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Spatial accessibility and (dis)advantage in the Helsinki Metropolitan Area

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Abstract

As inequality has increased globally, so has its spatial expression, socio-economic segregation. Traditionally Finland has been considered an egalitarian social welfare state where inequality and segregation are low. While inequality decreased until the 1990s, it has since started to grow and so has socio-economic segregation. In Helsinki Metropolitan Area this development is seen in the growing welfare differentiation between neighbourhoods. As policies to prevent segregation have proven inadequate, the role of spatial accessibility in connecting people with opportunities has grown increasingly important.

Using data on travel times and population statistics on a 250m x 250m grid this thesis tries to answer two questions; (1) to what extent does spatial accessibility differ for different socio-economic groups in the Helsinki Metropolitan Area and (2) how has spatial accessibility developed from 2013 to 2018 and how have different socio-economic groups been affected.

Spatial accessibility was defined by calculating the average travel time by public transport and by car between every 250m x 250m grid cell in the Helsinki Metropolitan Area using Helsinki Region Travel Time Matrix. To identify advantaged and disadvantaged grid cells in the area, an index of disadvantage was calculated using Statistic's Finland's Population Grid Database. Data from these two sources were combined to assess whether there is a difference in spatial accessibility between the least and most disadvantaged quintiles in Helsinki Metropolitan Area. While the main focus of the thesis is on public transport, spatial accessibility by car is also of interest, especially in relation to public transport.

This thesis finds that there is a difference between spatial accessibility from the least and most disadvantaged grid cells in favour of the most disadvantaged, though the results are statistically significant only for public transport. Furthermore, the difference in spatial accessibility by public transport has increased from 2013 to 2018 in the area in favour of the disadvantaged grid cells while spatial accessibility by car has decreased. Furthermore, spatial accessibility is far better by car than by public transport and despite two major investments in public transport in the area during the study period, spatial accessibility by public transport as defined by average travel time has decreased.

Keywords

Spatial accessibility, disadvantage, segregation, public transport

Where deposited

Additional information

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Tiivistelmä

Eriarvoisuus on kasvanut maailmanlaajuisesti ja sen myötä alueellinen eriytyminen. Suomea on perinteisesti pidetty tasa-arvoisena hyvinvointivaltiona, jossa sosioekonominen epätasa-arvo ja alueellinen eriytyminen on vähäistä. Tämä on kuitenkin muuttunut, sillä sekä eriarvoisuus että alueellinen eriytyminen ovat kasvaneet 1990-luvulta lähtien. Tämä kehitys näkyy myös pääkaupunkiseudulla asuinalueiden kasvavana sosioekonomisena eriytymisenä. Vaikka sosioekonomista eriytymistä on pyritty aktiivisesti estämään, tulokset ovat olleet pääosin laihoja. Niinpä saavutettavuudesta on tullut entistä tärkeämpää, sillä näin myös huono-osaisten asuinalueiden asukkaat voidaan yhdistää työpaikkoihin ja palveluihin.

Käyttäen keskimatka-aikoja ja väestötietoja 250 metrin ruututarkkuudella, tässä tutkielmassa pyritään selvittämään (1) kuinka maantieteellinen saavutettavuus eroaa eri sosioekonomisten ryhmien välillä pääkaupunkiseudulla ja toisaalta (2) kuinka maantieteellinen saavutettavuus on kehittynyt vuosien 2013 ja 2018 välillä ja miten muutokset ovat vaikuttaneet eri sosioekonomisiin ryhmiin.

Maantieteellinen saavutettavuus on määritelty laskemalla keskimääräinen matka-aika julkisella liikenteellä ja autolla kaikkien pääkaupunkiseudun 250 m x 250 m ruutujen välillä käyttäen matka-aikamatriisia. Hyvä ja huono-osaiset alueet on tunnistettu Tilastokeskuksen ruututietokannan väestötiedoista lasketun huono-osaisuuden indeksin avulla. Näiden kahden tietojen avulla on pyritty arvioimaan sitä, onko saavutettavuudessa eroja hyvä ja huono-osaisimpaan viidennekseen kuuluvien ruutujen välillä. Pääpaino on julkisessa liikenteessä, mutta maantieteelliseen saavutettavuuteen autolla on myös kiinnitetty huomiota, varsinkin suhteessa julkiseen liikenteeseen.

Tulokset viittaavat siihen, että pääkaupunkiseudulla huono-osaiset alueet ovat keskimäärin maantieteellisesti paremmin saavutettavissa kuin hyväosaiset alueet, joskin ero on tilastollisesti merkittävä ainoastaan julkisen liikenteen osalta. Tämän lisäksi, ero näyttäisi julkisen liikenteen osalta kasvaneen vuodesta 2013 vuoteen 2018 huono-osaisten alueiden hyväksi ja pienentyneen auton osalta. Huomionarvoista on, että keskimäärin maantieteellinen saavutettavuus on huomattavasti parempi autolla kuin julkisilla kulkuvälineillä ja että huolimatta kahdesta merkittävästä julkisen liikenteen investoinnista tutkimusaikana, keskimääräinen matka-aika julkisella liikenteellä on kasvanut alueella.

Avainsanat

Saavutettavuus, huono-osaisuus, alueellinen eriytyminen, joukkoliikenne

Säilytyspaikka

Muita tietoja

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1. Introduction

For the first time in human history more than half of world's population live in urban areas (55.3% in 2018, United Nations, 2019). Urbanisation has been rapid. When in 1950, only 30% of people lived in urban areas, the share is expected to rise to 68% by 2050 which means that there will be over 6 billion urban dwellers in the world (United Nations, 2019). At the same time the economic importance of cities has grown even faster. According to Dobbs et al. (2011) cities generated 80% of world GDP, far more than would be expected by their share of population alone. As cities have become increasingly important, the economic power of countries has become tightly linked to the power of its cities and with globalisation the influence of cities reaches far beyond national borders (Zevi, 2019).

As cities have grown in wealth and importance, more attention has been drawn to inequality and spatial segregation in cities. Inequality has risen dramatically globally from 1980's onwards (Alvaredo, 2018). While Europe still enjoys relatively low levels of inequality, inequality has been on the increase in the old continent too, if somewhat more moderately than in much of the rest of the world (Alvaredo, 2018). Increasing inequality has consequences for cities in the form of segregation as people from different socio-economic groups increasingly settle in different neighbourhoods (van Ham et al., 2021). While neither inequality nor segregation are a uniquely urban phenomenon, it is in cities that they are most pronounced.

Spatial accessibility is seen as one way to mitigate the effects of segregation by connecting people with opportunities. Recently a global trend of those well-off returning to city centres and the subsequent suburbanisation of both poverty and low-skilled jobs has sparked concerns that spatial accessibility for the most disadvantaged groups is worsening and thus further increasing inequality (Hochstenbach & Musterd, 2018, Hulse & Reynolds, 2018, Zhang & Pryce, 2020, van Ham et al., 2021). As disadvantaged groups tend to be more reliant on public transport its provision becomes increasingly important.

This thesis looks at spatial accessibility in the Helsinki Metropolitan Area and whether different socio-economic groups enjoy different levels of spatial accessibility. Furthermore, the data available allows assessment of whether spatial accessibility has changed from 2013 to 2018 in the area and whether these changes have affected different socio-economic groups differently.

This thesis attempts to answer two questions.

(1) To what extent does spatial accessibility differ for different socio-economic groups in the Helsinki Metropolitan Area?

(2) How has spatial accessibility developed from 2013 to 2018 and how have different socio-economic groups been affected?

Cycling and especially walking are important modes of transport in the Helsinki Metropolitan Area on shorter journeys. In fact, based on journeys made, walking is the second most popular mode of transport right after driving (Brandt et al., 2019). However, due to the large study area, walking and cycling are not realistic options in areawide transit and are therefore not considered in this thesis. The main focus is on spatial accessibility by public transport although spatial accessibility by car is also considered, especially in relation to public transport.

2. Background

2.1. Segregation – what is it and why are we worried about it?

Segregation has become one of the main concerns in cities worldwide. Segregation is usually referred to as the unequal spatial distribution of class or ethnic groups which creates neighbourhoods with different socio-economic or ethnic profiles (Maloutas, 2020). Segregation can also be demographic (Musterd, 2020, City of Helsinki, 2019). While segregation tends to have a negative connotation, it is not automatically a negative thing. Segregation can be beneficial especially for individuals and households when it is voluntary as living with similar people can reduce conflict and provide sense of safety and social networks (Merry, 2013, van Ham et al., 2018). Segregation is sometimes referred to with somewhat more neutral terms. Merry (2013) for example uses the term voluntary separation, Cheshire (2009) talks of specialized neighbourhoods and Vilkama (2011) uses the term differentiation (*eriytyminen*) in the study of the phenomenon in the Helsinki Metropolitan Area. The terms, however, essentially refer to the same phenomenon in which people sort into different neighbourhoods due to certain characteristics. In this thesis, the term segregation is used.

2.1.1. When does segregation occur?

Unwanted segregation tends to occur when people have little or no choice as to where they live. Those with little means end up living where they can afford to, not where they want to, often in the least desirable parts of the city (van Ham et al., 2021). Spatial segregation is often seen as a problem from the societies point of view as when distance between those well-off and those not increases, there's a risk that it leads to estrangement and fear of the other and to social unrest and even conflict and riots (van Ham, 2018). Segregation is also seen as a problem through what is called a neighbourhood effect, which refers to the effect the environment one lives in has on a person's life trajectory. Neighbourhood effect will be discussed further in a later chapter.

There is a strong correlation between socio-economic inequality and socio-economic segregation, with higher inequality typically leading to higher levels of segregation (van Ham et al, 2021). Income and wealth inequality have been rising globally since the 1980's though the process has been uneven, and some areas have seen greater increase in inequality than others (Alvaredo et al., 2018). Van Ham et al. (2021, p. 4) have concluded that '*Since the 1980s, globalisation, restructuring of labour markets, and liberalisation of the economy, have led to rising income and wealth inequality across the globe...*' Growing inequality in turn has led to an increase in socio-economic segregation. However, the relationship between inequality and segregation is not straight forward and there are other factors in play which can have either a positive or a negative effect on segregation. Besides inequality, socio-economic segregation is shaped by changing economic structures and levels of global connectedness, welfare regimes and housing systems (Musterd et al., 2017) which tend to differ from location to location. The welfare regime of a country can have a significant impact on segregation through state interventions such as taxation, health care provision, social security and education (Musterd et al., 2017). The geography of housing is crucial for spatial segregation. The more clustered the low-cost housing is, the more disadvantage concentrates in these neighbourhoods (Tammaru et al., 2020). Therefore, while segregation is driven by inequality, there are many factors which can either intensify or mitigate the spatial distribution of inequality. In global comparison Finland and the Helsinki Metropolitan Area fair quite well as inequality and segregation are relatively low though income and wealth differences as well as segregation have been increasing since the 1990s (Vilkama et al., 2014, Kiuru, 2015a, Riihelä & Tuomela, 2020, City of Helsinki, 2021). While disadvantaged areas have not been performing worse than before, advantaged areas have been growing even more advantaged and thus drifting further away from disadvantaged areas (Vilkama et al., 2014). However, more recently signs have been found which suggest that this may have changed. As Bernelius and Vaattovaara (2016, p. 3168) put it, *'Socio-spatial research has recently challenged the belief of a society shielded from processes of cumulative decline by pointing out that urban segregation appears to have begun to operate also – or possibly even mainly – through the decline of disadvantaged areas…*' This despite the cities actively promoting mixing policies in order to reduce segregation.

The growing spatial segregation seen in cities globally has been linked to an increase in the share of high-income earners. It is especially evident in high-income cities where the share of high-income earners can be up to 40% compared to 15% in low-income cities (van Ham et al., 2021). Sassen (2001) has argued that we are witnessing a polarisation of occupational structure and couple increase of high-income earners with increase of low-income earners such as those in the service sector. Others however find that occupational structure is professionalising, and the share of low-income workers has in fact decreased (van Ham et al., 2020). It has been suggested in the international literature that as the share of high-income earners increases, so does the demand for high-end housing which then leads to increase in land and housing prices in the most attractive areas (Tammaru et al., 2020). The increasing demand eventually spills over to new areas which means that low-income earners are priced out of an increasing number of neighbourhoods (van Ham et al., 2020). As a growing share of high-income earners are showing a preference for residential districts in city centres and coastal areas, low-income earners are pushed towards the less desirable peripheral areas (van Ham et al., 2021). In the Helsinki Metropolitan Area not only are people better educated and enjoy higher income than those living elsewhere in the country (Vilkama et al., 2014, Hyypiä, 2016), but people drawn to the area from elsewhere in Finland are likely to be better education and have higher household income than those already in the region (Karhula et al., 2020) thus contributing to the rising share of high-income earners in the area.

2.1.2. Where does segregation occur?

While segregation can occur in all kinds of environments, it is especially pronounced in urban areas (Musterd, 2020) and most segregation studies are concerned with urban segregation. Based on comparisons made between segregation in larger and smaller cities, it has been argued that larger cities appear more segregated than smaller ones due to scale. This is because in larger cities there are more similar people to cluster together and because of population density, census tracks often used to measure segregation tend to cover smaller areas in larger cities and therefore appear less mixed compared to those in smaller cities (Gordon & Monastiriotis, 2006, Krupta, 2007, Cheshire, 2009). This implies that segregation may also appear in rural villages if meaningful differences are developed (Musterd, 2020). Therefore, while segregation perhaps cannot be considered a uniquely urban problem, it is where problems associated with segregation tend to become visible.

Segregation is often understood as residential segregation, yet it goes much further than that and occurs also in contexts such as work, school, public spaces, leisure, and even choice of transport (Boterman et al., 2021). Therefore, since segregation is reproduced in all domains of life (Zhang, Wang & Kan, 2022), it is not enough to study residential segregation alone. Level of segregation also varies in different contexts as well as between different groups of people. School segregation for example has been found to be higher than residential segregation (Oberti, 2020) while high-income earners tend to be less exposed to diversity than others (Boterman & Musterd, 2016). Furthermore, people from different backgrounds tend to lead very different lives which is evident even when residential segregation is low. Even when people live in mixed neighbourhoods it does not necessarily lead to increased interaction between different groups of people (van Kempen & Wissink, 2014, Blokland and van Eijk, 2010). This has been seen in Helsinki, in Athens, and in Berlin where in mixed neighbourhoods people from different socio-economic groups often end up living within their own spheres of life with few contacts outside them (Vaattovaara et al., 2018, Maloutas, 2020, Blockland & Vief, 2021).

While urban segregation is usually studied at neighbourhood level, it can and does occur also in smaller scale, within neighbourhoods, between blocks of houses, even within buildings. In Athens vertical segregation has been observed in apartment buildings built mainly in the 1960's and 1970's where lower floors are occupied by low-income households and higher floors by high-income households (Maloutas, 2020). In Hong Kong's super high-rise buildings, a similar trend has been observed, where especially in the upscale areas of downtown it is more expensive to live in the higher floors (Forrest et al., 2020). With the trend of high-rise buildings in cities across the globe, vertical segregation has increased and is likely to do so in the future (Musterd, 2020). Small-scale segregation could also become more of an issue as gentrification, a development process which leads to the displacement of poorer residents with the arrival of more affluent residents, creates socially mixed neighbourhoods, at least temporarily (Maloutas, 2020). Small-scale segregation can be difficult to detect and can easily be mistaken for social mixing. This is especially a risk when larger areal units are researched.

2.1.3. What drives segregation?

Segregation is driven by those who have the means to choose where to live rather than those who live where they can. In segregation studies, however, the focus is often on the neighbourhoods considered poor or problematic. This can be distracting since the driving force of segregation is not found in the disadvantaged but in the advantaged areas. The most socio-economically advantaged groups have been found to be most segregated (Boterman et al., 2021) and mixing policies often fail because few well-off households are willing to move to poorer neighbourhoods (Korsu & Wenglenski, 2010) while the least advantaged groups have often been priced out of the wealthier neighbourhoods. Atkinson et al. (2017) have turned their gaze to the super-rich of London and point out that though a small group, it is a very influential one and has the power to change the city directly but also indirectly as the city orients itself to meet the needs of capital and those holding it. The solution to segregation may not thus be found in the disadvantaged neighbourhoods but in the advantaged.

According to the international literature there is a global trend of suburbanisation of poverty meaning that those well-off are increasingly concentrating in central cities while the poor are migrating towards peripheral regions (Hochstenbach & Musterd, 2018, Hulse & Reynolds, 2018, van Ham et al., 2021). This has led to increased inequality in access to both employment and amenities between poor and wealthy households (Zhang & Pryce, 2020). While there seems to be a shift in preference towards a more urban lifestyle (Siedentop et al, 2018), it has been argued that it is not so much changing residential preferences that is drawing people to city centres but the changing demographic and socio-economic composition of residents as well as changing housing stock that is behind the increased demand for centrally located housing (Booi & Boterman, 2020). It is especially the young, highly educated professionals working in the cultural sector that are drawn to centrally located neighbourhoods (Boterman et al, 2017). In Amsterdam, the share of highly educated, child-free residents who prefer living centrally has increased overall and so has the stock of owner-occupied housing and these, it has been argued, are the most important factors behind the increased share of those well-off in the city centre (Booi & Boterman, 2020). However, it seems that this may be too simplistic an explanation. In United States suburban poverty has also been linked to suburbanisation of employment (Swanstrom et al., 2002) as well as to new patterns of migration and the influx of Hispanic population who are more likely to settle in the suburban areas rather than central cities (Holliday, 2009). However it may be, the international literature suggest that the end-result has been an increase in the share of well-educated, high-earning households in centrally located neighbourhoods and suburbanisation of poverty.

2.1.4. What should we do about segregation?

Creating socio-economically mixed neighbourhoods has become a popular policy to prevent segregation and its undesired effects (van Ham & Manley, 2010). However, these policies have been criticised for lack of sound evidence. Van Ham and Manley (2010) for example found no evidence that mixing social renters and homeowners within neighbourhoods improved individual labour market outcomes. Mixing policies may even have negative effects. Luttmer (2005) found that self-reported happiness is relative to the earnings of one's neighbours meaning that living among people wealthier than yourself can make you unhappy. In similar vein, Nieuwenhuis et al. (2017) found that moving to a more affluent neighbourhood affected the psychosocial well-being of adolescents negatively. Najib (2020) argues that mixing policies may even intensify the problem if policies only target the effects of inequality rather than the causes such as the separatism of the wealthiest districts while according to Cheshire (2009) forcibly mixed neighbourhoods only treat the symptoms rather than causes of inequalities. Furthermore, attention may be deflected away from the real problems (Bolt et al., 2010). There is a danger with mixing-policies that rather than solving a problem, they only mask it, and the most disadvantaged groups may grow even more disadvantaged without anyone noticing. In fact, concentration of disadvantage may in some cases even turn out to be a blessing. Arbaci and Rae (2013) found that neighbourhoods with a high concentration of social housing rather than mixed tenure made public intervention possible, providing training and employment initiatives and thus improving socio-economic opportunities. Mixing policies may also lead to gentrification and in fact, Huning and Schuster (2015) suggest that social mixing and gentrification are essentially the same thing, the term used only differs depending on the perspective. It has been argued that social mixing policies can have a beneficial effect on social cohesion as well as improve the overall service level of a neighbourhood (Vaattovaara et al., 2018, Blokland & van Eijk, 2010). However, in London it was found that as neighbourhoods gentrified the new service infrastructure catered the wealthy new residents while public services important for the poorer may have been lost (Atkinson, 2000). Furthermore, as discussed above, since residential segregation is only one aspect of segregation and since mixed neighbourhoods are not alone enough to encourage meaningful interaction between different groups of people, segregation cannot be solved by creating mixed neighbourhoods alone. However, mixed neighbourhoods, while not automatically leading to contacts that cross class and ethnicity, do make them possible and increase the chances of interaction compared to fully segregated neighbourhoods. Research by Blokland and Nast (2014) suggest that even superficial contacts can be important. They found that public familiarity - talking to strangers you bump into on the street - is enough to create a sense of belonging and induce trust (Blockland & Nast, 2014). This would suggest that even small encounters could be of some meaning and diverse neighbourhoods can make those encounters between different groups of people possible.

Helsinki, the capital of and largest city in Finland, has had a social-mixing policy in place from as early on as the 1960s (Vaattovaara et al., 2018) which aims to reduce segregation. This has had some success in creating more mixed neighbourhoods and until the 1990s the policy worked quite well but has proven inadequate since (Vaattovaara et al., 2018). Maloutas (2020) argues that social mixing policies were effective when they were part of broader policies during the development phase of the welfare state. Today in the Helsinki Metropolitan Area disadvantaged areas often have a high level of social rented housing and the municipalities have chosen a policy of infill developments to increase the share of other housing types in areas with high levels of disadvantage (City of Helsinki, 2021, City of Vantaa, 2018, Kiuru, 2015a). This is rather understandable course of action since housing structure is the main factor explaining socio-spatial variation in the area and changes in the housing structure through construction seems to be the main explanation given for improved socio-economic status of neighbourhoods (Vilkama et al., 2014). The policy has had some success in creating more mixed neighbourhoods and for example in the neighbourhood of Myllypuro in eastern Helsinki the socio-economic status of the area has risen thanks to considerable infill construction (City of Helsinki, 2019).

The reasoning behind mixing policies assumes that disadvantaged households somehow benefit from the presence of advantaged households in a mixed neighbourhood (Huning & Schuster, 2015). Therefore, to be able to assess whether mixing policies are worthwhile or not it is important to understand how the neighbourhood could affect residents' life chances.

2.2. Neighbourhood effect – what is it and why does it matter?

If segregation is about how inequality affects spatial distribution of residents, then the neighbourhood effect is the opposite, of how segregation affects inequality and especially how "*living in deprived neighbourhoods has a negative effect on residents' life chances over and above the effect of their individual characteristics*" (van Ham & Manley, 2010, p. 257). Neighbourhood effect has been much researched but the evidence for it has been found a little elusive. Much of the research on neighbourhood effect comes from United States where inequality and segregation are at a far higher level than in Europe (Musterd & Ostendorf, 2008). It has been argued that in Europe, where inequality and segregation are much lower, neighbourhood effect can be expected to be of less significance (Musterd, 2005). This could explain why in Europe neighbourhood effects have proven difficult to detect. However, this claim has been argued to be based on an idealised view of European cities. European cities are not in fact very different from American cities, according to Korsu and Wenglenski (2010), but have experienced urban sprawl and suburbanisation of both residents and low-skilled jobs and most have high-poverty neighbourhoods. They were also able to detect a significant neighbourhood effect in the Paris region and found that the risk of unemployment was greater for low-skilled workers living in poor neighbourhoods (Korsu & Wenglenski, 2010). Musterd and Osterdorf (2008) also find a weak neighbourhood effect in the Dutch cities, but one that surprisingly did not seem to affect those in the weakest position, but those just above them. They believe it is due to the weakest benefiting from the resources of the welfare state more than those slightly less disadvantaged (Musterd & Osterdorf, 2008) which would emphasise the importance of welfare state in reducing inequality and its effects. In Sweden it has been found that while neighbourhood effect may not be of concern to most, it does matter to those from the most advantaged and most disadvantaged neighbourhoods (Andersson & Malmberg, 2018) whereas a study set in United Kingdom found a neighbourhood effect in educational outcomes but concluded that this was because the most advantaged benefited, not because the disadvantaged were further disadvantaged. These different results imply a complicated relationship between neighbourhood (dis)advantage and its (potential) effect on residents' life chances.

The neighbourhood effect can operate in at least three different ways; through the physical characteristics of the environment, through social-interactive mechanisms and through stigmatisation.

2.2.1. The physical environment

The physical characteristics of a neighbourhood, such as services available or environmental degradation, can have an effect on the life trajectory of a person. In United States, where local jurisdictions are responsible for providing many public services, spatial segregation has led to a situation where poorer jurisdictions provide poorer services at a higher cost to taxpayers (Swanstrom et al., 2002). This may mean that due to poor public services, such as schools and public transport, residents in poor neighbourhoods are further disadvantaged. Children are considered especially vulnerable to neighbourhood effects as children often spend more time in their residential neighbourhood and are thus more likely to be affected by their environment but also because through children, disadvantage can be reproduced and passed on (van Kempen & Wissink, 2014, Andersson & Malmberg, 2018, Blockland & Vief, 2021). In America, where school funding tends to vary from school district to school district, it has been found that schools reproduce the class inequalities of the society (Swanstrom et al, 2002). Improved spatial accessibility or proximity to jobs has been found to have a positive effect on employment (Haltivanger et al., 2020), suggesting that poor spatial accessibility could lead to increased risk of unemployment. Another study found that while improved spatial accessibility did not affect employment rates, it could have a positive impact on the median income of poor households which was speculated to mean that, at least in the area in question, spatial accessibility did not form a barrier to employment, however, better spatial accessibility lead to more employment opportunities thus allowing employees to choose better paying jobs (Delmelle et al., 2021). Spatial accessibility can thus affect the employment status and income of those living in disadvantaged areas.

Finnish comprehensive school has a reputation of being relatively equal and providing uniform teaching for all pupils (Kosunen et al, 2020). However, it is feared that the educational system is going to face challenges as segregation driven by social and urban change increases (Bernelius & Vaattovaara, 2016). While little difference has been found in the quality of teaching in Finnish schools, there is increasing differentiation between learning results between schools driven by increasing residential segregation (Bernelius et al, 2021). While spatial accessibility in the Helsinki Metropolitan Area is mostly quite good, there is significant variation between modes of transport and different locations. Spatial accessibility by car is good everywhere while by public transport it is relatively poor in peripheral areas (City of Helsinki, 2012). Spatial accessibility will be further discussed in a later section. However, if the global trend of low-income households being pushed to the peripheral areas is also taking place in the Helsinki Metropolitan Area, it could well have a considerable effect on the spatial accessibility of the poor.

2.2.2. Social-interactive mechanisms

Somewhat more elusive than the physical characteristics of a neighbourhood are social-interactive mechanisms and their effect on individuals. The theory suggests that '*the impact of the neighbourhood composition is transmitted through social interaction in the area*' (Miltenburg, 2015, p. 274). In other words, by socialising with residents of the neighbourhood for example attitudes, behaviour, and social norms can be passed on as well as knowledge, resources, and information (Galster, 2012). Vandecasteele and Fasang (2021) found that re-entering employment is least likely for those living in disadvantage neighbourhoods who mainly socialize with locals compared to those who have contacts outside their own neighbourhood or live in advantaged neighbourhoods. The results not only suggests that the neighbourhood and especially the social contacts people have do have an effect but also that neighbourhood effect perhaps is not so much a geographic phenomenon than a social one (Vandecasteele & Fasang, 2021). However, a study which focused on the connection between local social networks and socio-economic outcomes did not find that those with more local contacts were more affected (Miltenburg, 2015). As for the transmission of values and behaviour, Airaksinen et al. (2021) have studied the relationship between neighbourhood disadvantage, offender concentration and criminal behaviour in Finland and found that while all three are connected, this is likely more due to social selection than social causation and that individual characteristics better explain criminal behaviour than neighbourhood effect. Therefore, at least in Finnish context, living in a deprived neighbourhood with higher concentration of offenders does not lead to criminal behaviour.

In Finland, there is a strong link between family background and (dis)advantage. Vauhkonen et al. (2017) found that in families where parents had dropped out of school, received social assistance, or where unemployed social disadvantage was passed down to children. They further conclude that while the Finnish welfare state effectively compensates for material disadvantage, it is not able to do so for cultural and other non-material factors (Vauhkonen et al., 2017). Education of children is strongly linked to parental education, not only in the level of education but also in the field of study (Myrskylä, 2009). The neighbourhood, on the other hand, has not been found to have as strong an influence. However, a study by Kauppinen (2006) did find that while there was not a significant difference in entry to secondary education for children in advantaged and disadvantaged neighbourhoods, those in disadvantaged neighbourhoods were more likely to choose vocational school over high school compared to those who grew up in advantaged neighbourhoods. This would suggest that while parents and family background may influence children the most, the neighbourhood can have at least some effect too.

2.2.3. Stigmatisation

Neighbourhoods have reputations which can stigmatise both the area as well as its residents. Stigmatisation can have a profound effect on the attractiveness of a neighbourhood leading to a situation where certain residential groups as well as businesses avoid a neighbourhood, to discrimination in employment and to poorer services and amenities, including schools (Arthurson, 2012) and even affect access to credit (Taylor, 1998). The perceived reputation of a neighbourhood has been found to have a significant effect on moving intensions, even among those satisfied with their place of residence (Permentier et al., 2009). Bernelius et al. (2021) have found a stigmatising effect for schools in Helsinki's disadvantaged neighbourhoods. Even schools with high institutional quality and performance in educational outcomes struggle to overcome the negative views held of the neighbourhood (Bernelius et al, 2021). When comparing deprived and mixed neighbourhoods in Scotland, Atkinson and Kintrea (2001) found that residents of deprived neighbourhoods not only were much more likely to feel that the poor reputation of their neighbourhood made finding a job more difficult but that they believed that the poor image others had of their area was not accurate. However, Tunstall et al. (2014) found no evidence of discrimination in the labour market due to place of residence in England and Wales.

Residents themselves also hold very different views of their neighbourhood. Yacubovick et al. (2020) found that there is much variation between perceived and objective neighbourhood disadvantage which they believe to be explained by individual-level social factors while Najib (2018) found that residents who had chosen their neighbourhood were more satisfied with their place of residence. Residents thus hold very different views of the same neighbourhood depending on their personal situations. Taylor (1998) also points out that the negative image of a neighbourhood is internalised by people, and this then affects the way they view themselves and expect to be treated. The stigma attached to a neighbourhood can be very lasting and even extensive urban renewal does not necessarily change the view held of a neighbourhood (Najib, 2020). Reputation of a neighbourhood can therefore have a significant effect that goes beyond the facts making certain places seem worse than they actually are, affect how people are perceived and how people perceive themselves, induce avoidance and discrimination, and thus produce further inequality and segregation. Due to the persistence of a stigma and the importance people put on reputation, it can be very difficult to change the social status of a neighbourhood.

