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Socioeconomic and ethnic segregation in Finland: A multi-scale analysis of diverse urban sizes

Antti Kurvinen [a,b,c,d,*], Aleksi Karhula [c,d,e], Sanna Ala-Mantila [c,d]

[a] Faculty of Built Environment, Tampere University, Tampere, Finland
[b] Tampere Institute for Advanced Study, Tampere University, Tampere, Finland
[c] Faculty of Biological and Environmental Sciences, University of Helsinki, Helsinki, Finland
[d] Helsinki Institute of Sustainability Science (HELSUS), University of Helsinki, Helsinki, Finland
[e] INVEST Flagship Centre, University of Turku, Turku, Finland

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ABSTRACT

Rising residential socioeconomic segregation is a globally acknowledged phenomenon that also occurs in the Nordic welfare states. Our study provides a comprehensive view of residential socioeconomic and ethnic segregation across 20 Finnish cities, including both large and smaller cities. We highlight the importance of the scale of analysis by comparing the results from a residential area classification to other neighbourhood definitions, including zip code and statistical grid levels. Instead of relying on a single city-level indicator, we also zoom into different residential area types and illustrate the development of their socioeconomic and ethnic structure between 2000 and 2018. The results show increasing levels of socioeconomic segregation in all studied cities and scales. The increasing levels of segregation are linked to the relative deprivation of residential mid-rise areas built from the 1960s until the 1990s and to the increasing positive selection by income and education in the residential low-rise areas built after 2000. The results for ethnic segregation are more diverse showing increases in some cities but decreases in others. The overall average of ethnic segregation in the 20 studied cities has slightly decreased although ethnic minorities are still overrepresented in the socioeconomically disadvantaged residential areas.

1. Introduction

The global reach of rising levels of socioeconomic segregation (Bischoff & Reardon, 2014; Musterd, Marcińczak, van Ham, & Tammaru, 2017; Owens, 2016; Ross, Houle, Dunn, & Aye, 2004; van Ham, Tammaru, Ubarevičienė, & Janssen, 2021) begs a question of whether the rise can be dammed in any national context. Also, the Nordic region has revealed evidence of growing socioeconomic segregation (Andersson & Turner, 2014; Tammaru, Marcin'czak, Aunap, van Ham, & Janssen, 2020). Despite this, Helsinki, Finland's capital, has had low levels of ethnic residential segregation compared to other Nordic cities (Skifter Andersen, Andersson, Wessel, & Vilkama, 2016; Wessel, Andersson, Kauppinen, & Andersen, 2017). However, recent studies suggest a slight increase in residential segregation in Finland. Bernelius and Vilkama (2019) observed an increase in socioeconomic and ethnic segregation in Helsinki from 1995 to 2015, and Tammaru et al. (2020) from 1990 to 2010. Moreover, Kauppinen, van Ham, and Bernelius (2022) found that ethnic and socioeconomic segregation are intertwined in complex ways, necessitating that both phenomena need to be studied: even though socioeconomic segregation and ethnic segregation are often linked (Jargowsky, 2020), their developments can follow diverse paths.

Although several segregation studies have focused on capital cities and largest metropolises, there has been a lack of quantitative research on residential segregation patterns in smaller cities, where a significant portion of the population resides. This is particularly true in Finland, despite majority of Finnish cities being small in international comparisons. Some research has explored residential segregation in small cities and non-metropolitan areas especially in the United States. These studies have shown that residential segregation is not just a phenomenon of big cities (see Krupka, 2007; Lichter, Parisi, and Taquino, 2016; Massey and Tannen, 2018; Logan, Kye, Carlson, Minca, and Schleith, 2023). However, there is a scarcity of research on socioeconomic residential segregation in smaller European or Nordic cities. Malmberg, Andersson, Nielsen, and Haandrikman (2018) and Malmberg and

* Corresponding author at: P.O. Box 600, FI-33014, Tampere University, Finland.
E-mail address: antti.kurvinen@tuni.fi (A. Kurvinen).

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Andersson (2021) have conducted some notable studies on ethnic and school segregation in smaller cities in Sweden. Their findings highlight that many of the most segregated areas are located in smaller cities, and that school segregation is negatively related to the number of students in the municipality.

In this study, we examine the residential socioeconomic and ethnic segregation across the 20 largest cities in Finland using high-quality full population register data. The cities in our sample collectively account for over 50 % of the population, and their sizes range from small to large, allowing us to track trends in segregation between 2000 and 2018. We utilize a building age and characteristics based residential area classification (Ala-Mantila, Kurvinen, & Karhula, 2023) as our primary measurement unit, while also employing multiple other neighbourhood definitions to adopt a multiscalar approach. Studying segregation using only predefined, often administrative, spatial units can yield different results compared to using alternative units, as indicated by the modifiable areal unit problem (MAUP). Taking this into account is important when studying various neighbourhood-level issues, as noted by previous research (e.g., Andersson & Musterd, 2010; Andersson, Lyngstad, & Sleutjes, 2018; Johnston et al., 2004). This approach enables us to see whether segregation trends persist when using different scales of subarea measurement.

In the current study, we concentrate on the residential socioeconomic and ethnic segregation in the whole national urban context of one of the most equal states in the world, namely Finland. Our contribution to literature is threefold. First, we illustrate that from 2000 to 2018 the levels of socioeconomic segregation have been increasing in Finland both in larger and smaller cities. The development of ethnic segregation has been more varied across the cities with an overall slightly decreasing trend. Although this is in line with many other studies from different country contexts, we would have expected the Nordic welfare state context to limit or completely offset the increases in residential socioeconomic segregation. Our results suggest that the increasing residential segregation in the US and Europe can be seen to result from very persistent processes that are hard to counter even with equalizing welfare policies. Even in Finland, the rise of segregation has been a clear trend in cities ranging from the capital region of Helsinki to smaller cities of just over 50,000 residents, such as Salo or Kotka.

Second, the rich individual and household level register data allows us to use a multiscalar approach and compare the results using different neighbourhood definition scales. We show that our results hold in all four used neighbourhood definition scales and illustrate that the levels of segregation appear the higher, the smaller the areal unit of the analysis is. The latter is a basic fact of population distribution in space, and studies using traditional units of segregation measurement (Haandrikman, Costa, Malmberg, Rogne, & Sleutjes, 2023) and studies using the nearest neighbourhood method (e.g. Östh, Clark, & Malmberg, 2015) show this. Further, we can observe that using geographically larger areal units, zip codes, tend to give higher levels of segregation in the bigger cities compared to smaller ones, and vice versa the smallest areal units, 250 m × 250 m grid cells, tend to give higher levels of segregation in the smaller cities compared to the larger ones.

