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Resident group specific accessibility analysis and implications for the Great Helsinki Region using Structural Accessibility Layer

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ABSTRACT

This research analyses accessibility for different age population groups in the Great Helsinki Region (GHR). After discussing previous approaches done in the GHR, the authors use the *Structural* Accessibility Layer (SAL) as a tool for accessibility categorization for a grid with 8325 zones. SAL method was applied to assess accessibility categories for specific age population groups and the spatial distribution of the groups was used for identifying potential areas for urban development or requiring additional service allocation. The results for the general map show that 74,52% of residents have access to the services with public transport; however dissimilarities appear when calculating accessibility for specific groups: while 39,6% of pensioners enjoy accessibility by all transport modes, 32,8% and 32,0% of students and children between 0 and 7 years old reside in areas of car-dependent accessibility. The findings highlight the benefits of population group specific accessibility measures. Urban and transport planners of the region have validated the method derivation as a useful and reliable approach for public services planning and accessibility forecasting. Authors propose this accessibility approach for management of public services allocation and further research is indicated.

1. Introduction

In many cities all over the world there is a growing concern over car dependence and strategic decisions have been made to support more sustainable modes of transportation (European Comission, 2007; Banister 2008; Deng and Nelson 2013; EEA, 2013). Consequently, in all planning exercises, it is increasingly important to model accessibility not only for car, but more importantly for the existing public transport network and for non-motorized transport, in order to guide future policies and reallocate public services in the urban area.

The measurement of accessibility and its use for the optimization of the location of services is especially relevant in fast growing and changing urban areas, where the changes of services and transport network are in need of a more intense re-design. Accessibility has been defined in various ways by different authors (see for example Geurs and van Eck (2001, 2003), Bhat et al. (2000), Geurs and van Wee (2004) or Bertolini et al. (2005) for a complete review). In the current paper, the accessibility is based on the definitions proposed by Bertolini et al. (2005) as *“the amount and diversity of places that can be reached within a given travel time and/or cost”* (page 209) and Geurs and van Eck (2001) as *“the extent to which the land use-transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport mode(s)”* (page 36).

Ensuring similar levels of accessibility throughout a given urban area has been an often-used policy in order to reduce transport related social exclusion between neighbourhoods. In this sense, a balanced transportation network and a judicious spatial distribution of public services, such that all residential areas have good accessibility, are tools often used in urban planning and policy making. However, this practice it is based on the False Assumption of Older Cohort Homogeneity firstly observed by Davies and James (2011). Davies and James showed that the dissimilarity between individuals, even under the assumption that all other variables/characteristics were equal through them (e.g. income level, education, household structure), is too large, to consider the group a homogeneous cohort in the accessibility studies. Therefore, age population groups should be subdivided in sub-

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groups as homogeneous as possible. Previous research papers focusing on different age groups have emphasized the importance of this subdivision of the groups, to obtain detailed accessibility measures. For example, elder population has been considered in specific studies (see for example Frändberg and Vilhelmson, 2011; Horner et al., 2015; Love and Lindquist, 1995; Mercado et al., 2010 or Sikder and Pinjari, 2012). However, to our knowledge, no approach so far, examined all population groups. Moreover, no attempt has been done to measure group-specific accessibility in the Great Helsinki Region (GHR).

This article proposes a derivation of the Structural Accessibility Layer (SAL – Silva, 2008) to categorize accessibility for different age population groups. This is done in the GHR as a case study, due to availability of data and opinion from experts in the region for its evaluation. This article is of interest for scholars, transport planners and city planners as it discusses a tool to evaluate service allocation, transport network and housing development possibilities in the urban area. As the results are validated by experts in the region, we have greater confidence in the usability and benefits of the method for urban planning purposes.

The remainder of this article is organized as follows: i) first, it reviews previous accessibility studies in the Great Helsinki Region (Section 2); ii) then it describes the method used in the paper and its derivation (Section 3); iii) results are presented next, as well as the potential housing development areas in the city and the evaluation done by expertise in the region (Section 4); iiii) finally, the paper discusses the suitability of the method for urban planners and policy makers to categorize accessibility for different age population groups, as well as for service allocation planning (Section 5), as well as the contributions of the case study results to the scientific debate involving use of accessibility methods (Section 6).

2. Review of previous accessibility studies in the Great Helsinki Region

GHR (Fig. 1) is formed by the cities of Helsinki, Espoo, Vantaa and Kauniainen. These four cities occupy 964 km^2 and are home for 1,022,380 residents (which represents approximately 19.5% of the Finnish population). The GHR provides an example of a region that has witnessed a rapid growth in the past decades (Haapanen 1998, 2001; Vaattovaara, 2011) due to its economic development and national socio-economic dynamics; GHR currently represents the 6th biggest growing rates of the European metropolitan areas (e-Geopolis, 2014).

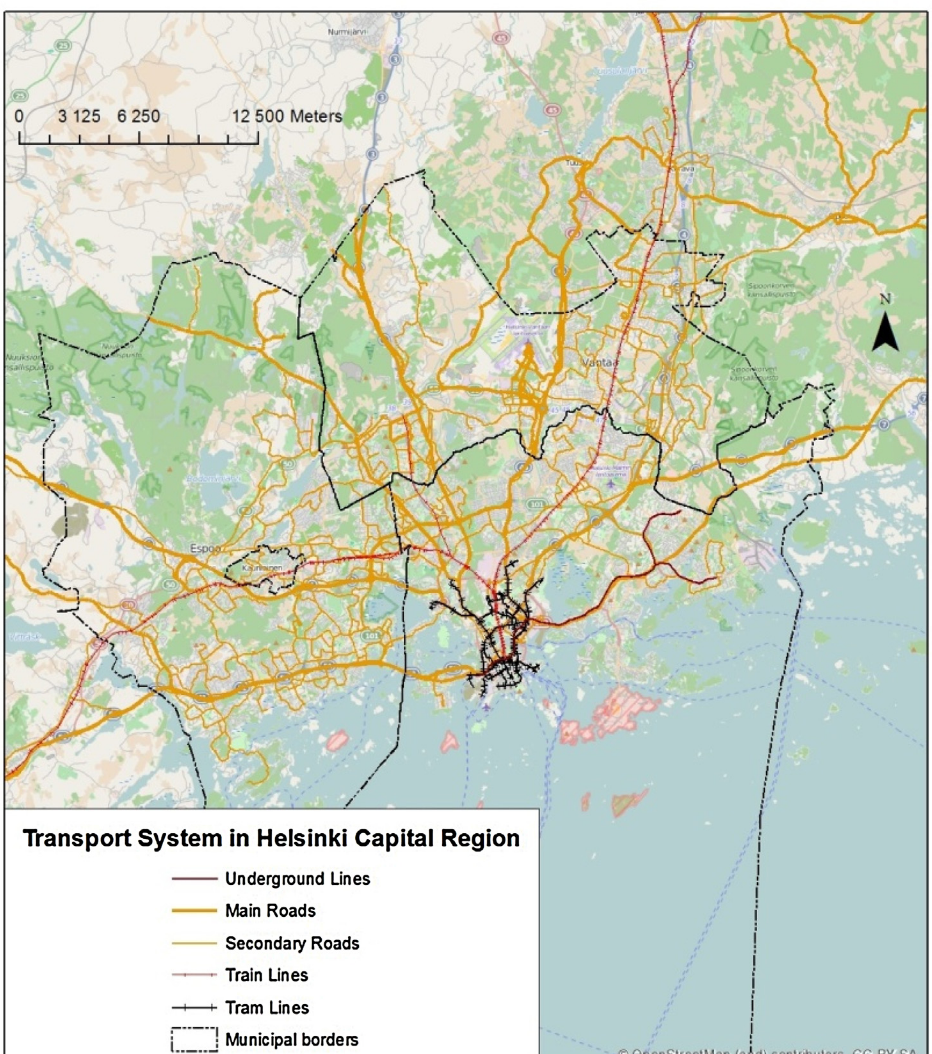

Fig. 1. GHR and the transport network.

The transport network for commuting within the GHR is diverse, as illustrated in Fig. 1. Residents use various transport modes for commuting and other purposes (car, public transport, walking, cycling, and other transport modes) (see HSL, 2010). During working days, mode split for the dominant activities (work and work related, school, shopping, leisure and returning home), indicates that most trips are done from home to work, shopping and leisure (see Table 1).

Previous research in mobility within the GHR was based on travel surveys and explored travel behaviour in several neighbourhoods of the city area. Kanninen and Rantanen's report (2010) revealed differences in travel behaviour for retail trips to different shopping malls in the GHR. Retail centres with public transport connection showed larger catchment areas, as well as it influenced the threshold times for the selection of the transport mode. While traveling to the retail centres located at the outskirts of the GHR is done mostly by car (between 61 and 78% of the trips, in Helsinki centre most of the trips were done by public transport (51%), with only 10% by car. Compared to other centres, retail centres connected by public transport presented higher relative accessibility indices for times between 20 and 40 min. These findings suggest that in the GHR, public transport infrastructure does have an impact on catchment areas and on the travel behaviour of the population.

Later, Ratvio (2012) supported the findings from Kanninen and Rantanen (2010) of spatial differences, showing that citizens that had moved to the outskirts of the GHR display different housing preferences and mobility patterns than those living in the inner city. Ratvio's results were based on mobility surveys done in four neighbourhoods of the GHR (three of them in the outskirts and one in Helsinki center). The mobility in the outskirts was shown to be car-based, whereas in the inner city makes use of diverse transport modes.