2.2.4. How important is the neighbourhood?

High level of inequality and segregation have been found to affect the socio-spatial mobility of people negatively: those in disadvantaged areas become less likely to move to a more advantaged neighbourhood (Nieuwenhuis et a., 2020). This suggest that once you end up in a poor area it gets hard to get away. As the gap between the advantaged and disadvantaged is growing, it is likely that upward socio-spatial mobility becomes even harder for those in disadvantaged neighbourhoods. However, it has also been argued that the importance of the neighbourhood is in decline. Neighbourhoods are still very important to certain groups, such as children, elderly, poor and ethnic groups who are more bound to their neighbourhoods and tend to have fewer contacts outside of them (van Kempen & Wissink, 2014). However, with increased mobility, immigration and communication technologies, people are more and more interacting with people outside their neighbourhoods (van Kempen & Wissink, 2014). This would suggest that even if neighbourhood had a role in reproducing disadvantage, it could be growing less important.

While the evidence for neighbourhood effect is rather inconclusive, this does not mean there is not one. However, the more important question perhaps is, what is the best way to tackle these problems. Cheshire (2009) points out the high cost of mixing policies. Therefore, if their effect is contested or only mild, perhaps other approaches could be better suited to tackle the many problems associated with segregation. This is exactly what many argue, that anti-poverty policies should target individuals rather than neighbourhoods and better results could be achieved by investing in people and opportunities through, for example, education and employment (Najib, 2020, van Ham et al, 2018, van Ham & Manley, 2010, Musterd & Oestendorf, 2008).

While neighbourhood effect is not, as such, a topic of this thesis, it is important in understanding why segregation matters. If living in an impoverished neighbourhood produces inequality and disadvantage, then steps must be taken to prevent segregation and mitigate its effects.

2.3. Spatial accessibility – what is it and why is it important?

According to Cervero, Al and Guerra (2017) spatial accessibility is about the ease with which people reach places they want to go to. Geurs and van Wee (2004) take the viewpoint of passenger transport and define it as to what extend land-use and transport network make it possible for people to reach places and activities by transport modes. Geurs and van Wee (2004) have identified four components important to measuring spatial accessibility. These are the land-use component - of where opportunities and people are -, the transport component - of the transport network available -, the temporal component - of variation of supply and demand at different times-, and individual component - of the needs, abilities, and opportunities of individuals (Geurs & van Wee, 2004). All four of these components are important in assessing spatial accessibility. After all, it is not enough to be able to reach a place if you have no need or want to go there or there may be barriers to spatial accessibility which arise from personal characteristics, such as disability or poverty. People have different mobility needs and therefore spatial accessibility means different things to different people, in different situations and at different times. Albacete et al. (2017) have studied spatial accessibility of different resident groups by different transport modes in the Helsinki Metropolitan Area and found that there is much variation in spatial accessibility. Not only do different resident groups have different accessibility needs, but they also inhabit areas with different levels of spatial accessibility. Children and students for example often live in areas of medium to low spatial accessibility or where spatial accessibility is car based while pensioners often live in areas where spatial accessibility is high for all modes of transport (Albacete et al., 2017).

Investing in spatial accessibility is one way to prevent or mitigate the effects of segregation. Policies based on connectivity can link deprived neighbourhoods with places of opportunity (van Ham et al, 2018) and it has been found that earnings of young adults for example increased considerably with improved spatial accessibility to formal job market (Haltiwanger et al., 2020). Spatial accessibility is also an important factor when people consider their place of residence or location of business (Lawton et al., 2013, Laakso, 2015). In Helsinki there is indication that new high quality public transport investments can raise the status of an area (Kiuru, 2015b). Good spatial accessibility can thus be a pull factor which draws businesses and those better-off to an area as well as connect neighbourhoods with services, jobs, and other opportunities. Furthermore, as residential segregation tends to be higher than some other types of segregation (Zhang, Wang & Kan, 2022, Xian, Qi & Yip, 2022) investment in spatial accessibility could reduce segregation, even if people from different socio-economic groups continued to reside in different neighbourhoods. For disadvantaged groups the quality and availability of public transport is especially important as they are more likely to rely on public transport to meet their spatial accessibility needs. Households with low income are less likely to own a car (Islam & Saphores, 2022) and households without a car are more dependent on public transport (Hu & Wang, 2019). Therefore, to reduce inequality and its impacts, attention must be paid to spatial accessibility by public transport especially.

There are signs internationally that city centres are now growing more affluent again, even in places where they have not previously been so, which has led to fears of those less well-off being pushed to marginalised, peripheral regions where spatial accessibility is poor. This reversal of the spatial orientation of socio-economic groups may lead to worsening relative access to employment and amenities (Zhang and Pryce, 2020, Blockland and Vief, 2021) and thus increase inequality. Furthermore, it is not only poverty that has suburbanised, but so have low-skilled jobs. This brings a further challenge to spatial accessibility as not only the physical distance between jobs and workers has increased, but they are also both now located in an area where public transport tends to be poorer and far more difficult to organise efficiently. So much so in fact that Korsu and Wenglenski (2010) came to the conclusion based on their study in the metropolitan area of Paris that the easiest way to improve the spatial accessibility of jobs for low-skilled workers would be to provide them with a car rather than invest in public transport. Since access to resources is essential to why segregation matters (Blockland and Vief, 2021), suburbanisation of poverty can lead to further disadvantage through poor access to opportunities. Therefore, attention must be paid to both where things are located and how they can be accessed.

3. Data and methods

3.1. Study area

The Helsinki Metropolitan Areas is in the south coast of Finland and consists of four municipalities that have essentially grown into each other (see Figure 1). Helsinki is the capital of and largest city in Finland with a population of 658 000 in 2021 (Statistics Finland, 2021). Espoo is the second largest city in Finland with a population of 297 000, Vantaa the fourth largest with a population of 239 000 and Kauniainen, a relatively small municipality with a population of 10 000, sits firmly within Espoo (Statistics Finland, 2021). All in all, 1 205 000 people lived in the Helsinki Metropolitan Area in 2021, a total of 21.6% of the population of the country

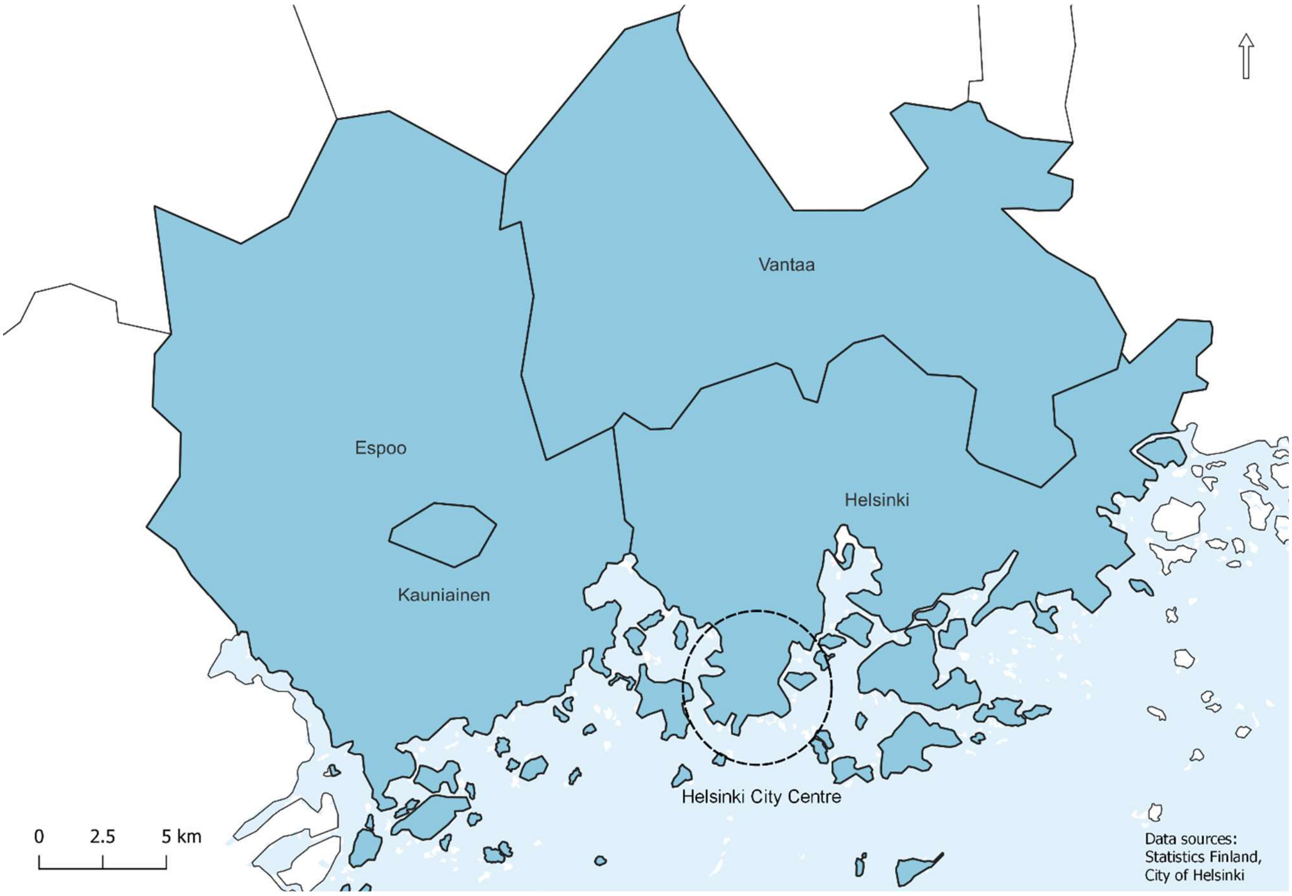

Figure 1. The study area, the Helsinki Metropolitan Area, highlighted in blue.

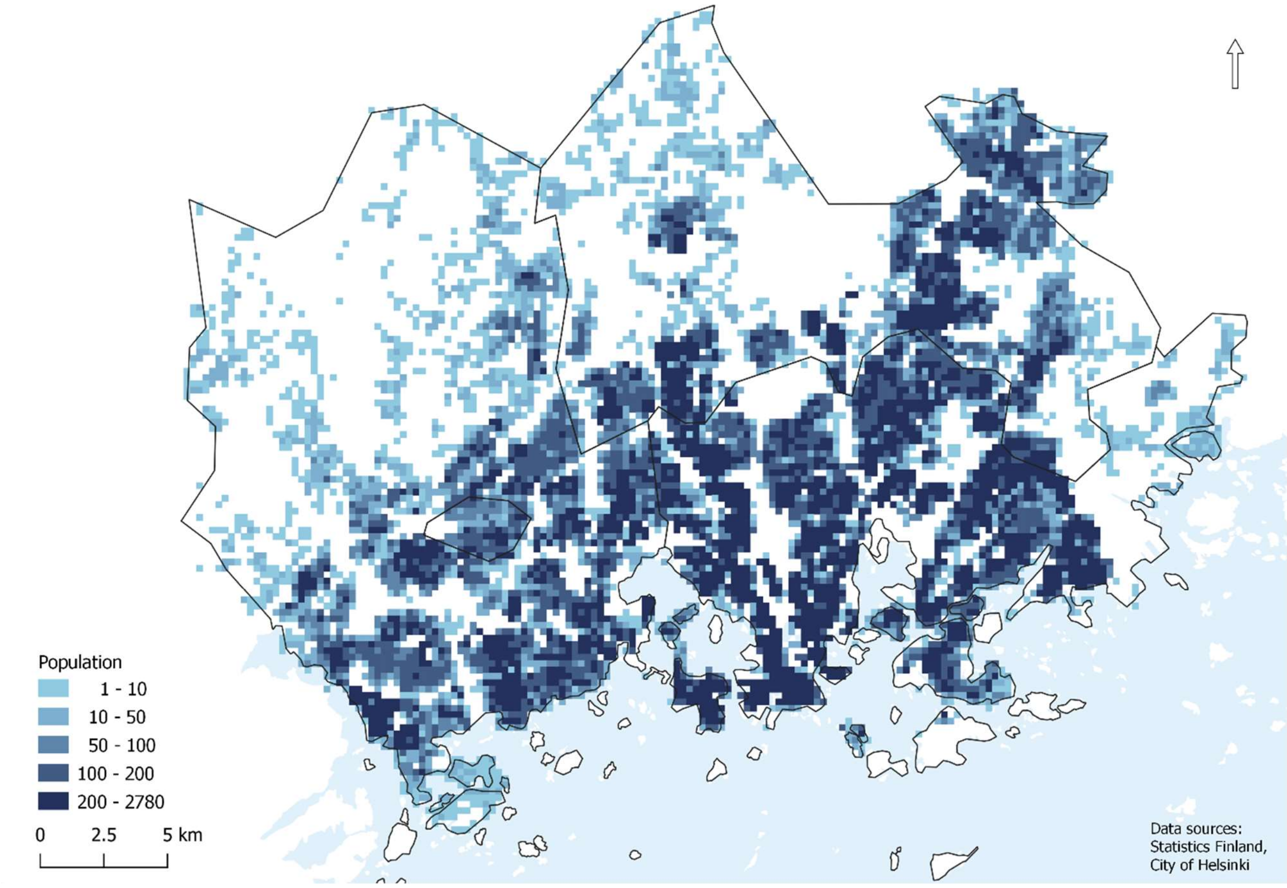

Figure 2. The distribution of residents in the Helsinki Metropolitan Area in 2019.

Population in the area concentrates in Helsinki city centre, coastal areas in the South and eastern parts of Vantaa (see Figure 2).

3.2. Transport in the Helsinki Metropolitan Area

Public transport network in the Helsinki Metropolitan Area consists of metro, railways, trams, and buses. Of these, trams only operate in central Helsinki while the other modes cross municipality borders. The bus network is the most extensive servicing most of the area. The metro with two lines runs in the South connecting Espoo in the West and eastern Helsinki with the city centre. Railway lines run from Helsinki city centre northwards to Vantaa and westwards to Espoo. While too small for details, Figure 3 shows well the distribution of services between different modes of transport in the area. Best served areas are also those with some of the highest population densities (see Figures 2 and 3).

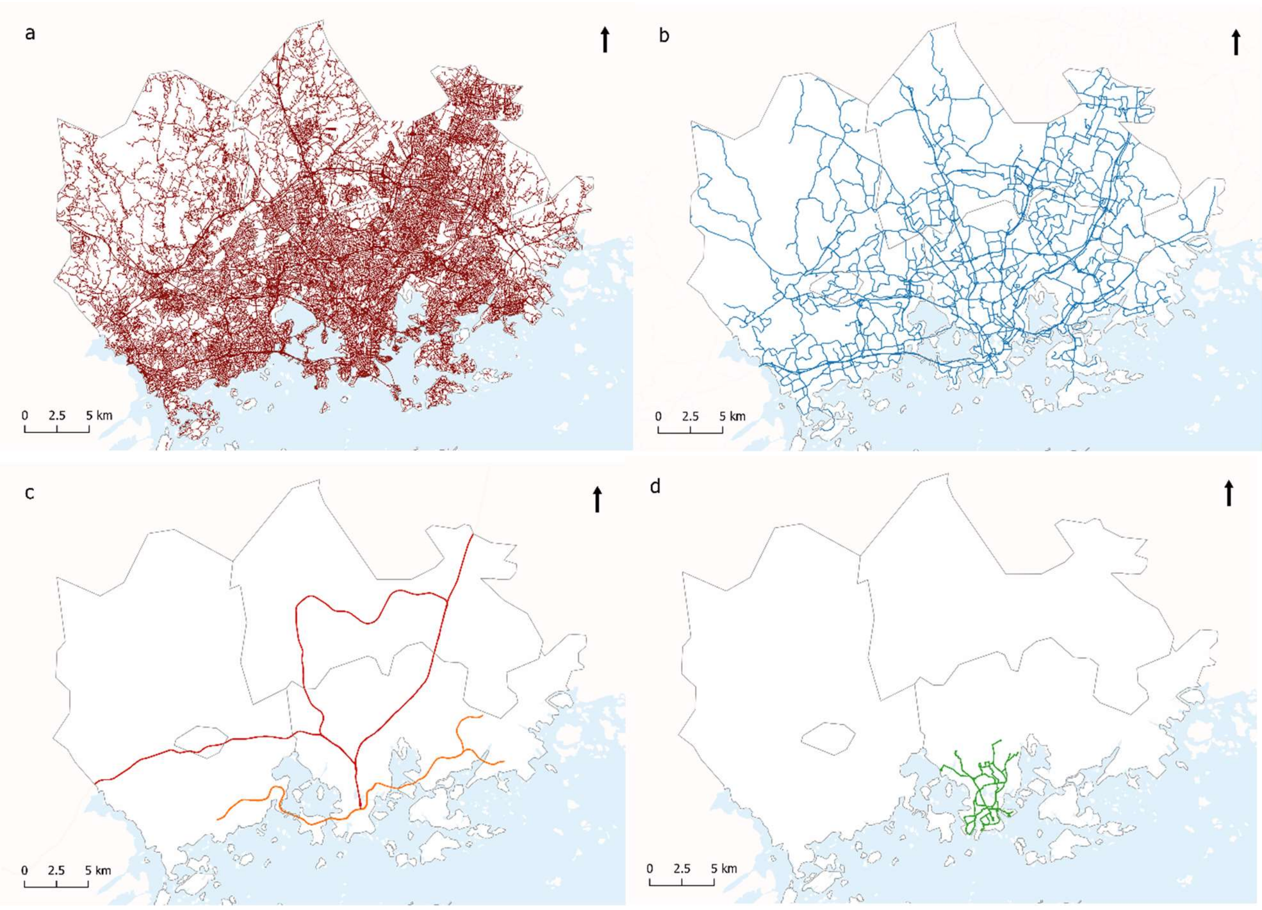

Figure 3. The transport network in the Helsinki Metropolitan Area; a) the street network, b) the bus network, c) train (red) and metro (orange) and b) the tram network (Data sources: Finnish Transport Infrastructure Agency, Helsinki Regional Transport, Statistics Finland, City of Helsinki).

Helsinki city centre is the main centre of activity in the area with a significant concentration of jobs and services (City of Helsinki, 2013). This can be seen in the radial orientation of especially rail services (including metro) but also other public transport as well as main roads. Public transport best serves Helsinki city centre and commuting to and from the city centre while cross-town services are scarcer.

In 2018 the residents of the Helsinki Metropolitan Area made 3.5 journeys a day on average (Brandt et al., 2019). Of these journeys 1.2 were made by car, 1.1 by foot, 0.9 by public transport, and 0.3 by bike (Brandt et al., 2019). While the largest share of journeys is made by car (34%), walking and public transport account for a significant share of journeys (Brandt et al., 2019). Furthermore, the share of driving has decreased slightly since 2012 (from 36%) as has the share of public transport (from 27% to 25%), while the share of walking (from 27% to 30%) and cycling (from 7% to 9%) has increased (Brandt et al., 2019). The most popular means of public transport in the area is bus followed by metro, railway, and tram (Brandt et al., 2019).

The modal share of transport varies between municipalities. Of journeys made in Helsinki, the most popular modes of transport are walking and public transport while in Espoo and Vantaa driving is by far the most popular mode (Traficom, 2018, Brandt et al., 2019). Of journeys made during morning rush hour on weekdays towards Helsinki City Centre 62% are made by public transport (Laakso, 2015). This number includes also journeys beginning outside the Helsinki Metropolitan Area and as the share of journeys made by public transport is higher the closer to Helsinki city centre the starting point is (Laakso, 2015), the share can be expected to be even higher for journeys beginning in the metropolitan area. Furthermore, Helsinki city centre stands out as an area where driving, with only a 10% share of all journeys made, is especially unpopular (Traficom, 2018). This suggests that vast variation in modal shares can also be found within municipalities as well as between destinations and the time of day. Variation in modal share is likely to reflect differences in spatial accessibility in the area.

There have been two major public transport investments in the Helsinki Metropolitan Area in the past decade, the so-called Ring rail line (*Kehärata*) and Western extension of metro (*Länsimetro*). The Ring rail line connected the main railway line with the Martinlaakso line in Vantaa and provides Helsinki Airport in Vantaa with a rail connection. The Ring rail line was opened in 1.7.2015 and proved popular from the start with boardings from Vantaa’s train stations rising by 47% almost immediately (Väylävirasto, 2020). The Western extension of the metro line consisting of 8 new stations was opened to traffic in 18.11.2017 and connected southern parts of Espoo with Helsinki (Länsimetro, n.d.). A second extension consisting of 5 more stations is due to be opened in Espoo in 2023 (Länsimetro, n.d.). As this thesis looks at changes in travel times from 2013 to 2018 both these investments may have affected travel times in the area.

3.3. Data

The main datasets used in this thesis are the Helsinki Region Travel Time Matrix (*Pääkaupunkiseudun matka-aikamatriisi*) from 2013, 2015, and 2018 and Statistics Finland's 250m x 250m Population Grid Database (*Ruututietokanta*). Both datasets are compatible with the Finnish Environmental Institute's YKR (*Yhteiskuntarakenteen seurantajärjestelmä*) grid which allows the data to be joined and visualized on map. Additional data was drawn from the YKR commuting dataset which is compatible with both Helsinki Region Travel Time Matrix and Statistics Finland's 250m x 250m Population Grid Database. A full set of data sources are presented in Table 1.

Table 1. A description of data sources used.

Dataset	Owner	Use	Data
Helsinki Region Travel Time Matrix	Digital Geography Lab, https://blogs.helsinki.fi/accessibility/helsinki-region-travel-time-matrix/	Spatial accessibility	Travel times between grid cells
250m x 250m (Population) Grid Dataset	Statistics Finland, restricted	Index of disadvantage, population statistics, housing statistics	Population, educational level, household income, employment status, housing type
250m x 250m YKR Dataset (commuting dataset)	Finnish Environmental Institute & Statistics Finland, restricted	Car ownership	Car ownership
Geographic data	Statistics Finland, https://www.stat.fi/org/avoindata/paikkatietoaineistot_en.html	Visualisation	Municipality borders
Digiroad	Finnish Transport Infrastructure Agency (*Väylävirasto*), https://vayla.fi/vaylista/aineistot/digiroad/aineisto/rajapinnat	Visualisation	Road network
HSL transport network	Helsinki Region Transport (*HSL*), https://public-transport-hslhrt.opendata.arcgis.com/	Visualisation	Public transport network
Helsinki Region Map	City of Helsinki, https://hri.fi/data/fi/dataset/seutukartta	Visualisation	Sea

The data used has been joined and processed using Rstudio (for code see Appendix 12) and results have been analysed and visualized using QGIS and Microsoft Excel. Microsoft Access was used to convert YKR commuting dataset to Excel format and IBM SPSS Statistics to test whether the results are statistically significant. For a simplified flow chart of the study see figure 4.

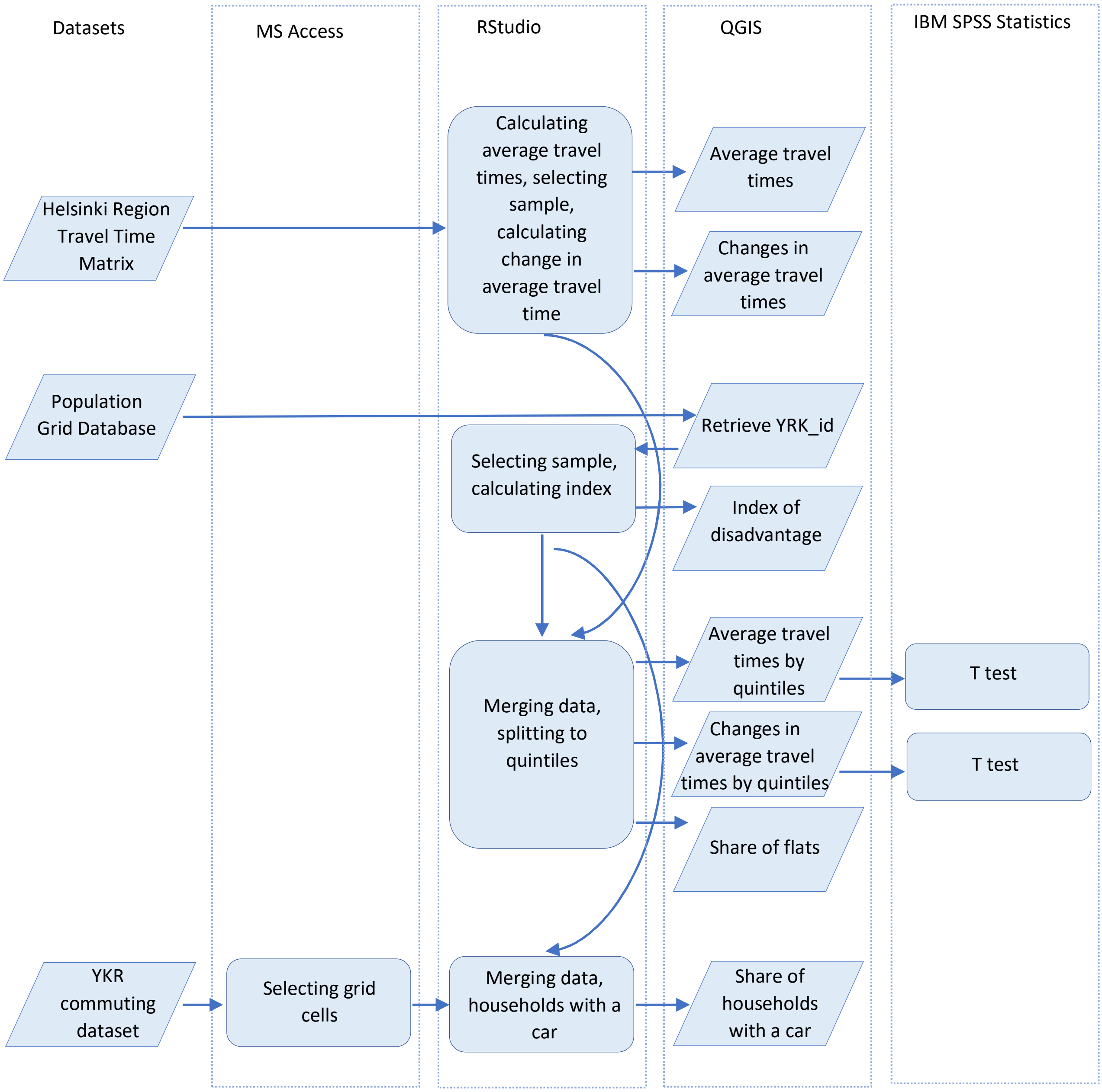

Figure 4. A simplified flow chart of study.

3.3.1. Helsinki Region Travel Time Matrix

The Helsinki Region Travel Time Matrix is a dataset by University of Helsinki's Digital Geography Lab that contains travel times and distances of routes by different means of transport between all

13 231 grid cells of 250m x 250m in size covering the Helsinki Metropolitan Area (Digital Geography Lab, *https://blogs.helsinki.fi/accessibility/helsinki-region-travel-time-matrix/*). The dataset is available for three years; 2013, 2015, and 2018. Each of the three datasets have been divided into 13 231 text files according to route destination each containing 13 231 lines of data (Digital Geography Lab, n.d.). The datasets make it possible to calculate travel times between all 13 231 different grid cells by different means of transport. These datasets are used to assess spatial accessibility in the Helsinki Metropolitan Area as well as possible changes in spatial accessibility. Once joined with data from the Population Grid Database spatial accessibility for different socio-economic groups can be assessed. The primary interest of this thesis is spatial accessibility by public transport though spatial accessibility by car is also referred to especially in relation to public transport. Changes in spatial accessibility are derived from changes in average travel times between the three years travel times are available for. Besides the Statistics Finland's Grid Dataset, the Helsinki Region Travel Time Matrix is also compatible with the Finnish Environmental Institute's YKR dataset (Digital Geography Lab, 2022).

The Helsinki Region Travel Time Matrix provides travel times and distances by car, by public transport, by foot, and since 2018 also by bicycle. Travel times are provided for midday traffic for all three years and from 2015 also for rush hour traffic. For public transport, travel times are provided with and without the waiting time at home. For the purpose of this thesis, which is primarily interested in changes in travel time, it was most important to have comparable data from each year. For public transport travel time at midday traffic with the whole travel chain from origin to destination without waiting time at home is used (field *pt_m_t*) and for car travel time at midday traffic with the whole travel chain from origin to destination (field *car_m_t*). Thus, not only are travel times comparable from each year for both means of transport, travel times by public transport and by car are comparable too, to an extent. As too low speed limits were used on certain roads when calculating travel times by car for 2015, the data is not fully comparable with data from 2013 and 2018 (Tenkanen et al., n.d.). Therefor, changes in travel times by car from 2013 to 2015 and 2015 to 2018 will not be considered.

In this thesis spatial accessibility is purely about the possibility of mobility. It does not try to understand where people want to or need to go to or if they are able to use the transport available. It values each journey equally, despite of what is on the end point of each journey, even though, in fact, some journeys are more valuable than others. Therefore, far reaching conclusions about spatial accessibility in the Helsinki Metropolitan Area cannot be drawn in this thesis.