Third, our residential area classification allows us to show that the increasing levels of segregation are linked to the relative deprivation of residential mid-rise areas (blocks of flats) built from the 1960s to 1990s and to the increasing positive selection by income and education in the residential low-rise areas (single-family houses and rowhouses) built after the year 2000. It is almost certain that municipal planning monopoly (giving the Finnish municipalities the final decisions about how the land is used within their borders), strong welfare state compensation, and relatively low levels of income inequality have curbed the residential segregation and relative deprivation of the old mid-rise areas. At the same time, the fact that we still see increased levels of segregation to be linked with the deprivation of certain types of residential areas should be alarming.

2. Previous literature and research questions

The international rise in socioeconomic segregation been linked to the general increases in inequality (Reardon & Bischoff, 2011; van Ham et al., 2021), and as the rise of wealth inequality is more and more pronounced (Piketty & Saez, 2014), we could expect it to be reflected in growing levels of residential segregation. Some of the most equal regions, e.g., in terms of tackling income inequality (Walker et al., 2022) and intergenerational inequalities (Björklund & Jäntti, 1997; Grätz et al., 2021) are the Nordic countries. Still, when it comes to wealth inequalities, most of the Nordic countries have relatively high levels of wealth inequality compared to other European countries (Pfeffer & Waitkus, 2021), or in some estimations even to the US (Cowell, Karagiannaki, & Mcknight, 2018). Finland, on the other hand, has lower wealth inequality compared to other Nordic countries (Pfeffer & Waitkus, 2021)). Based on the harmonized data from the Luxembourg Wealth Study (LWS), Pfeffer and Waitkus estimate Finland's wealth inequality among the lowest of the 15 countries included in the study. Yet, for example, Credit (2022) estimates all Nordic countries to have relatively high wealth inequality although, when measured with the Gini coefficient, Finland has the lowest level in the Nordics. In conclusion, Finland is among the most equal countries in the world as, for example, the Global Social Mobility Index published by the World Economic Forum (2020), ranks Finland in third place, indicative of success in ensuring equal and meritocratic opportunities regardless of an individual's socio-economic background, geographic location, gender, or origin. Maybe partly because of this, very low levels of residential segregation have been traditionally seen in Finland (Wessel et al., 2017).

In Finland, municipalities have a highly independent role in their housing policies, including urban renewal and segregation related policies. There is a lot of variation in implementation between cities of different sizes, and segregation is clearly visible only in the agendas of the largest cities (Rosengren, Rasinkangas, & Ruonavaara, 2023). The housing system is primarily market-driven and only rents of state-subsidized housing supply are regulated. However, compared to, for example, the US the system includes elements of central planning and state and municipal housing policies, usually aimed at providing affordable housing and creating mixed neighbourhoods, even though also here the practices of implementation differ (Tunström et al., 2020). For example, the capital, Helsinki, has a long history of preventive measures, such as small-scale social mixing from the 1970s and reactive measures, such as area-based initiatives from the 1990s (Rosengren et al., 2023), but other cities are mostly lacking far behind. For example, only three out of eleven medium-sized cities mention segregation in their strategic level or relevant sectoral policy documents (Rosengren et al., 2023).

In Helsinki, historically, the segregation reduction policies together with low levels of unemployment were able to tackle socioeconomic segregation and it was minimal still in the 1980s, but after the 1990s recession, residential segregation significantly increased (Vaattovaara, Joutsiniemi, Kortteinen, Stjernberg, & Kemppainen, 2018), although the levels are still relatively low in international comparison (Haandrikman et al., 2023). Further, in the 2000s, the construction of subsidized rental housing has been declining in Finland (Kurvinen, 2020), which might also be reflected on the segregation patterns. Regarding migration patterns, Finland is still urbanizing country with increasing levels of immigrants from abroad (Karhula, McMullin, Sutela, Ala-Mantila, & Ruonavaara, 2020). Overall, Finnish cities provide an interesting context to study segregation, with equalizing welfare state context on the national level, high power on the local level, but very different types and scales of local level implementations in cities of different sizes. As our first research question we therefore ask.

(RQ1) What are the major trends in residential socioeconomic and ethnic segregation in the 20 Finnish cities between years 2000 and 2018?

Comparative segregation studies, both national and international, always face the question of suitable area units, as the creation of comparable neighbourhoods is known to be problematic (Openshaw, 1981), especially when comparing cities of different sizes. Previous studies recognizing the problem of modifiable areal units (MAUP) have often focused on using either predetermined numbers of nearest neighbours or fixed kilometre radius (Clark, Anderson, Östh, & Malmberg, 2015; Costa & de Valk, 2018; Deurloo, Musterd, Sleutjes, & Slot, 2022; Haandrikman et al., 2023; Östh et al., 2015). This approach does not inherently solve the MAUP problem, but it is very valuable especially in the case when no specifically constructed neighbourhood classifications are available. However, an analysis using defined areal units further reveals to us how and on which level segregation has or has not been increasing.

Another difficulty in analysing multiple cities, and especially the smaller towns, is that the areal definitions tend to differ, and different definitions produce varying results. To mitigate this uncertainty when analysing different cities, we rely on a multiscalar approach. As an area unit, we utilize a residential area classification that is defined similarly to all the 20 biggest Finnish cities (Ala-Mantila et al., 2023), as well as more traditionally used zip code areas, 1 km × 1 km grid cells, and 250 m × 250 m grid cells. In addition to the scales, these areal definitions also differ in kind as the grids are originally created for statistical purposes, zip code areas represent a more administrative definition, and the residential area classification is specified based on the characteristics of the built environment. As our second research question, we ask.

(RQ2) Does the overall picture of segregation change when comparing the residential area classification to other areal definitions?

Regarding the dynamics behind segregation, it is not only a question of segregation on different scales, but previous literature has highlighted that some types of neighbourhoods are systematically facing socioeconomic decline. In Europe, these are typically the housing estates built in the decades following the Second World War (Hess, Tammaru, & Van Ham, 2018). It is identified in the previous research that in Finland, in particular, the mid-rise suburbs built in the 1960s and 1970s (*lähiö* in Finnish) have developed unfavourably compared to other areas (Stjernberg, 2019; Vaattovaara et al., 2018). In these residential areas, rental and especially social rental domination is associated with contextual social disadvantage (Kemppainen, Kauppinen, Stjernberg, & Sund, 2018), and common challenges include e.g. social exclusion and deteriorating housing stocks. However, regarding other residential area types, the previous research is very limited. Here, we address this void in knowledge by analysing proportion measures of low-income households, levels of education, and foreign language speakers in the seven different residential area types, asking.