The report presented by Toivonen et al. (2012) examined the number of locations reachable by bike, public transport and car within 15, 25 and 25 min respectively. These results served to building specific maps for commercial centres, basic services, leisure services and working places centrums that can be reached by a transport mode in a certain time interval. The maps were similar between the various types of services, with the exception of the working centrums, which, by being more equally distributed in GHR, showed higher accessibility and more uniform across the city. The work from Toivonen et al. (2012) showed accessibility dissimilarities between transport modes, however, the measurement was based on a simple contour, with few service groups, with no group differentiation and without joining the access by different transport modes in a single final accessibility index.

Later on, Salonen and Toivonen (2013) developed a more complete travel time accessibility in GHR by applying three computational models. The data for the most complete model included congestion, real routes, and parking time, and estimated door-to-door times for public transportation and car travel. Their results showed that more complete data for modelling accessibility substantially improved the reliability of the results, without increasing too much the computational requirements.

Finally, special attention has to be put on the developments done in this matter by the Helsinki Regional Transport Authority (HSL). There are three main tools from HSL: first, a contour-based measurement of travel times by public transport on an online based map (HSL, 2015); second, a tool for measuring accessibility by public transport (MASA); and third, an tool based on potential-accessibility measurement (SAVU) which integrates the transportation network, land-use, travel mode and trip purpose (HSL, 2014).

SAVU represents the most developed and relevant and accessibility tool applied in the GHR. The potential accessibility was constructed based on decay log-functions for 10 different destinations by four different transport modes (walk, bike, public transport and car). These log functions had been previously created and validated by household travel survey data. The final outputs from SAVU are seven accessibility categories: 1) walking, cycling or very dense public transport without transfers; 2) walking, cycling or dense public transport with or without transfers; 3) quite dense public transport with transfers or by car; 4) car or public transport with transfers; 5) car and some journeys with public transport; 6) accessibility mainly by car and; 7) by car (see Fig. 2). Each of these categories is defined in terms of mode share, travel distance per person and CO_2 emissions for car and public transport. SAVU has been later used for evaluating the impact on accessibility of suppressing or opening public services (HSL, 2012). This tool has allowed to evaluate accessibility in new scenarios with new transport infrastructure, while considering the specificity of the travel decay function for the different destinations; however, it could not differentiate accessibility categories for different age population groups.

Although previous work in the GHR has made substantial improvements in collecting more detail data and providing more specific maps of accessibility by services, there is still a need, expressed by city and transportation planners in the GHR to explore accessibility based on all transport modes, for different age population groups, and for various services, using the best data available. In the current paper, using contour based accessibility measures, we aim to demonstrate the suitability of the current policies in the GHR in relation to the location of basic services and existing transport infrastructure for different age population groups. The accessibility results have been additionally validated through interviews with experts from Helsinki Urban Planning and Helsinki Transport Authority (HSL). The current paper uses Structural Accessibility Layer (SAL) (Silva and Pinho, 2010). SAL is a contour-based accessibility measure which combines the diversity of activities reachable within observed threshold times by car, public transport and walk. The output of SAL is a land categorization of the potential accessibility of the area for the different transport modes. In the following section, the main advantages and limitations of the chosen accessibility measure are exposed in more detail.

Table 1
Frequency of trips during working days within the Helsinki Metropolitan Area. Table adapted from (HSL, 2010, Picture 27).

Origin/Destination	Home	Work	School	Shopping	Leisure	Work Related	Total Origins%
Home	6	22	10	20	23	1	82
Work	–	1	0	2	3	1	8
School	–	–	0	1	1	0	2
Shopping	–	–	–	2	3	0	5
Leisure	–	–	–	–	3	0	3
Work related	–	–	–	–	–	0	0
Total Destinations%	6	23	10	25	33	2	100

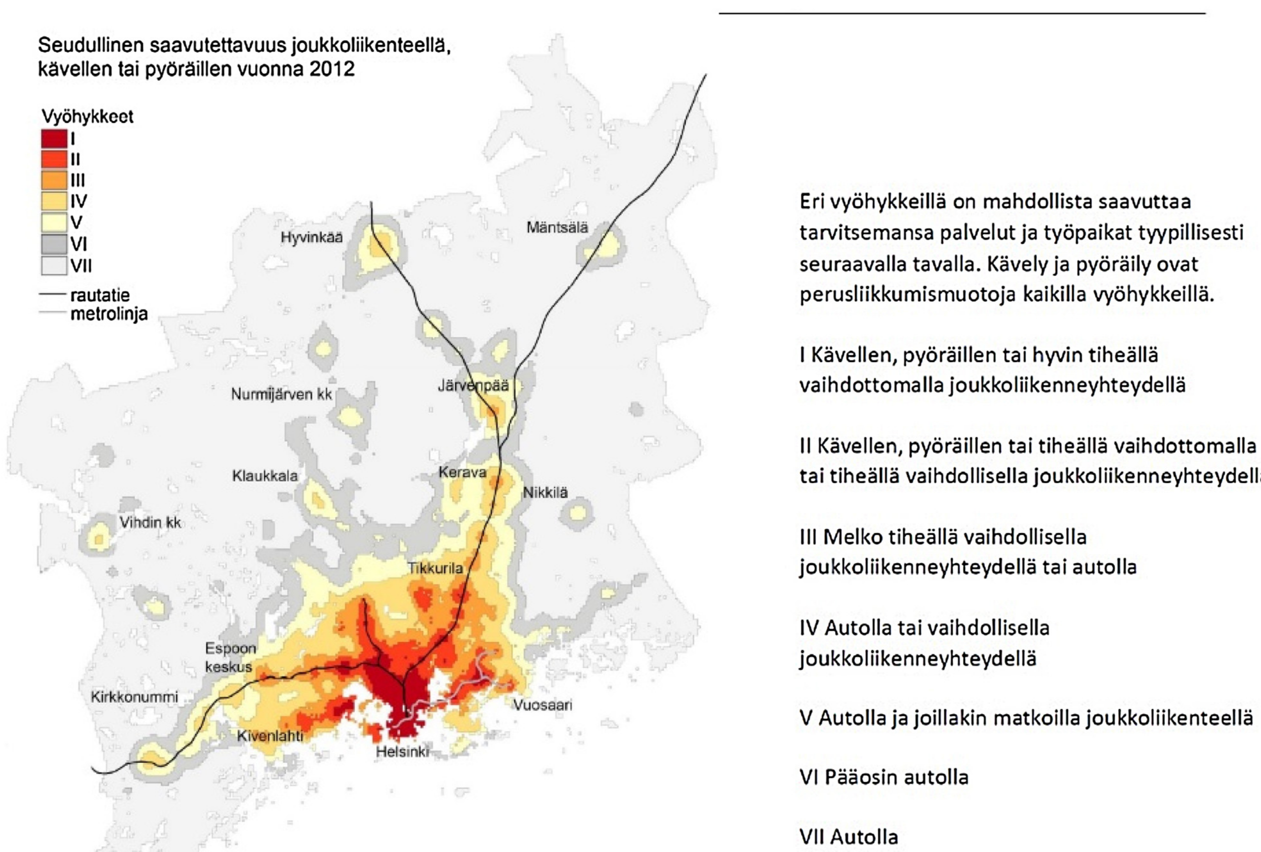

Fig. 2. Accessibility categories by public transport, cycling and walking using SAVU tool (figure extracted from MAL, 2015).

3. Data and methods

3.1. Data

Our data sources (Table A1) included gridded population data (250 × 250 m grid resolution) (Statistics Finland, 2012), data on service locations (Service Map n.d.; LIPAS, 2013) and a travel time matrix, describing travel times by different modes of transport (car, public transport and walking) from each grid cell (n = 13,230) to all other cells (MetropAccess 2014). Travel time calculations were based on complete travel chains, in order to make the values comparable across different transportation modes. The car travel time calculations included: 1) average access walking time from the origin to the parking lot; 2) travel time from parking lot to destination; 3) average time for searching a parking lot at the destination; 4) egress walking time. The public transport calculation included: 1) walking from the point of origin to the appropriate stop (access time); 2) waiting for the transport vehicle to arrive and to depart; 3) in-vehicle travel time between the initial and final stops; and 4) walking from the last stop to the final destination (egress time). In addition, many public transport journeys include transfers, which possibly imply walking from one stop to another and waiting for the next vehicle to depart (Salonen et al., 2013).

3.2. The use of structural accessibility layer for accessibility categorization

There are several models for relating land-use and transportation (see Wegener, 2004 for a full review) and several tools for accessibility have been created (Handy, 1996; Geurs and van Wee, 2004, 2010; Te Bömmelstroet et al., 2014). In the current study, Structural Accessibility Layer (SAL) (Silva and Pinho, 2010; Silva, 2008) was found specially relevant because: first, it explains potential travel modes constrained by the built environment; second, it allows for the stratification of the population and the use of detailed working scale; third, it evaluates possible travel modes without pre-determining the one used by the resident. Finally, it allows the identification of potential areas for development.

Silva (Silva, 2008), defined SAL as a "*tool* [that] *measures structural accessibility by comparing accessibility levels between different transport modes to a range of activities in a given territory*". In other words, SAL evaluates what mobility choices that are made available by the urban structure. It does not measure mobility itself, neither its sustainability, it rather measures the extent to which the urban systems provide the necessary conditions to enable sustainable mobility patterns (Silva, 2008). Therefore, the measure is not capable to measure actual accessibility because it does not consider the individual desires of destinations, but the potential possibilities based on the land-use and transportation characteristics.