Average travel times were calculated as follows. First all text files for each year were read one file at a time using RStudio. Next average travel time and number of grid cells with a valid value were calculated for each destination for both public transport and car. This gave three tables, one for each year, with a line for each of the 13 231 destinations. While the original dataset contains 13 231 grid cells, some of these have been excluded from the final dataset. In the older, 2013 and 2015, datasets some grid cells had a missing id. These were excluded. For some grid cells no travel times were available. These were excluded. A closer look at the data also revealed that in some cases travel time was available from only a handful of other grid cells, often close to the original cell. These grid cells often received an unnaturally low average travel time and were excluded. This was done by counting the number of grid cells from which travel time was available and excluding all those with travel time from 50 grid cells or less. This was done separately for both public transport and for car. It was quite clear that travel times were available either from all or close to all grid cells or from only a few therefore the number 50 was chosen for reasons of convenience only. In the end, average travel times were available as follows (see Table 2).

Table 2: The number of grid cells average travel times have been calculated for in 2013, 2015 and 2018.

	2013	2015	2018
Grid cells	13 231	13 231	13 231
After exclusion			
Public transport	12 533	13 017	13 101
Car	13 093	13 140	13 074

Figures 5 and 6 show the average travel time from each grid cell to all other grid cells in the Helsinki Metropolitan Area in 2018 by public transport and by car (for average travel times for years 2013 and 2015 see Appendix 1 and 2). As can be seen, travel times are the shortest from grid cells in the central area increasing towards the periphery. Average travel times also tend to be lower close to main roads while for public transport average travel times tend to be lower also close to railway and metro lines (see Figures 5 and 6). The average travel time in the Helsinki Metropolitan Area by public transport in 2018 was 86.2 minutes while the travel time by car was 37.8 minutes. The average travel time by public transport is thus more than twice the average travel time by car. Furthermore, not in one grid cell was public transport the faster option.

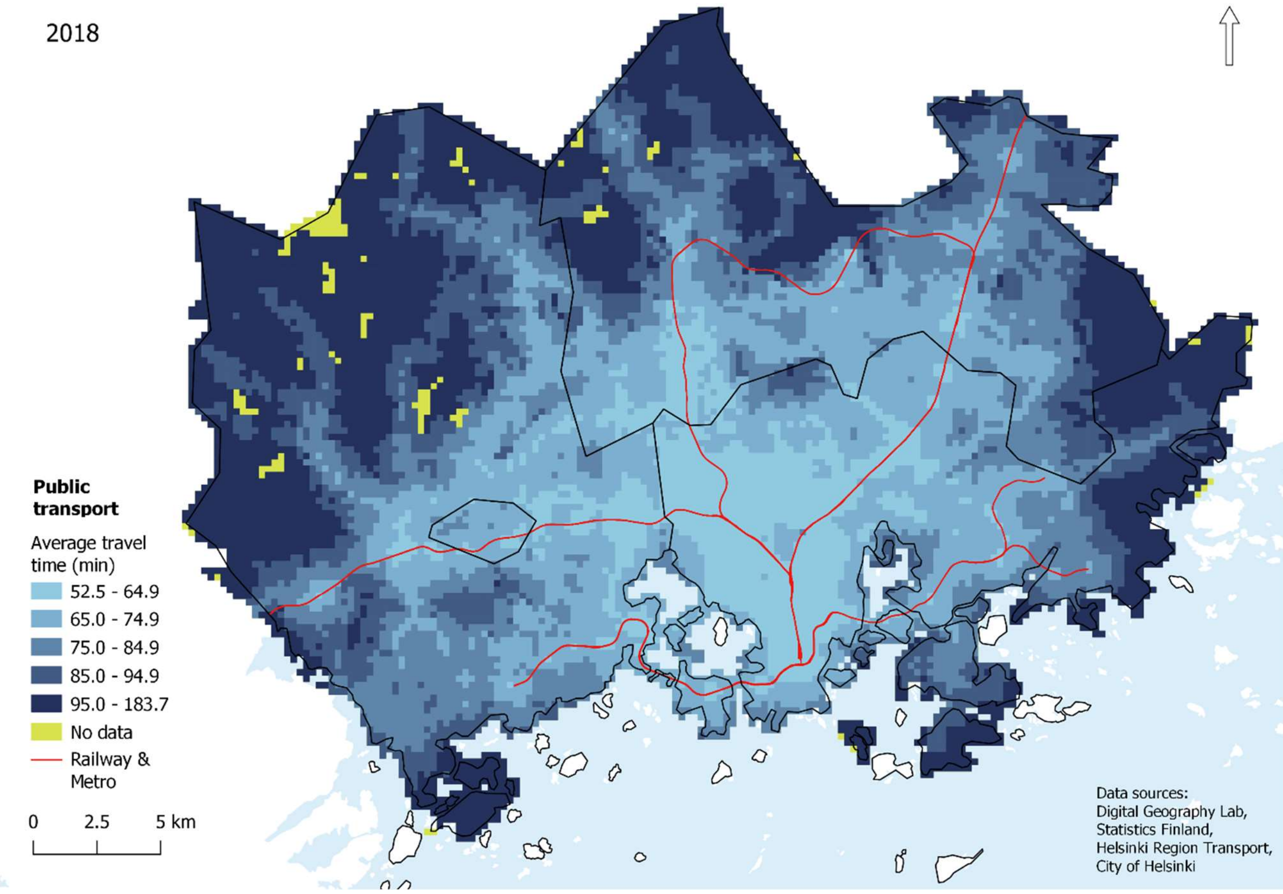

Figure 5: Average travel times by public transport in the Helsinki Metropolitan Area in 2018.

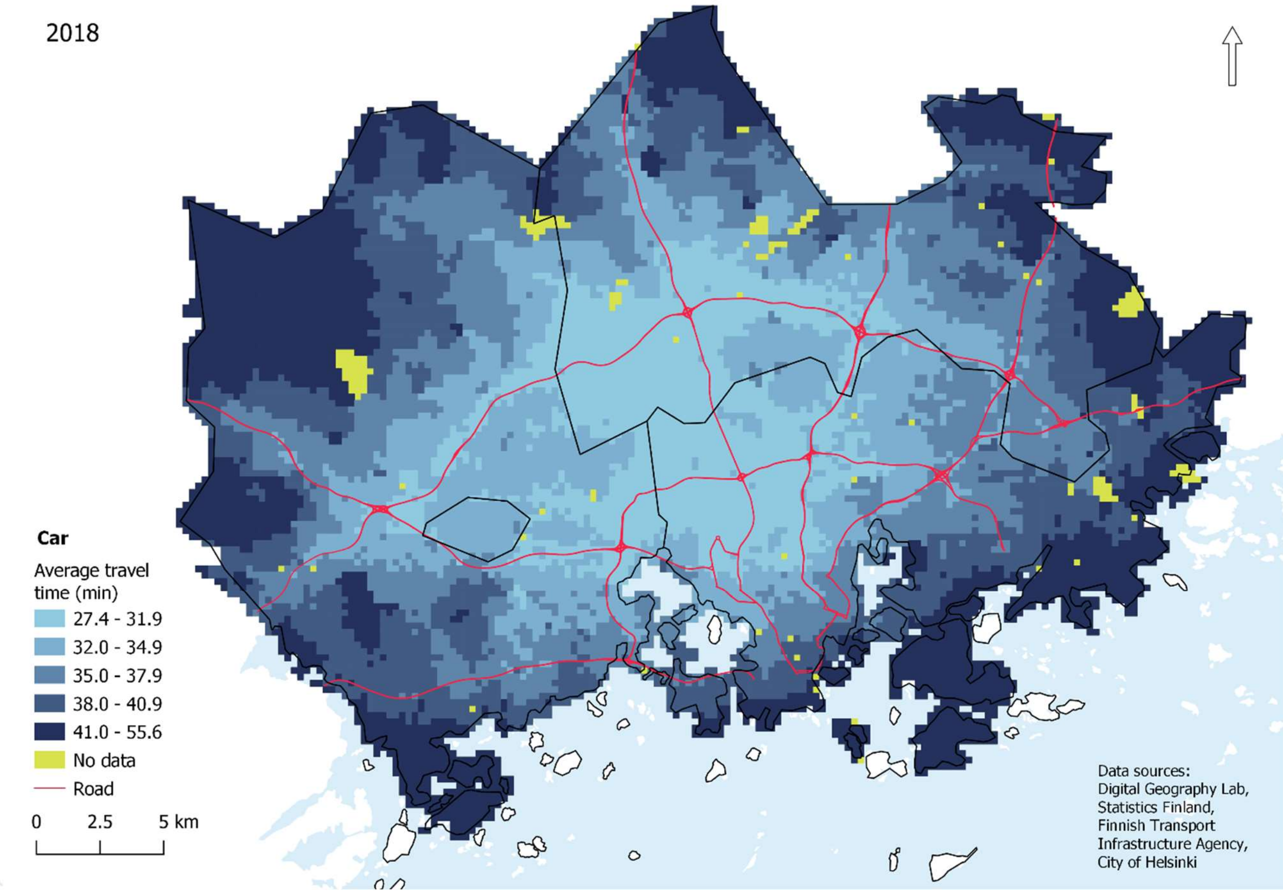

Figure 6. Average travel times by car in the Helsinki Metropolitan Area in 2018.

3.3.2. Statistics Finland's 250m x 250m Population Grid Database

Statistics Finland's 250m x 250m Population Grid Database (*Ruututietokanta*) from 2020 forms the basis of this thesis. The dataset containing data about Finland's population, educational and workplace structure, inhabitants' disposable income, the stage and size as well as disposable income of households, buildings and housing, and main type of activity in 104 different variables (Statistics Finland, n.d.). This data is used to define the advantaged and disadvantaged grid cells in the Helsinki Metropolitan Area. Since this thesis is concerned with the changes in spatial accessibility rather than changes in spatial distribution of (dis)advantage, the socio-economic composition of grid cells is calculated for one year only and thus fixed in time. This means that this thesis cannot consider the possible impact of changes in spatial accessibility to the socio-economic composition of a grid cell or changes in distribution of disadvantage more generally in the area. However, while it is possible that the socio-economic composition of grid cells may vary from year to year it has been found that at neighbourhood level changes are not very common (Vilkama et al., 2014). Therefore, it is assumed that there would not be major changes in the spatial distribution of disadvantage over time, at least not during the relatively short period of time this thesis covers.

The initial sample size is 8 193 grid cells, in other words, the grid cells that are found in both Population Grid Database and the Helsinki Region Travel Time Matrix. The two datasets do not contain all the same grid cells. Helsinki Region Travel Time Matrix, with a total of 13 231 grid cells, has a better coverage of the peripheral areas away from the coastal and central areas, whereas the Population Grid Database, with 8 356 grid cells in the Helsinki Metropolitan Area, covers some of the coastal areas not included in Helsinki Region Travel Time Matrix. How the Population Grid Database grid cells fall on the different municipalities is presented in Table 3. However, results will not be discussed separately for the different municipalities in this thesis.

Table 3. Population and Population Grid Database grid cells by municipality in the Helsinki Metropolitan Area.

	Population (2021) *	%	Population Grid Database grid cells **	Grid cells without protected cells **
Finland	5 548 000	100.0%		
Helsinki	658 000	11.9%	2 657	1 833
Espoo	297 000	5.4%	3 065	1 462
Vantaa	239 000	4.3%	2 263	1 133
Kauniainen	10 000	0.2%	83	76
Helsinki Metropolitan Area	**1 205 000**	**21.7%**	**8 193**	**4 526**

**) Population structure, Statistics Finland, 2021*
***) The sample includes (125 and 22) grid cells with a municipality code other than that of Helsinki, Espoo, Vantaa or Kauniainen. The municipality code is from the Statistics Finland's Population Grid Database and in some cases, the grid cells in the Helsinki Region Travel Time Matrix receive a code of a neighbouring municipality.*

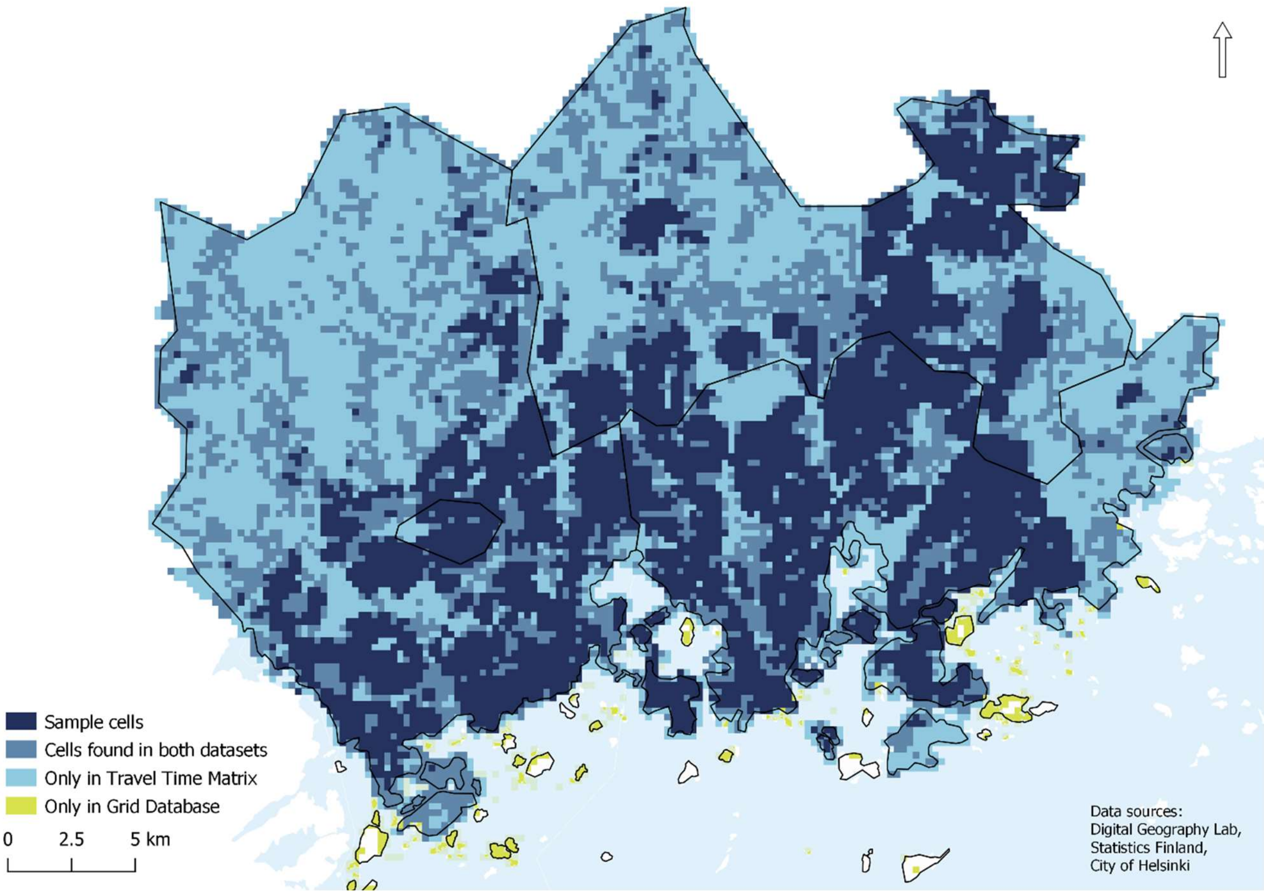

Figure 7. Grid cells in the Helsinki Region Travel Time Matrix, the Population Grid Database and the final sample.

The index of disadvantage is calculated based on education, household income and unemployment. However, data is not available for grid cells with less than ten inhabitants or households, and therefore, the index cannot be calculated for these grid cells. These grid cells have been excluded from the sample. This means that the final sample consists of 4 526 grid cells. The distribution of grid cells in Helsinki Region Travel Time Matrix, the Population Grid Database and the final sample are presented in Figure 7. The excluded grid cells contain only a small portion of the population (2.0%) in the original sample before exclusion. Furthermore, excluding these grid cells did not affect the share of low-income households, those without education after compulsory education or unemployed in the final sample either. Table 4 shows well how while the number of grid cells in the sample is considerably smaller than the grid cells available in the Population Grid Database and Helsinki Region Travel Time Matrix, the number of inhabitants included in the sample has not decreased significantly. The sample includes no grid cells with no inhabitants and the average and median number of inhabitants are considerably higher.

Table 4: Selected population statistics of grid cells included in Statistic's Finland Population Grid Database, Helsinki Region Travel Time Matrix, and the final sample. Note that the Population Grid Database and Helsinki Region Travel Time Matrix both contain some grid cells which the other does not.

	Number of cells	Inhabitants Total	Per grid cell	Median	Min.	Max.
Grid Database (Helsinki, Espoo, Vantaa, Kauniainen)	8 356	1 163 500	139	42	0	2 780
Helsinki Region Travel Time Matrix	8 193	1 164 900	142	47	0	2 780
Sample	4 526	1 141 400	252	163	13	2 780

3.3.3. Miscellaneous datasets

The YKR (*Yhteiskuntarakenteen seurantakanta*) commuting dataset from Finnish Environmental Institute and Statistics Finland provided statistics about car ownership in the area by 250m x 250m grid cells.

The map illustrations take advantage of several open data sources. Municipality borders are from Statistics Finland, road and street network from Finnish Transport Infrastructure Agency (*Väylävirasto*), public transport networks from Helsinki Regional Transport (*HSL*) and sea from City of Helsinki. A detailed list of data sources used can be found in Table 1

3.4. Calculating the index of disadvantage

In this thesis a sum index of disadvantage is used to recognise advantaged and disadvantaged grid cells. The focus of this thesis is on socio-economic segregation rather than ethnic. However, ethnic segregation does occur in the Helsinki Metropolitan Area, and it is often closely tied to socio-economic factors. Both income and employment rate tend to be lower than average among ethnic minorities and they are often also located in the same areas as low-income ethnic Finns, in areas with high share of social rental housing (Vilkama, 2011). However, ethnicity cannot be seen as a disadvantage in itself and therefore will not be of concern in this thesis.

The three indicators used to calculate the index of disadvantage in this thesis are income, education, and unemployment. These are widely used to measure inequality, also in the Helsinki Metropolitan Area, and there are very similar indexes found in literature (for example City of Vantaa, 2018, City of Helsinki, 2021). However, it is important to note that even though the indexes may be seemingly similar, there are a number of different ways to calculate the index which may (or may not) have an effect on the index value itself and the spatial distribution of disadvantage. Therefore, results of this thesis may not be comparable with results from other studies. The logic and reasoning behind the index used in this thesis will be presented later in this chapter.

As there is no universal definition for disadvantage the indicators used are, at least to an extent, always value choices and reflect the views of the researcher. These choices are likely to affect the results as well. For example low educational level, as Vilkama (2014) points out, is not a problem as such, yet it is commonly used to indicate disadvantage. While perhaps the most commonly used indicator is income, it does not mean that, if asked, all low-income earners consider themselves disadvantaged. Besides income, education and unemployment, City of Helsinki (2019) has also used indicators such as homelessness, alcohol use, loneliness, social benefit recipiency, health, and mortality to measure disadvantage and well-being. Availability of data is also likely to affect indicators used. Furthermore, indexes are context specific. As the data usually comes from different sources and the value of an index is always related to an average, it cannot be used to make comparisons between different locations.

Despite segregation covering all fields of life, this thesis is only concerned with residential segregation. Though it only covers one aspect of segregation, it has been argued that since home is where people live, the starting point of daily activities and strongly reflects one’s socio-economic status it makes sense (van Ham et al., 2018). Furthermore, place of residence shapes access to work, school, and leisure activities (Tammaru et al., 2021). It is also a practical decision as reliable spatial census data by place of residence is readily available.

Income, education, and employment have a significant effect on a person's well-being. Education not only leads to a better paid job but also to more opportunities for self-accomplishment, social interaction, and independence as well as to better health, happier marriages, and more successful children, among other things (Oreopoulos and Salvanes, 2011). Unemployment on the other hand has a strong negative effect on life-satisfaction, greatly exceeding the effect of loss of income even (Winkelmann and Winkelmann, 1998). There is also a positive correlation between income and health. Whether higher income leads to better health or vice versa is not clear, yet those with higher income tend to be in better health (Larrimore, 2011). Vilkama et al. (2014) compared spatial distribution of low education, low income, unemployment, and ethnicity in the Helsinki Metropolitan Area and found that all four factors have very similar patterns suggesting that they strongly correlate with each other. They also found that they overlapped with other indicators of disadvantage such as social benefit recipiency, long term unemployment and use of child protection services (Vilkama et al., 2014). The three factors in the index of disadvantage can therefore be expected to overlap strongly. Areas of low education can be expected to also be areas of low income and high unemployment and vice versa. These three indicators - education, income, and unemployment - can thus be used to describe the well-being of a person on a wider scale.

The index is based on the 250m x 250m Population Grid Database by Statistics Finland from 2020 which gives more detailed information about spatial distribution of disadvantage than neighbourhood level data. In other words, spatial segregation is likely to be greater when using the 250m x 250m grid cells instead of neighbourhoods. However, it is still not able to detect small-scale segregation, rather, small-scale segregation is likely to show up as social mixing. The database contains data on 8 356 grid cells in the four municipalities in the Helsinki Metropolitan Area though once grid cells not in the Helsinki Region Travel Time Matrix as well as protected grid cells are removed, the index can be calculated for 4 526 grid cells. The three components of the index - income, education, and unemployment - were calculated as follows.

3.4.1. Income

The income component is the share of households in the lowest two deciles in the Helsinki Metropolitan Area calculated from the households' disposable monetary income. The data is for 2018 when the lowest quantile (two lowest deciles) had a household income of 17 301 euros or less per year (Statistics Finland, n.d.). The household income is an equivalent income which means the household income is divided by the consumption units in the household (Statistics Finland, n.d.). The OECD's adjusted consumption unit scale recommended by Eurostat used gives the first adult a weight of 1, all others over 13 years a weight of 0.5 and children 13 years or under a weight of 0.3 (Statistics Finland, n.d.). The household income was chosen over the per capita income as it takes better into account the different household structures and shared consumption benefits (Hyypiä, 2016). The income component is thus defined as

$$\frac{tr\_pi\_tul}{tr\_kuty}$$

where *tr_pi_tul* is the number of households in the lowest two income deciles and *tr_kuty* is the number of households. The average share of low-income households in the sample (defined as $\frac{\sum tr\_pi\_tul}{\sum tr\_kuty}$) is 19.5% while the sample grid cell average (defined as $\frac{1}{n}\sum_{i=1}^{n}\frac{tr\_pi\_tul_i}{tr\_kuty_i}$ where n is the number of grid cells) is 13.6%. This difference comes from the different spatial distribution of low- and high-income households. Low-income households tend to live in densely populated grid cells while high-income households more typically are found in the less densely populated grid cells. The share of low-income households varies from none to 94.7%.

3.4.2. Education

The education component is the share of those with no education after compulsory education of those 18 years and above in 2019. Sometimes tertiary education, or the lack of, is used to describe disadvantage but that would have meant that 63.5% of residents in the Helsinki Metropolitan Area would be, in essence, considered disadvantaged due to their education, including professionals with vocational training such as practical nurses and electricians. It would also have given education a far greater weight in the index compared to the other two indicators. Therefore, the share of those with no education after compulsory education was considered more appropriate indicator of disadvantage in this case. Having said that, when it comes to residential segregation, it does seem that education, or cultural capital, may be increasingly relevant, even more so than income (Boterman, Musterd & Manting, 2021). The education component is thus defined as

$$\frac{ko\_perus}{ko\_ika18y}$$

where *ko_perus* is the number of residents with no education after compulsory education and *ko_ika18y* the number of residents 18 years and above. The average share of inhabitants with no education after compulsory school in the sample is 21.2% while the sample grid cell average is 19.5%. This indicates that those with some education after compulsory education are slightly more likely to reside in grid cells that are less densely populated though the difference is much smaller than with household income. The share of those with no education varies from none to 92.9%.

The educational level of Finns has steadily increased. The share of population with educational qualification has risen from 59.4% to 74.2% from 2000 to 2020 alone while in the same period the share of those with only basic education has fallen from 40.6% to 25.8% (Statistics Finland, 2022). As the share of those with no education after compulsory education is higher in the older generations, areas with a large share of older residents are also likely to have a larger share of those with no education after compulsory education (City of Vantaa, 2018). The no education after compulsory education category also holds those with unknown qualification (Statistics Finland, n.d.). This includes foreigners who have been in Finland for a short period of time only and may therefor affect the share of those with no education after compulsory education in areas with a high share of foreign-born residents (City of Vantaa, 2018).

3.4.3. Unemployment

The unemployment component is the share of unemployed from those 15 years and above in 2018. Quite often it is the employment rate that is used, the share of unemployed from the workforce (those unemployed or employed). However, in this scale it led to a situation where in some grid cells, one unemployed person could have a significant effect on the unemployment rate of a grid cell. Typically, these grid cells either had a relatively low number of inhabitants or a large share of inhabitants outside labour force, such as pensioners. It was felt that in these cases, the unemployment rate perhaps did not give an accurate picture of disadvantage in these grid cells. In the end, this proved rather a marginal problem. When compared to index where unemployment was described with unemployment rate, only 58 grid cells were affected. 36 grid cells moved between quintiles 1 and 2 and 22 between quintiles 4 and 5. Movement between quintiles 2, 3 and 4 is irrelevant as only the two quintiles at the opposite ends are of interest here. Many of the grid cells most affected by the method of calculating unemployment fell in quintile 5 independent of the method of calculation and therefore were unaffected. Those that did move, were often on the border of two quintiles. Furthermore, in every grid cell with a low number of inhabitants individuals have much more weight therefore values calculated for these grid cells are subject to greater variation than those with higher number of residents. The unemployment component is thus defined as

$$\frac{pt\_tyott}{pt\_vakiy - pt\_0\_14}$$

where *pt_tyott* is the number of unemployed, *pt_vakiy* is the number of residents and *pt_0_14* is the number of 0- to 14-year-olds. The average share of unemployed from those 15 years or over in the sample is 5.4% while the sample grid cell average is 4.5%. As before, this suggests that the share of unemployed is slightly lower in sparsely populated grid cells. For comparison, the unemployment rate (share of unemployed from labour force) in the sample grid cells is 7.2%. The share of those unemployed varies from none to 48.0%.

3.4.4. Index of disadvantage

The value of disadvantage was thus calculated for each grid cell as

$$\frac{tr\_pi\_tul}{tr\_kuty} + \frac{ko\_perus}{ko\_ika18y} + \frac{pt\_tyott}{pt\_vakiy - pt\_0\_14}$$

The average value of disadvantage is 0.3766, the value ranging from 0 to 1.8262. There was a total of 11 grid cells with no disadvantage. Calculated this way, the index gives most weight to education and least weight to unemployment. Weighing the different components was considered but in the end the idea was rejected as the knowledge of how to weigh these different components is lacking. However, as discussed earlier, all three indicators are connected. Low level of education increases the risk of unemployment and both low level of education and unemployment often lead to low income (City of Vantaa, 2018).

The results were indexed so that the mean value (0.3766) received an index value of 100. An index value below 100 means that the grid cell has less disadvantage than average and an index value of above 100 means that the grid cell has more disadvantage than average. The index value varies from 0 to 485. Once the grid cells are split into quantiles, the least disadvantaged grid cells have an index value ranging from 0 to 51 and the most disadvantaged grid cells have an index value ranging from 146 to 485. These two groups - the least disadvantaged quintile and the most disadvantaged quintile - are compared to assess possible differences between spatial accessibility between advantaged and disadvantaged areas.

Table 5: Population and average share of low-income households, those with basic education only and unemployed as well as the average index of disadvantage in the least disadvantaged (Q1) and most disadvantaged (Q5) grid cells in 2020. The shares have been calculated from sums of all grid cells (not from grid cell averages).

	Q1	Q5	Q1 - Q5
Inhabitants	113 700	331 600	1 141 400
Share of			
low-income households	3.6%	31.1%	19.5%
those with no education	9.1%	33.8%	21.2%
unemployed	2.1%	8.5%	5.4%
Index of disadvantage, mean	36	196	100

The least and most disadvantaged grid cells differ from each other and from the sample by number of inhabitants as well as share of low-income households, lack of education and unemployment and index of disadvantage (see Table 5). While each of the quintiles contains equal number of grid cells (901, except for Q1 which contains 902 grid cells), the number of residents is much higher in the most disadvantaged quintile, which suggests that population density is considerably higher in the most disadvantaged grid cells. This could well be expected as disadvantage in the Helsinki Metropolitan Area tends to concentrate on areas of high-rise buildings (Vilkama et al., 2014) while areas dominated by detached houses tend to be more affluent. There is a considerable difference in the average share of low-income households, those with basic education only and unemployed between the least and most disadvantaged quintiles. The difference is especially pronounced in the share of low-income households as the share in the most disadvantaged grid cells is more than eight times that found in the least disadvantaged grid cells. This may suggest that of these three indicators, the impact of income is the most significant. This could be explained by income imposing the greatest restriction when choosing a place of residence. Furthermore, the three components of the index overlap spatially so that areas with a high share of low-income households likely also have a high share of those with no education after compulsory education and those unemployed (for a comparison see Appendix 11).

Figure 8 illustrates the distribution of the grid cells with least and most disadvantage in the Helsinki Metropolitan area as indicated by the index of disadvantage (for distribution of all five quintiles see Appendix 3). Least disadvantaged grid cells, marked in green, are predominantly found in the West, especially in Espoo and most disadvantaged grid cells, marked in blue, in the East, especially in Helsinki. The pattern is similar to those found in previous studies (for example Kiuru, 2015b, City of Helsinki, 2013). It is noticeable that disadvantaged grid cells cluster by the metro line in the East and by the railway lines. Interesting is also that Helsinki city centre does not appear as an especially advantaged area, despite some of the most expensive postal codes in Helsinki Metropolitan Area and Finland (Harjunen, 2019).