(RQ3) How does the increasing segregation reflect in different kinds of residential areas?

This is important to contextualize our city-level findings to concrete developments in the residential areas. The further analysis on residential area types contextualises the processes behind segregation and informs us where the urban policies combating segregation should be targeted.

3. Data and methods

3.1. Finnish register data

Our analysis leans on fine-grained full population register data from Statistics Finland, covering the 20 biggest cities in Finland. For calculation of the segregation indexes, we used household level data for the income segregation, and individual level data for the ethnic and educational segregation. As a measure of income, we used the municipality specific income quintiles of household level disposable income per consumption unit (according to modified OECD scale). In the calculation of dissimilarity indexes, we compare the highest quintile of residents in a city to the lowest quintile. Our household level data consists of 1,166,778 households in 2000 and 1,469,904 households in 2018. The income information was obtained from the income tax register, and the predefined measure of disposable income from the Statistics Finland ready-made FOLK household module was used for the analysis.

In the case of education, we examined the highest level of education of persons over age 20. Education was defined in three categories: primary school or less, upper secondary or post-secondary non-tertiary education, and tertiary education or higher. In the dissimilarity indexes we compare the highest and lowest educational groups, i.e. residents with primary school education or less and residents with tertiary education or higher. The data consists of 1,873,161 individuals in 2000 and 2,258,141 in 2018.

As in some previous studies (e.g. Dhalmann & Vilkama, 2009), we use mother language as a proxy to measure ethnic segregation. This works well in the Finnish context as larger scale immigration is relatively new phenomenon and using mother language catches mostly both first- and second-generation immigrants. The mother language was defined for the over 18 years-olds as one of the official domestic languages (Finnish or Swedish) or any other. This data included 1,935,036 individuals in 2000 and 2,421,715 in 2018. The largest immigrant groups in Finland in 2022 were Russians (93,535) and Estonians (50,318) followed by speakers of Arabic (39,069), English (29,448) and Somali (24,647). On average, immigrants are less educated compared to native Finns, but the immigrant groups are diverse. Overall immigrants are overrepresented in the largest cities, and this particularly applies for immigrants from non-western origin (Andersson et al., 2010). Here we focus only on the main lines of ethnic segregation and do not separate the immigrants by countries of origin.

3.2. Residential area classification

To allow multiscalar approach, our analyses utilize various areal units. Our primary spatial unit of analysis involves classifying residential areas according to their built environment characteristics, specifically building age and type (see Ala-Mantila et al. (2023) for a more thorough discussion on the typology). Built environment based classification is relevant as the age and type of buildings in Finland reflect the historical planning trends, with a relatively young housing stock predominantly influenced by urbanization since the 1950s, followed by a significant increase in multi-story apartment constructions during the 1960s and 1970s, typically located outside city centres, succeeded by a transition towards smaller-scale housing developments in the 1990s and 2000s. Whereas, in recent years, there has been a shift towards denser urban structures and infill developments to meet sustainability goals. More detailed description of Finnish planning, from the perspective of housing estates, can be found in e.g. Vaattovaara et al. (2018).

Our classification is based on residential property data collected from 250 m × 250 m grid cells, enabling the categorization of residential areas by most typical building type and age, thus reflecting planning principles across different decades. We define seven types of residential areas: 1) city centre, 2) mid-rise areas from 1950s and before, 3) mid-rise areas from 1960s and 1970s ("Finnish suburbs"), 4) mid-rise areas from 1980s and 1990s, 5) mid- and high-rise areas built since 2000, 6) low-rise areas built before 2000, and 7) low-rise areas built since 2000. The residential areas were created by combining the grid cells of same area class that shared a border or vertex (queen contiguity) until there were no adjacent grid cells of same class available. In the final classification, there were 7989 (in 2000) and 11,592 (in 2018) residential areas in the 20 studied cities. When interpreting the results, it is important to bear in mind that not necessarily all residential area types exist in all cities. This does not mean that the respective residential building type would be absent from the city but that its share is not great enough to characterize a residential area. Furthermore, it is not meaningful to present the result of newer areas for the cross-section year 2000 as these were still at the beginning of their construction phase. The classification methodology is presented in detail in (Ala-Mantila et al., 2023), also including information about the sizes of residential area classes per city per year. Moreover, the corresponding spatial classification datasets for the years 2000 and 2018 are openly available in GeoJSON format in

Zenodo (https://doi.org/10.5281/zenodo.7416027). The classification is illustrated in the following Fig. 1, along with zip code areas that are also utilized as areal units.

3.3. Dissimilarity index

To examine development of residential segregation in the 20 largest cities of Finland, we employed a widely used indicator, index of dissimilarity, that depicts distribution of two social groups among areal units in a city (Massey & Denton, 1988). However, it is well known that the standard estimator of dissimilarity index suffers from bias that potentially results in large values of the segregation index when unit sizes or minority proportions are small (Allen, Burgess, Davidson, & Windmeijer, 2015). To address this, we use R package 'segregation' to estimate the bias through bootstrapping, which then allows reporting bias-adjusted estimates for the index of dissimilarity (Elbers, 2023).