SAL is composed by two main accessibility-based measures: the "*diversity of activity index*" (DivAct) and the "*comparative accessibility measure*" (the accessibility cluster) (Silva, 2008). The DivAct is an accessibility contour measure that evaluates the accessibility level for each transport mode and it is based on the "*dissimilarity index*" proposed by Cervero and Kockelman (1997) (see Eq. (1)).

$$DivAct = \frac{\sum_i Act_i * f_i}{\sum_i f_i} \quad (1)$$

where i is the type of activity (out of a set of 29), Act_i is a binary variable indicating whether the activity i is accessible within the threshold time or otherwise, and f_i their potential frequency of use.

However, in the current study, data about the frequency of use for each of the 29 services was not available and same frequency was assumed for all services included in the study.

Its range from zero (no accessible activities within the set boundaries) to one (all activities accessible within the threshold) shows how close residences are to a variety of activities considering a certain travel mode.

The comparative accessibility measure is *"made operational by the benchmarking cube, dividing the full range of accessibility levels by the three transport modes into a linked number of categories and clusters"* (Silva and Pinho, 2010; Silva, 2008). In addition to the analysis of the accessibility categories for the general case, we disaggregated the accessibility categories by the main type of residents in the GHR. The final accessibility categories are the result of combining the 27 different analysis categories. The analysis categories are the combination of each travel modes divided into three accessibility classes A (very good accessibility by the travel mode), B (good accessibility) and C (poor accessibility). The same two thresholds as SAL (0.50 and 0.85) were applied. The combination between the three coefficients (one for each transport mode) defines the point within the 3D space. This space is divided in 27 categories, which combines these 27 cubes into the 10 final accessibility categories (Silva and Pinho, 2010; Silva, 2008) (see Table A2).

As threshold times, we used 38 min (st.dev. 13) for PT; 15 min (+st.dev 6) for car; and 10 min (st.dev. 16) for walking. These threshold times were obtained from Salonen et al. (2013) which collected data from 4669 trips made by 711 respondents in the GHR (not shown). The general accessibility categories were calculated using both the mean commuting time and the time adding the standard deviation; whereas the accessibility categories for the household members has been calculated only using the mean commuting times.

In the current study, accessibility categories were considered depending on the services targeted to be important for each type of resident (see Table 2). The allocation of the services for each age group was obtained from discussions with local urban planners, members of the urban unit from City of Helsinki and transportation experts from the transport agency of the Helsinki Capital Region. A binary variable was used to indicate if the facility was relevant to the population group of not, since no data regarding frequency was available. The allocation of services was based on identifying residents as potential users of the service. All types of residents were used when the targeted user was not defined by the service. The threshold times for every transport mode trip had to be the same as in the general map, since no specific threshold times references where found for each type of resident. The accessibility categories were calculated for the whole population and for few age-stratified groups of inhabitants (defined based on socio-economic data from GridDataBase 2010): children from 0 to 7 years old, children from 7 to 17 years old, students (from 18 to 24 years old), young adults (from 25 to 34 years old), mid age adults (from 35 to 54 years old) and pensioners (over 65 years old). These population groups allowed us to include the 96.64% of the total population. We note here that the population between 54 and 65 years old could not be included (3.36% of the population) since no survey data was available for that age group (see Appendix B).

Finally, in order to facilitate the interpretation of the results, we visualized the distribution of the percentage of population living in the different accessibility categories using bar charts and we jointly mapped the walk-based categories with the population distribution.

4. Results

4.1. Spatial distribution of the accessibility categories

The accessibility categories obtained from the SAL calculation inform about the transport modes available to the GHR residents to reach different urban opportunities within set threshold times. "Medium" and "Low" categories represent those locations where hardly or none of the opportunities could be reach by any transport mode. Additionally, two categories, 6 ("PT and Car (better walk)") and 7 ("PT and Car (worse walk)"), were created by splitting higher values of walking index for category 6 and lower walking index for

Table 2
Allocation of services for every type of resident included in the study.

SERVICE	Child 0 TO 7	Child 7 TO 17	Student	Young Adult	Mid Age Adult	Pensioners
1.YouthHobby		X	X			
2.University			X			
3.Theater			X	X	X	X
4.SubstanceAbuseCare					X	
5.PreSchoolEd	X					
6.ChildrenDayCare	X					
7.SocialAssistance				X	X	X
8.Restaurant			X	X	X	X
9.Shopping			X	X	X	X
10.ReligiousBuilding				X	X	X
11.PupilStudentCare		X	X			
12.Museum			X	X	X	X
13.Library		X	X			X
14.CulturalFacility			X	X	X	X
15.Internet		X	X			
16.HealthStation	X	X		X	X	X
17.DisableCareService					X	X
18.Park	X	X	X	X	X	X
19.ElderlyService						X
20.Boating			X	X	X	
21.ChildreFamilyWelfare	X	X		X		
22.EmploymentCare				X	X	
23.AdultEd				X	X	X
24.MorningAfternoonAct		X	X	X	X	X
25.AllSport		X	X	X	X	X
26.Playground	X	X				
27.VocationalEd			X	X	X	
28.BasicEd		X				
29.SecondaryEd		X				

category 7 (see Table A2). These categories, which were originally amalgamated as one in SAL (Silva and Pinho, 2010), assist us to obtain better spatial differentiation in the region. This study then applies ten categories of accessibility, instead of seven (Table 3).

The accessibility maps for the general case (the whole population) included all the services in the calculation of the DivAct. In the first general map (Fig. 3) the mean value for commuting times across GHR were used as threshold times for the calculation. There are no areas with accessibility classes 1 ("Walk"), 2 ("Walk & PT") or 4 ("Walk and Car"). This means that there are no areas with a clear dominance of walk accessibility over the other transport options, and in areas where there are suitable options for walking, the options for PT and Car are equally available.

Areas with a high DivAct index for walk mode are located close to the rail network. Only six exceptions of neighbourhoods appear to have high DivAct for walking mode and are not close to rail network. High index of DivAct for public transport appears to follow the rail network as well. The only exception can be found at the south of Espoo, where the high index for public transport is explained by good bus connections (not shown).

The DivAct index for car is clearly following two spatial patterns. First, there is a high index for all areas within the outer ring road surrounding the HCR; they can be observed on the DivAct map for the car mode. The second spatial pattern follows the three main radial motorways leading to the city centre of Helsinki (one from the west crossing Espoo, one from the north and a third one from east crossing Vantaa).

Accessibility class "All modes" appears only in two areas close to the centre of Helsinki city (approximately the neighbourhoods of Kamppi and Kallio), whereas the city centre of Helsinki has accessibility category as PT & Car (better walk) (Fig. 3).

The use of mean commuting times expresses the accessibility categories based on the most common travel mode choices, while adding one standard deviation to the average better describes the actual transport opportunities in the region, after incorporating some uncertainty associated with traffic conditions. The lower values from the standard deviation of threshold times could also be calculated as an indicator of the accessibility categories for those citizens with more physical restrictions for mobility; however, in the current study we wanted to focus on the restrictions by age population groups assuming that all GHR residents commute experiencing the average commuting times. Adding one standard deviation to the mean commuting times, leads to slightly different results (Fig. 4). The accessibility category "All modes" occupies all Helsinki city centre and the areas close to the metro stations in the eastern part of Helsinki. This is consistent with anecdotal evidence on the perceived accessibility levels in Helsinki, as expressed by its residents as well as experts.

Finally, most of the areas of Helsinki and Espoo outside the outer ring road present medium of low level of accessibility, even when considering the maximum amount of time that residents would be willing to use for every travel mode (see Fig. 4).

4.2. Specific accessibility categories for the main types of residents in HCR

From the resulting accessibility categories for each type of resident (Appendix A) we first checked the proportion of residents of a certain age group living in each of the accessibility categories (see Table 3 and Fig. 5). The results indicate that, when considering the location of the residents in 2010, there are big dissimilarities between population groups across GHR. It is worthwhile pointing out the cases of Child 0–7 years old and Students, where 32.0% and 32.8% of the respective groups reside in areas with accessibility categories were "Car", "Medium accessibility" or "Low accessibility". Results from Children from 0 to 7 years old call for further assessments of accessibility, based on trip chains, since children are chauffeured or accompanied by adults when they travel; however, the results still indicate that a walk-based accessibility is not a priority for those families with young children when selecting their residence. On the other hand, 39.6% of pensioners reside in areas with "All modes" as accessibility categories, which ensures the possibility of reaching the services for pensioners also by walking.

In a final step, we focused on finding those areas where some transport or urban development could improve accessibility. For this aim, we selected from the general map those areas presenting a high amount of population (between 422 and 2521 inhabitants) located in areas with accessibility categories "Car", "Medium" or "Low" accessibility. The results show that there is a need for more public transport development in the northern part of Vantaa, west of Espoo (close to Kauniainen) and some little neighbourhoods in Espoo.

A similar procedure was used in order to find potential urban development areas for specific population groups. Areas with walking as an optional mode and relative low population (between 0 and 37 inhabitants) of each type of resident where marked in a single map (see Fig. 6a).