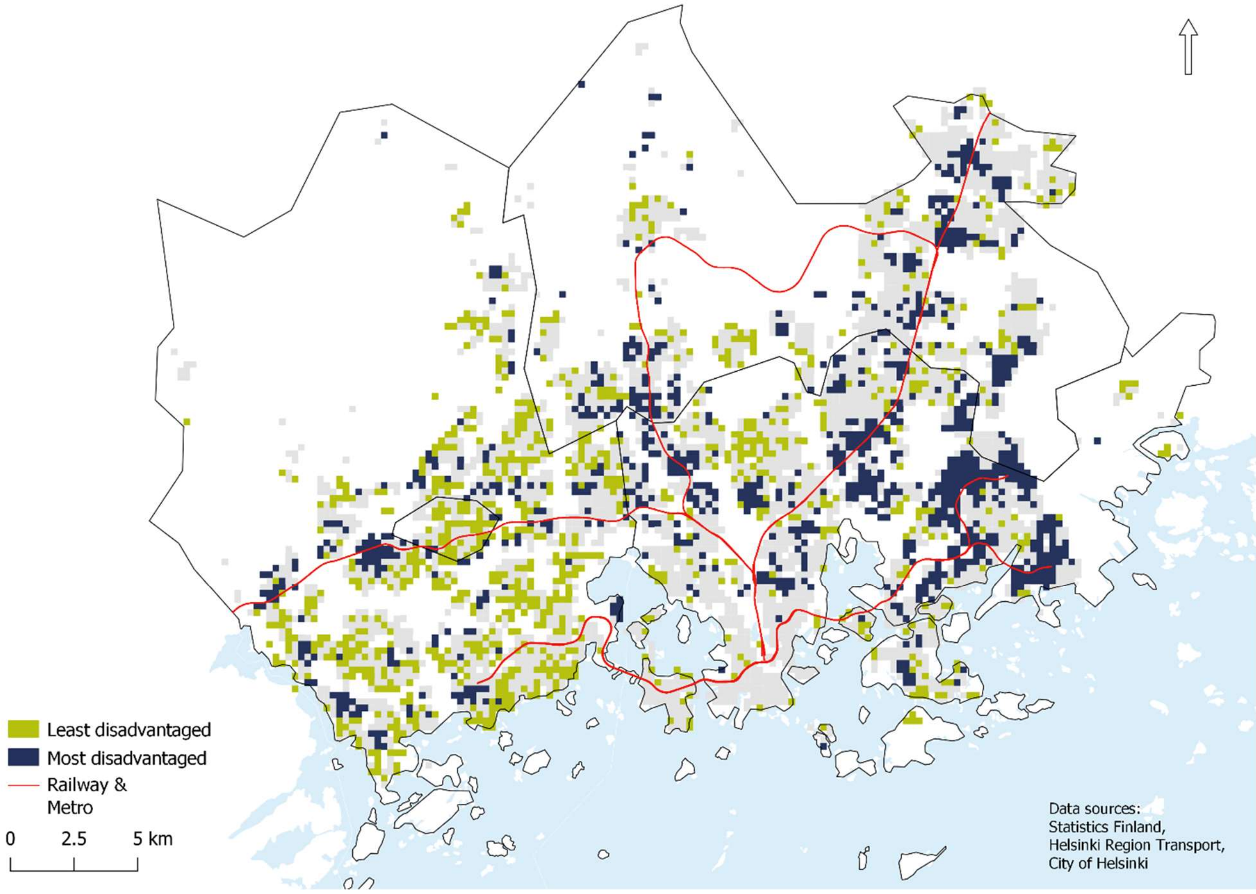

Figure 8. The distribution of the least and most disadvantage grid cells in the Helsinki Metropolitan Area as indicated by the index of disadvantage.

4. Results

4.1. Average travel times in the Helsinki Metropolitan Area

Average travel times in the Helsinki Metropolitan Area in 2013, 2015, and 2018 by public transport were 81.3, 84.3, and 86.2 minutes (for grid cell averages see Appendix 1) and by car 37.7, 37.2, and 37.8 minutes (for grid cell averages see Appendix 2). Average travel times by public transport have thus steadily increased in the area while there has hardly been a change for journey times by car. Spatial accessibility by public transport is thus not only considerably poorer than access by car, but the difference has also increased in the 5 years the travel time data is available for.

4.2. Temporal changes in average travel times in the Helsinki Metropolitan Area

Average travel times in the Helsinki Metropolitan Area have increased by 4.8 minutes by public transport and 0.1 minutes by car from 2013 to 2018 when calculated from the average travel times of the two years. However, these numbers may be slightly inaccurate as the grid cells in the 2013 and 2018 datasets are not necessarily the same. A somewhat more accurate result may be given by the average calculated from the average change for each grid cell as only those grid cells included in both 2013 and 2018 datasets are then included. When the average change in travel time is calculated from the average change for each grid cell, the increase for public transport is slightly more modest 3.6 minutes and for car 0.1 minutes. This is rather a surprising result considering that two major investments in the public transport network were made in this period. First, the Ring rail line opened in 2015 which improved the rail connection in northern Vantaa and the Western extension of the metro line in 2017 which provided southern Espoo with a metro connection. Both of these could be expected to improve spatial accessibility in the area.

However, it is to be kept in mind that these average travel times are calculated from the average time it takes from each grid cell to every other grid cell and do not take into account the actual travel patterns in any way. Improvements may have taken place where it matters the most. It is also likely that other factors have affected average travel times in the area, such as changes in public transport routes or schedules. Furthermore, the change in average travel time by public transport between grid cells varies considerably from a significant decrease of 39.1 minutes to an increase of 19.3 minutes. Figure 9 shows how average travel time by public transport has developed in different parts of the Helsinki Metropolitan Area (for change in average travel time from 2013 to 2015 and from 2015 to 2018 see Appendix 4).

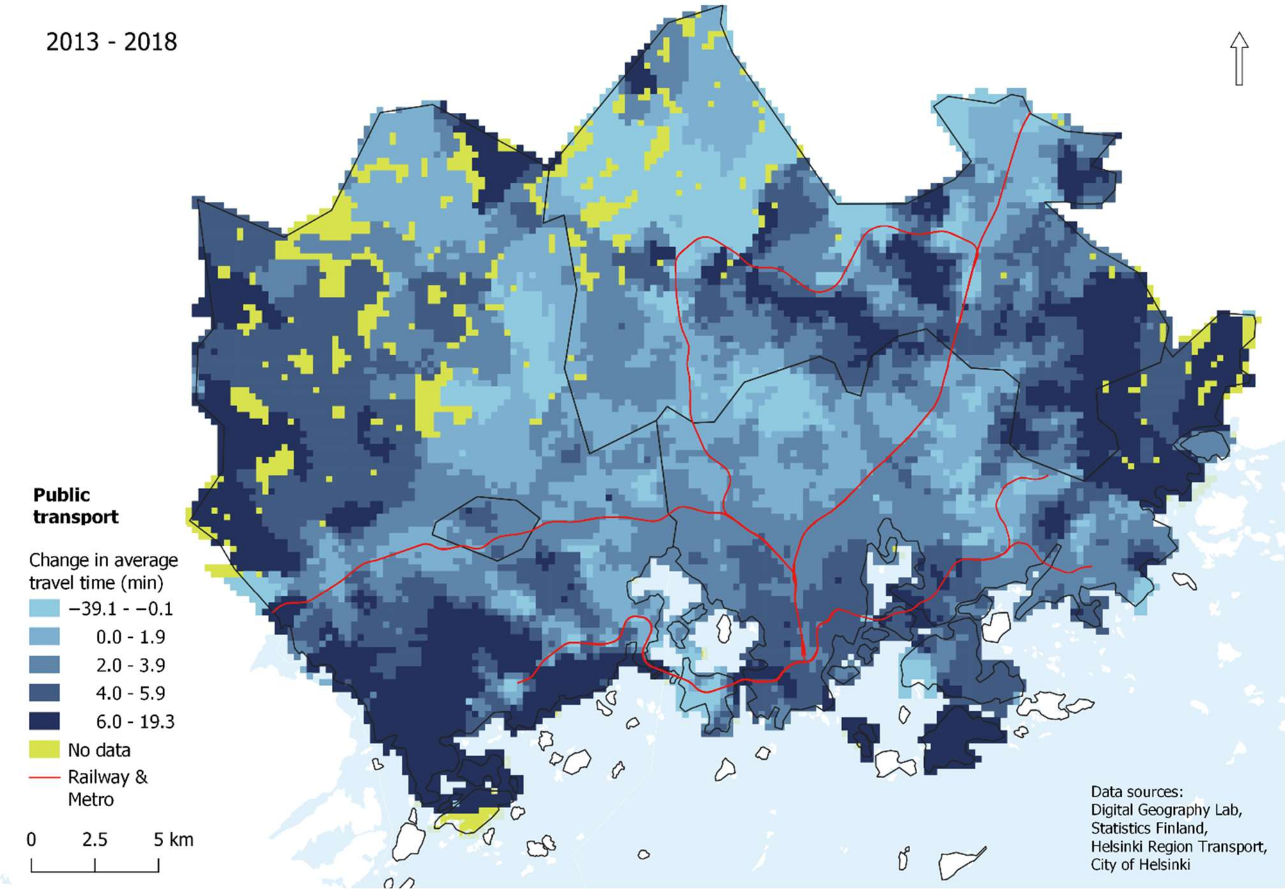

Figure 9. Change in average travel time by public transport in the Helsinki Metropolitan Area 2013 - 2018.

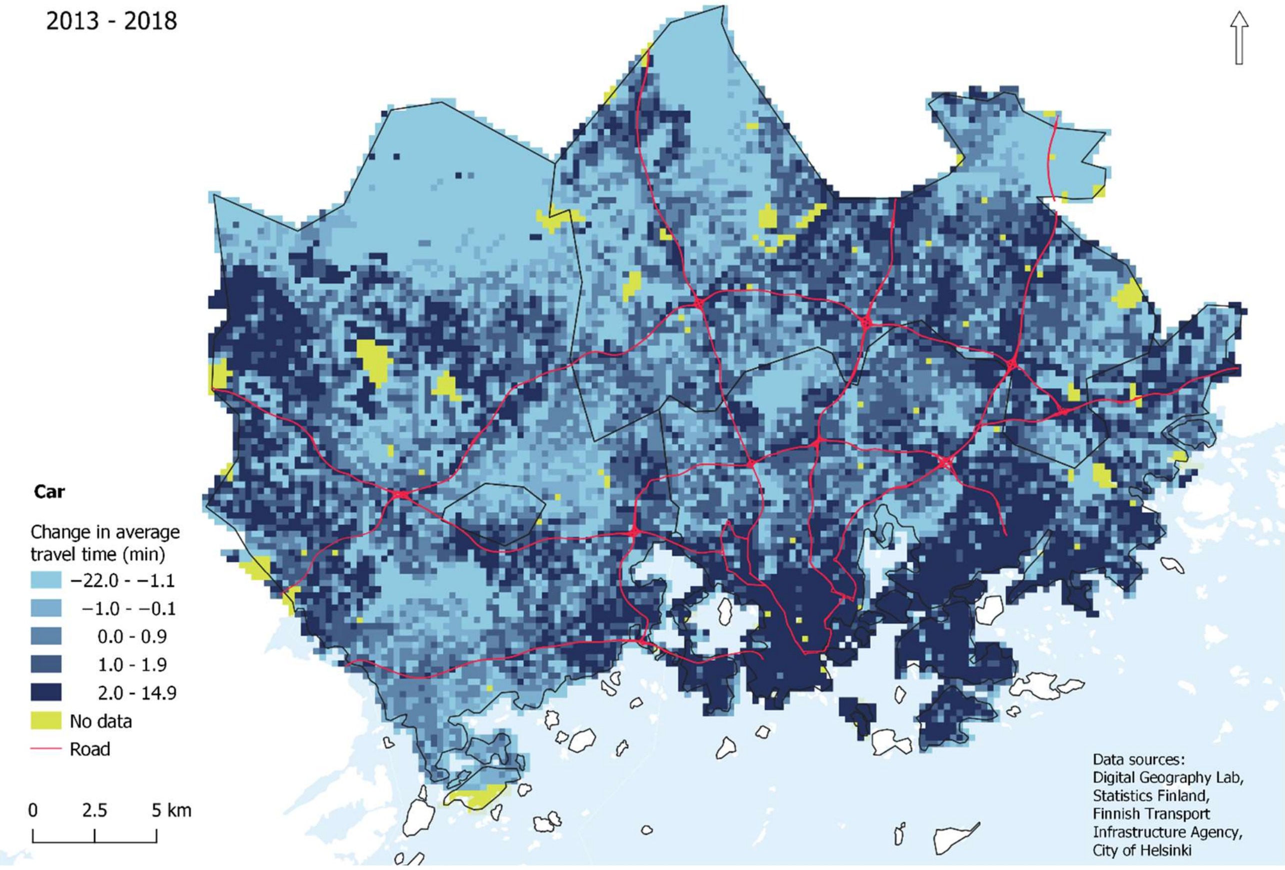

Figure 10. Change in average travel time by car in the Helsinki Metropolitan Area 2013 - 2018.

While the average travel time by car has stayed almost exactly the same in the area from 2013 to 2018, there is again variation with some areas seeing an improvement of up to 22 minutes while average travel time has for some areas increased by up to 14.9 minutes (see Figure 10). Spatial accessibility has thus developed very differently for different grid cells.

The change in average travel time from 2013 to 2018 for the 4 526 sample grid cells show a similar development. The average travel time has increased by 3.4 minutes by public transport and by 1.1 minutes by car. Again, the variation between individual grid cells is quite large, though by no means as large as for the whole area. At the most average travel time has decreased by 9.1 minutes and at most increased by 15.0 minutes by public transport (see Figure 11, for changes from 2013 to 2015 and from 2015 to 2018 see Appendix 5) while for a car the numbers are a decrease of 11.6 minutes and an increase of 11.0 minutes (see Figures 12). The difference between the average travel times for the whole area and the sample grid cells can likely be explained by sample grid cells being much more centrally located. It could perhaps also be argued that they better reflect the changes in average travel times for the residents as many grid cells included in Helsinki Region Travel Time Matrix but not in the sample are grid cells with few or no residents. This would suggest that the changes in average travel times have been greatest in peripheral areas where population density is low and spatial accessibility poorer to start with, especially by public transport.

Of the grid cells where the average travel time by public transport has decreased, many are located close to railway and metro lines, especially close to stations. However, many areas further away from the new railway and metro line have also seen improvements in average travel time and some grid cells close to railway and metro lines have seen an increase in travel time. This suggest that there may have been other changes in the public transport services besides the Ring rail line and Western extension of the metro which have affected average travel times.

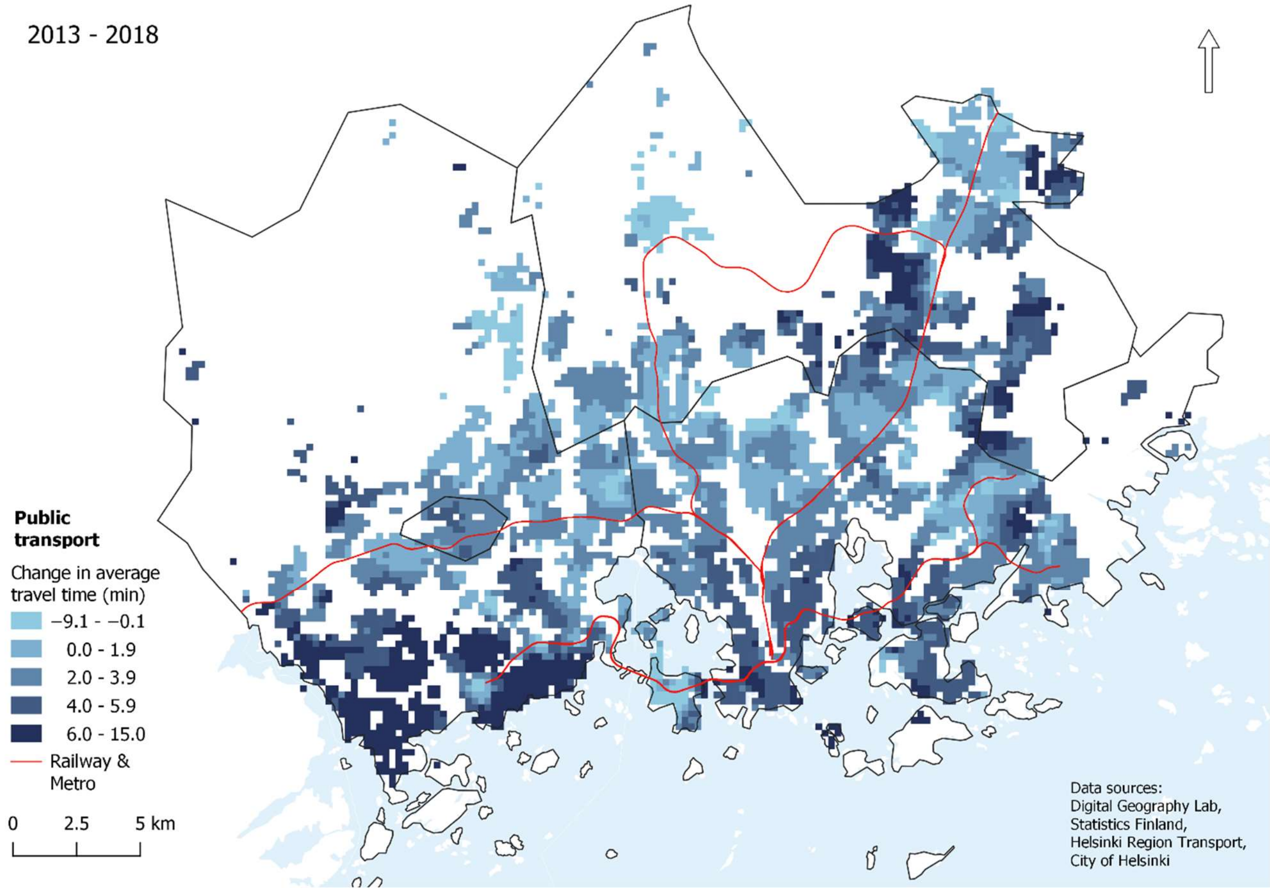

Figure 11. Change in average travel time by public transport in sample grid cells from 2013 to 2018.

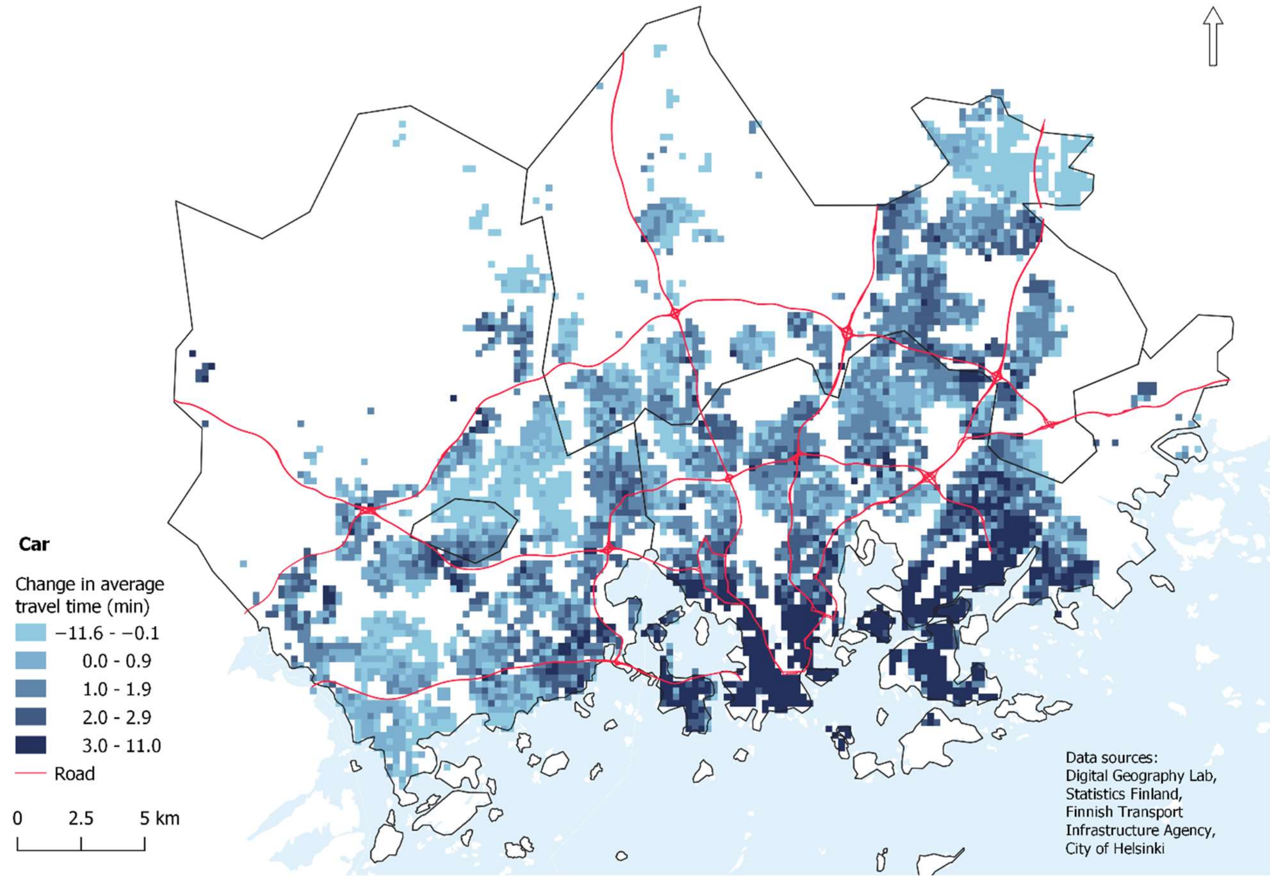

Figure 12. Change in average travel time by car in sample grid cells from 2013 to 2018.

4.3. Average travel time from the least and the most disadvantaged grid cells

Comparing average travel times between the least and the most disadvantaged grid cells shows that there seems to be a small difference (see Table 6). The average travel time from the most disadvantaged grid cells is lower than from the least disadvantaged. From the most disadvantaged grid cells the average travel time by public transport in 2018 was 70.4 minutes while from the least disadvantaged grid cells the average was 74.4 minutes. By car the averages are 35.8 minutes and 36.1 minutes respectively meaning that even by car, average travel time is slightly lower for those living in the most disadvantaged grid cells. The statistical significance of these differences was tested with independent samples t test. For public transport it gave t a value of 10.014 and significance (2-tailed) a value of <0.001 while df was 1 809. The results confirm that the difference in average travel times by public transport between the least and most disadvantaged grid cells is statistically significant. However, the same is not true for the difference in average travel times by car. The independent samples t test gave t a value of 1.078 and significance (2-tailed) a value of <0.281 while df was 1 806. The small difference in average travel time by car between the least and most disadvantaged grid cells is thus not statistically significant.

Table 6: *Average travel time in 2013, 2015 and 2018 by public transport and by car from the least (Q1) and most (Q5) disadvantaged grid cells as well as the whole sample.*

Year	Public Transport Mean Travel Time, minutes			Car Mean Travel Time, minutes		
	Q1	**Q5**	**Q1 - Q5**	**Q1**	**Q5**	**Q1 - Q5**
2013	70.6	67.6	69.0	35.2	34.8	34.8
2015	72.1	68.9	70.6	34.2*	33.9*	33.9*
2018	74.4	70.4	72.3	36.1	35.8	36.0

**) The Helsinki Region Travel Time Matrix from 2015 used too low speed limits for certain roads in its calculations (Tenkanen et al., n.d.) and the values are thus not fully comparable with those from 2013 and 2018.*

Furthermore, the increase in the average travel time by public transport in the Helsinki Metropolitan Area from 2013 to 2018 has been greater for those living in the least disadvantaged grid cells. The average travel time by public transport from the most disadvantaged grid cells increased by 2.8 minutes and from the least disadvantaged by 3.8 minutes. For journeys by car the development has been the opposite. The average travel time by car increased from 2013 to 2018 by 1.0 minutes from the most disadvantaged grid cells and by 0.8 minutes for the least disadvantaged (see Table 7). Average travel times have thus also developed in different ways from the least and most disadvantaged grid cells between the two modes of transport. The average travel time by public transport has increased less from the most disadvantaged grid cells while the average travel time by car has increased less, if only slightly, from the least disadvantaged grid cells. This may be explained by the spatial distribution of least and most disadvantaged grid cells and the two rail investments that took place in this period. Many of the most disadvantaged grid cells can be found by railway and metro lines (see Figure 8) and could thus be expected to benefit from the new Ring rail line and Western extension of the metro while least disadvantaged grid cells are found further away from railway and metro and are thus less likely to benefit from the investment.

Table 7. Change in average travel time from 2013 to 2015, from 2013 to 2015 and from 2015 to 2018 by public transport and by car from the least (Q1) and most (Q5) disadvantaged grid cells as well as the whole sample (Q1 – Q5).

	Public Transport			Car		
Year	Change in Mean Travel Time, minutes			Change in Mean Travel Time, minutes		
	Q1 (%)	Q5 (%)	Q1 - Q5 (%)	Q1 (%)	Q5 (%)	Q1 - Q5 (%)
2013 - 2018	3.8 (5.4)	2.8 (4.1)	3.4 (4.9)	0.8 (2.4)	1.0 (3.0)	1.2 (3.3)
2013 - 2015	1.6 (2.2)	1.3 (1.9)	1.7 (2.4)	-1.0 (-2.8)*	-0.9 (-2.5)*	-0.9 (-2.6)*
2015 - 2018	2.2 (3.1)	1.5 (2.2)	1.7 (2.4)	1.8 (5.3)	1.9 (5.7)	2.1 (6.1)

**) The Helsinki Region Travel Time Matrix from 2015 used too low speed limits for certain roads in its calculations (Tenkanen et al., n.d.) and the values are thus not fully comparable with those from 2013 and 2018.*

The change in travel times from 2013 to 2018 from the least and most disadvantaged grid cells were compared with independent samples t test. The results indicate that while the difference in the increase in the average travel time by public transport between most and least disadvantaged grid cells is small, only 1.0 minute, it is statistically significant. The independent samples t test gave t a value of 8.544 and significance (2-tailed) a value of <0.001 while df was 1 809. The difference in average increase in travel time by car from the least and most disadvantaged grid cells is even less, only 0.2 minutes, yet this too is statistically significant. The independent samples t test gave t a value of -2.149 and significance (2-tailed) a value of 0.032 while df was 1 803. It can thus be concluded that spatial accessibility has indeed developed in different ways for the least and most disadvantaged grid cells, by public transport in favour of the most disadvantaged and by car in favour of the least disadvantaged.

Comparing changes in average travel times from 2013 to 2015 and from 2015 to 2018 seems to indicate that average travel times by public transport increased less from the least disadvantaged grid cells from 2013 to 2015 than it did from 2015 to 2018. While average travel time from the least disadvantaged grid cells increased from 2013 to 2015 by 1.6 minutes, the difference was 2.2 minutes from 2015 to 2018. The change in the same periods from the most disadvantaged grid cells was 1.3 and 1.5 minutes respectively, the difference being considerably smaller (see Table 7). The difference could mean that the Ring rail line and Western extension of the metro line affected the different socio-economic groups differently. The Ring rail line was opened on 1.7.2015 and since the travel times by public transport are based on the schedules of 28.9.2015, changes in travel times due to the opening of the new rail line would be included in the changes in travel times that occurred between 2013 and 2015 while the effect of the metro extension opened in 2017 would be included in the changes in travel times between 2015 and 2018.

While for the whole sample the increase in average travel time by public transport is quite evenly split (49.6% and 50.4%) between 2013 - 2015 and 2015 - 2018, for the least disadvantaged quintile the shares are 41.2% and 58.8% and for the most disadvantaged quintile they are 47.6% and 52.4% in the two periods. This could suggest not only that the Ring rail line increased travel times from the least disadvantaged and most disadvantaged grid cells slightly less than the Western extension of the metro line but that the Western extension of the metro line increased travel times from the least disadvantaged grid cells more than from the most disadvantaged. This difference is likely to be linked to the high concentration of most disadvantaged grid cells by the metro line in the East, while in the West the least disadvantaged grid cells lie slightly further away from the metro line. Spatial accessibility from the least disadvantaged grid cells may also have been affected negatively by the changes in bus services which followed the opening of the metro extension. For example, while previously southern Espoo was connected to Helsinki city centre by direct bus services, later commuters had to rely on a combination of bus and metro which likely increased travel time for many (Tenkanen et al., n.d.).