Moreover, to study and demonstrate the impact of the selected areal scale, the results using residential area classification were compared to dissimilarity index values that were calculated using alternative areal units, including zip codes, and statistical grids with spatial resolutions of 250 m × 250 m and 1 km × 1 km. For a broader overall picture, dissimilarity index was calculated for several socioeconomic groups based on three different variables, including income (low- vs. high-income households), language (foreign vs. domestic language speaking households), and education (people with only primary vs. people with post-secondary education). More precisely, index of dissimilarity was calculated as follows in Eq. (1):

$$D = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{a_i}{A}-\frac{b_i}{B}\right| \quad (1)$$

where a_i is the population of group A in the neighbourhood i, b_i is the population of group B in the neighbourhood i, and A and B are the total populations in groups A and B in the whole city that is subdivided into n neighbourhoods, according to the residential neighbourhood classification, and for which the index of dissimilarity is being calculated. To address the potential bias in the index values and allow reporting bias adjusted index values, we use a bootstrap bias correction (Elbers, 2023). According to Horowitz (2001), the bootstrap provides a method for bias reduction by resampling the estimation data. First, dissimilarity indexes are calculated using the estimation data. Then, a bootstrap sample is generated by resampling the data randomly with replacement, and index values are again calculated using this new bootstrap sample. This is repeated several times, and finally the bias-adjusted index value is calculated by averaging the results of the many repetitions. There should be so many repetitions that the mean value does not significantly change anymore even if the number of bootstrap samples is increased. The bias can be calculated by subtracting the original index estimates from the bootstrap mean values. More precisely, the bootstrap is used to reduce the index estimator's finite-sample bias. To allow comparison over time, the indexes of dissimilarity were computed for two different cross-sections, namely the years 2000 and 2018. The index values vary between 0 and 1, representing the proportion of the total population in group A that should change their neighbourhood to achieve an even distribution of the two groups within the city. In the literature, value over 0.6 has mostly been considered as the limit for serious segregation (Cutler, Glaeser, & Vigdor, 1999; Massey & Denton, 2001; Peach, 2009).

As index of dissimilarity does not reveal the underlying dynamics of residential segregation development, we also computed residential area level descriptive statistics for the three variables of interest in the cross-section years of 2000 and 2018. In doing so, we allowed further analysis of the potentially different development paths of different residential area types and cities. Specifically, the statistics were produced by aggregating the data on individuals and household-dwelling units into geospatial residential area classes. Finally, the aggregated data was used to calculate residential area class and city specific location quotients for different variables. As opposed to the index of dissimilarity that compares the proportional distribution of two subcategories, the location quotient compares the relative distribution of a subcategory (i.e. the proportion of a variable of interest in a residential area class in a city) within a larger category (i.e. the overall proportion of the same variable of interest in the 20 studied cities altogether) (Wheeler, 2005).

4. Results

4.1. Increasing socioeconomic segregation in the Finnish cities

Income segregation has increased in all 20 studied cities between 2000 and 2018, as bias adjusted index values in Fig. 2 indicate. This is also the case when segregation is measured by education, although the magnitude of dissimilarity index then remains at lower level. Calculating segregation indexes for ethnicity measured with mother tongue, we find somewhat different patterns of development. In this case, the increase has been the greatest in Helsinki, but in many cities, we only find moderate increases that are smaller than index changes calculated using socioeconomic variables. Interestingly, we also observe that in case of ethnic segregation, the index value has decreased in 9 of the 20 studied cities, of which most are smaller ones. Still, it is important to be careful with the interpretations as the notable increases in the non-native population in smaller cities, where the low amount of non-native population in the beginning of the study period potentially inflates the index values for the first cross-section year (Table 1). At the same time, immigrants are overrepresented in large cities, which makes city comparisons difficult as the metrics often depend on group size.

To mitigate these concerns, we use a bootstrap correction to minimize the finite-sample bias and report bias adjusted index values. In general, the observed biases are relatively small. The bias correction is greater when the index is calculated using smaller units, and smaller corrections are needed with larger units. Also, the development trend of the variable of interest between the cross-section years affects the bias. As the proportion of foreign language speakers is small in 2000, but the share generally increases by 2018, the bias correction is smaller for the latter cross-section. For education, the impact is the opposite. As the level of education increases between the years, the sample of low educated is smaller in 2018, inducing a greater bias. In terms of income, the low- and high-income groups are defined based on income quintiles. This means that the samples (and trend derived impact on the bias) are dependent on the development of local populations and income levels. To allow a more detailed interpretation of the index values, some general descriptive information on the studied cities is provided in Table 1.

4.2. Increases across the scales

The results reveal that absolute values of residential segregation are strongly dependent on the neighbourhood definition, as can be seen from Table 2[1] where we report the bias adjusted dissimilarity index values for different groups and neighbourhood definitions Also, ranking of cities from most to least segregated varies based on the definition. Still, both the average and city wise socioeconomic segregation has increased at all studied scales. At the same time, the average level of ethnic segregation has decreased while the city wise development patterns remain more ambiguous at all scales. For both types of segregation, the smaller neighbourhood definitions produce higher values of dissimilarity while the larger neighbourhoods result in smaller measures, a fact well documented by the previous research (e.g. Haandrikman et al., 2023; Olteanu, Randon-Furling, & Clark, 2019). Also, the

[1] As an extension to Table 2, a more detailed description of the total number of households or residents within the analysed socioeconomic categories and their statistical distributions within different areal definitions is available in Appendix Table D.1.

