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Spatial Accessibility Assessment of Homecare Workers to the Older Population in the City of Zurich

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Abstract. Access to homecare is paramount for the older population wishing not to move to retirement homes. In Zurich, the organization "Spitex Zürich" is the public homecare provider, allowing the older population to experience high-quality life at home through regular visits. A major factor for ensuring self-determined living for the older population consists of a detailed understanding of the spatial accessibility to Spitex locations. Therefore, this paper is concerned with applying four different FCA methods for assessing the spatial accessibility of Spitex homecare workers to people aged 65 + in Zurich through the road and bike networks. The modified-Huff-model-three-step-FCA method is found to be best suited for modeling potential spatial accessibility in Zurich. Spatial accessibility index values show similar geographical distributions regardless of transportation mode. The neighborhoods of Seebach and Hottingen are identified as regions with relatively low spatial accessibility. Our findings contribute to a better understanding of the interpretation and the measurement of spatial accessibility, thereby facilitating autonomous living for the older population residing in Zurich, ultimately increasing the inclusiveness of the city.

Keywords. Spatial accessibility, floating catchment area method, homecare, older adults, inclusive city

1 Introduction

In 2020, 19% of 8.7 million people living in Switzerland were aged 65 + (BFS, 2020a), with the expectation to increase in the next few years. Additionally, there is a strong desire among the older population for self-determined living at home (Sidler, 2020). To ensure this, homecare plays a crucial role in Switzerland. Within Zurich, "Spitex Zürich" has a public mandate to ensure homecare in the city (Gebhardt, 2013). Out of the 10,000 clients, the organization supports over 75% aged 65+ (Spitex Zürich, 2022). A widely applied method to assess the distribution of public services such as healthcare is spatial accessibility analysis, describing the ease of access from a particular point to relevant infrastructure (Luo & Wang, 2003; Vo et al., 2015). The measurement of spatial accessibility incorporates supply, demand, and mobility, (see Fig. 1). Spatial accessibility combines the availability and accessibility of services or infrastructure to the population, allowing for the description of potential accessibility.

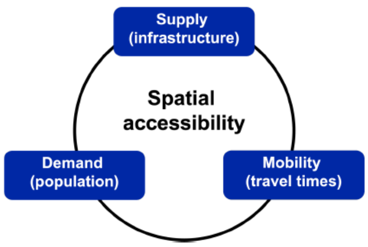

Figure 1. Spatial accessibility elements

According to Penchansky & Thomas (1981), non-spatial accessibility aspects like accommodation, affordability, and acceptability are neglected. Therefore, spatial accessibility does not describe the realized accessibility. Assessing spatial accessibility is nevertheless paramount to evaluating how well service provision matches the population distribution (Jörg et al., 2019), highlighting disparities in accessibility across a specific area. In healthcare, floating-catchment-area (FCA) methods provide a state-of-the-art approach to assessing spatial accessibility.

Due to the abundance of FCA methods, there is limited insight concerning which method is appropriate for different accessibility-related studies. Previous studies using FCA methods usually focus on the general population (Luo & Qi, 2009; Jörg et al., 2019), looking at accessibility of primary healthcare (Guagliardo, 2004), and following the conceptual model of the demand traveling to the supply. The assessment of spatial accessibility of sociomedical institutions, such as homecare, has been neglected so far. Furthermore, FCA methods can also be applied when travel directions are reversed, as is the case for homecare. In addition, previous studies (Luo & Qi, 2009; Yang et al., 2006) predominantly deal with a large study area and strongly aggregated population data. While Grüebler et al. (2021) apply FCA methods to the entire Canton of Zurich, analysis incorporating high-resolution population data in the city of Zurich is missing.

Therefore, we aim to answer the question of how spatial accessibility of Spitex workers to the older population varies geographically within the city of Zurich, thereby exploring a novel, fine-grained setting with respect to location, scale, target population, and conceptual model. The approach allows us to identify regions with relatively low accessibility, which would profit from additional facilities. Since Spitex workers in Zurich visit their clients by car and electric bikes, we further investigate whether there are significant differences in accessibility between these two transport modes. By implementing the FCA methods outlined in Table 1, we intend to determine how different approaches impact the measurement and interpretation of spatial accessibility, while also assessing which method is better suited for our problem. Based on the observations by Jörg et al. (2019), the modified-Huff-model-three-step-FCA (MH3SFCA) method is expected to be most suitable.