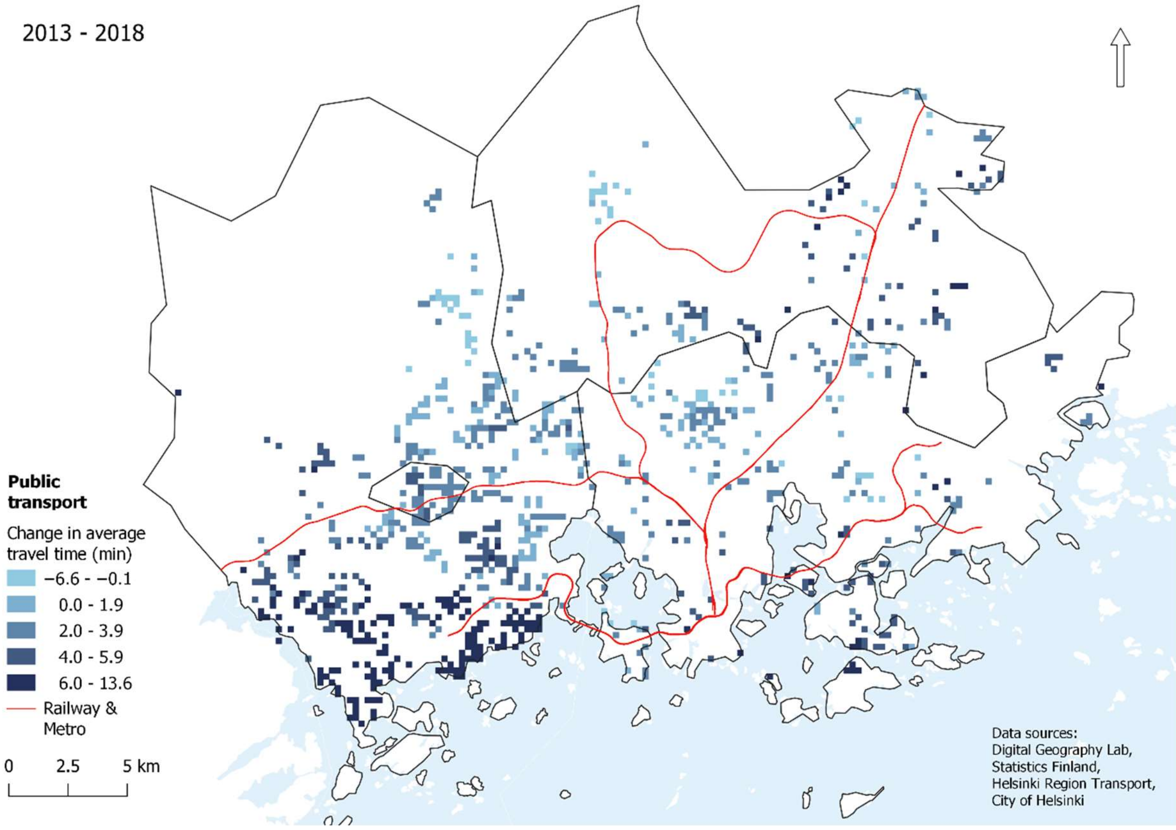

Figure 13. Change in average travel time by public transport in the least disadvantaged grid cells from 2013 to 2018.

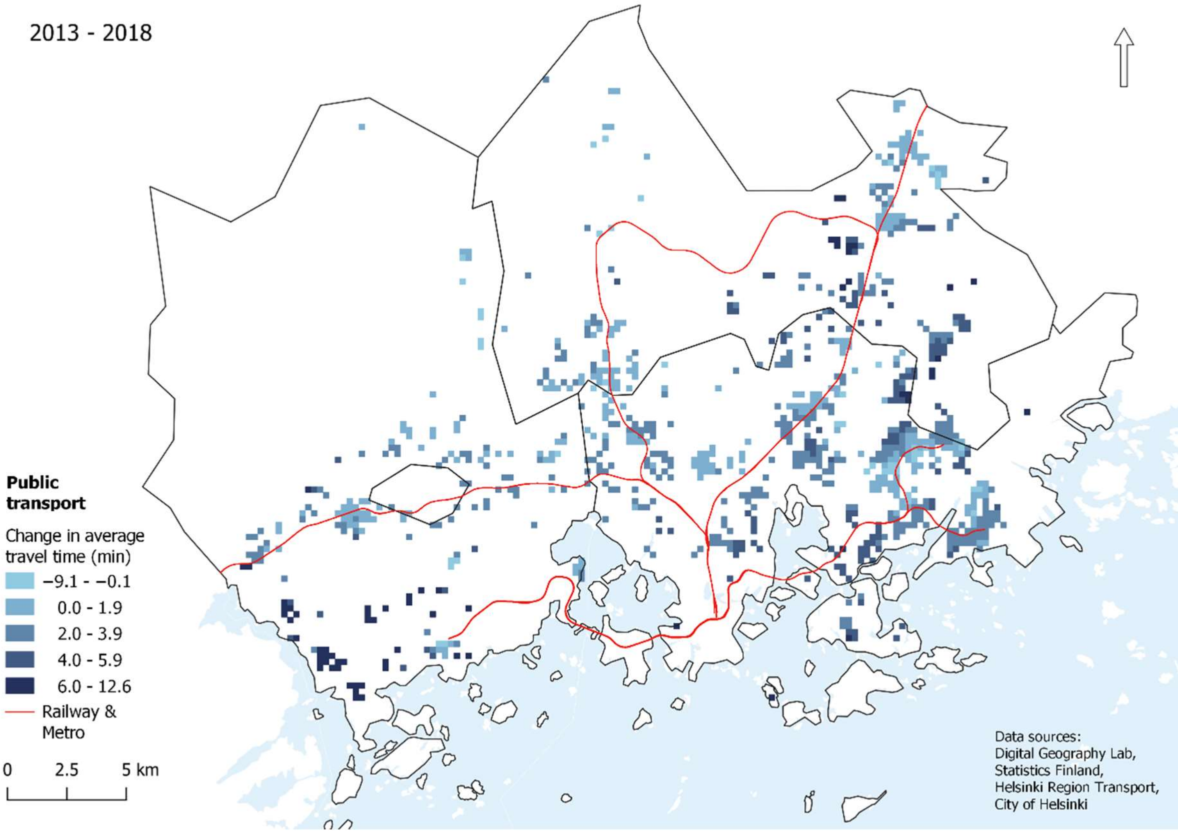

Figure 14. Change in average travel time by public transport in the most disadvantaged grid cells from 2013 to 2018.

Comparison of Figures 13 and 14 depicting changes in average travel time by public transport between the least and most disadvantaged grid cells from 2013 to 2018 (for change from 2013 to 2015 and from 2015 and 2018 see Appendix 6 and 7) shows how in most disadvantaged quintile the most improvement in travel times is found in grid cells close to the railway and metro lines while for least disadvantaged quintile much of the improvement seems to have taken place further away from them (for a comparison for car see Appendix 8).

5. Discussion

5.1. Disadvantaged grid cells enjoy better accessibility

In answer to the research questions put forward in the introduction,

(1) The results suggest that spatial accessibility differs for different socio-economic groups. The most disadvantaged grid cells enjoy better spatial accessibility by both public transport and by car, though the difference is statistically significant only for public transport.

(2) Spatial accessibility has overall decreased in the area by public transport and stayed more or less the same by car. However, the decrease has been less for the most disadvantaged grid cells by public transport and for the least disadvantaged by car. In both cases, the difference is statistically significant.

The results would thus suggest that disadvantaged areas enjoy better spatial accessibility by public transport as well as by car in the Helsinki Metropolitan Area. Not only do the most disadvantaged grid cells enjoy lower average travel time by public transport and by car, but average travel time by public transport has increased more from the least disadvantaged grid cells from 2013 to 2018. In other words, most disadvantaged grid cells enjoy better spatial accessibility compared to least disadvantaged and the difference has increased for public transport. This is likely due to the two major rail investments that took place in the area, the Ring rail line opened in 2015 and Western extension of the metro opened in 2017, and disadvantage concentrating by rail transport. It has been suggested that distance is an important factor when people consider place of residence. However, when certain level of wealth is reached, people start to prefer space over proximity which leads to a situation where those well-off gravitate towards peripheral areas (Brueckner, 2011). This has been especially true in the United States where, for the exception of large cities such as New York and Chicago, the poor tend to live in city centres and the wealthy in the suburbs (Brueckner, 2011). This preference for space over spatial accessibility could explain why spatial accessibility seems to be poorer for those least disadvantaged in the Helsinki Metropolitan Area.

However, there has been much concern over the suburbanisation of poverty in the international literature and its effect on the spatial accessibility of the poor. The results from this thesis do not indicate that disadvantaged groups concentrate in areas with poor accessibility in the Helsinki Metropolitan Area, at least if we only look at the different modes of transport separately. The spatial distribution of the least and most disadvantaged grid cells does not suggest that centrally located neighbourhoods would be drawing especially advantaged residents (see Figure 8) and as noted earlier, the most disadvantaged grid cells enjoy better spatial accessibility. However, since this thesis does not look at changes in spatial distribution of disadvantage but changes in spatial accessibility, no conclusion can be drawn whether change has taken place over time or not. Other research does suggest that there has not, or that changes have been relatively small. Whether this is an indicator of a different preference of the Finnish well-off or that the changing trend does not yet show in the spatial distribution of the different socio-economic groups can only be speculated.

However, as noted earlier, the Helsinki Metropolitan Area is drawing educated, high-income earners (Karhula et al., 2020) as well as young adults (Laakso, 2019) who have been indicated as the groups most interested in living in centrally located neighbourhoods. Furthermore, Helsinki city centre postal codes are among some of the most expensive in the area and the whole of Finland and prices having increased faster in these already expensive centrally located neighbourhoods suggests that demand has continued to be high (Harjunen, 2019). It also takes a while for socio-spatial reorganisation to take place. Tammaru et al. (2020) found that it takes a decade, even longer, for changes in income inequality to change residential segregation patterns. The neighbourhood of Kallio, a previously working-class neighbourhood with a dubious reputation close to Helsinki City Centre, is an example of a gentrified neighbourhood (Haapanen, 2017) which does not stand out as especially advantaged. Furthermore, in the initial stage gentrification may well appear as social mixing. This suggests that the gentrification process may well still be on-going in Kallio. It is, therefore, possible that the spatial redistribution of (dis)advantage in the Helsinki Metropolitan Area is taking place but does not yet show as poor spatial accessibility for the most disadvantaged.

5.2. Those least disadvantaged achieve better accessibility by choosing car over public transport

There is indication that people of different means prefer different modes of transport. As income increases so does car ownership and longer commuting distance is associated with commuting by car (Islam and Saphores, 2022) and those with higher income are also likely to use car more (Boterman & Mustard, 2016). Comparing car ownership in the least and most disadvantaged grid cells in the Helsinki Metropolitan Area shows that in the least disadvantaged quintile 86.3% of households have a car while in the most disadvantaged quintile the share is 47.1%. Car ownership is especially low in centrally located grid cells and those by the railway and metro lines (see Appendix 9). Since those better off are more likely to own a car, this could well mean that while spatial accessibility, when looking at individual modes of transport only, seems to favour those living in the most disadvantaged grid cells, those living in the least disadvantaged grid cells may choose to use a car rather than public transport therefore achieving a shorter travel time and thus better spatial accessibility. This is, in fact, what Glaeser et al. (2008) suggest.

Instead of land value being the main driver of centralisation of poverty, as suggested earlier, Glaeser et al. (2008) argue that it is transport, and especially the availability of affordable public transport, that drives the segregation pattern in cities. The high cost of owning a car makes them unattractive to the poor making public transport an appealing time-intensive alternative and as public transport tends to be better closer to city centres, these are the areas that draw the poor (Glaeser et al., 2008). Hu and Wang (2019) have come to a similar conclusion; households that do not own a car tend to be more dependent on public transport and areas best served by public transport tend to be city centres. Furthermore, Glaeser et al. (2008) suggest that metro, with a lower time cost than a bus, makes public transport an attractive option even further away from the city centre leading to decentralisation of poverty while Pathak et al. (2017) suggest that access to public bus transit may have a similar decentralisation effect on poverty. Whether a preference or a necessity, this tendency for those less well-off to take residence by public transport, and especially by rail transit, could explain why the most disadvantaged grid cells seem to enjoy better spatial accessibility in the Helsinki Metropolitan Area.

5.3. Those most disadvantaged achieve better accessibility due to the housing structure

In the Helsinki Metropolitan Area, the main driver of segregation is housing structure. Disadvantage concentrates in blocks of flats and social rental housing and advantage to owner occupied single-family homes (Vilkama, 2014). If neighbourhoods by railway and metro lines as well as centrally located neighbourhoods are dominated by blocks of flats, then it would not be unreasonable to assume that these are also areas that draw disadvantage. It would also explain why spatial accessibility seems to be better for disadvantaged grid cells. The Population Grid Database contains data on housing types in grid cells which shows that in 2019 the average share of flats in the most disadvantaged grid cells was 84.4% while in the least disadvantaged grid cells the share was only 8.7%. Furthermore, grid cells with a high share of flats are also very much concentrated in Helsinki city centre and by railway and metro lines (for spatial distribution see Appendix 10) while grid cells with low share of flats concentrate in peripheral areas. This pattern is very similar to that of disadvantage and would suggest that there is a spatial connection between distribution of housing types and the distribution of disadvantage.

Creating truly mixed neighbourhoods may be difficult due to the well-off households' strong preference for single-family homes and high-rise buildings and single-family homes tending to be in different neighbourhoods. The neighbourhoods in the Helsinki Metropolitan Area that have improved their socio-economic status have gone through extensive infill building (Vilkama, 2014) suggesting that infill building can be used to diversify the housing structure of a neighbourhood and therefore its socio-economic composition. However, the potential of infill building may be limited. This can be seen in Myllypuro, a neighbourhood where socio-economic status has improved at least partially due to infill building but where the development has not been uniform. The neighbourhood has distinctive areas for high-rise buildings and single-family homes and the socio-economic status of the area with the single-family homes has improved more (Tavi, 2019).

5.4. Spatial accessibility can reduce inequality

While the effect of improved spatial accessibility on segregation is beyond the scope of this thesis, literature allows for some speculation. While spatial accessibility is an important factor in neighbourhood desirability in the Helsinki Metropolitan Area, improved spatial accessibility does not automatically reduce residential segregation, rather, the effect differs from area to area (City of Helsinki, 2013). Some neighbourhoods benefit from improvements, others do not. This may be because spatial accessibility is already good and further improvement does not make a difference anymore or that factors other than spatial accessibility are more important when considering the attractiveness of these neighbourhoods (City of Helsinki, 2013).

In Tokyo neighbourhoods near train stations have been found to be growing increasingly attractive to those better-off (Uesugi, 2021) which is the opposite of what is seen in the Helsinki Metropolitan Area according to this thesis. This could be due to the difference in scale. The Greater Tokyo Area alone has a population more than 10 times that of the Helsinki Metropolitan Area, 13.5 million in 2015 (Tokyo Metropolitan Government, n.d.). The Helsinki Metropolitan Area on the other hand is a relatively small agglomeration with a relatively low population density. Therefore, it could be that spatial accessibility by public transport is not as important as it may be in bigger cities and therefore it is not as highly valued by the advantaged groups who, after all, are those who can freely choose their place of residence and therefore drive segregation patters. However, in Oslo region in Norway, a capital region roughly the same size as the Helsinki Metropolitan Area in a Nordic well-fare state does show signs of disadvantaged groups living in areas with poorer access (Lunke, 2022) suggesting that size does not alone explain the different pattern found in the Helsinki Metropolitan Area.

Furthermore, if public transport draws especially low-income households, as suggested earlier, improved spatial accessibility could even cause a neighbourhood to grow even more segregated. When a person living in a disadvantaged neighbourhood improves their lot by, for example getting a job, the likelihood that they will move to a better neighbourhood and be replaced by someone more disadvantaged than them will increase (Cheshire, 2009). However, this would not mean that investment in infrastructure has been wasted, even if it does not reduce segregation, quite the opposite. In fact, it has been argued that improving public transport is likely to benefit poor households significantly, especially when it connects households with job opportunities (Hu & Wang, 2019). Therefore, while improved spatial accessibility might not reduce residential segregation by producing more mixed neighbourhoods, it could still significantly benefit those already in the area by connecting them with jobs, services and other opportunities and reduce segregation in other, non-residential, domains of life.

5.5. Limitations of datasets and analyses and thoughts for further study

The findings of this thesis suggest that spatial accessibility is better for the most disadvantaged compared to least disadvantaged and that the difference has grown from 2013 to 2018 for public transport. However, referring to Geurs and van Wee (2004), spatial accessibility consists of four different components, most of which have not been considered in this thesis at all. Only the place of residence and availability of transport have been considered, but no thought has been given to where people need to go, possible barriers imposed by personal circumstances nor to temporal aspects. Thus, the average travel time to each grid cell from all other grid cells used is rather a crude measure of spatial accessibility. It is very possible that the results do not reflect the actual mobility needs and opportunities of people. It may be that the decentralisation of jobs and services for example, if taken place, has affected spatial accessibility of low-income households negatively. It could be that spatial accessibility of the most disadvantaged is, in fact, poorer due to low car ownership. Data on transport modes used as well as travel patterns could improve the understanding of spatial accessibility in the area.

Another theme that was shortly touched upon in this thesis is how different socio-economic groups take advantage of different modes of transport. Segregation takes place in all domains of life, including transit. Not only are those better off more likely to own and use a car to meet their transport needs, but different socio-economic groups also use different modes of public transport. The results of this thesis raised the question, but was unable to answer, whether the Ring rail line and Western extension of the metro affected spatial accessibility of the least and most disadvantaged differently. Glaeser et al. (2008) argue that metro may lead to suburbanisation of poverty while Stafford et al. (2020) find that in the city of Greater Manchester those with professional occupations and higher qualifications tend to use rail and tram transit more and low-skilled workers bus. This is linked to the radial nature of rail transit and orbital nature of bus transit, and the different distribution of jobs (Stafford et al., 2020). If suburbanisation of low-skilled jobs is taking place, the question of who uses what mode of transport may become increasingly important.

Since Population Grid Database was available for one year only, the possible decentralisation of poverty cannot be tested for in this thesis. It can only be said that spatial accessibility by public transport for those grid cells that were the most disadvantaged in 2019 has decreased less than it has for the least disadvantaged. It would be interesting to see if the Helsinki Metropolitan Area is in fact following the international trend of decentralisation of poverty and low-skilled jobs and if disadvantaged groups are being pushed to areas of poorer spatial accessibility. It would give a different view of changes in spatial accessibility and how different transport investments affect different socio-economic groups as well as perhaps also indication of how transport investment should be targeted to reduce inequality.

6. Conclusion

Inequality and segregation are on the increase also in Finland, a Nordic welfare state where inequality and segregation have traditionally been low. As spatial accessibility is one aspect that can either intensify or mitigate inequality, it is important to assess the possible differences for advantaged and disadvantaged groups. This thesis used grid data on average travel times and an index of disadvantage to assess whether there is a connection between spatial accessibility and distribution of disadvantage in the Helsinki Metropolitan Area. Comparing spatial accessibility for the least and most disadvantaged quintiles revealed that there is a difference, and that spatial accessibility is better for the most disadvantaged, both by public transport and by car, though the difference is statistically significant only for public transport. Furthermore, this difference seems to have grown from 2013 to 2018 for public transport while it has diminished for car. The results thus indicate that the most disadvantaged enjoy better spatial accessibility than least disadvantaged. It also seems that the investments made in public transport in the study period, the new Ring rail line and Western extension of the metro, may have benefited the most disadvantaged more than the least disadvantaged. However, spatial accessibility by car is far better in the Helsinki Metropolitan Area and as those better off are more likely to own and use a car for their mobility needs, it is possible that the least disadvantaged in fact enjoy better spatial accessibility by choosing car over public transport.

The disadvantaged groups being pushed to areas of poor spatial accessibility reported in the international literature does not seem to have taken place in the Helsinki Metropolitan Area. However, whether there has been a change in the spatial distribution of disadvantage is beyond the scope of this thesis as data on the socio-economic structure of the area was only available for one year. If data was compared for several years over a longer period, it is possible that we would see a change. However, based on the literature, it seems that at least in the neighbourhood level major changes in the socio-economic status are not common in the Helsinki Metropolitan Area. This would suggest that disadvantaged groups are not being pushed towards areas of poor spatial accessibility. Whether this is down to a different preference of the Finnish wealthy, the trend not yet fully having set in or not showing in the data cannot be said. As the housing structure is the main factor explaining the spatial distribution of disadvantage in the area and changes in the housing structure are very slow, it is possible that subtle change is taking place.

Spatial accessibility has an important role in reducing inequality and segregation. Not only is spatial accessibility an import factor when people and businesses consider where to settle but also because through mobility, people can access opportunities not available in their immediate neighbourhood and mix with people outside their own neighbourhood. With inequality, the main driver of segregation on the increase and measures to reduce segregation having proven disappointing, the role of spatial accessibility is likely to grow. Even though neighbourhood effect and the ills of segregation are still debated, there is support in the literature for the benefits of good spatial accessibility. Furthermore, due to climate change and the overall densification of cities, the role of public transport is going to grow in the future. There are several major public transport investments either under way or planned in the Helsinki Metropolitan Area which have the potential to affect spatial accessibility in the area. As the most disadvantaged are often the most dependent on public transport, it is essential to invest in public transport and make sure the mobility needs of those most in need are considered.

7. References

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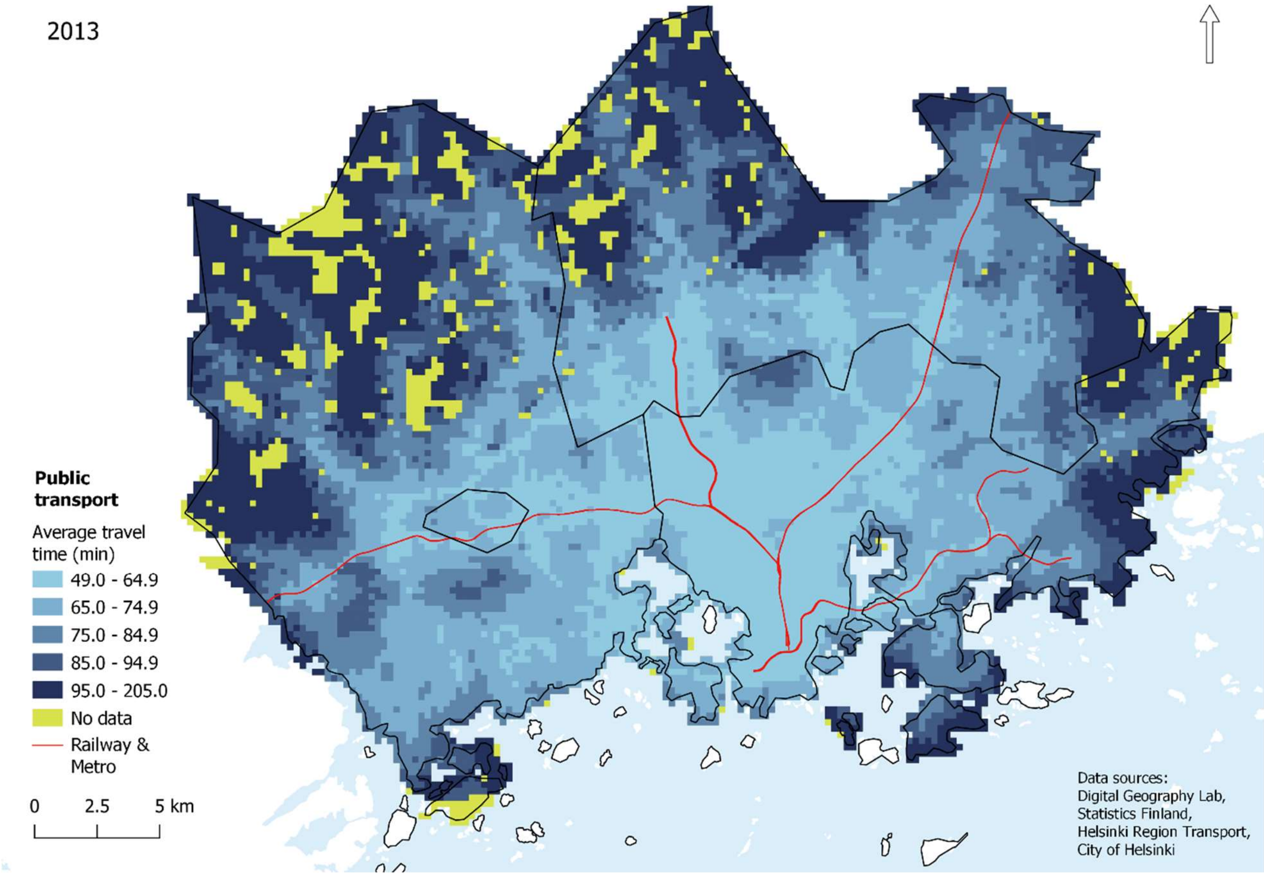
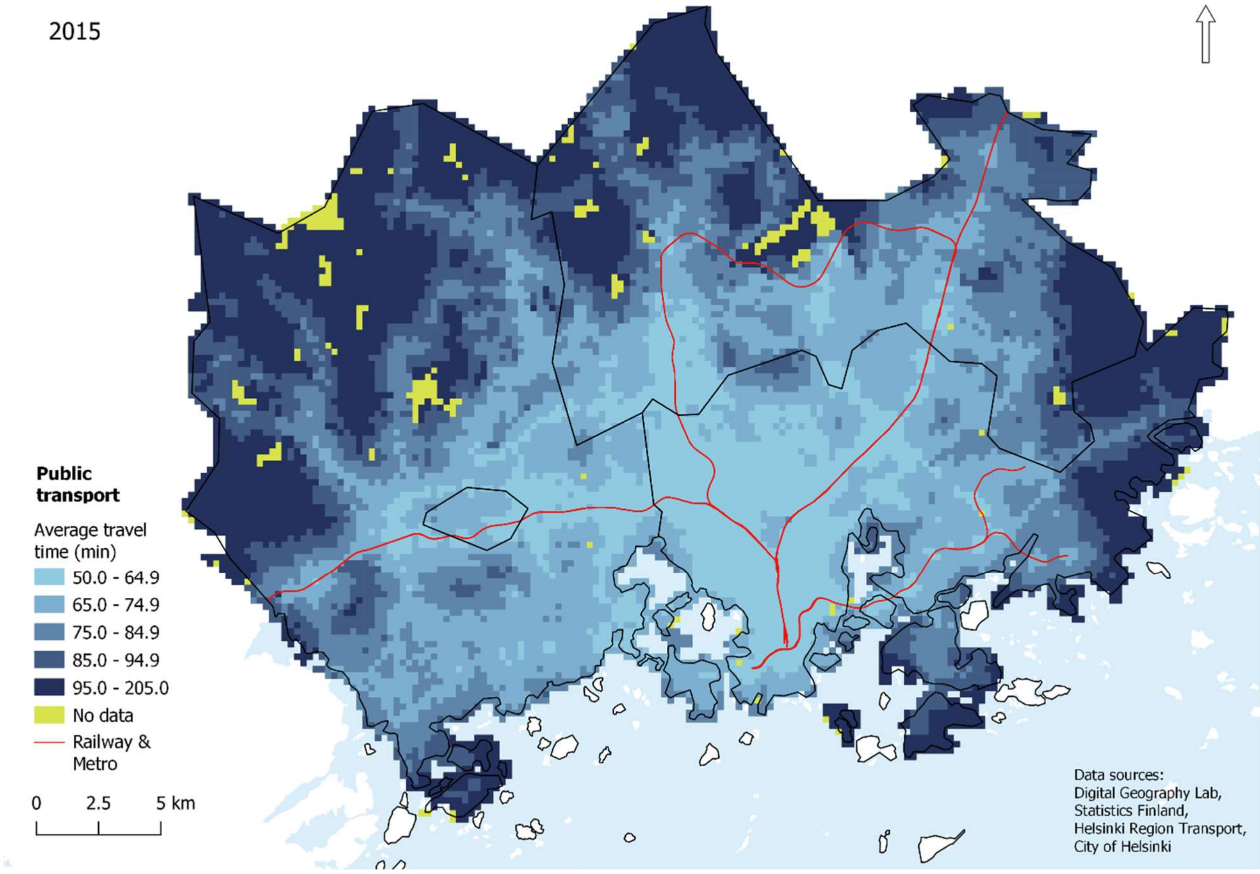
8. Appendix

Appendix 1. Average travel times by public transport in Helsinki Metropolitan Area in 2013, 2015, and 2018.