When aggregating all the individual areas of potential development, there are more urban clusters suitable for urban development in Helsinki City (Fig. 6b). Notably there are three main areas with strategic planning focus; two of them are located in the centre of Helsinki. Additionally, there is a third one located around the area of Ruoholahti.

When looking at the characteristics of areas for potential development for each population group (Fig. 6a), we note much smaller and dispersed areas for the Children 0–7 and Children 7–17 population groups, compared to the rest of residents; Moreover, these areas are more located outside of Helsinki centre (where the other types of residents mostly live).

Table 3
Percentage of population in 2010 living in the different accessibility areas for specific household members and for the whole population.

Accessibility Classes/% population	Children 0–7	Children and teenagers 7–17	Students	Young Adults	Mid Age Residents	Pensioners	General population map	General population map (+st. dev.)
1. Walk	0	0	0	0	0	0	0	0
2.Walk & PT	0	0	0	0	0	0	0	0
3.All modes	0.57	7.80	0	0.16	5.92	**39.60**	1.41	16.11
4.Walk & Car	0	0	0	0	0	0	0	0
5. PT	**34.16**	17.12	**43.89**	9.21	**25.87**	2.14	**33.17**	13.34
6. PT & Car (better walk)	12.22	**50.79**	3.93	**47.78**	18.94	**46.60**	17.41	**52.23**
7. PT & Car (worse walk)	21.07	16.50	19.37	**37.99**	**42.27**	10.60	22.53	13.31
8. Car	0.48	1.23	0.77	0.76	0.84	0.47	0.36	0.77
9. Medium accessibility	**29.00**	6.14	15.70	2.59	4.00	0.27	23.31	3.94
10. Low accessibility	2.60	0.42	16.34	1.51	1.94	0.24	1.82	0.30
Total	100	100	100	100	100	100	100	100

In bold those accessibility categories with over 25% of a specific household member or the whole population.

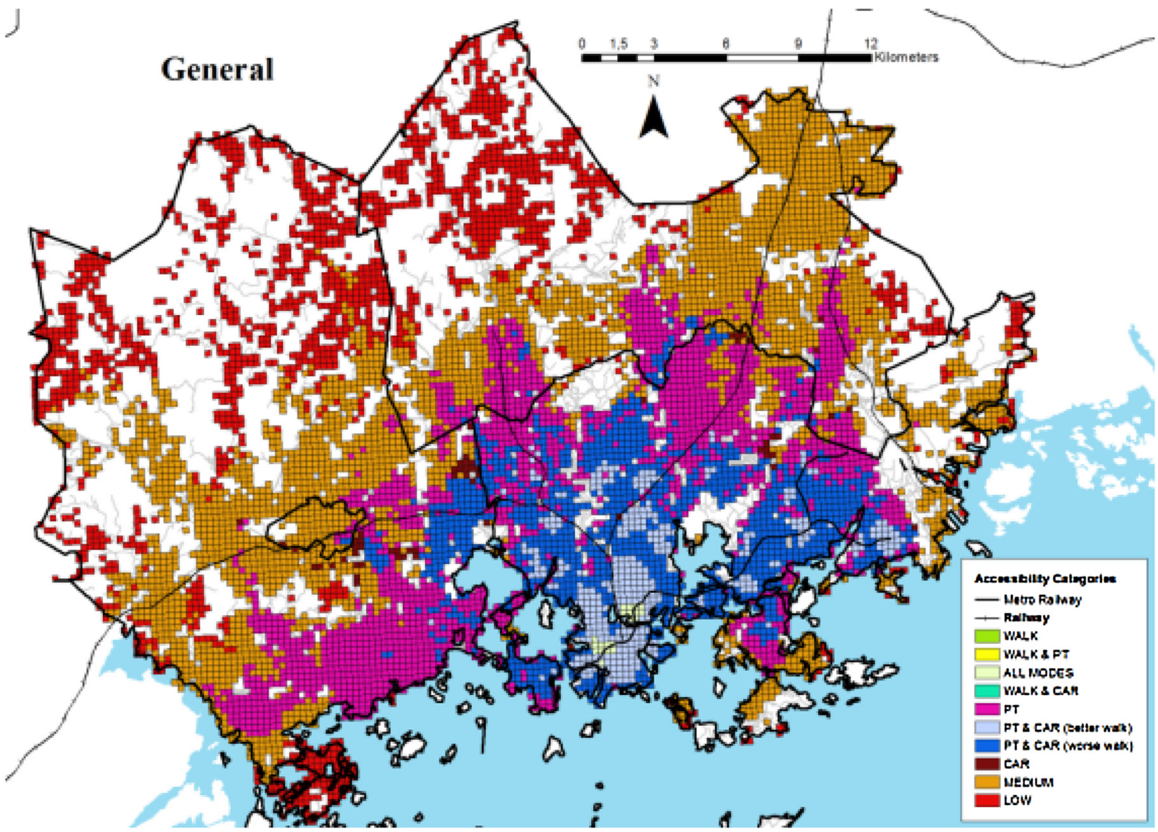

Fig. 3. Accessibility classes in the Helsinki Capital Region considering all services and using the mean commuting time (minutes) as threshold time (PT = 38, Walk = 10 and Car = 15).

4.3. Interview and evaluation of the results with specialists

In order to cross-validate our results, we interviewed three specialists from the City Planning Department of the City of Helsinki, which have been using accessibility measurements for their tasks in the past, and additionally three more specialists from the Transport System Department of the Helsinki Region Transport (HSL). The interviews were conducted in two rounds and they were recorded. The purpose of the interview was to assess the usefulness of SAL and check the reliability of the presented results on this paper.

The six interviewees had various professional backgrounds – transportation technology and planning, economic geography, political sciences and statistics, planning geography and engineering. Their responsibilities were related to the design of the transportation system, demand forecast, measurement of accessibility in the city, and development of the city master plan.

During the interview, the respondents were asked about the use of accessibility concepts and tools in their work and about their preferred indicators of accessibility. Main answers pointed out the need of accessibility for different age population groups: *"I could also see what is in the services and places and if really people want to go there. If a place has a good accessibility from somewhere, but do people want really to go to those places? Those kind of individual measurements would be good."*; (transport planner) or the need to be able to measure accessibility for the future development scenarios: *"It is also useful to measure accessibility in the future with the new tram network and see where it should be built in the city so that we can redesign the city. Usually people want to live where there is good accessibility, and therefore measurements can also support building the network."* (geographer). On the other hand, the specialists from HSL pointed out the utility of SAVU tool for providing easy to understand maps to politicians who have to make the final decisions. Some statements explicitly support this view: *"My use of accessibility is very practical. I just look at the map of accessibility and use it for justifying the decisions of the actions that are needed to be done. We show the map and say: 'Look at this, this is the right thing to do'. Another way I use it, is by collecting information from certain areas and showing that 'these are the areas you should focus on'. This was the way it was used for the development of cycling paths, we showed that the accessibility was so low, that there were certain trips that could be done by bike."* (planning). Also accessibility*"has been pretty important tool because when we see the map we can discuss how to improve and develop the region."* (economist). Finally, all of them stated a need "*to plan considering land-use, transport and housing; and it would be nice that we could also plan the services with all those things together and also where the services and business should be placed.*"

In the second part of the interview, the methods and the results of the current study were presented. The respondents were asked about the utility and reliability of the resulting maps. Respondents then emphasized the utility of such maps for service planners and pointed out the dependence of the calculations on the set of services included in each group and the lack of weighting of the frequency of use of the services:

"Comparing the groups of population with their specific services seems to me interesting and relevant. Of course, you could also discuss that universities should be located in places with good public transport. But then, you should pay a lot attention to which services are included in each category group. For the kids 7–17 they might go only to one school or secondary school and then it happens something similar than university students. But as a general approach, why not?" (engineer)

"This tool is very good for planning. These maps could also very useful in the future because nowadays we need to plan considering the integration of land-use, transport and housing" (urban planner)