2 Data and Methods

2.1 Data and data processing

High-resolution population data by the BFS (2020b) of people aged 65+ for every 100x100m raster cell in Zurich will act as the demand, while the location of Spitex facilities (Stadt Zürich, 2016) will serve as supply points. Due to a lack of data, the capacities of the Spitex facilities are defined by evenly distributing all Spitex workers over the 15 locations (Spitex Zürich, 2022). The geographical distributions of the population and Spitex locations are displayed in Fig. 2.

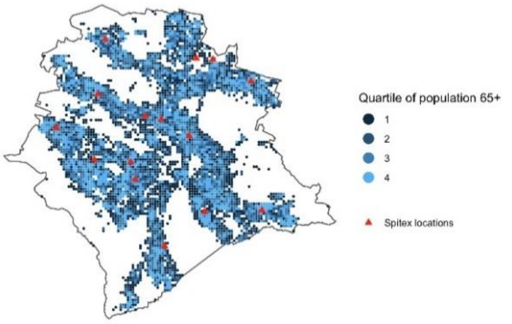

Figure 2. Spitex locations and population aged 65+ in Zurich.

Since Spitex employees use cars and electric bikes to visit their clients, we incorporate the road and bike network, Fig. 3, provided by Stadt Zurich (2021; 2022) to separately calculate the travel times between supply and demand in the form of an origin-destination (O-D) matrix using the QGIS plugin QNEAT3. Regarding the road network, we assumed velocities of 50km/h for main roads and 30km/h for side roads. To account for traffic, a correction factor of 1.3 was applied to the O-D matrix. This factor was determined by manually comparing 30 values returned by the O-D matrix calculation to the effective travel times according to the Valhalla routing engine (Valhalla contributors, 2018), which can account for traffic. Regarding the bike network, we assume a constant speed of 20 km/h since inclination is a negligible factor for electric bikes.

2.2 Method

FCA methods are concerned with calculating a spatial accessibility index (SPAI) for every population point. The calculation of the SPAI is conducted with respect to dynamic catchment areas, whose radii determine the maximum distance at which locations are still considered

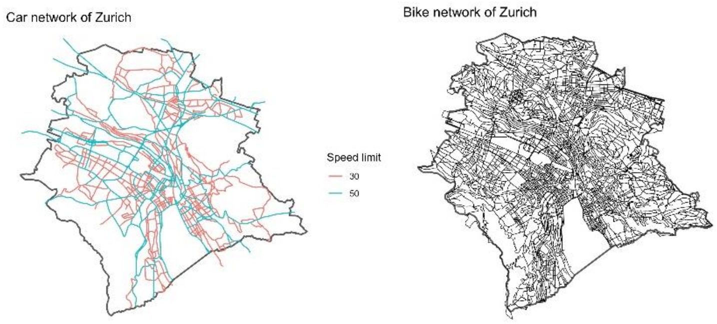

Figure 3. Road and bike network of the city of Zurich

accessible (Jörg et al., 2019). We compare four FCA methods, whose properties are summarized in Table 1.

- 2SFCA: two-step-FCA (Luo & Wang, 2003)
- E2SFCA: enhanced-2SFCA (Luo & Qi, 2009)
- 3SFCA: three-step-FCA (Wan et al., 2012)
- MH3SFCA: modified-Huff-model-3SFCA (Jörg et al., 2019)

We use FCA methods over traditional spatial accessibility indicators since they enable the conservation of the first four properties listed in Table 1. We use a value of $d$max=10 minutes for the size of the FCAs, which is a reasonable maximum time for Spitex employees to reach their clients. Furthermore, this value seems sensible, as Grüebler (2021) uses a value of 20 minutes for her large-scale analysis. We abstain from the generation of subzones and instead directly incorporate the continuous distance measurements into the calculation.

Grüebler et al.'s (2021) package was used to calculate the 3SFCA methods in R, while the 2SFCA methods were manually implemented. As the E2SFCA can consider relative distances, we incorporated distance weights using a Gaussian Weighting function (Equation 1).