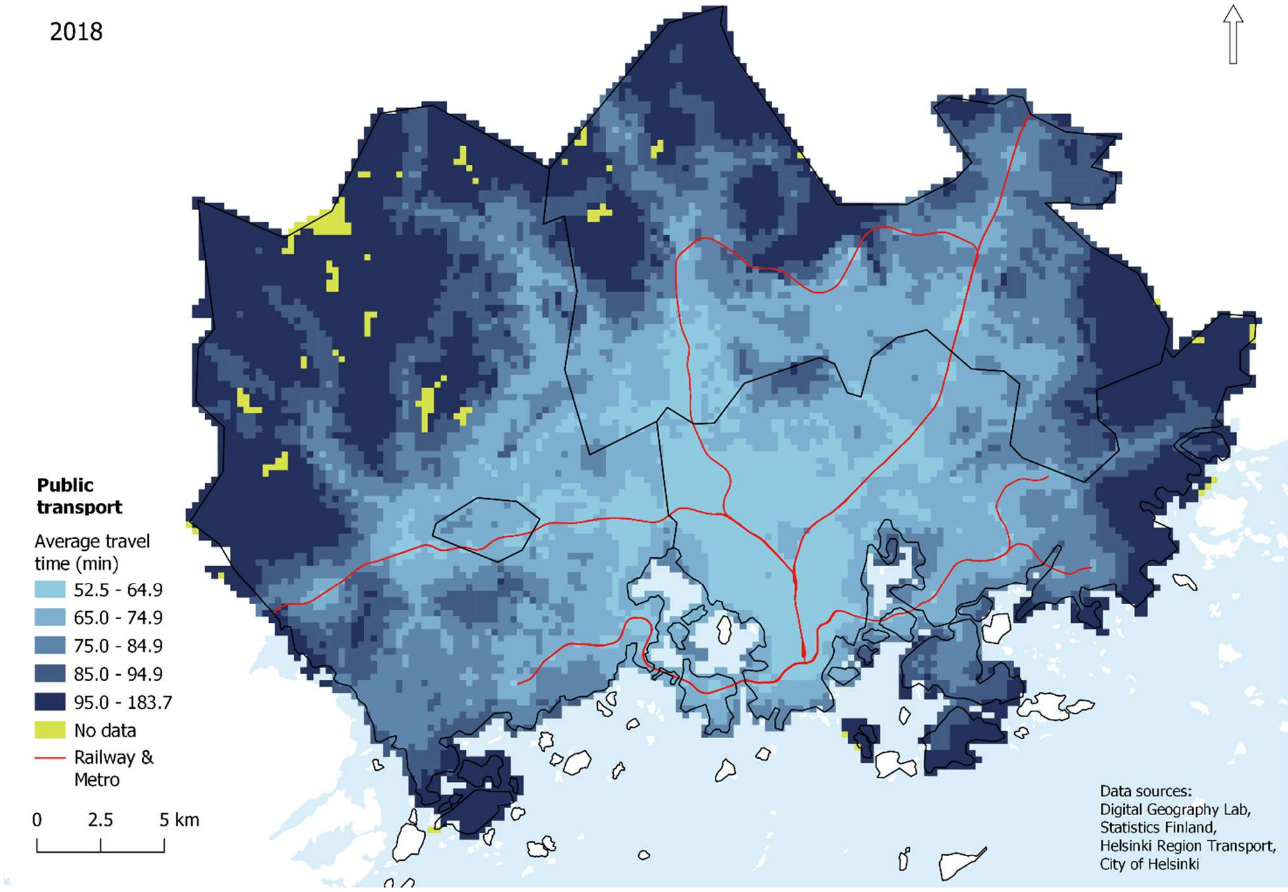


2015



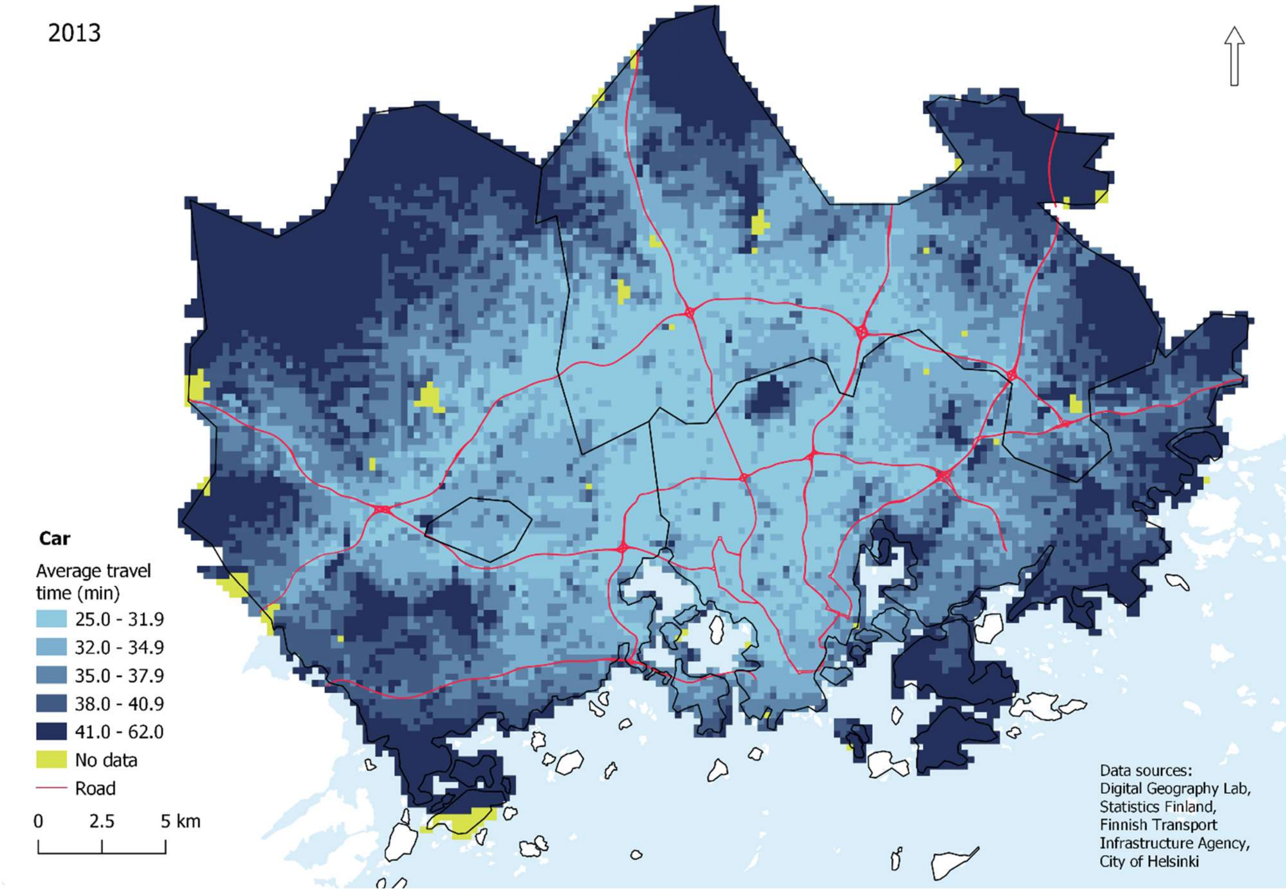
Public transport
Average travel time (min)
50.0 - 64.9
65.0 - 74.9
75.0 - 84.9
85.0 - 94.9
95.0 - 205.0
No data
Railway & Metro
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Helsinki Region Transport,
City of Helsinki

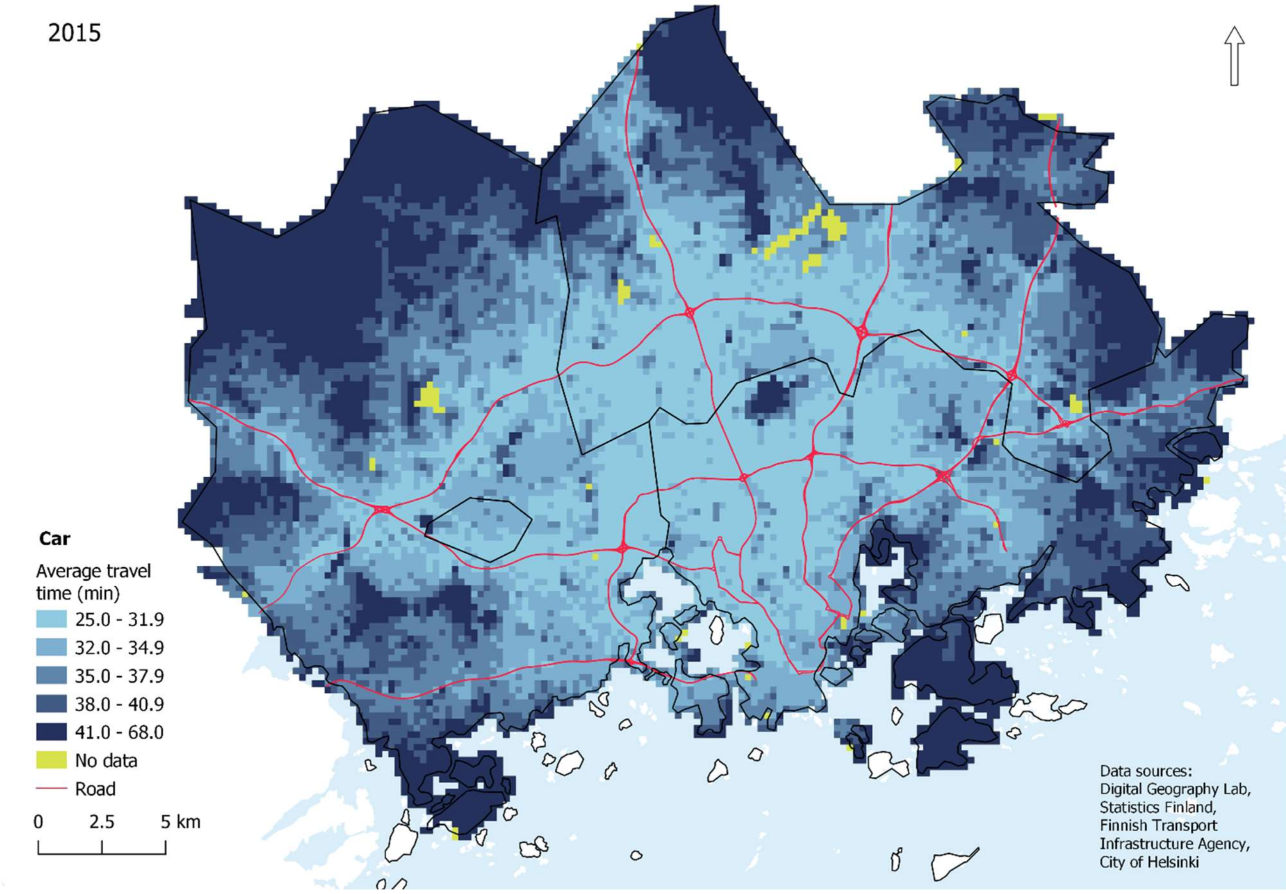
2018

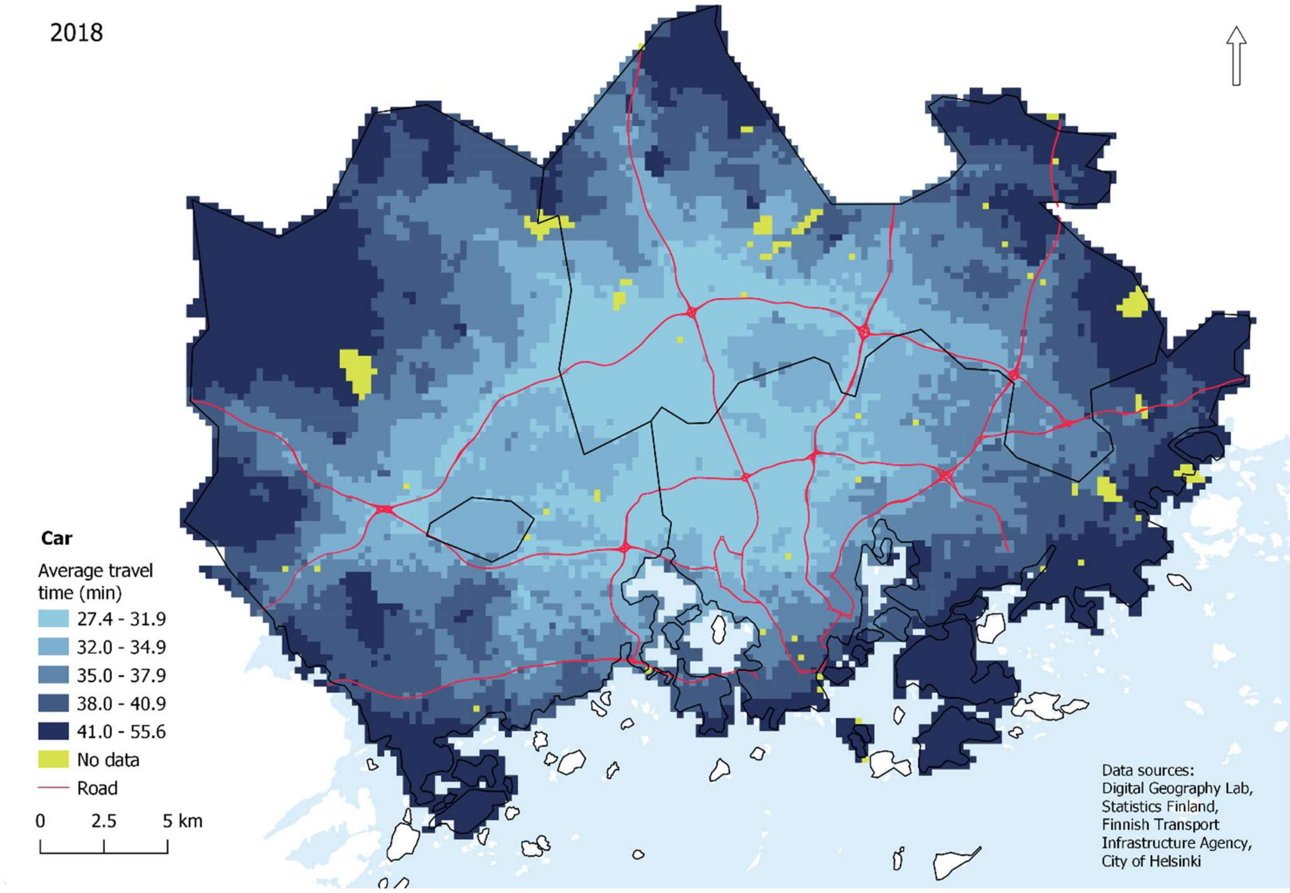


Public transport
Average travel time (min)
52.5 - 64.9
65.0 - 74.9
75.0 - 84.9
85.0 - 94.9
95.0 - 183.7
No data
Railway & Metro
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Helsinki Region Transport,
City of Helsinki

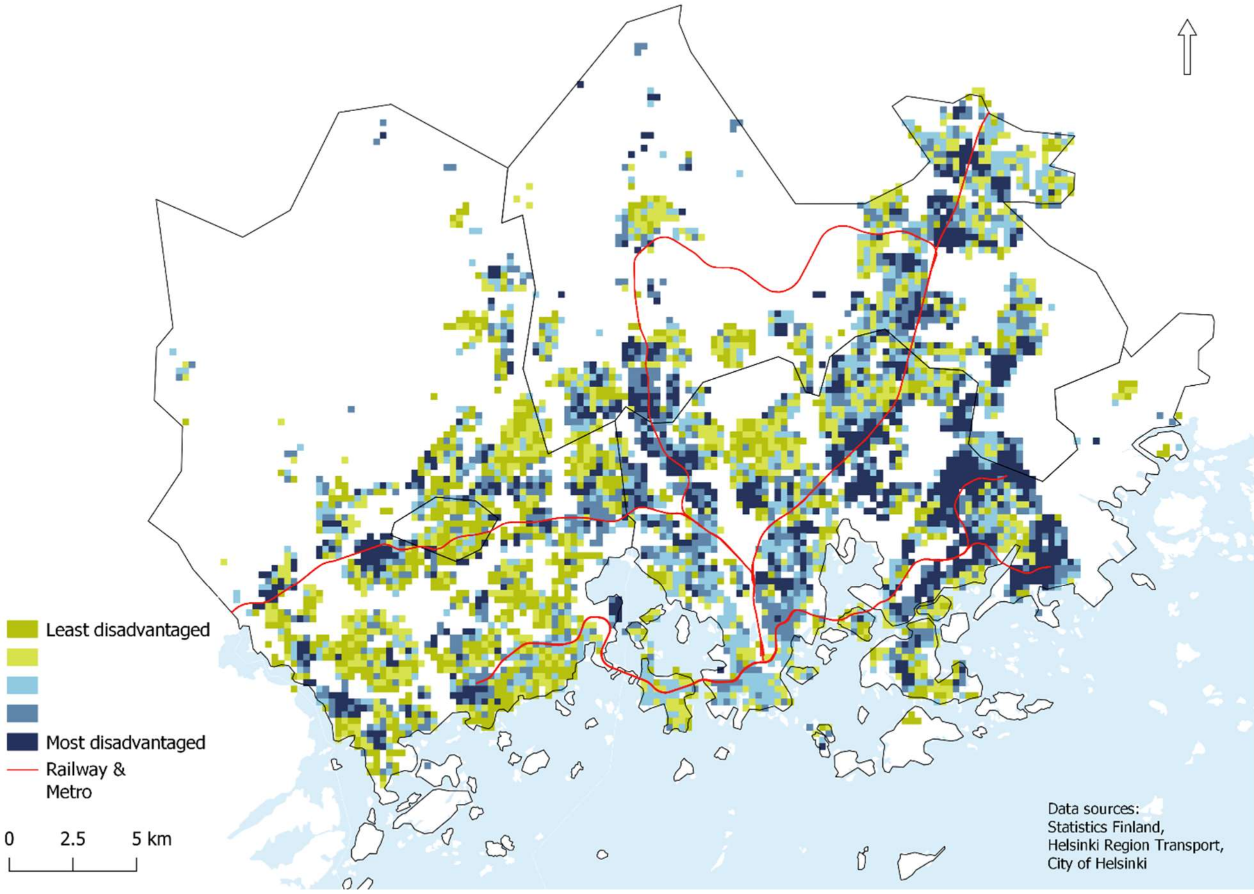
Appendix 2. Average travel times by car in Helsinki Metropolitan Area in 2013, 2015, and 2018.



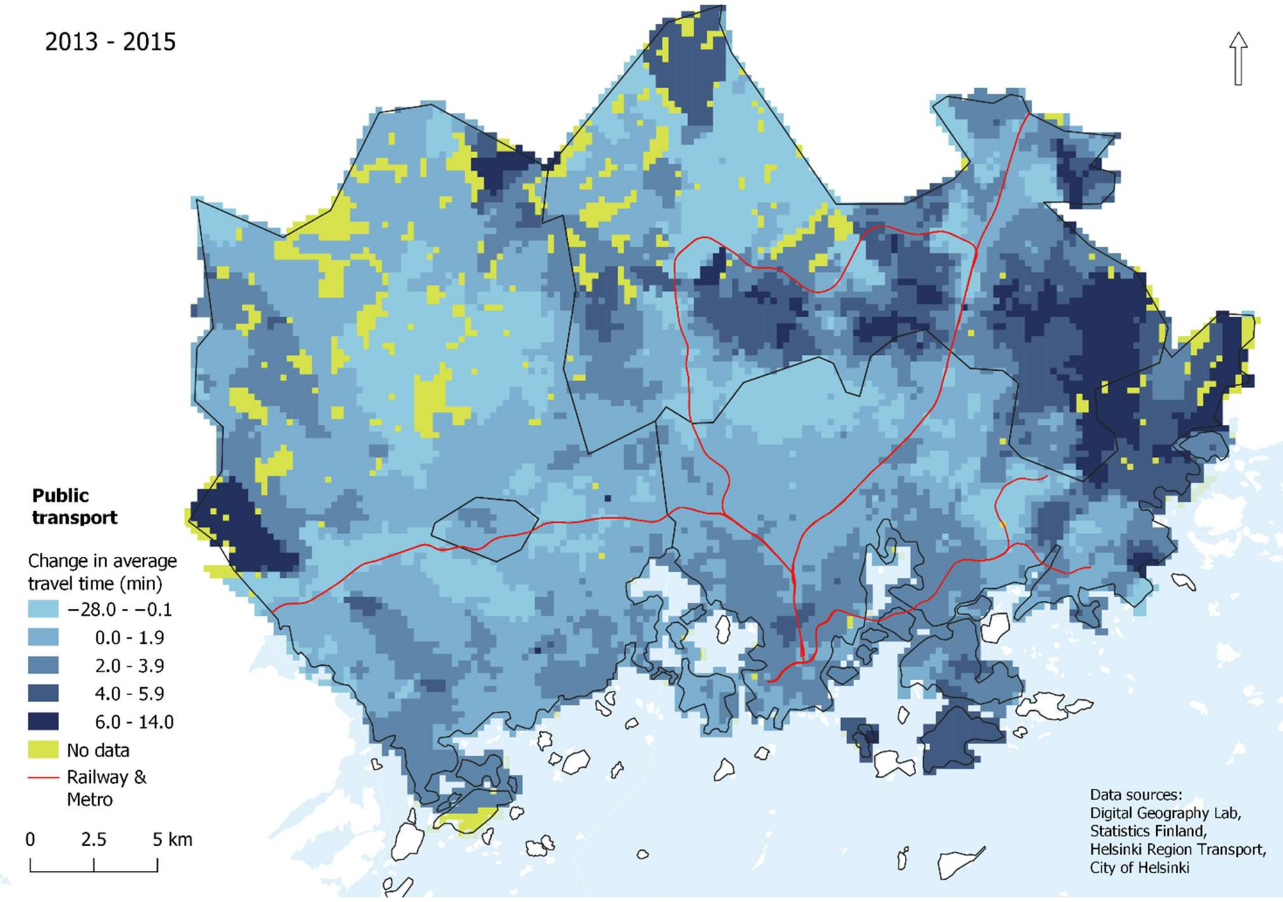


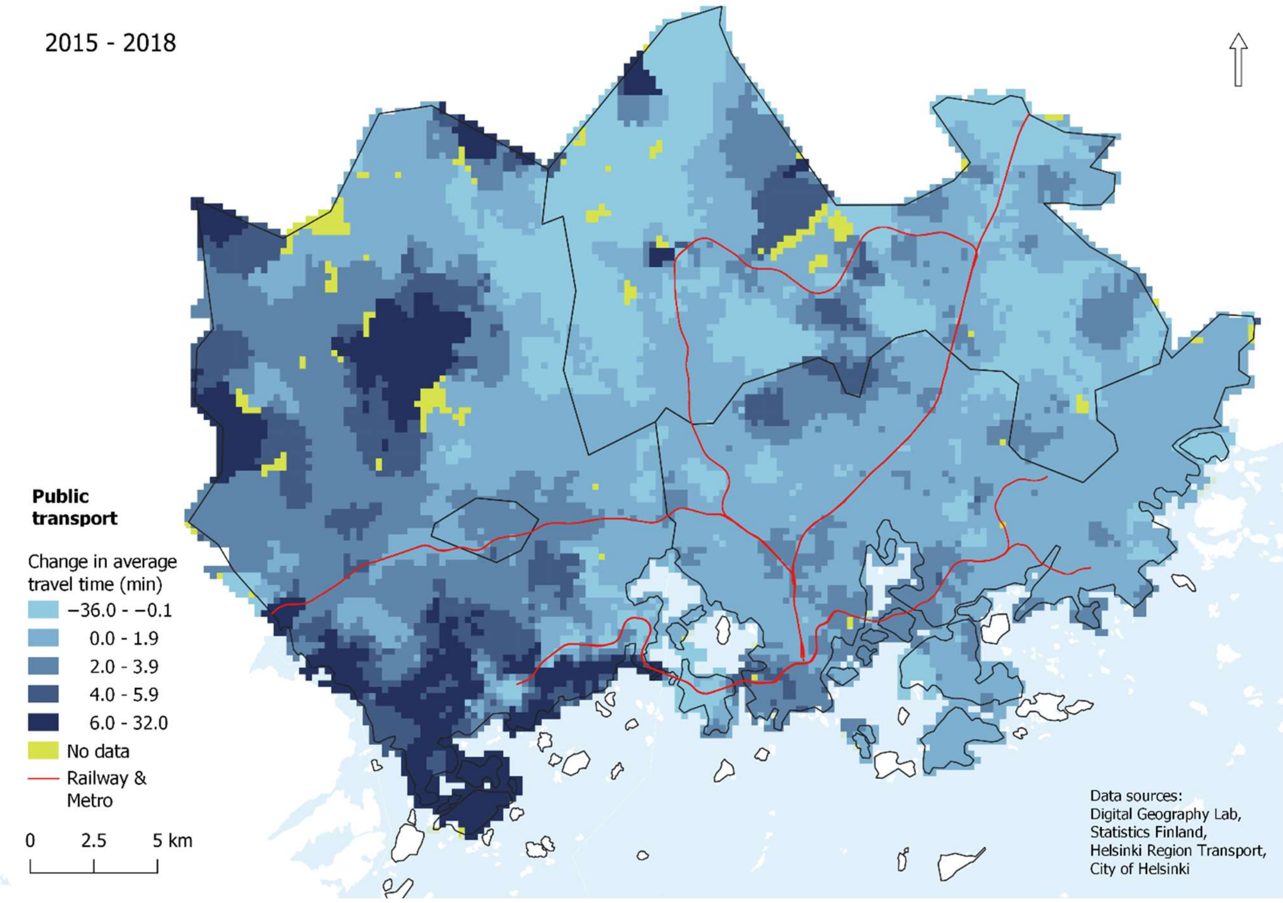

2018
Car
Average travel time (min)
27.4 - 31.9
32.0 - 34.9
35.0 - 37.9
38.0 - 40.9
41.0 - 55.6
No data
Road
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Finnish Transport
Infrastructure Agency,
City of Helsinki

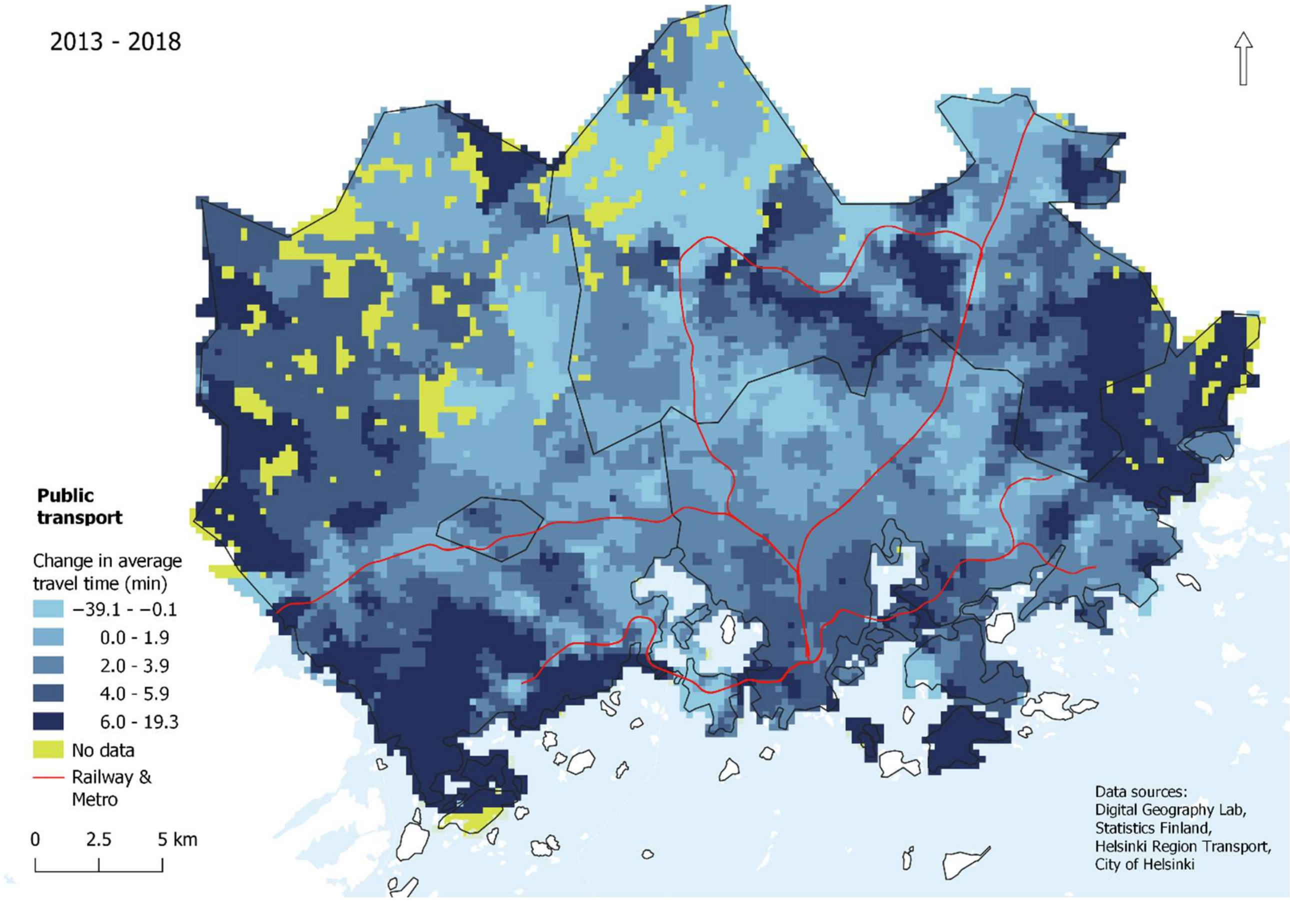
Appendix 3. The distribution of disadvantage in Helsinki Metropolitan Area as indicated by the index of disadvantage.