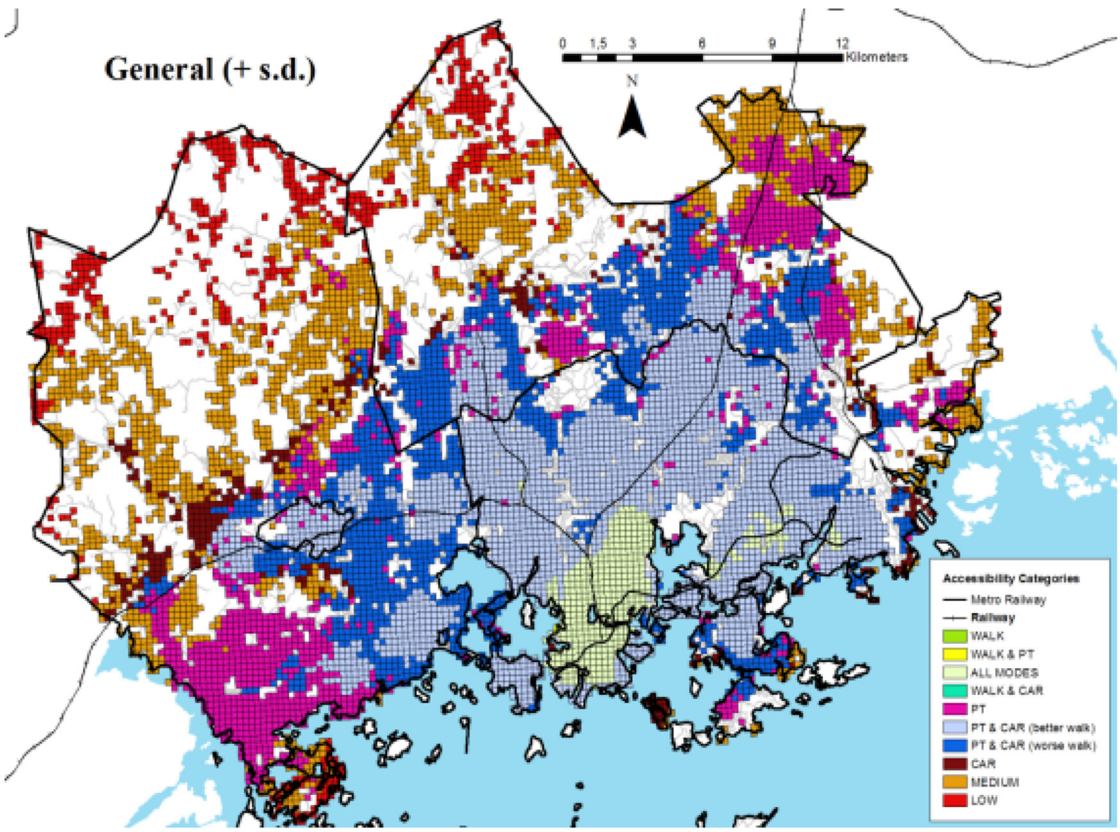

Fig. 4. Accessibility classes in the Helsinki Capital Region considering all services and using the mean commuting time (minutes) plus the standard deviation as threshold time (PT = 51, Walk = 26 and Car = 21).

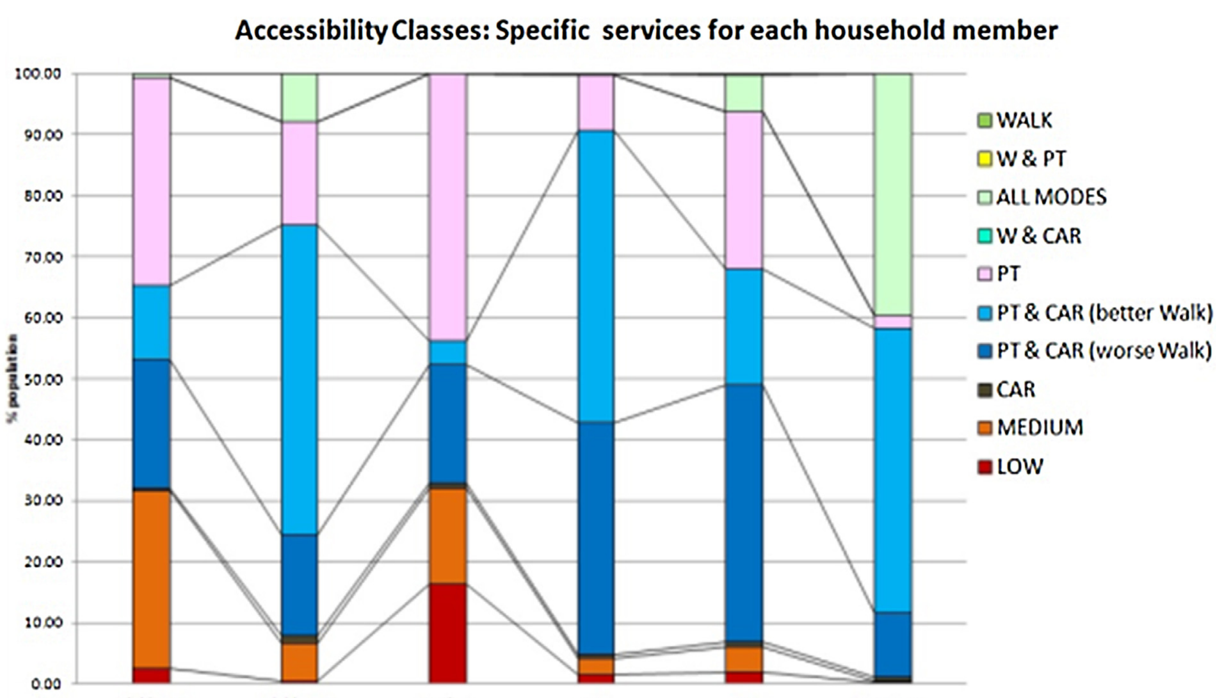

Fig. 5. Distribution of population age groups using their specific services.

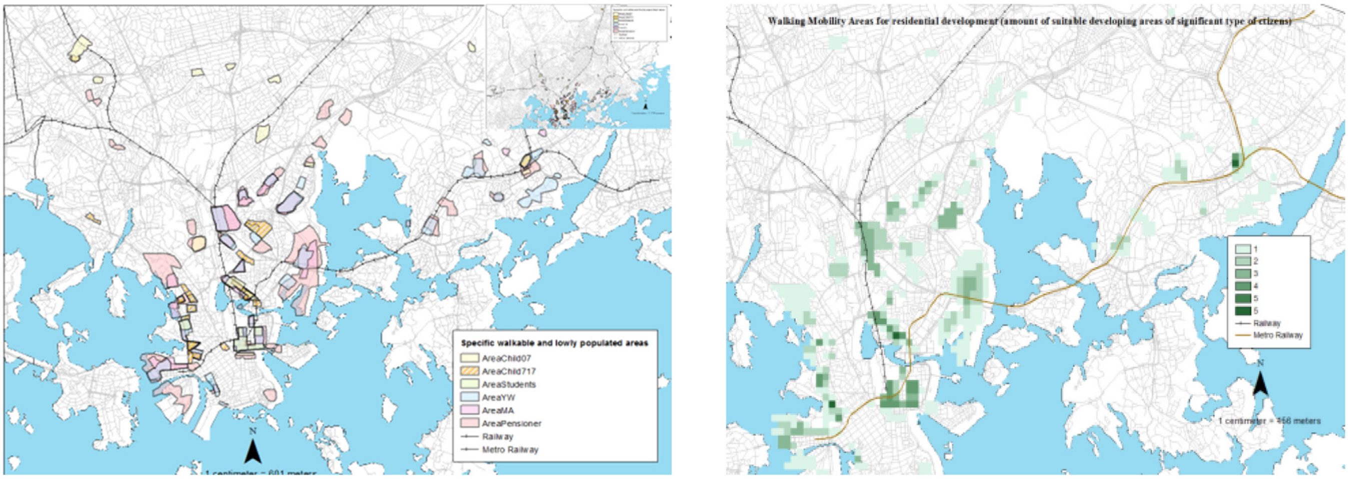

Fig. 6. Potential urban developing areas based on the specific accessibility categories of the main type of residents. a) Specific potential development areas for each population group; b) Aggregation of potential development areas.

"For me this categorization with SAL looks good and interesting. This kind of results could be very useful for smaller municipalities at the north of Helsinki, because with this kind of results you could show them that they are of good value too, even if accessibility is not as good as in Helsinki. I think that these studies based on services are interesting, primarily for the service network planners" (planner)

"These maps are very important for those who plan services. They should take a look on different population groups. Services would need to be categorized based on their usage (e.g. daily, weekly). Because for daily services you have to have good access." (transport modeller).

5. Discussion

This paper has presented an adaptation of SAL method with disaggregated data and its results for the GHR region in general and for six main types of residents. Results showed the potential mobility patterns in the different areas of the city, based on the current transport network and the distribution of urban services.

One of the main goals of this research was to evaluate the accessibility for the main type of residents and indicate transport and service reallocation needs. The disaggregation by six types of residents was done based on a previous analysis of the population structure (see Appendix C). The results presented in Table 3 and Fig. 5, show that some policy in allocation of services or in urban transportation should be done for the groups of Children 0–7 and Students, since both groups present high percentage of their population residing in areas categorized as car dependent or with medium or low accessibility. On the other hand, Pensioners seem to benefit from a fairly good accessibility, considering that all pensioners reside in areas where at least PT is one of the available transport modes. The strategy used for Pensioners could be analysed and used for balancing the cases of Children 0–7 and Students. Additionally, the cases of Child 7–17 and MA should be further examined since in both cases, there is a small proportion of individuals (7.8 and 5.9%) living in areas categorized as All Modes; they also present a 6.6 and 6.8% respectively of their residents living in car dependent or medium/low accessibility areas.

The significant difference in the accessibility levels across various population groups supports the False Assumption of Older Cohort Homogeneity proposed by Davies and James (2011). Additionally, the interviews with local experts supports the idea that specific accessibility maps for the age population groups would be of special utility when planning public services in the region.

Findings from Ratvio (2012) where citizens located in the outskirts of the region (further from Ring III) were traveling mostly by car are supported by our results. General maps (Figs. 2 and 3) showed how the outskirts of the region were classified as car-based (car mode, medium or low accessibility category). When looking at the accessibility categories for the six age groups (Figures in Appendix A), all areas located further than Ring III are classified as car-based, medium or low accessibility levels, regardless of the age group.

This study is not able to support, neither contradict, the findings of Kanninen and Rantanen (2010) where public transport infrastructure was found to have an effect on travel behaviour. As travel survey data is missing in the current study, we only provide insights on the potential accessibility based on the available modes, not necessarily the ones used by residents to travel. Further work will explore whether residents living in areas where public transport is an option, differ in their travel routines from those that do not have that option. Nevertheless, interviews with local experts and general statistics on share mode of citizens in the different neighbourhoods seem to indicate, in a qualitative way, that the share of public transport, walk and bike is higher in those areas that have been categorized with at least public transport as one feasible option.