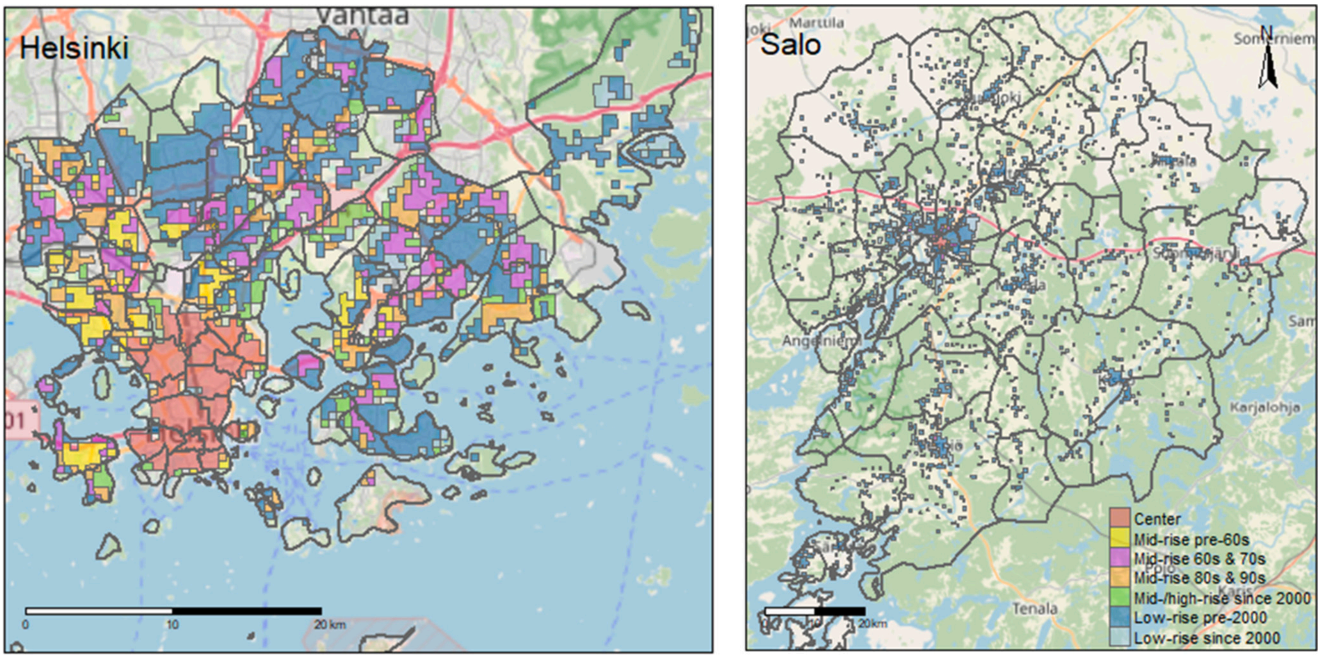

Fig. 1. Examples of residential area classification from two cities: Helsinki (the biggest city in Finland) on the left and Salo (the 20th largest city in Finland) on the right.

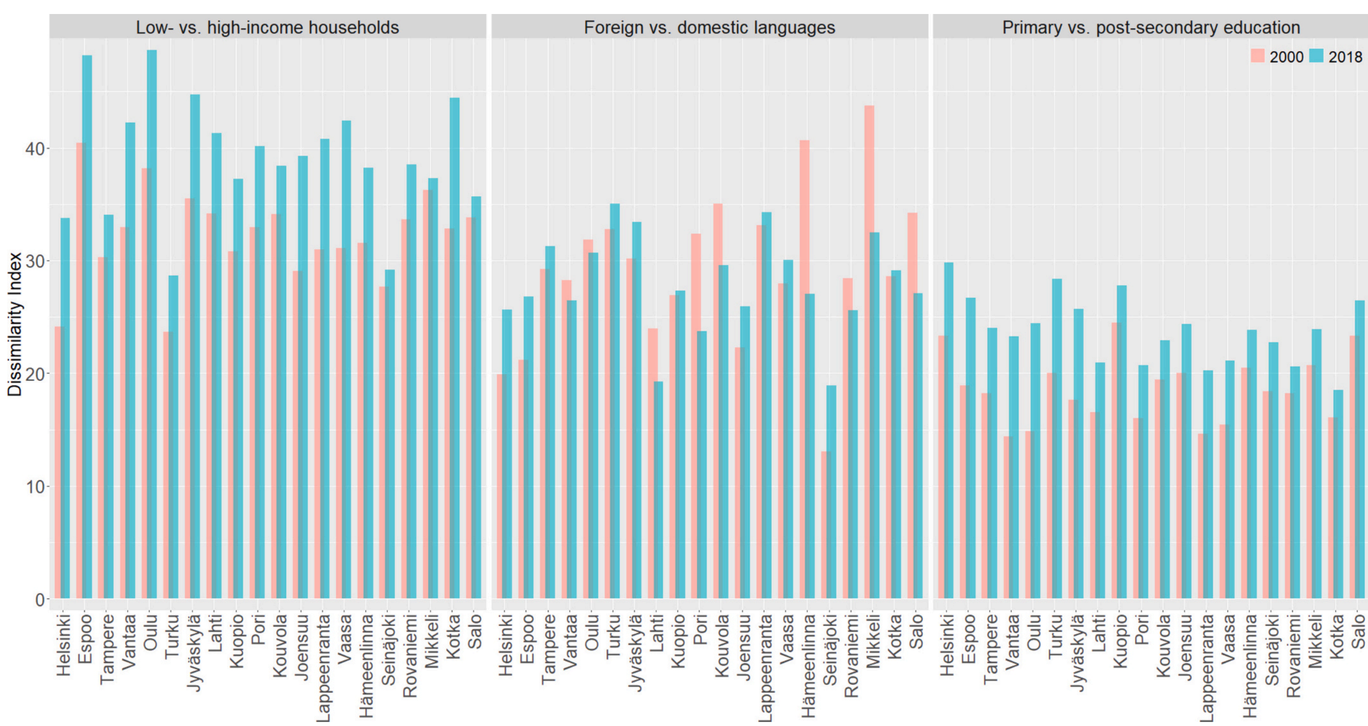

Fig. 2. Dissimilarity indexes for different groups and cities in 2000 and 2018 (the values are calculated using residential area classification).

estimated bias is greater when using smaller neighbourhood definitions as the number of units with a low number of observations increases.[2] The reported numbers in Table 1 are the mean values of the 20 biggest Finnish cities.

Even though the scale of neighbourhood definition is mainly discussed above, it is critical to understand that the scale effect is only one aspect to the Modifiable Areal Unit Problem (MAUP), and another important aspect is known as the zonation effect (Manley, 2021). While the scale effect refers to differing results based on the scale of aggregation, the zonation effect is observed when the scale of aggregation remains constant, but the shape of aggregation is altered. Thus, different regional definitions also affect index values, as they are linked with the size and shape of studied areal entities and how close the neighbouring

[2] More specific results per each city are reported in Appendix Fig. A.1 and Appendix Tables A.1, B.1, and C.1. Moreover, the bootstrap bias estimates for all indexes are reported in Appendix Tables A.2, B.2, and C.2.

Table 1
Descriptive information on the studied cities.