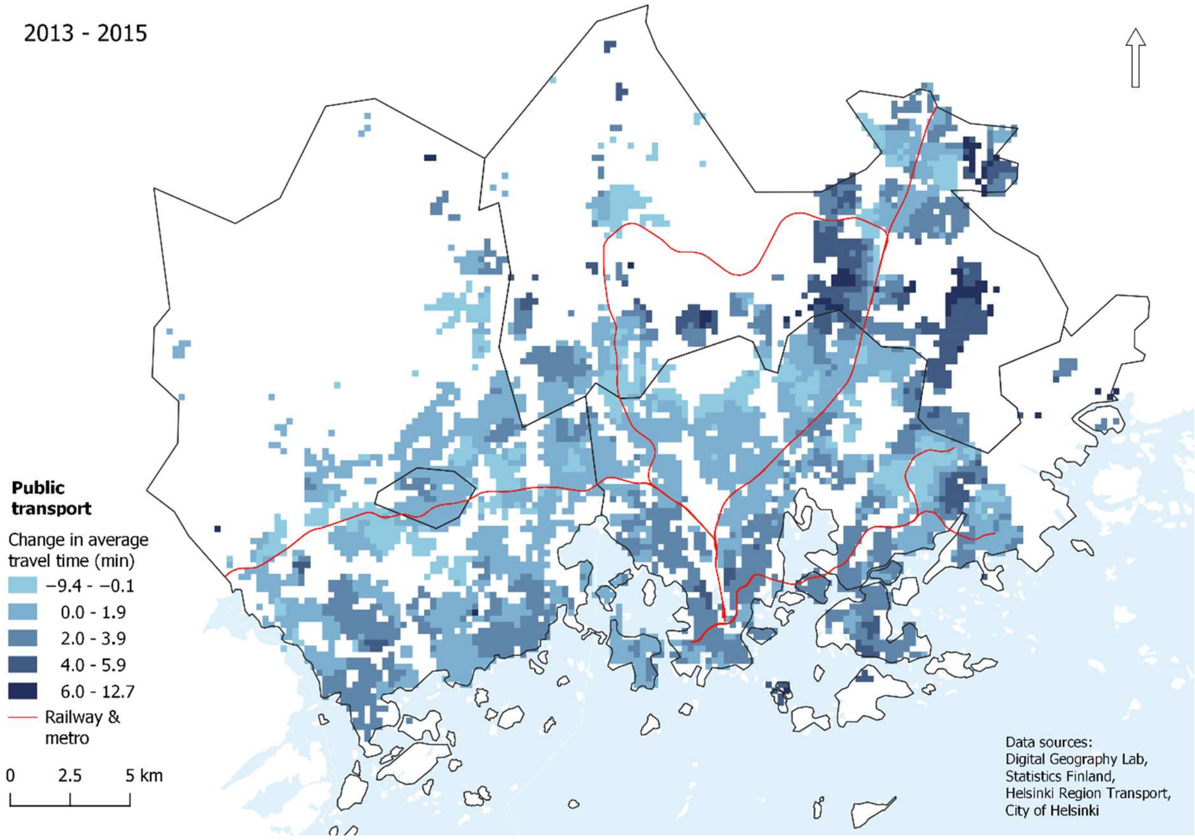
Appendix 4. Change in average travel time by public transport in Helsinki Metropolitan Area from 2013 to 2015, from 2015 to 2018, and from 2013 to 2018.

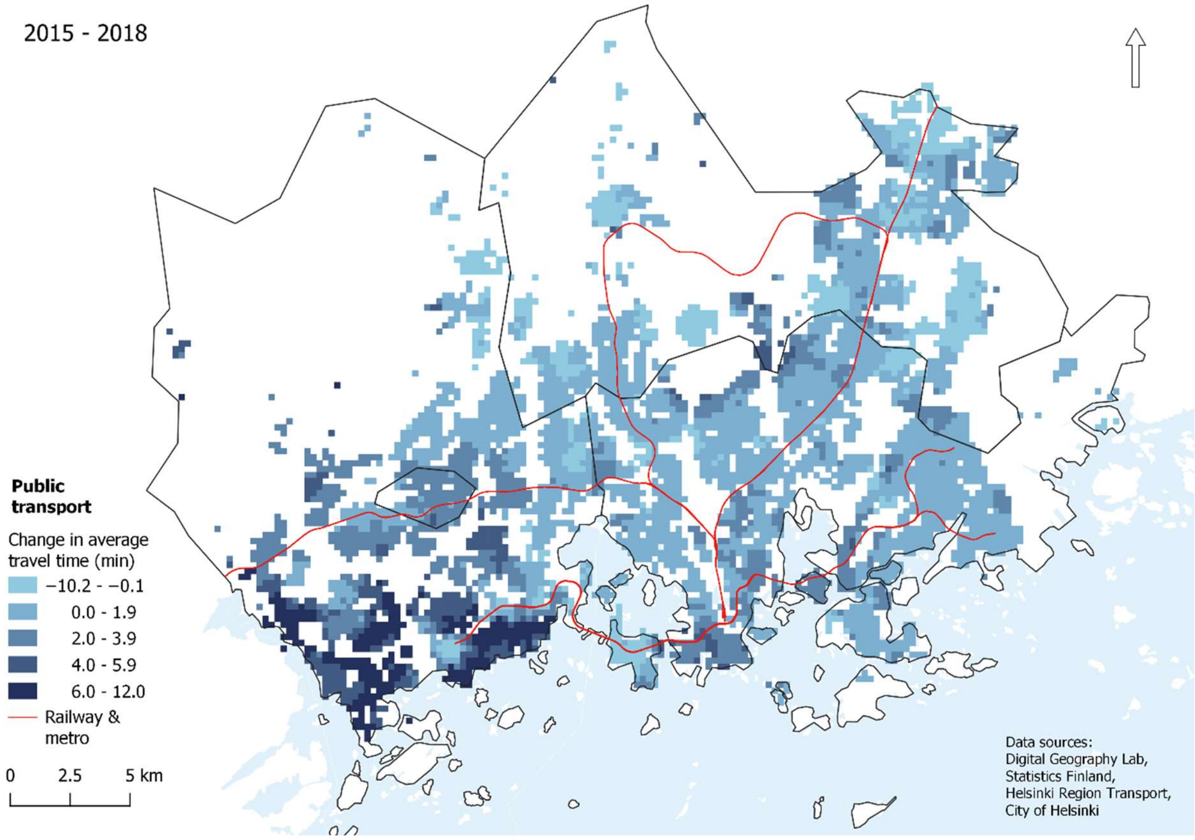


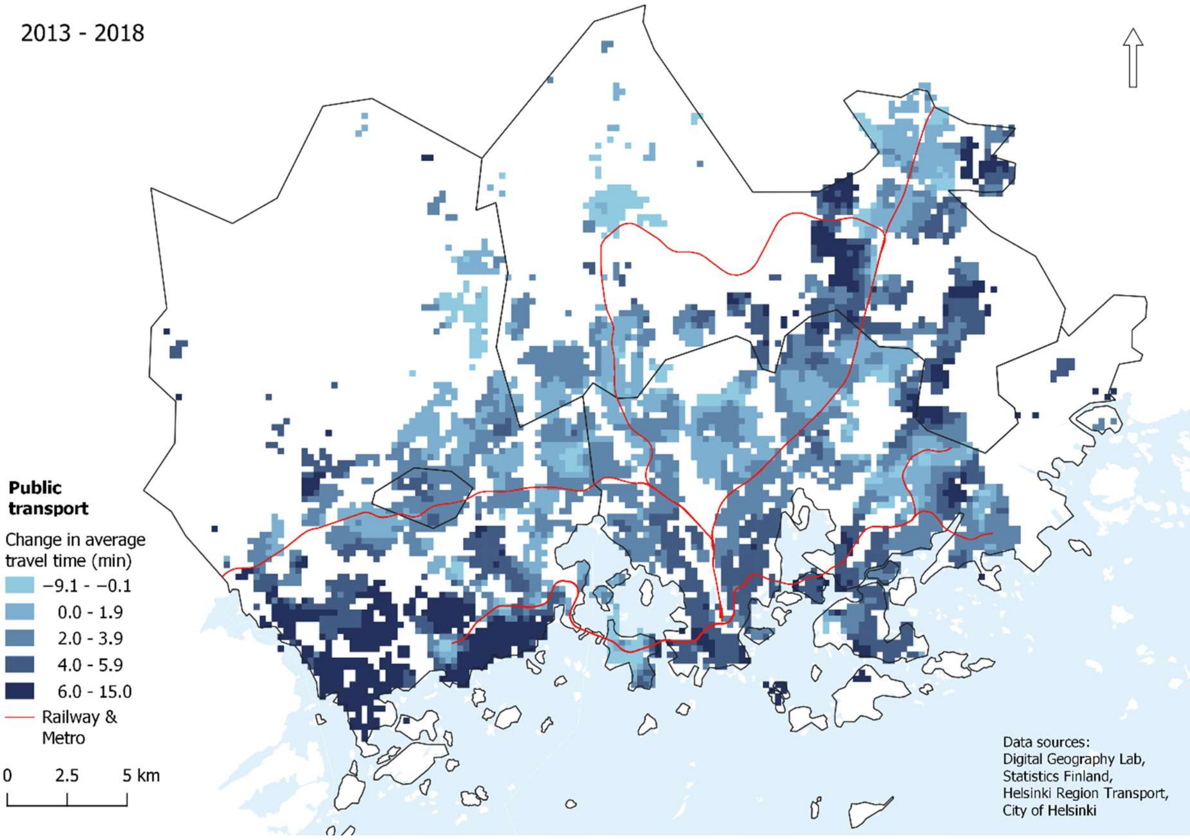



2013 - 2018
Public transport
Change in average travel time (min)
−39.1 - −0.1
0.0 - 1.9
2.0 - 3.9
4.0 - 5.9
6.0 - 19.3
No data
Railway & Metro
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Helsinki Region Transport,
City of Helsinki

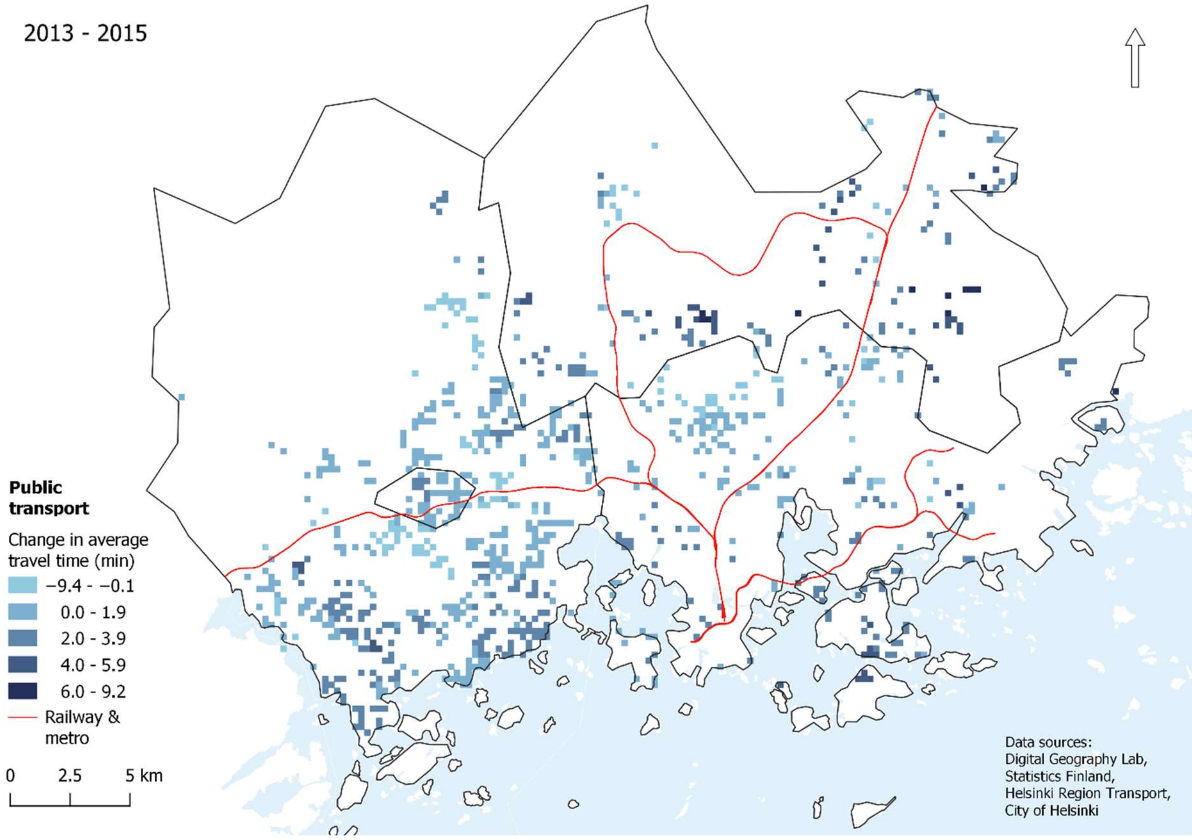
Appendix 5. Changes in average travel time by public transport in the sample grid cells in Helsinki Metropolitan Area from 2013 to 2015, from 2015 to 2018, and from 2013 to 2018.

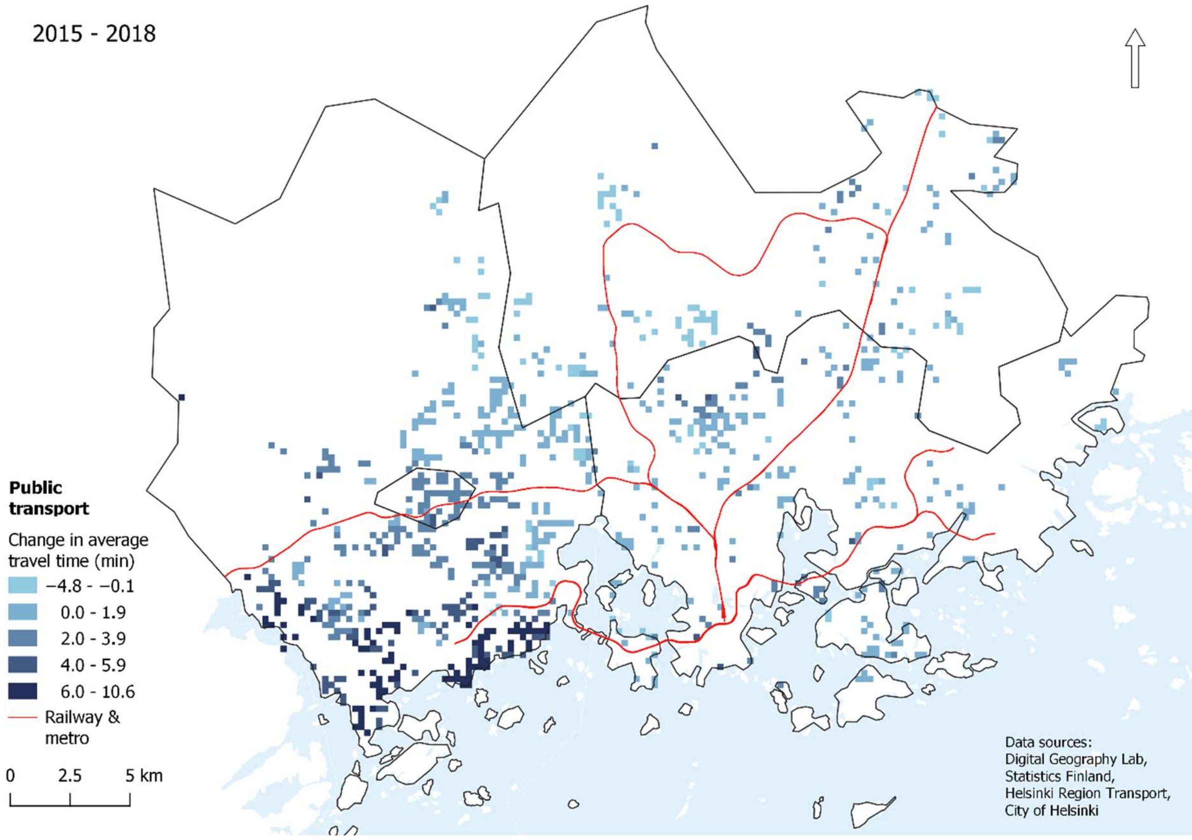


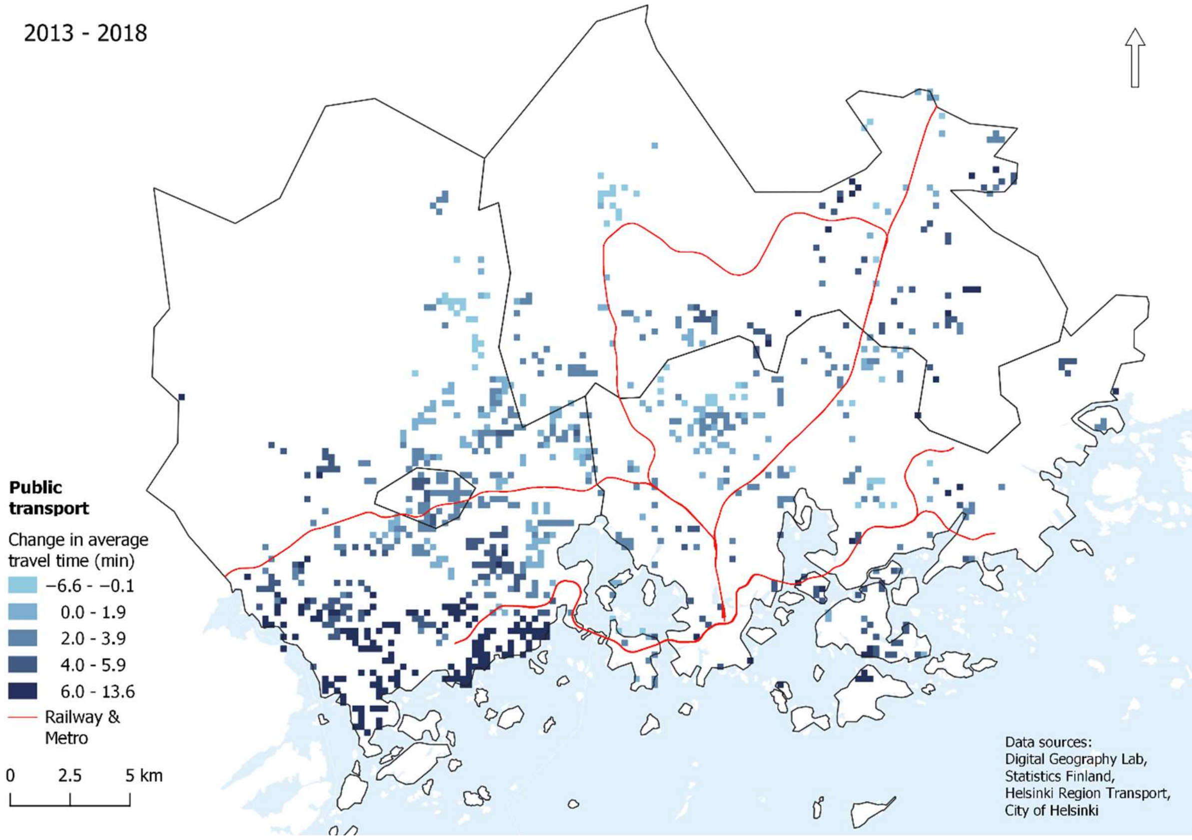



2013 - 2018
Public transport
Change in average travel time (min)
−9.1 - −0.1
0.0 - 1.9
2.0 - 3.9
4.0 - 5.9
6.0 - 15.0
Railway & Metro
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Helsinki Region Transport,
City of Helsinki

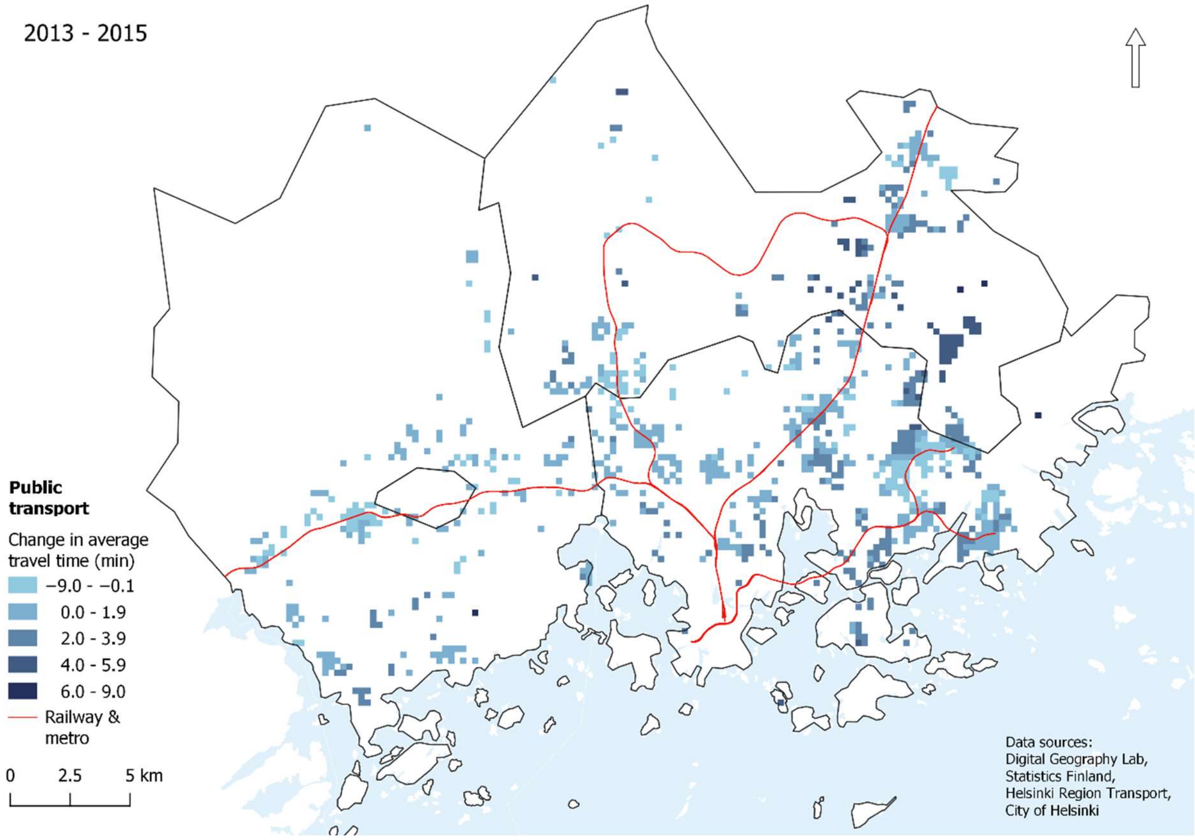
Appendix 6. Changes in average travel time by public transport in the least disadvantaged quintile in Helsinki Metropolitan Area from 2013 to 2015, from 2015 to 2018, and from 2013 to 2018.

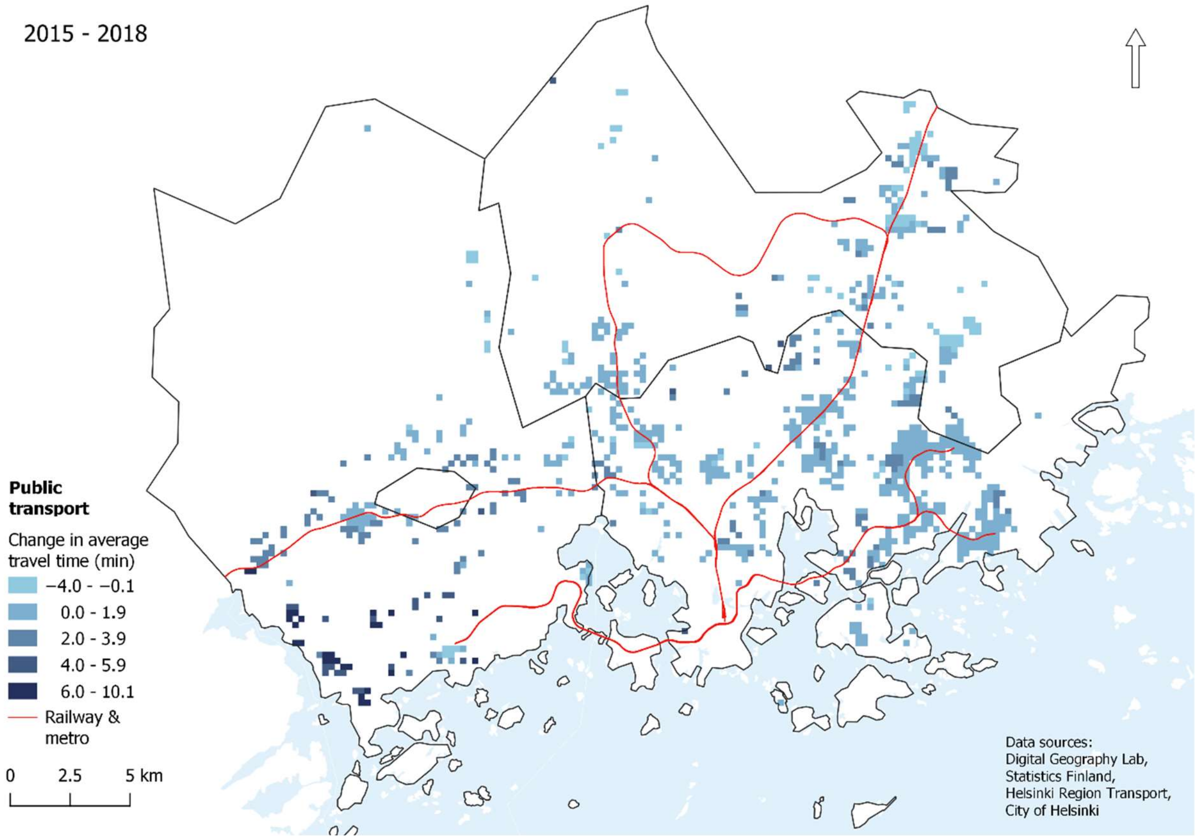


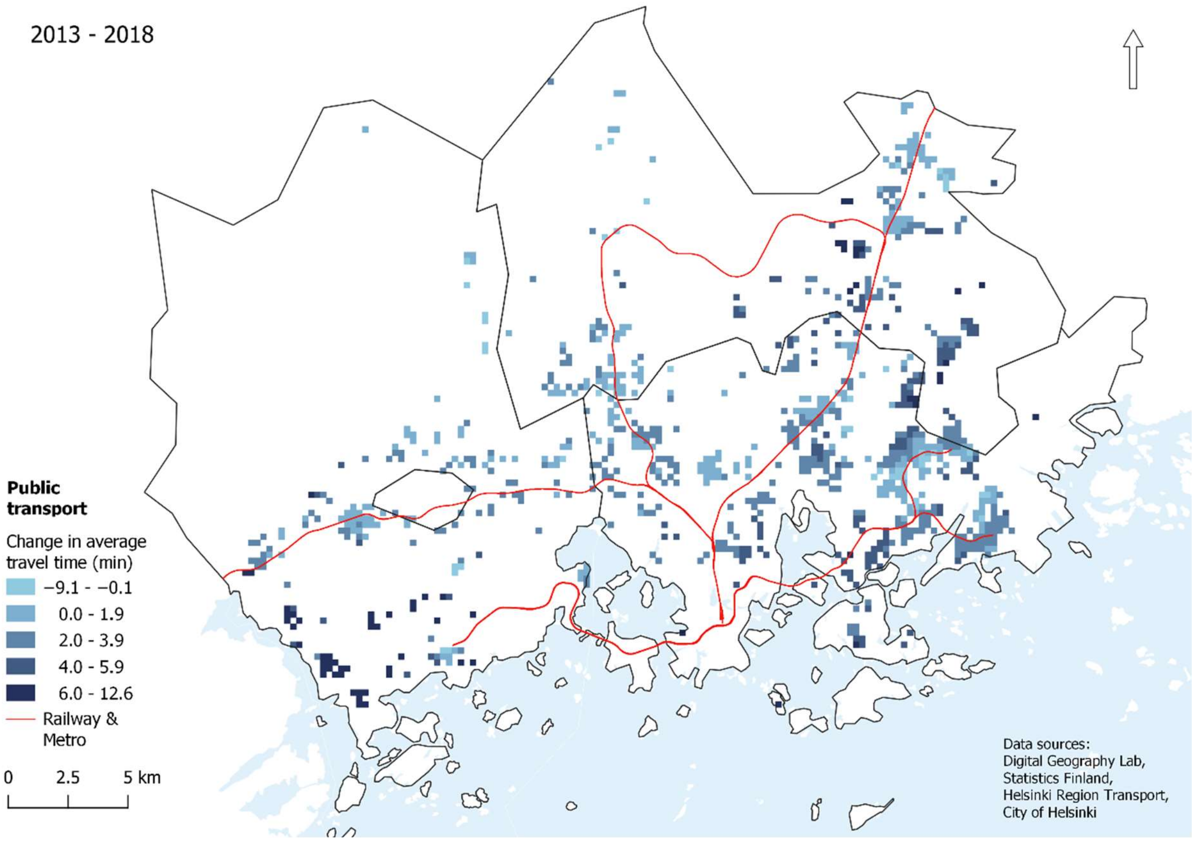



2013 - 2018
Public transport
Change in average travel time (min)
−6.6 - −0.1
0.0 - 1.9
2.0 - 3.9
4.0 - 5.9
6.0 - 13.6
Railway & Metro
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Helsinki Region Transport,
City of Helsinki

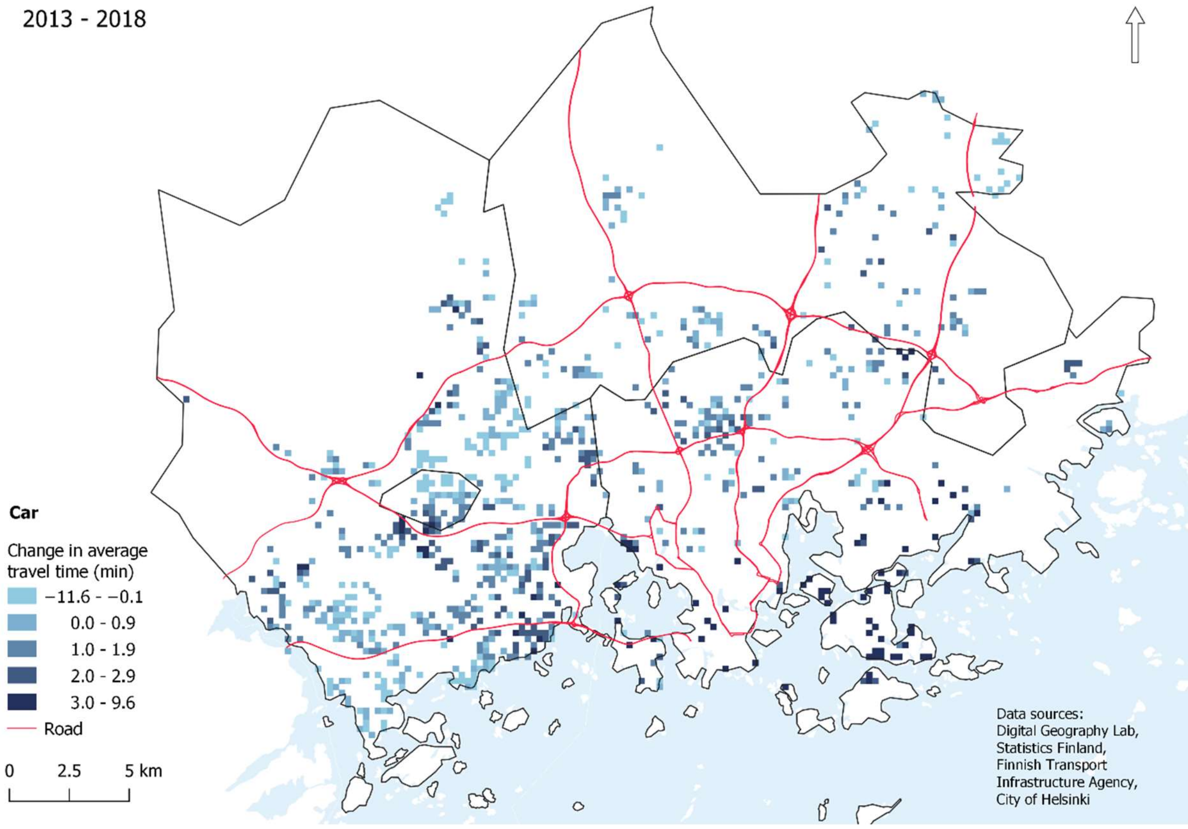
Appendix 7. Changes in average travel time by public transport in the most disadvantaged quintile in Helsinki Metropolitan Area from 2013 to 2015, from 2015 to 2018, and from 2013 to 2018.