The distance friction coefficient β was calculated to satisfy the condition $f(d\text{max})=0.01$ (Bauer & Groneberg, 2016).

$$f(d) = e^{\frac{-d^2}{\beta}} \quad (1)$$

2.3 Data availability and software

All datasets and software utilized in this study are openly available. The script used to generate the results, together with the precise datasets and a README file, are accessible through our GitHub repository. The analysis was conducted using R (R Core Team, 2022) and QGIS (QGIS Development Team, 2022).

3. Results

The results of the analysis can be viewed in Figure 4. For better visualization, the quartiles of the SPAI are used. Analogously to the methodology proposed by Fransen et al. (2015), we normalize the SPAI values and calculate the difference between the transportation modes to create difference maps, highlighting which areas are better accessible by car or by bike.

3.1 2SFCA

2SFCA method results in high SPAI values towards the city center, where many Spitex facilities can be reached within 10 minutes, since alternative supply options cannot be accounted for, causing the demand to be overestimated in these regions, Fig. 4. For the 2SFCA method, accessibility is defined by absolute distances, which further amplifies the effect. Furthermore, the SPAI values in the peripheral regions such as Wollishofen, Witikon, or Schwamendingen are low (Appendix, Fig. A1), despite these neighborhoods containing Spitex facilities. These effects are especially pronounced for the road network but are also visible for the bike network. Based on the difference map, locations in the city center seem to be better accessible by car, while SPAI values tend to be higher for the bike network in the city's outskirts.

3.2 E2SFCA

Compared to the 2SFCA, the E2SFCA accounts for relative distances. Thus, the SPAI tends to decrease with increasing distance from Spitex facilities for both transportation modes, Fig. 4. The population points in the outskirts close to a Spitex facility that showed low accessibility for the 2SFCA method are now highly accessible, while the regions around the northern shore of the lake become relatively inaccessible. There is a shift of high SPAI values from the city center towards the outskirts. The difference map shows that the E2SFCA favors the road network; only population points in the immediate vicinity of Spitex facilities are better accessible by bike.

3.3 3SFCA

The 3SFCA additionally considers supply competition, the lack of which leads to an overestimation of demand in regions with alternative supply locations by the 2SFCA methods. This is reflected in Fig. 4, showing that the SPAI values decrease in the city center, where there are multiple Spitex locations. The high accessibility trend towards the outskirts is even more apparent. These effects are especially pronounced for the road network, while the result obtained through the bike network looks similar to the E2SFCA case. In both cases, the SPAI values decrease with increasing distance from the Spitex locations, since the 3SFCA also accounts for relative distances. The difference map shows the 3SFCA favors the road network; only population points around the facilities in Wipkingen and Oerlikon are better accessible by bike.

Table 1. Properties of different FCA methods (adapted from Jörg et al., 2019).

Properties	2SFCA	E2SFCA	3SFCA	MH3SFCA
Consideration of demand competition	x	x	x	x
Results are independent of the analysis unit	x	x	x	x
Dependencies among analysis units are reflected in the results	x	x	x	x
Consideration of multiple supply options	x	x	x	x
Consideration of relative distances (within the max. radius)		x	x	x
Consideration of supply competition			x	x
Consideration of relative and absolute distances				x
Constant total demand per population				x