City	Population		Low-income households		People with only primary education or less		People with tertiary education		Foreign language speakers	
	2000	2018	2000	2018	2000	2018	2000	2018	2000	2018
Helsinki	555,474	648,042	20 %	20 %	30 %	20 %	35 %	47 %	5 %	14 %
Espoo	213,271	283,632	20 %	20 %	24 %	18 %	44 %	52 %	4 %	16 %
Tampere	195,468	235,239	20 %	20 %	30 %	17 %	30 %	40 %	2 %	7 %
Vantaa	178,471	228,166	20 %	20 %	34 %	25 %	29 %	34 %	4 %	17 %
Oulu	160,851	203,567	20 %	20 %	27 %	15 %	32 %	41 %	1 %	4 %
Turku	172,561	191,331	20 %	20 %	33 %	20 %	28 %	37 %	3 %	10 %
Jyväskylä	116,519	141,305	20 %	20 %	29 %	16 %	31 %	40 %	2 %	5 %
Lahti	111,656	119,951	20 %	20 %	38 %	24 %	23 %	31 %	2 %	6 %
Kuopio	108,890	118,664	20 %	20 %	30 %	16 %	29 %	37 %	1 %	4 %
Pori	84,573	84,403	20 %	20 %	37 %	23 %	23 %	30 %	1 %	3 %
Kouvola	91,550	83,177	20 %	20 %	37 %	24 %	22 %	28 %	1 %	4 %
Joensuu	71,013	76,551	20 %	20 %	31 %	17 %	27 %	35 %	2 %	5 %
Lappeenranta	70,587	72,699	20 %	20 %	36 %	22 %	24 %	33 %	2 %	7 %
Vaasa	61,470	67,552	20 %	20 %	32 %	19 %	30 %	39 %	2 %	8 %
Hämeenlinna	63,033	67,532	20 %	20 %	36 %	22 %	27 %	35 %	1 %	5 %
Seinäjoki	50,670	63,288	20 %	20 %	31 %	17 %	29 %	36 %	1 %	2 %
Rovaniemi	57,253	62,922	20 %	20 %	28 %	16 %	30 %	37 %	1 %	4 %
Mikkeli	55,222	53,818	20 %	20 %	34 %	21 %	26 %	33 %	1 %	4 %
Kotka	54,846	52,883	20 %	20 %	36 %	23 %	23 %	29 %	1 %	8 %
Salo	52,604	52,321	20 %	20 %	41 %	28 %	23 %	28 %	2 %	6 %

Table 2
Dissimilarity indexes for different groups and neighbourhood definitions.

	2000				2018			
	Residential area	Zipcode	Grid 1 km × 1 km	Grid 250 m × 250 m	Residential area	Zipcode	Grid 1 km × 1 km	Grid 250 m × 250 m
Low- vs. high-income households	0.32	0.20	0.29	0.43	0.39	0.26	0.36	0.50
Primary vs. post-secondary education	0.19	0.16	0.20	0.28	0.24	0.18	0.24	0.33
Foreign vs. domestic languages	0.29	0.24	0.31	0.46	0.28	0.23	0.28	0.39

municipalities are located (e.g. municipalities vs. sub-regions). Therefore, it is necessary to emphasize that segregation index values are not directly comparable between different studies, unless the used definitions and scale of analysis are similar enough. Still, comparing results from studies using multi-scalar measurements of segregation allows comparison across countries. Considering the multiscalar nature of our research, we can conclude that the level of segregation in Finnish cities seems moderate relative to many other countries.

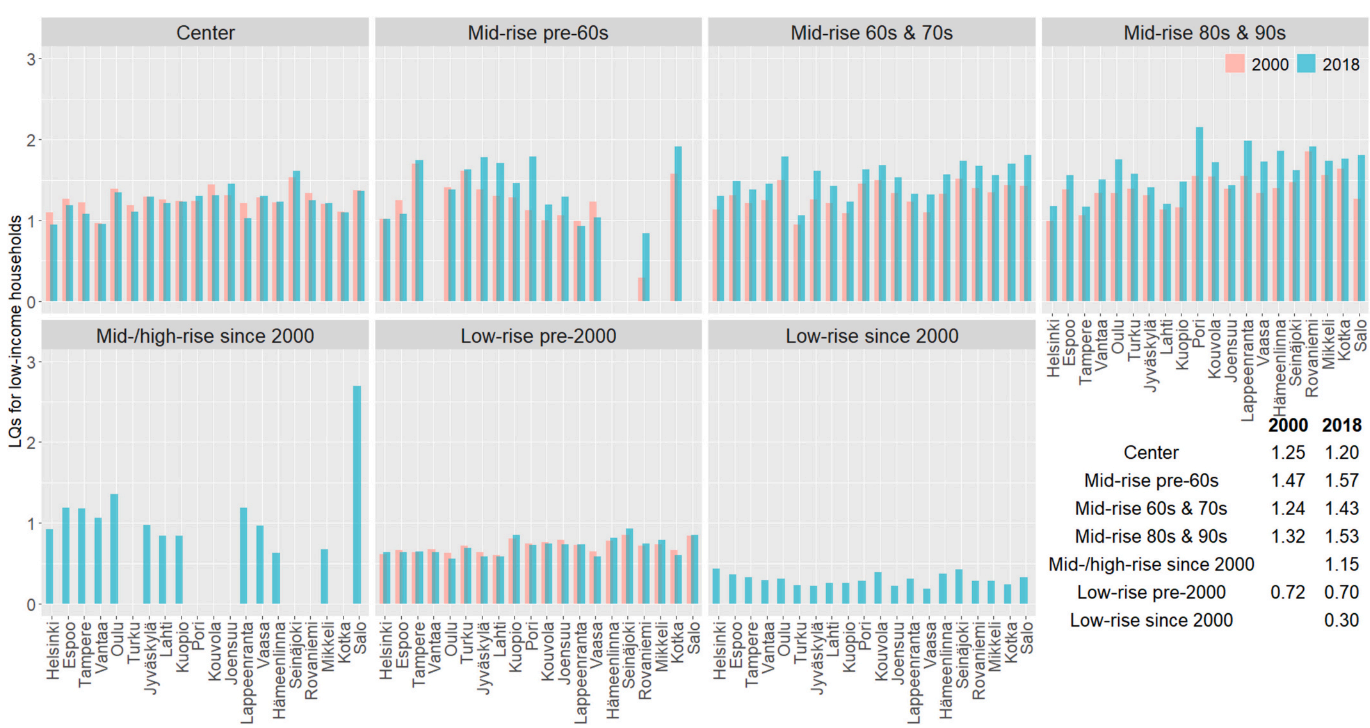

Fig. 3. Location quotients for low-income households in different residential area types and cities.

4.3. Share of segregated groups overrepresented in certain residential area types

To elaborate on our analysis of residential segregation within the cities and examine our RQ3, we also performed descriptive analysis on some relevant indicators of residential segregation in different residential area classes and cities. Those were computed based on the same variables of interest that we used to calculate the indexes of dissimilarity. The reported indicators include location quotients for (i) low-income households, (ii) population with only primary education or less, and (iii) foreign language speaking individuals. The location quotients (LQ) are calculated by dividing the city-wise proportions of the group of interest in a residential area class by the total share of the same group in all the 20 studied cities. For example, an LQ of 1.0 means that the residential area class in a city and in the entity of 20 studied cities have equal shares of the group of interest; while an LQ of 1.5 means a higher concentration of the group of interest than in the 20 cities altogether. This allows us to contrast, for example, the changes in the share of foreign language population independent of the general rise during our observation period.