The results presented in the current study improve the usability of the information obtained from SAVU, since they can bring more specific findings on accessibility for different population groups. These results have direct implications in detecting inequalities in accessibility between population groups; and therefore, unlike SAVU, gives to transport planners and policy makers more specific information on where to focus for delivering better accessibility. These results have additionally indirect implications regarding housing development and public services management. The spatial location of different population groups indicate possible interventions or promotions for, in one hand, providing housing offer adapted to the needs and economic capacities of those population groups; and on the other hand, it targets population groups which voluntarily have chosen car-dependent locations but who could be pursued to switch to other modes made available to them. Regarding the service management, the method used in the current study, which included 29 services instead of the original 10 services in SAVU, shows that accessibility categorization can be done at any detail level. This methodological advantage opens the opportunity to evaluate the accessibility for targeted services in the city.

5.1. Limitations and further research

The main limitation of the current method is the discreet behaviour of DivAct which counts only if the service is within the assigned threshold. This creates therefore two potential sources of bias in the results: 1) we are assuming the same threshold time for all age groups, and 2) the lower is the number of services for each group, the more impact will have in the final DivAct score since, due to lack of complete data, no weighting through frequencies of used could be applied in the calculations. However, interviews with transport and urban planning experts showed that the presented results are useful for location and reallocation of services in the region. Experts indicated that this approach was useful for gaining more specific spatial evaluation of accessibility categories for different group members; and therefore, observe the services and neighbourhoods that must be improved. Further research should focus on including specific threshold travel times for each group, include frequency of use weighting (if data becomes available) and compare the accessibility results with travel survey data.

Additionally, accessibility categories that included the standard deviation in their threshold time, might express better the perception of the population about the accessibility in the neighbourhoods and a higher correlation with the housing market value should be expected. Fig. 2 shows a gap between the potential accessibility and mobility of the areas, which indirectly might affect the price of the real estate market; there is room for economic evaluation of accessibility perception and quantify the value brought about by accessibility. Previous research has shown a significant relation between the built environment and travel patterns (Cervero and Kockelman, 1997; Halden, 2002; Handy and Niemeier, 1997; Bertolini et al., 2005; Halden et al., 2000; Straatemeier, 2006; Straatemeier and Bertolini, 2008; Aditjandra et al., 2013). However, given data availability, the current paper cannot contribute to this debate.

As the GHR is under a constant need for housing new population, this research could indicate suitable areas for future urban development, as well as areas presenting car-based accessibility categories only. The detailed level of the data allowed us to provide more detailed results on accessibility for various population groups with different activity needs; however, the lack of frequencies of use for each of the services means that we assume similar importance for the facilities in a certain population group. Future research should focus on the accessibility at the household level and if possible consider a categorization of trip chains, in order to understand the value of accessibility when selecting a new living residential area.

In conclusion, the SAL has shown to be a useful method for estimating the transport mode possibilities constrained by the urban structure and service network. Moreover, what-if scenarios can be created for simulating the effects service allocation on the accessibility categories in the area.

6. Conclusion

Drawing on previous work with SAL (Silva, 2008), we provide a detailed application for estimating accessibility in GHR.

Previous studies in the region and interviews with experts have validated the derivation used in the current study as a useful way not only to spatially categorize accessibility, but also to study future actions regarding allocation of services, housing and transport infrastructure. Additionally, the current research has remarked the importance of considering the heterogeneity of the group for a more realistic accessibility measurement approach.

The specification by services and threshold times used in this paper presented significant differences in the results. Future research should be focus on two main directions, first, on the inclusion of specific threshold times for each type of resident when calculating accessibility categories; and second, on the inclusion of usage frequency of the services and it validation with travel survey data.

Acknowledgements

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Appendix A.

See

Table A1
Data sources.

Data Source	Variables
MetropAccess 2014	Following SYKE YKR grid: ID origin, ID destination, walking, public transport and car total time between grids.
GridDatabase 2010	Socioeconomic data of the population resident in the HGR.
Service Maps of Healsinki, Vantaa, Espoo and Kauniainen	Social, leisure, culture and education services located in the HGR.
LIPAS	Updated sport facilities locations in the HGR.

Table A2
Accessibility Categories.

Accessibility Categories		Threshold values of DivAct		
PT	WALK	CAR		
1. WALK	Favourable conditions for the use of walking mode.	PT < 0.85	W > =0.85	C < 0.85
2. WALK & PT	Favourable conditions for the use of walk and public transport mode	PT > =0.85	W > =0.85	C < 0.85
3. ALL MODES	Favourable conditions for the use of all modes.	PT > =0.85	W > =0.85	C > =0.85
4. WALK & CAR	Favourable conditions for the use of walking and car modes.	PT < 0.85	W > =0.85	C > =0.85
5. PT	Favourable conditions for the use of public transport.	PT > =0.85	W < 0.85	C < 0.85
6. PT & CAR (better walk)	Favourable conditions for the use of public transport and car with better walking conditions.	PT > =0.85	0.50= < W < 0.85	C > =0.85
7. PT & CAR (worse walk)	Favourable conditions for the use of public transport and car with worse walking conditions.	PT > =0.85	W < 0.50	C > =0.85
8. CAR	Favourable conditions for the use of car.	PT < 0.85	W < 0.85	C > =0.85
9. MEDIUM	Medium accessibility levels.	PT < 0.85	0.50= < W < 0.85	C < 0.85
10. LOW	Low accessibility levels.	PT < 0.50	W < 0.50	C < 0.50

Appendix B.

See Table B1

Table B1
Formation of the age population groups used in the study.

Population Groups	% Of Total Population	Groups of the Study and% of the Total Presentation
Under school age (0–7 years)	8.86	Children 0–7 8.86
Primary school age (7–12 years)	6.61	Children 7–17
Teenagers (13–17 years)	6.15	12.76
Young adults (18–24 years)	10.62	Students 10.62
Settling down age (25–34 years)	18.65	Young Adults
Settled age (35–44 years)	15.71	34.36
Middle-aged (45–54 years)	15.26	Middle Age 15.26
Pensioners (65 years –)	14.78	Pensioners 14.78
Total Population		96.64

Appendix C.