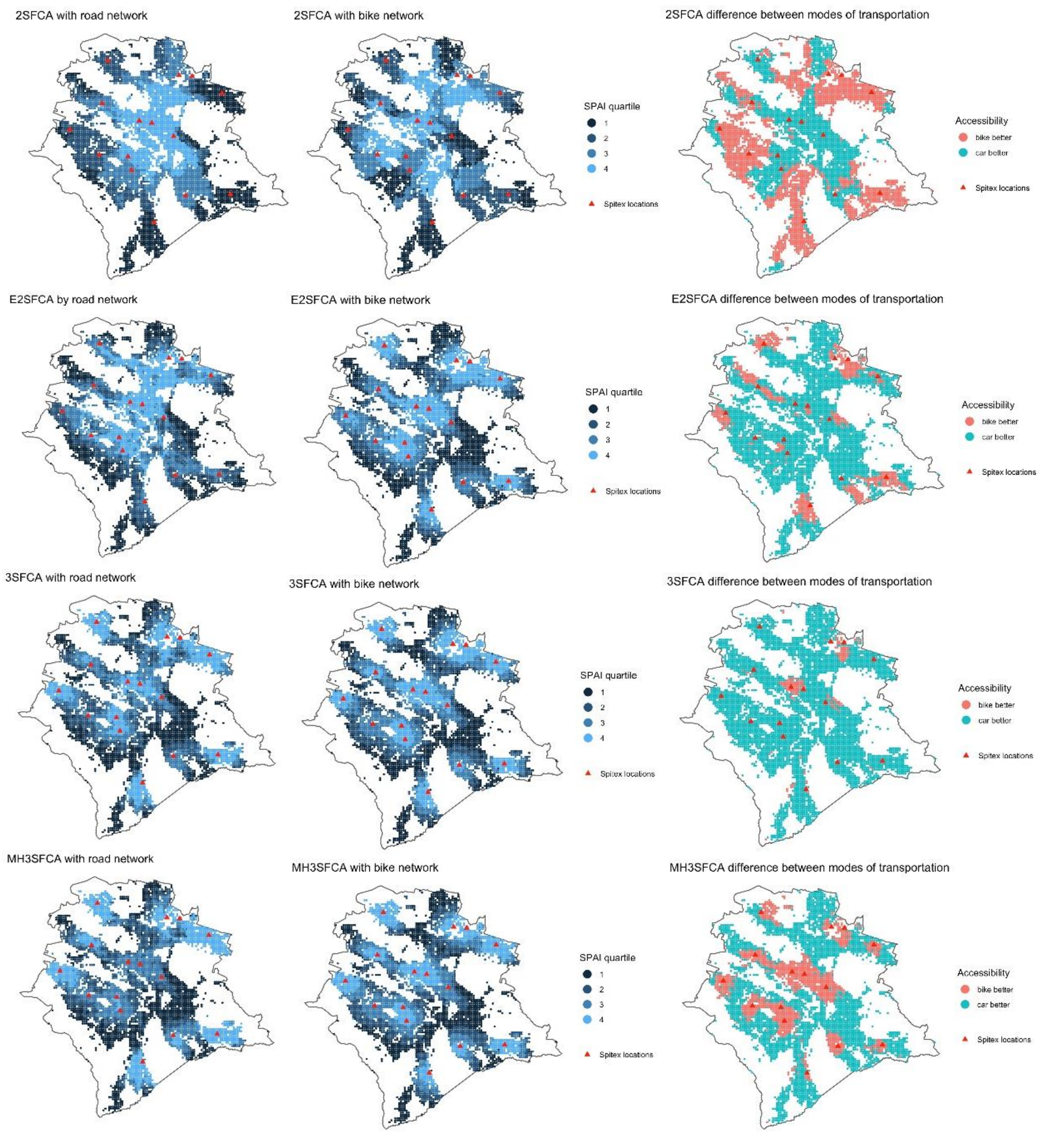

Figure 4. SPAI values from FCA methods for road and bike networks and difference map between transportation modes.

3.4 MH3SFCA

Compared to the 3SFCA method, MH3SFCA can keep the total demand per population constant, implying that higher supply does not automatically induce higher demand. Fig. 4 shows that the SPAI values decrease with increasing distance from the supply locations for both networks, but the effect is more pronounced for the bike network. The high SPAI values are narrowly concentrated around Spitex locations. The distributions of SPAI values obtained are similar to the result from 3SFCA. The difference map shows that population points near a Spitex facility are better accessible by bike, while the other population points are better accessible by car.

3.5 Correlation analysis

Fig. 5 shows a pairwise correlation analysis of SPAI values obtained from different methods. Overall, the correlations between the results are high since all methods partly consider the same aspects. The correlation is especially high between the 3SFCA and MH3SFCA, regardless of transportation mode. The only exception is the 2SFCA, which exhibits a low correlation compared to the other methods for both transportation modes. The correlations for the different transportation modes when keeping the method constant are high at 0.54, 0.7, 0.83, and 0.84 for the 2SFCA, E2SFCA, 3SFCA, and MH3SFCA, respectively.