4.3.1. Concentration of low-income households

Fig. 3 reveals that the share of low-income households, i.e. households in the lowest quintile measured with consumption unit corrected household income, has increased in residential mid-rise areas from 1960s and 1970s and in mid-rise areas from 1980s and 1990s in all studied cities. These are also the residential area types where the increase has been the greatest on average. At the same time, in city centres and low-rise neighbourhoods built before 2000, the average LQs for low-income households have slightly decreased. However, analysis on a city level reveals clear differences between the cities, as the share of low-income households has clearly increased only in the city centres of three smaller cities, while decreasing or remaining at about the same level in other cities. In residential mid-rise areas from 1950s and before, the proportion of low-income households has increased on average, but the development notably varies between cities. Still, when interpreting the results of this area class, it is important to remember that their volume is relatively small outside the capital region. In residential low-rise areas built before 2000, the average LQ for low-income households has remained about the same over time, and differences between cities are relatively moderate. In general, the share of low-income households is observed to be notably lower in residential low-rise areas than in mid- and high-rise areas. The average LQs below 1 in low-rise areas refer to lower concentrations of low-income residents than in the 20 studied cities on average, while the LQs higher than 1 in mid-rise areas suggest higher shares of low-income households than on average. Moreover, the LQs for low-income households in newer low-rise areas built since 2000 are well below 0.5 with an average of 0.3, referring to notably lower concentrations of low-income households than in older low-rise areas. The average level of low-income households in new mid- and high-rise areas built since 2000 is close to the level of city centres. For residential area classes with only newer buildings, only results for the cross-section year 2018 are reported, as presenting results for the cross-section year 2000 is not meaningful due to the early stage of development at that time. Overall, the findings are in line with our earlier observations from the dissimilarity index, as we find variation between cities and decreasing proportions of low-income households in some residential area types while increasing shares in some others, which should support our view of varyingly growing segregation in our study period.

4.3.2. Concentration of residents with primary education or less

In Fig. 4, we take a further look at the proportion of people with only primary education or less within different residential area classes and cities. When we earlier examined changes in dissimilarity index, we found increased levels of segregation in all studied cities. This is also supported by our further analysis using location quotients per residential area classes and cities. The increase in the LQ average values is particularly strong in residential mid-rise areas that were built in 60s and 70s, or 80s and 90s, where also the highest city-wise LQ increases occur. In 2018, the average concentration of low educated is notably higher in these area classes than the total average share in the 20 studied cities, even if differences between individual cities are clear. In newer mid-rise areas since 2000, the average share of low educated is lower

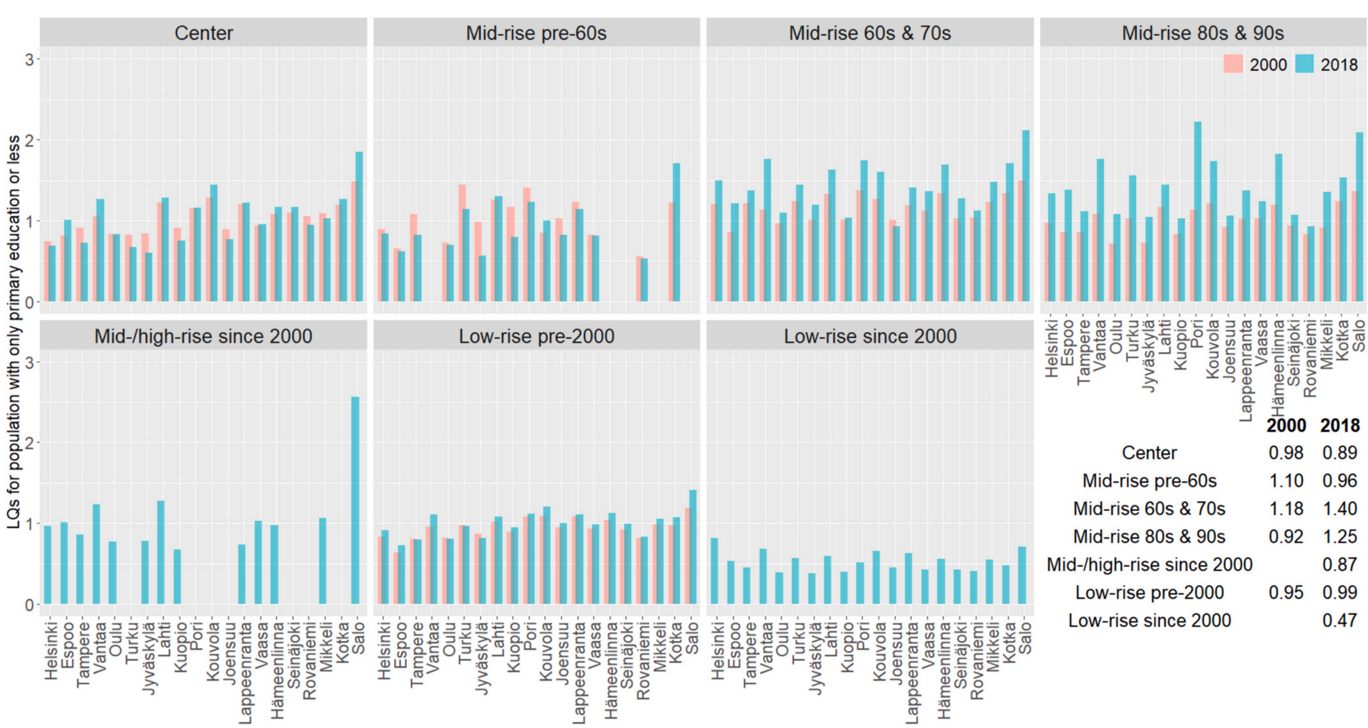

Fig. 4. Location quotients for people with only primary education or less in different residential area types and cities.

than the total average concentration in the 20 studied cities, while city-wise differences occur. For low-rise areas that were built before 2000, the results indicate that average share of people with low education is about at the same level as in the 20 studied cities in total. The differences between cross-section years are relatively small both city-wise and on average. Also, the city-wise variation between cities is moderate. In low rise areas since 2000, the average concentration of low educated is about half of the total concentration in the 20 studied cities altogether.