See Figs. C1–C6

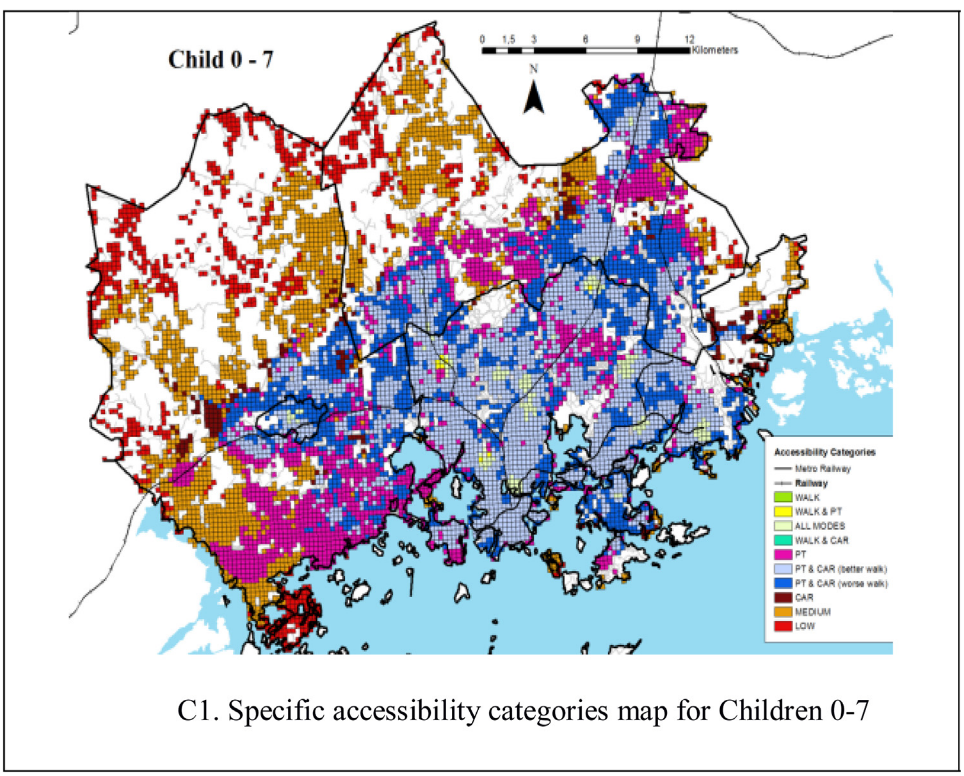
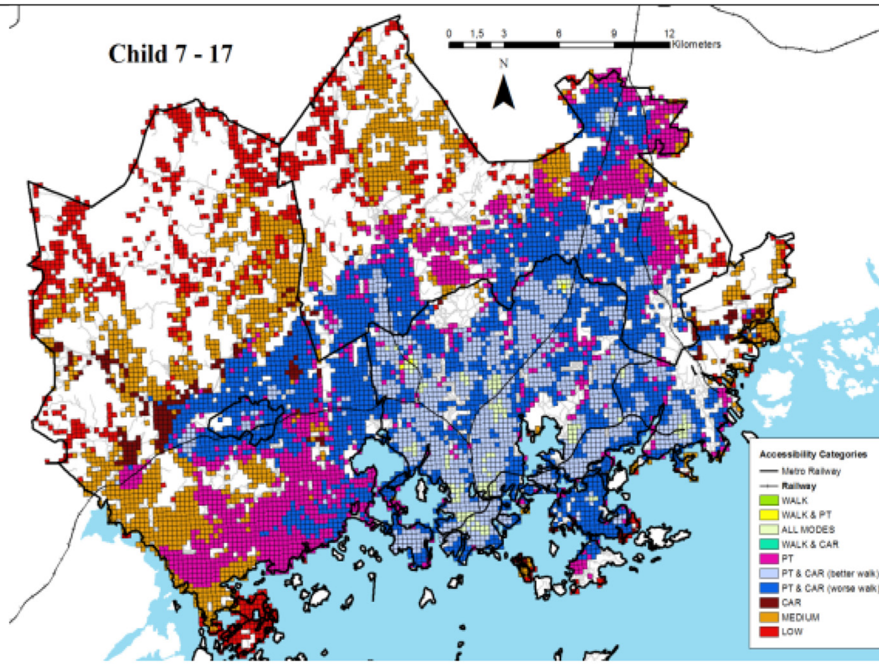
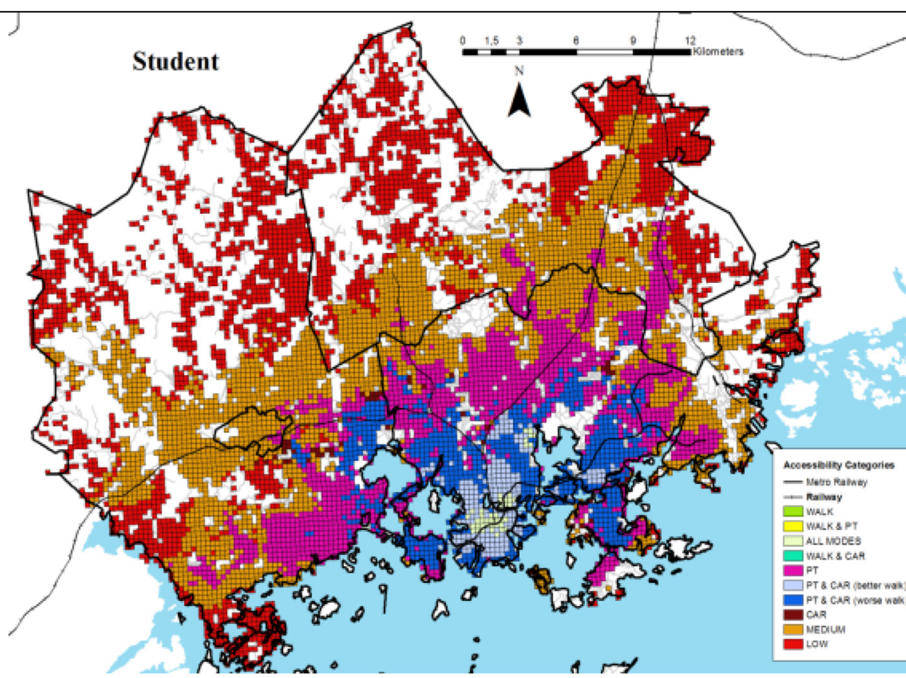


Fig. C1. Specific accessibility categories map for Children 0–7.



C2. Specific accessibility categories map for Children 7-17

Fig. C2. Specific accessibility categories map for Children 7–17.



C3. Specific accessibility categories map for Students

Fig. C3. Specific accessibility categories map for Students.

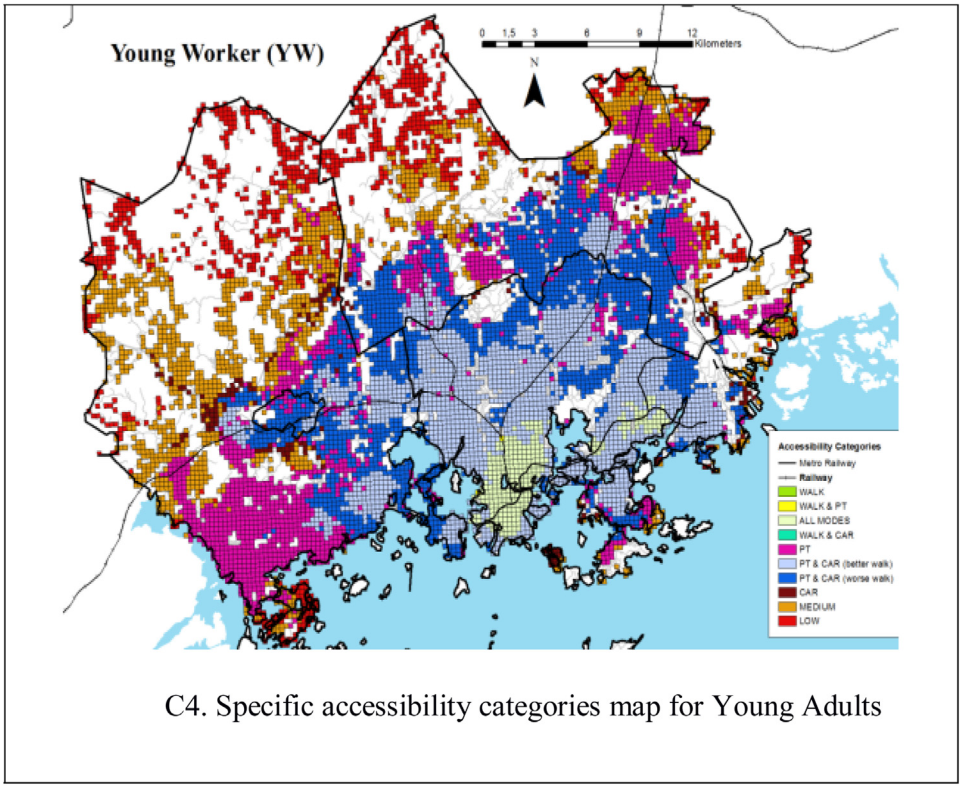


Fig. C4. Specific accessibility categories map for Young Adults.

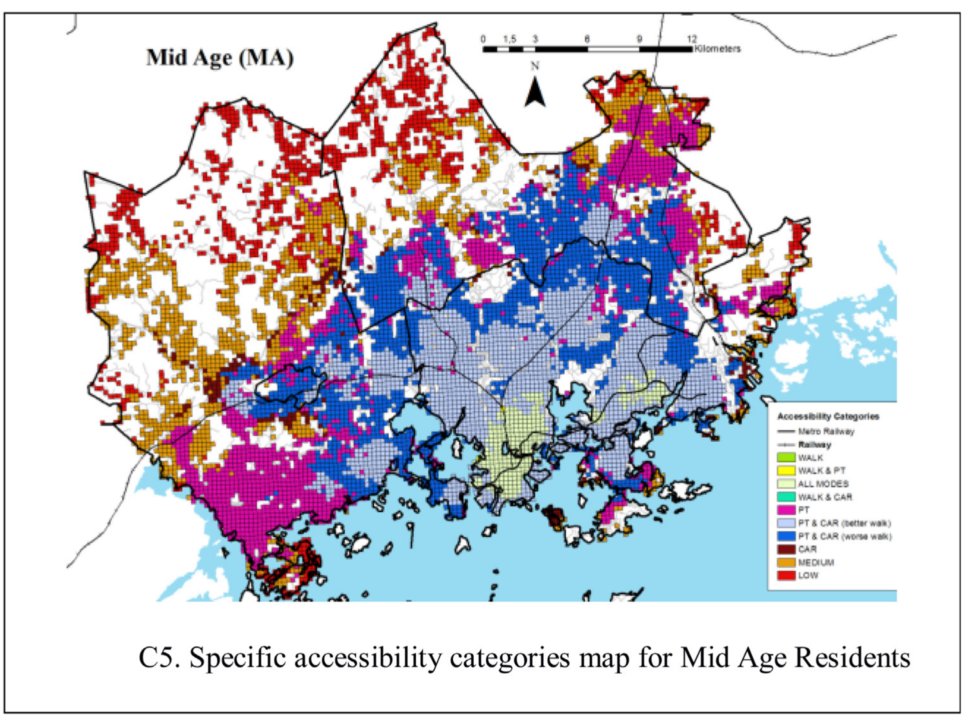
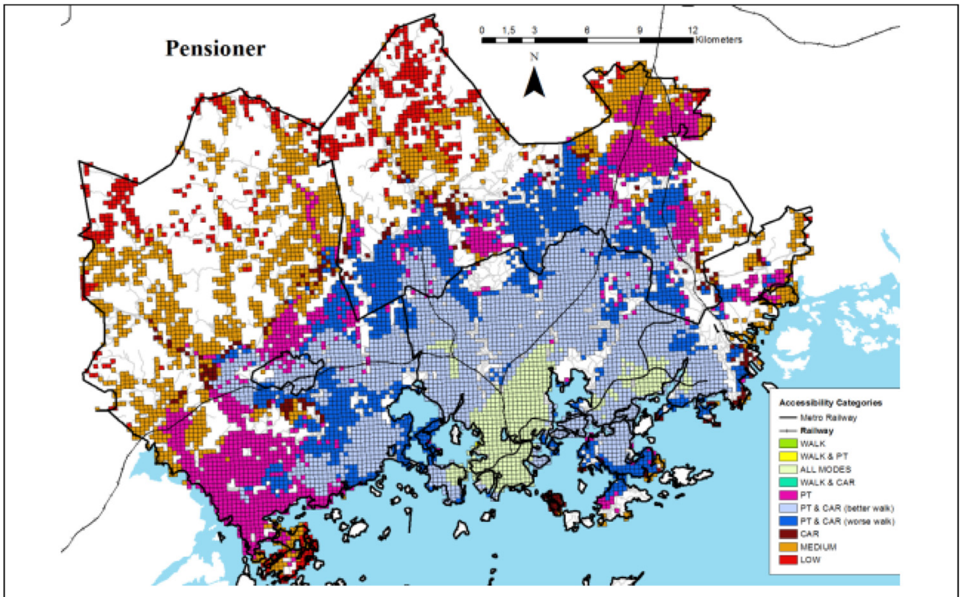


Fig. C5. Specific accessibility categories map for Mid Age Residents.