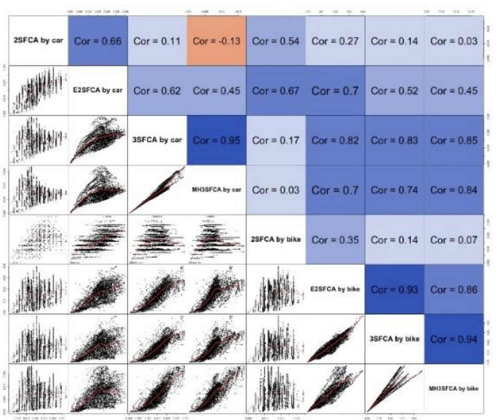

Figure 5. Correlation analysis between FCA methods.

4 Discussion

4.1 Method

As the SPAI maps show, from 2SFCA to MH3SFCA, the high accessibility values move from the center to the outskirts of the city. For 3SFCA and MH3SFCA, the highest SPAI values are concentrated around the Spitex facilities on the outskirts of the city, where older people mainly reside (Fig. 3). The main reason is that the 2SFCA methods do not allow consideration of supply competition and constant total demand, leading to an overestimation of demand and accessibility in the city center. As the comparably small correlations between 2SFCA, E2SFCA, and 3SFCA indicate, relative distances and supply competition are most important. Conceptually, MH3SFCA is the most appropriate method for our problem because we are focusing on the potential spatial accessibility, and the method assumes constant total demand among the population. However, as the results of MH3SFCA and 3SFCA and their correlations show, the consideration of constant total demand does not significantly affect the outcome in our setting.

4.2 Spatial accessibility in the city of Zurich

By comparing the results of MH3SFCA for both transportation modes with the distribution of the older population, Hottingen, and Seebach can be identified as the two regions with low spatial accessibility. With an additional Spitex facility in these two neighborhoods, the potential spatial accessibility could be improved. The relatively low spatial accessibility to the people in Seebach is surprising because there are two Spitex facilities nearby in Oerlikon. While the MH3SFCA difference map shows that locations around Spitex facilities are better accessible by bike, the classified SPAI values show a similar pattern for both transportation modes.

4.3 Conclusion and further research

By applying various FCA methods, we modeled the spatial accessibility of Spitex employees to the older population in Zurich. The relative SPAI values show similar geographical distributions, regardless of transportation mode. Thematically, our study identifies the neighborhoods Hottingen and Seebach as regions within Zurich with relatively low spatial accessibility of homecare. Additional Spitex facilities in these neighborhoods could contribute to self-determined living for more older people and increase the inclusiveness of the city.

Methodologically, the MH3SFCA method is the most suitable approach to assess the potential spatial accessibility of Spitex workers to the older population, given our small study area and high-resolution population data. The validity of our results is inherently affected by our conceptual model: To allow for the application of FCA methods, Spitex employees are assumed to always visit their clients starting at a Spitex facility. In reality, Spitex employees may consecutively visit multiple clients in an area before returning to a Spitex facility, which could significantly alter the results. Furthermore, the data and data processing also impose limitations on our results. We could not obtain information regarding the distribution of Spitex employees to the facilities. One location could host a disproportionate number of employees, affecting the spatial configuration of accessibility. Additionally, our rudimentary approach towards traffic modeling leads to a distortion of the travel times by the road network, as temporal variations in traffic flows are not considered. Future research could incorporate more sophisticated traffic modeling, leading to better estimates of the travel times between the population and homecare workers. Furthermore, a holistic approach that accounts for both potential and realized accessibility combined with a complete dataset could enable a more profound understanding and evaluation of the accessibility of Spitex employees to the older population within Zurich.

Acknowledgments

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Appendix

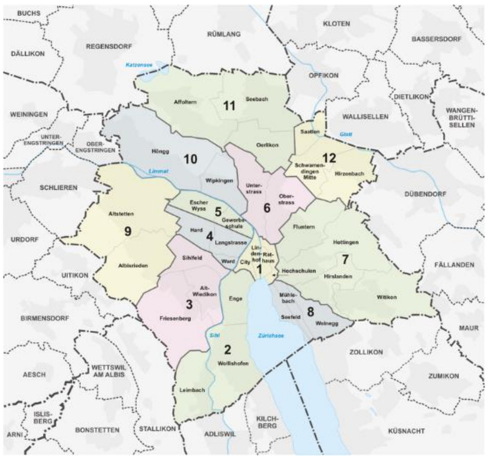

Figure A1. Zürich Neighborhoods, CC BY-SA 3.0,

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