of the issue. However, we are of the belief that the methods presented in this paper can be applied to various problems in various locations and scales. The methods excel in changing a challenging multidimensional spatial reallocation problem into a form in which it can be grasped without extensive academic knowledge and thus could be of broader use in Finnish rural decision making – or anywhere else such reorganizations are being made.

Role of the Funding Source

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