C6. Specific accessibility categories map for Pensioners

Fig. C6. Specific accessibility categories map for Pensioners.

References

Aditjandra, P.T., Mulley, C., Nelson, J.D., 2013. The influence of neighbourhood design on travel behaviour: empirical evidence from North East England. Transp. Policy 26 (0), 54–65.

Banister, D., 2008. The sustainable mobility paradigm. Transp. Policy 15 (2), 73–80.

Bertolini, L., Clercq, F., Kapoen, L., 2005. Sustainable accessibility: a conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward. Transp. Policy 12, 207–220.

Bhat, C., Handy, S., Kockelman, K., Mahmassani, H., Chen, Q., Weston, L. Development of an urban accessibility index: Literature review. Research project conducted for the Texas Department of Transportation. Technical Report. 2000.

Cervero, R., Kockelman, K., 1997. Travel demand and the 3Ds: density, diversity, and design. Transp. Res. Part D: Transp. Environ. 2 (3), 199–219.

Davies, A., James, A., 2011. Geographies of Ageing: Social Processes and the Spatial Unevenness of Population Ageing. Ashgate, Farnham, UK.

Deng, T., Nelson, J.D., 2013. Bus Rapid Transit implementation in Beijing: an evaluation of performance and impacts. Res. Transp. Econ. 39 (1), 108–113.

EEA – European Environment Agency (2013). A closer look at urban transport. TERM 2013: transport indicators tracking progress towards environmental targets in Europe. *EEA Report* No 11/2013. http://www.eea.europa.eu/publications/term-2013.

e-Geopolis 2014,. Available: http://www.e-geopolis.eu/[2014,04/07].

European Comission (2007). Green paper on urban mobility. Towards a new culture for urban mobility. <http://ec.europa.eu/transport/themes/urban/urban_mobility/green_paper/doc/2007_09_25_gp_urban_mobility_memo_en.pdf>.

Frändberg, L., Vilhelmson, B., 2011. More or less travel: personal mobility trends in the Swedish population focusing gender and co98hort. J. Transp. Geogr. 19 (6), 1235–1244.

Geurs, K.T., van Wee, B., 2004. Accessibility evaluation of land-use and transport strategies: review and research directions. J. Transp. Geogr. 12, 127–140.

Geurs, K.T., van Eck, J.R.R., 2001. Accessibility Measures: Review and Applications. Evaluation of Accessibility Impacts of Land-use Transportation Scenarios, and Related Social and Economic Impact, RIVM *Report* 408505 006 Edn. National Institute of Public Health and the Environment, Bilthoven, Netherlands.

Geurs, K.T., van Eck, J.R.R., 2003. Evaluation of accessibility impacts of land-use scenarios: the implications of job competition, land-use, and infrastructure developments for the Netherlands. Environ. Plann. B 30, 69–87.

Haapanen, M., 1998. Internal migration and labour market transitions of unemployed workers. VATT-Discussion Papers Edn, Valtion Taloudellinen Tutkimuskeskus. Government Institute for Economic Research, Helsinki.

Haapanen, M., 2001. Labour Migration and Wages, School of Business and Economics. University of Jyväskylä.

Halden, D., 2002. Using accessibility measures to integrate land use and transport policy in Edinburgh and the Lothians. Transp. Policy 9, 313–324.

Halden, D., McGuigan, D., Nisbet, A., McKinnon, A., 2000. Accessibility: Review of Measuring Techniques and Their Application. Scottish Executive.

Handy, S., 1996. Methodologies for exploring the link between urban form and travel behavior. Transp. Res. Part D: Transp. Environ. 1 (2), 151–165.

Handy, S., Niemeier, D., 1997. Measuring accessibility: an exploration of issues and alternatives. Environ. Plann. A 29 (7), 1175–1194.

Horner, M., Duncan, M., Wood, B., Valdez-Torres, Y., Stansbury, C., 2015. Do aging populations have differential accessibility to activities? Analyzing the spatial structure of social, professional, and business opportunities. Travel Behav. Soc. 2, 182–191.

HSL, 2010. Liikkumistottumukset Helsingin Seudun Työssäkäyntialueella Vuonna 2008. Edita Prima Oy, Helsinki.

HSL, 2012, JULKI- Julkisen lähipalveluverkon vaikutukset kestävään liikkumiseen, report 17: 2012.

HSL, 2014, Saavutettavuustarkastelut ja joukkoliikenteen matka-aikasaavutettavuus, SAVU & MASA, report 3: 2014.

HSL, 2015, Matka-aikakartta [map]. Generated by OpenStreetMAp, CC-BY-SA, Sovellus and BusFaster. <mak.hsl.fi> (June 17, 2015).

Kanninen, V., Rantanen, A., 2010. Kauppakeskukset Osana Kestävää Kulutusta Ja Kaupunkirakennetta. Yhdyskuntasuunnittelun Tutkimus – ja Koulutuskeskuksen Julkaisuja, Espoo.

LIPAS. Liikuntapaikat.fi 2013, [Homepage of University of Jyväskylä], [Online]. Available: http://lipas.cc.jyu.fi/lipas. [2014,04/07].

Love, D., Lindquist, L., 1995. The geographical accessibility of hospitals to the aged: a geographic information systems analysis within Illinois. Health Serv. Res. J. 29 (6), 629–651.

MAL, 2015, Helsingin seudun maankäytön, asumisen ja liikenteen (MAL) aiesopimuksen 2012–2015 seurantaraportti III; HSY, HSL and Uusimaa Regional Council, May 2015.

Mercado, R., Páez, A., Newbold, K.B., 2010. Transport policy and the provision of mobility options in an aging society: a case study on Ontario, Canada. J. Transp. Geogr. 18, 649–661.

Ratvio, R., 2012. Elämää Keskustassa Ja Kaupunkiseudun Reunoilla Urbaani Ja jälkiesikaupungillinen Elämäntyyli Asumisen Valinnoissa Ja Arkiliikkumisessa Helsingin Seudulla. University of Helsinki.

Salonen, M., Broberg, A., Kyttä, M., Toivonen, T., 2013. Do suburban residents prefer time-wise optimal or sustainable travel modes? Combining public participation GIS and multimodal travel time analysis for daily mobility research. Appl. Geogr. 53, 4338–4448.

Salonen, M., Toivonen, T., 2013. Modelling travel time in urban networks: comparable measures for private car and public transport. J. Transp. Geogr. 31 (0), 143–153.

Service Map of Helsinki, Espoo, Vantaa and Kauniainen [Homepage of Helsinki City], [Online]. Available: http://www.hel.fi/palvelukartta. [2014,04/07].

Sikder, S., Pinjari, A., 2012. Immobility levels and mobility preferences of the elderly in the United States. 91rst Annual Meeting of the Transportation Research Board, January 22–26 2012.

Silva, C., 2008. Comparative accessibility for mobility management. The Structural Accessibility Layer. University of Oporto.

Silva, C., Pinho, P., 2010. The Structural Accessibility Layer (SAL): revealing how urban structure constrains travel choice. Environ. Plann. A 42 (11), 2735–2752.

Statistics Finland 2012, Population in 250 meter grid squares, a part of Ruutuaineistot yhdyskuntarakenteen seurantajärjestelmässä (YKR) data set by the Statistics Finland.

Straatemeier, T., 2006. Accessibility: an interesting concept to address strategic planning issues in the Amsterdam region? Proceeding of the AMIDSt: Transportation Planning a Policy Design Challenge, Amsterdam.

Straatemeier, T., Bertolini, L., 2008. Joint Accessibility Design: a framework developed for and with practitioners to stimulate the integration of regional land-use and transport strategies in the Netherlands. Proceeding of the TRB 2008, Washington D.C..

Te Bömmelstroet, M., C. Silva & L. Bertolini (Eds.) (2014). Assessing Usability of Accessibility Instruments. COST Action TU1002. <http://www.accessibilityplanning.eu/wpcontent/uploads/2014/05/COST-REPORT-II.pdf>.

Toivonen, T., Salonen, M., Jaakkola, T. & Jäppinen, S. 2012, Arjen saavutettavuus pääkaupunkiseudulla, Helsingin kaupunki. Kaupunkisuunnitteluvirasto.

Vaattovaara, 2011, Change of urban structure in the Helsinki Region (2011) Helsinki quarterly 3/(2011) Accessed 01.11.12.

Wegener, M., 2004, "Overview of land-use transport models" in Handbook 5 of the Handbook in Transport Pergamon/Elsevier Science, Kidlington, pp. 127–146- Chapter 9.