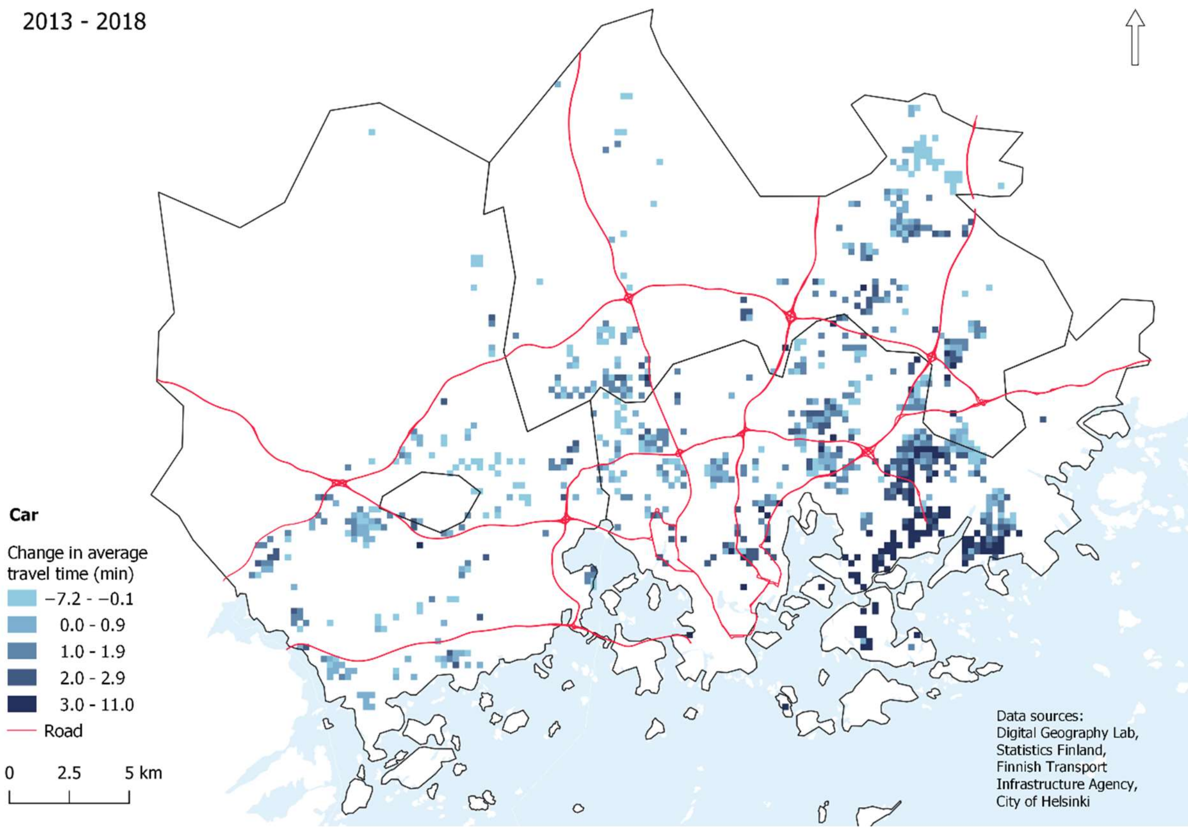




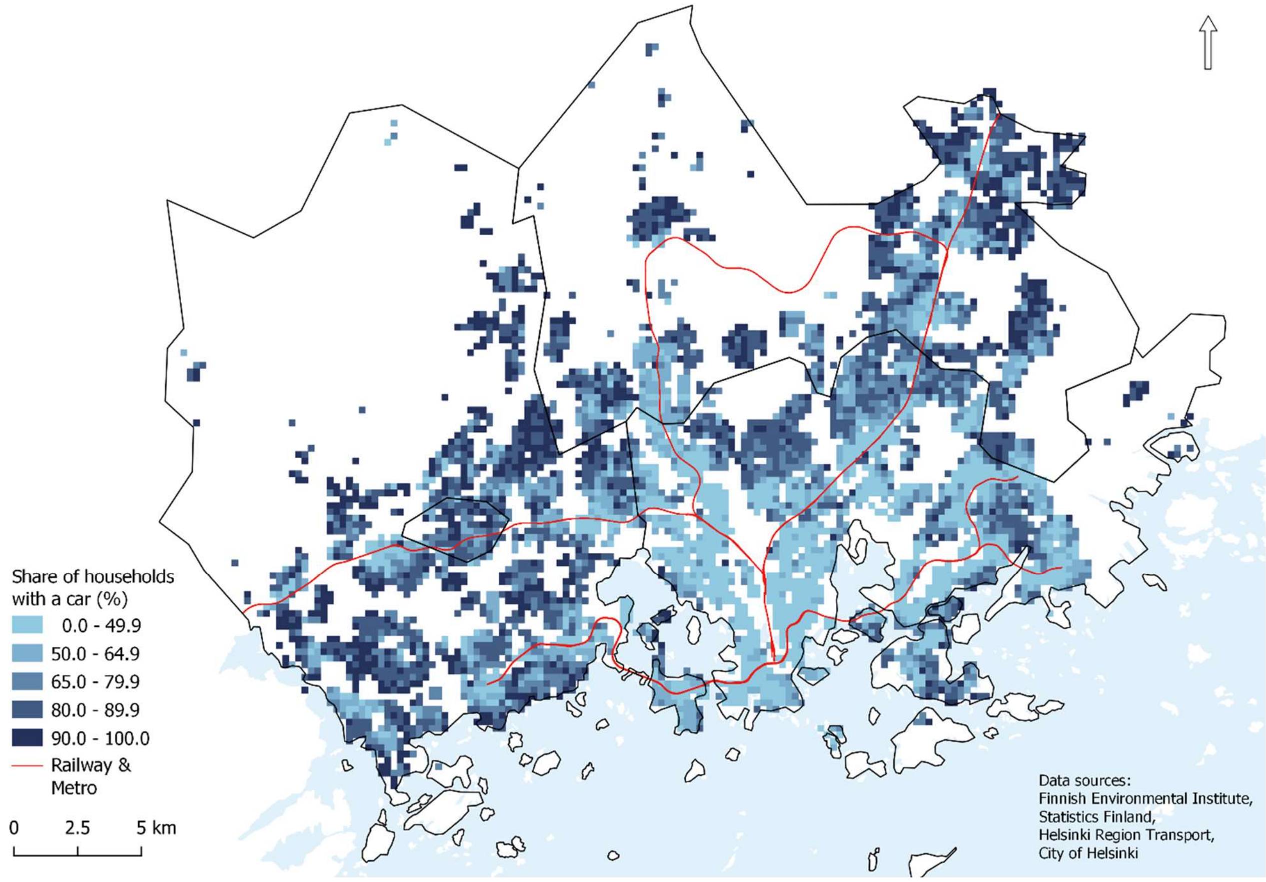

2013 - 2018
Public transport
Change in average travel time (min)
−9.1 - −0.1
0.0 - 1.9
2.0 - 3.9
4.0 - 5.9
6.0 - 12.6
Railway & Metro
0
2.5
5 km
Data sources:
Digital Geography Lab,
Statistics Finland,
Helsinki Region Transport,
City of Helsinki

Appendix 8. Changes in average travel times by car in the least (top) and most (bottom) disadvantaged quintiles in the Helsinki Metropolitan Area from 2013 to 2018.

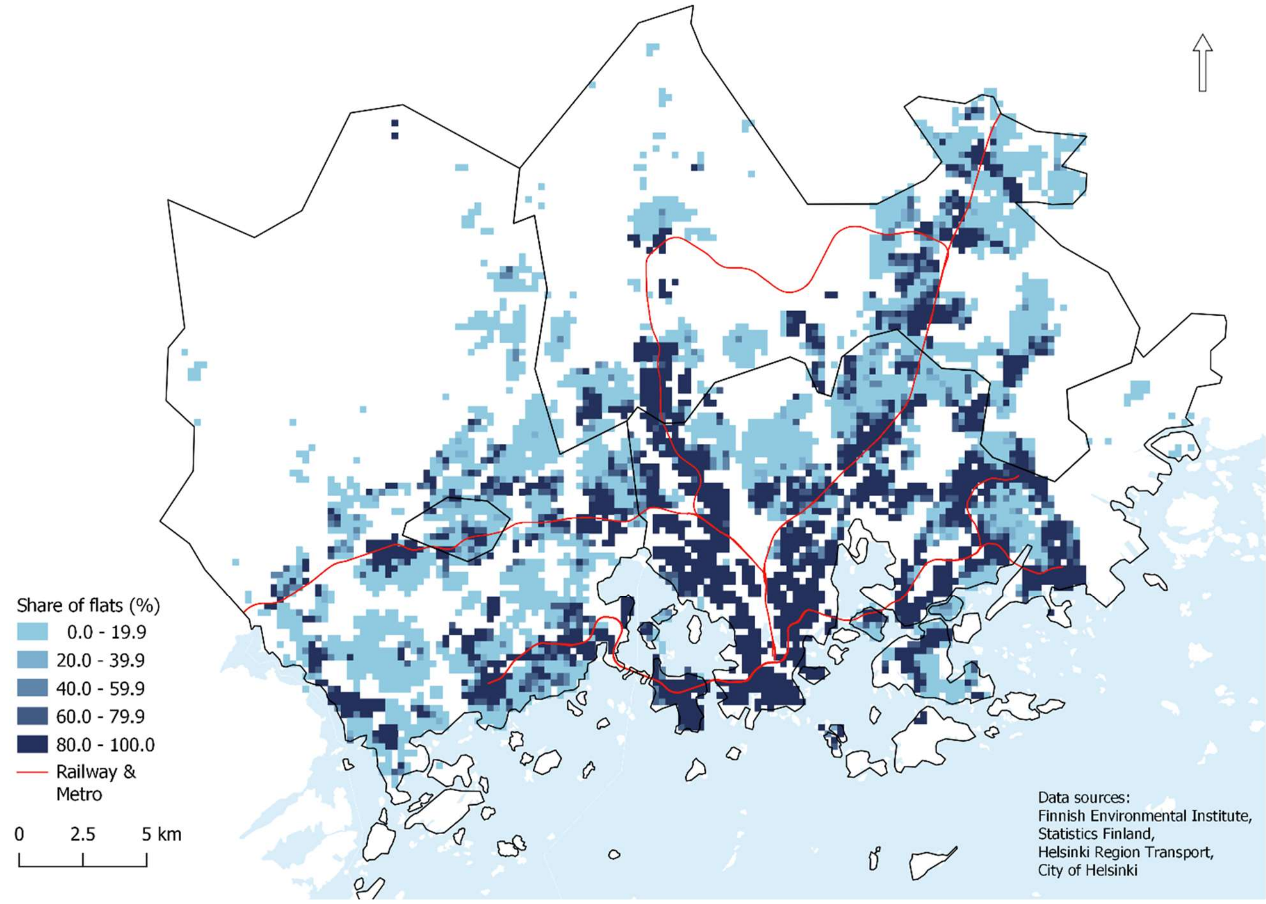




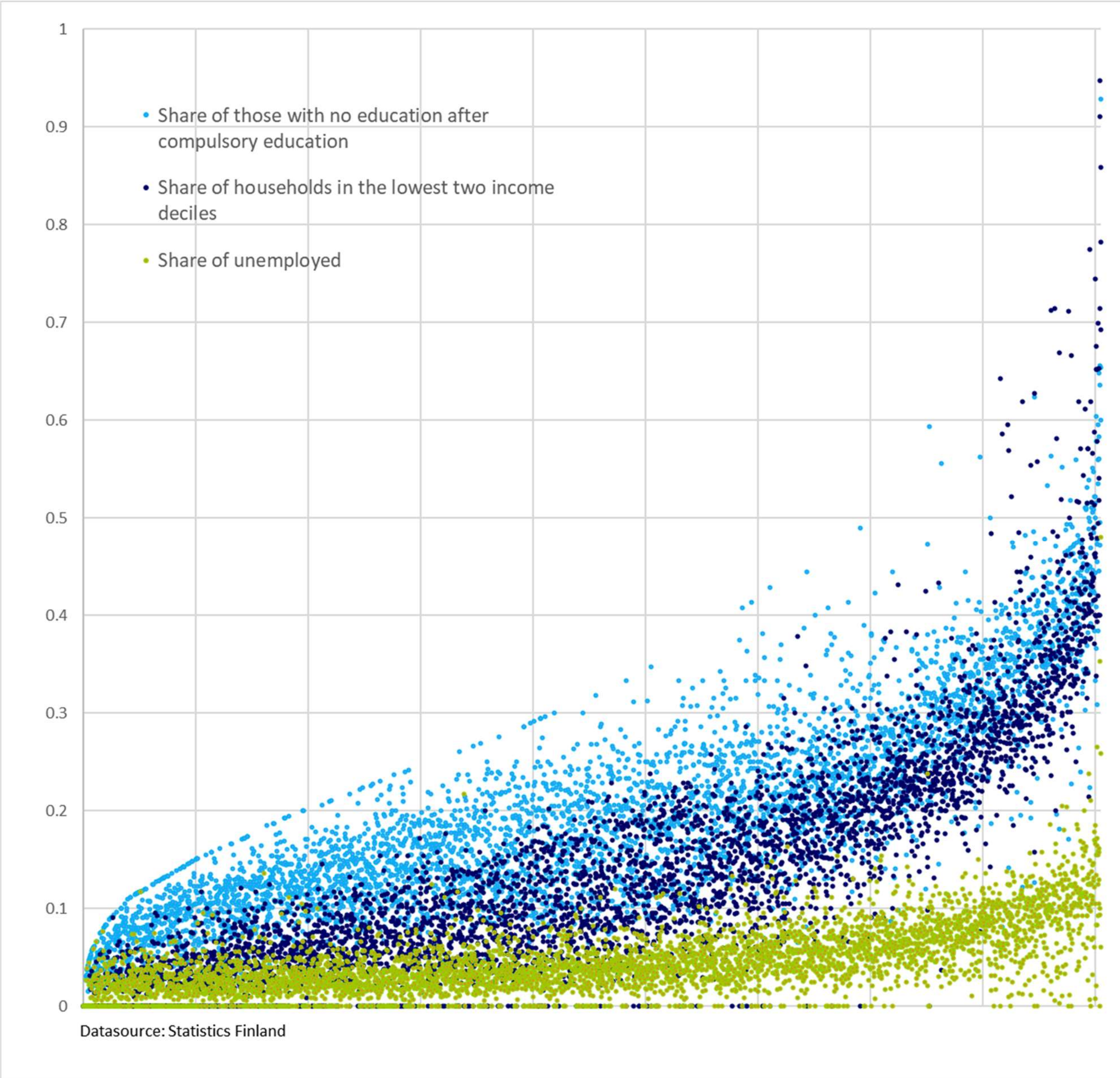
Appendix 9. The share of households with a car in Helsinki Metropolitan Areas in 2020.



Appendix 10. Share of dwellings in blocks of flats in Helsinki Metropolitan Area in 2019.



Appendix 11. The index of disadvantage broken into its three components - no education after compulsory education, households in the lowest two income deciles, and share of unemployed - by index of disadvantage.



Appendix 12. Data processing in RStudio.

```
#read data from helsinki region travel time matrix, years 2013, 2015 and 2018

#year 2013

library(dplyr)

file_list <- list.files(path="C:/data/HelsinkiTravelTimeMatrix2013", recursive = T, full.name = T)

dataset <- data.frame()

#Average travel time to each grid cell

for (i in 1:length(file_list))
 {
 temp_data <- read.csv2(file_list[i])
 summattu <- temp_data %>%
  group_by(to_id) %>%
  summarise(pt_m_t_mean = mean(pt_m_t[pt_m_t > 0]),
       car_m_t_mean = mean(car_m_t[car_m_t > 0]),
       count = n(),
       pt_count=sum(pt_m_t != -1),
       car_count=sum(car_m_t != -1))
 dataset <- rbind(dataset, summattu)
}

dataset2013 <- subset(dataset, to_id != -1)
dataset2013[is.na(dataset2013)] = -1

setwd("C:/data")
write.csv2(dataset2013, file = "TTM_summary_2013.csv")

#year 2015

file_list <- list.files(path="C:/data/HelsinkiTravelTimeMatrix2015", recursive = T, full.name = T)

dataset <- data.frame()

for (i in 1:length(file_list))
 {
 temp_data <- read.csv2(file_list[i])
 summattu <- temp_data %>%
  group_by(to_id) %>%
  summarise(pt_m_t_mean = mean(pt_m_t[pt_m_t > 0]),
       car_m_t_mean = mean(car_m_t[car_m_t > 0]),
       count = n(),
       pt_count=sum(pt_m_t != -1),
       car_count=sum(car_m_t != -1))
 dataset <- rbind(dataset, summattu)
}

dataset2015 <- subset(dataset, to_id != -1)
dataset2015[is.na(dataset2015)] = -1

write.csv2(dataset2015, file = "TTM_summary_2015.csv")

#year 2018
```

```
file_list <- list.files(path="C:/data/HelsinkiTravelTimeMatrix2018", recursive = T, full.name = T)

dataset <- data.frame()

for (i in 1:length(file_list))
 {
 temp_data <- read.csv2(file_list[i])
 summattu <- temp_data %>%
   group_by(to_id) %>%
   summarise(pt_m_t_mean = mean(pt_m_t[pt_m_t > 0]),
          car_m_t_mean = mean(car_m_t[car_m_t > 0]),
          count = n(),
          pt_count=sum(pt_m_t != -1),
          car_count=sum(car_m_t != -1)
   )
 dataset <- rbind(dataset, summattu)
}

dataset2018 <- subset(dataset, to_id != -1)
dataset2018[is.na(dataset2018)] = -1

write.csv2(dataset2018, file = "TTM_summary_2018.csv")

names(dataset2013)[names(dataset2013) == 'pt_m_t_mean'] <- "pt_2013"
names(dataset2013)[names(dataset2013) == 'car_m_t_mean'] <- "car_2013"
names(dataset2013)[names(dataset2013) == 'count'] <- "c2013"
names(dataset2013)[names(dataset2013) == 'pt_count'] <- "ptc2013"
names(dataset2013)[names(dataset2013) == 'car_count'] <- "carc2013"

names(dataset2015)[names(dataset2015) == 'pt_m_t_mean'] <- "pt_2015"
names(dataset2015)[names(dataset2015) == 'car_m_t_mean'] <- "car_2015"
names(dataset2015)[names(dataset2015) == 'count'] <- "c2015"
names(dataset2015)[names(dataset2015) == 'pt_count'] <- "ptc2015"
names(dataset2015)[names(dataset2015) == 'car_count'] <- "carc2015"

names(dataset2018)[names(dataset2018) == 'pt_m_t_mean'] <- "pt_2018"
names(dataset2018)[names(dataset2018) == 'car_m_t_mean'] <- "car_2018"
names(dataset2018)[names(dataset2018) == 'count'] <- "c2018"
names(dataset2018)[names(dataset2018) == 'pt_count'] <- "ptc2018"
names(dataset2018)[names(dataset2018) == 'car_count'] <- "carc2018"


atable <- merge(x = dataset2013, y = dataset2015, by.x = "to_id", by.y="to_id", all = TRUE)
btable <- merge(x = atable, y = dataset2018, by.x = "to_id", by.y="to_id", all = TRUE)

btable[is.na(btable)] = -1

btable$pt13_18 = ifelse(btable$pt_2013 == -1, -999,
              ifelse(btable$pt_2018 == -1, -999, round(btable$pt_2018-btable$pt_2013, 4)))

btable$pt13_15 = ifelse(btable$pt_2013 == -1, -999,
              ifelse(btable$pt_2015 == -1, -999, round(btable$pt_2015-btable$pt_2013, 4)))

btable$pt15_18 = ifelse(btable$pt_2015 == -1, -999,
              ifelse(btable$pt_2018 == -1, -999, round(btable$pt_2018-btable$pt_2015, 4)))

btable$car13_18 = ifelse(btable$car_2013 == -1, -999,
               ifelse(btable$car_2018 == -1, -999, round(btable$car_2018-btable$car_2013, 4)))
```

```
btable$car13_15 = ifelse(btable$car_2013 == -1, -999,
                  ifelse(btable$car_2015 == -1, -999, round(btable$car_2015-btable$car_2013, 4)))

btable$car15_18 = ifelse(btable$car_2015 == -1, -999,
                  ifelse(btable$car_2018 == -1, -999, round(btable$car_2018-btable$car_2015, 4)))


write.csv2(btable, file = "TTM_travel_time_change.csv")

#index of disadvantage

grid <- read.csv2("rttk250_YKR_coordinates.csv", header = TRUE, sep=';', stringsAsFactors = FALSE,
colClasses=c(kunta="character"))

index <- subset(grid, tr_kuty >= 10) #4527
index <- subset(index, ko_ika18y >= 10) #4526
index <- subset(index, pt_ika18y >= 10) #4526
index <- subset(index, pt_vakiy >= 3) #4526

index$income=index$tr_pi_tul/index$tr_kuty
index$unemp=index$pt_tyott/(index$pt_vakiy-index$pt_0_14)
index$ed=index$ko_perus/index$ko_ika18y

index$disadv=index$income+index$unemp+index$ed
index$disadv_avg=mean(index$disadv)
index$disadv_ind=index$disadv/index$disadv_avg*100

indexs <- index[order(index$disadv_avg) , ]

quintiles <- indexs %>% mutate(category = cut(disadv_ind,
                               quantile(disadv_ind, c(0, .20, .40, .60, .80, 1)),
                               labels = c('1', '2', '3', '4', '5'),
                               include.lowest = TRUE))

write.csv2(quintiles, file = "disadvantage_index.csv")

quintiles2 <- merge(x = quintiles, y = btable, by.x = "YKR_ID", by.y = "to_id", all.x = TRUE)

write.csv2(quintiles2, file = "TTM_quintiles.csv")

pt_2018  <- quintiles2[(quintiles2$ptc2018 > 50) & (quintiles2$pt_2018 > 0), ]
car_2018 <- quintiles2[(quintiles2$carc2018 > 50) & (quintiles2$car_2018 > 0), ]

write.csv2(car_2018, file = "TTM_quintiles_2018_car.csv")
write.csv2(pt_2018, file = "TTM_quintiles_2018_pt.csv")

TTM_pt_2013_2018 <- quintiles2[(quintiles2$pt13_18 != -999) & (quintiles2$ptc2013 > 50) &
(quintiles2$ptc2018 > 50), ] #4525
TTM_pt_2013_2015 <- quintiles2[(quintiles2$pt13_15 != -999) & (quintiles2$ptc2013 > 50) &
(quintiles2$ptc2015 > 50), ] #4520
TTM_pt_2015_2018 <- quintiles2[(quintiles2$pt15_18 != -999) & (quintiles2$ptc2015 > 50) &
(quintiles2$ptc2018 > 50), ] #4521

TTM_car_2013_2018 <- quintiles2[(quintiles2$car13_18 != -999) & (quintiles2$carc2013 > 50) &
(quintiles2$carc2018 > 50), ] #4506
TTM_car_2013_2015 <- quintiles2[(quintiles2$car13_15 != -999) & (quintiles2$carc2013 > 50) &
(quintiles2$carc2015 > 50), ] #4516
TTM_car_2015_2018 <- quintiles2[(quintiles2$car15_18 != -999) & (quintiles2$carc2015 > 50) &
(quintiles2$carc2018 > 50), ] #4510
```

```
TTM_pt_2013_2018 = subset(TTM_pt_2013_2018, select=c(YKR_ID, kunta, ko_ika18y, ko_perus, tr_kuty,
tr_pi_tul, pt_vakiy, pt_tyott, pt_0_14,
                                        income, unemp, ed, disadv, disadv_avg, disadv_ind, category, pt_2013, ptc2013,
                                        pt_2018, ptc2018, pt13_18))
TTM_pt_2013_2015 <- subset(TTM_pt_2013_2015, select=c(YKR_ID, kunta, ko_ika18y, ko_perus, tr_kuty,
tr_pi_tul, pt_vakiy, pt_tyott, pt_0_14,
                                        income, unemp, ed, disadv, disadv_avg, disadv_ind, category, pt_2013, ptc2013,
                                        pt_2015, ptc2015, pt13_15))
TTM_pt_2015_2018 <- subset(TTM_pt_2015_2018, select=c(YKR_ID, kunta, ko_ika18y, ko_perus, tr_kuty,
tr_pi_tul, pt_vakiy, pt_tyott, pt_0_14,
                                        income, unemp, ed, disadv, disadv_avg, disadv_ind, category, pt_2015, ptc2015,
                                        pt_2018, ptc2018, pt15_18))

TTM_car_2013_2018 <- subset(TTM_car_2013_2018, select=c(YKR_ID, kunta, ko_ika18y, ko_perus, tr_kuty,
tr_pi_tul, pt_vakiy, pt_tyott, pt_0_14,
                                         income, unemp, ed, disadv, disadv_avg, disadv_ind, category, car_2013,
carc2013,
                                         car_2018, carc2018, car13_18))
TTM_car_2013_2015 <- subset(TTM_car_2013_2015, select=c(YKR_ID, kunta, ko_ika18y, ko_perus, tr_kuty,
tr_pi_tul, pt_vakiy, pt_tyott, pt_0_14,
                                         income, unemp, ed, disadv, disadv_avg, disadv_ind, category, car_2013,
carc2013,
                                         car_2015, carc2015, car13_15))
TTM_car_2015_2018 <- subset(TTM_car_2015_2018, select=c(YKR_ID, kunta, ko_ika18y, ko_perus, tr_kuty,
tr_pi_tul, pt_vakiy, pt_tyott, pt_0_14,
                                         income, unemp, ed, disadv, disadv_avg, disadv_ind, category, car_2015,
carc2015,
                                         car_2018, carc2018, car15_18))


write.csv2(TTM_pt_2013_2018, file = "TTM_pt_2013_2018.csv")
write.csv2(TTM_pt_2013_2015, file = "TTM_pt_2013_2015.csv")
write.csv2(TTM_pt_2015_2018, file = "TTM_pt_2015_2018.csv")

write.csv2(TTM_car_2013_2018, file = "TTM_car_2013_2018.csv")
write.csv2(TTM_car_2013_2015, file = "TTM_car_2013_2015.csv")
write.csv2(TTM_car_2015_2018, file = "TTM_car_2015_2018.csv")

#share of apartments

apart <- quintiles

apart$ap_share = ifelse(apart$ra_asunn <= 0, -1, round(apart$ra_kt_as/(apart$ra_kt_as+apart$ra_pt_as), 4))

apart %>%
  group_by(category) %>%
  summarise(ap_mean=mean(ap_share[ap_share != -1]))

write.csv2(apart, file = "apartments_quantiles.csv")

#households with a car

YRK_cars <- read.csv2("YRK_autot_pks.csv", header = TRUE, sep=';', stringsAsFactors = FALSE,
colClasses=c(kunta="character"))

colnames(YRK_cars)[1] <- "id"
cars <- YRK_cars[ -c(1, 3:7, 9: 17, 20) ]

#remove duplicates
cars_sum <- cars %>%
```

```
  group_by(TK_id) %>%
  summarise(ak_yht_n=sum(ak_yht[ak_yht != -1]),
        autoja_1_n=sum(autoja_1[autoja_1 != -1]),
        autoja_2_n=sum(autoja_2[autoja_2 != -1]))

#Test for duplicates
cars_sum[duplicated(cars_sum$TK_id),]

cars_sum$cars_share = ifelse(cars_sum$ak_yht_n == 1, -1,
round((cars_sum$autoja_1_n+cars_sum$autoja_2_n)/cars_sum$ak_yht_n, 4))

cars_quint <- merge(x = quintiles, y = cars_sum, by.x = "id_nro", by.y = "TK_id", all.x = TRUE)
cars_quint[is.na(cars_quint)] = -1

cars_quint %>%
  group_by(category) %>%
  summarise(cars_avg=mean(cars_share[cars_share != -1]))

cars_quint %>%
  summarise(carst_avg=mean(cars_share[cars_share != -1]))

write.csv2(cars_quint, file = "cars_quantiles.csv")
```