4.3.3. *Concentration of foreign language speakers*

While the focus of previous two figures was on the socioeconomic dimension of segregation, ethnic segregation is scrutinized in Fig. 5 where the LQs for foreign language speaking households in different residential area classes and cities are presented. Our earlier findings based on different dissimilarity indexes showed that development patterns of ethnic segregation are more mixed than changes in socioeconomic segregation. While dissimilarity indexes for socioeconomic indicators demonstrated mostly increasing index values, we discovered decreasing language-based dissimilarity index values in nearly half of the studied cities. In the beginning of the study period, shares of foreign speakers were relatively low in all locations (see Table 1), and the proportions have notably increased during the study period. Our further analysis using LQs for foreign language speaking households reveals that the average concentration of foreign language speakers is the highest in mid-rise areas that were built since the 70s until the end of 90s. In these areas, the share of foreign language speakers is twofold relative to the total proportion in the 20 studied cities altogether. The relative average concentration of foreign language speakers has particularly increased in residential mid-rise areas that were built in the 60s and 70s. At the same time, in residential mid-rise areas that were built in the 80s and 90s, the average share has decreased relative to the overall development in the 20 studied cities.

In low-rise areas built before 2000, the concentration of foreign language speakers has increased and the analysis also reveals notable variation between cities. Even if the average share in these areas is less than the total average in the 20 studied cities, there are also cities where the concentration is around twofold. The same phenomenon can also be observed in newer low-rise areas that were built since 2000, even if average concentration is half of the total share in the 20 studied cities. In the high- and mid-rise areas built since 2000, the average concentration is less than the total average of the 20 studied cities, but in many cities these newer areas have notably higher concentrations of foreign language speakers. In the city centers, the average concentration of foreign language speakers has decreased and is below the average of the 20 studied cities. Still, there are also cities where the development has been against this trend.

Again, it is necessary to be careful with the interpretations of city-level comparisons as immigrants are overrepresented in large cities and metrics tend to be affected by the group size. Thus, it is difficult to evaluate to what extent the decreased DI values may be attributable, for example, to a more even distribution of foreign language speakers across the different residential areas rather than metrics related bias.

5. Discussion

Our analysis reveals that even in the equal country context of Finland socioeconomic residential segregation has increased in all studied cities between 2000 and 2018. The increases have been clear, but the levels are still moderate in international comparisons: on average, the income-based dissimilarity index for the 20 largest cities was 0.39 in 2018, representing a growing trend from the average index value of 0.32 in 2000. In contrast, the average level of income inequality in Finland has not grown in the same period (the change in gross income based Gini coefficient was −1 % between 2000 and 2018 (Official Statistics of Finland (OSF), 2024) and −2 % between 2005 and 2018 in the Helsinki region (Helsinki Regional Statistics, 2024). The increasing socioeconomic segregation might still reflect changes in income inequality in the previous decade as the income inequality did radically increase during the 1990s (Roikonen, 2022). Simultaneously, we find more mixed results for ethnic residential segregation. Overall ethnic segregation has slightly decreased in Finland, but it has increased in some cities and decreased in others. This is in line with previous studies finding clear increases for socioeconomic segregation but decline or stagnation for ethnic segregation (Boterman, Musterd, & Manting, 2020; Malmberg

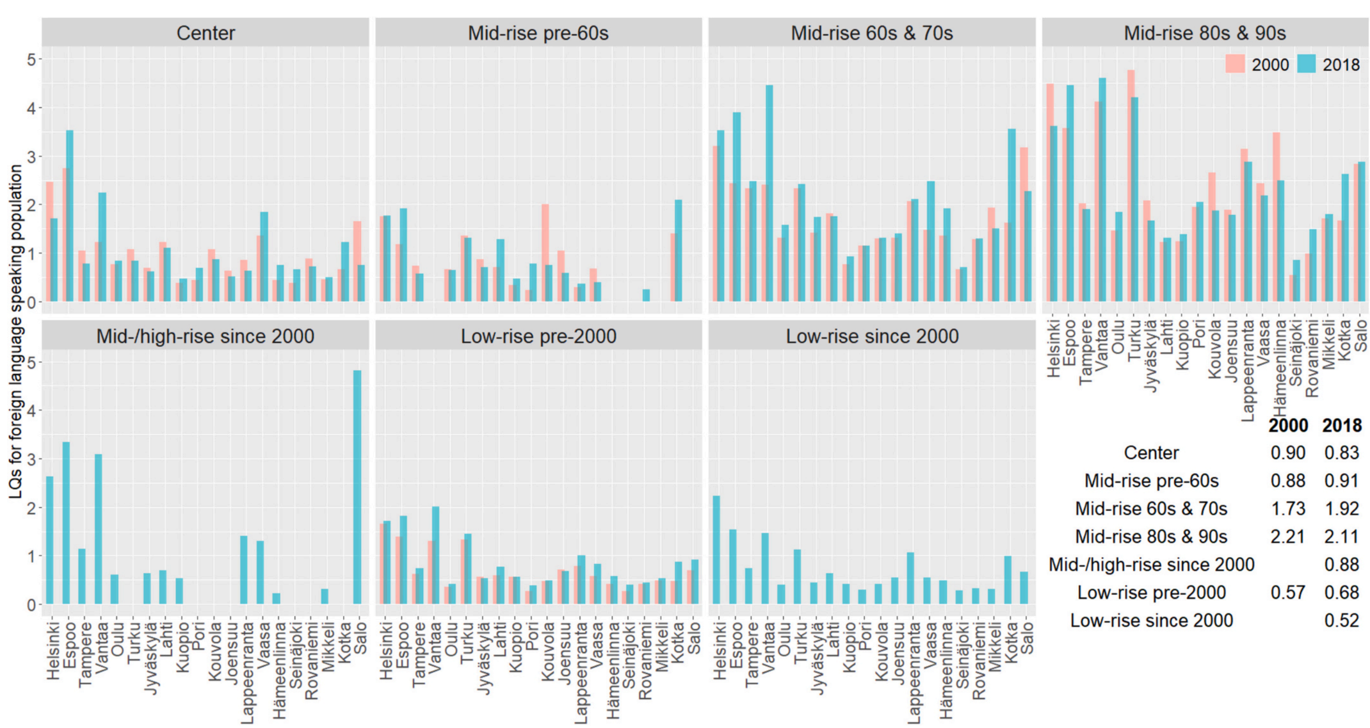

Fig. 5. Location quotients for foreign language speaking households in different residential area types and cities.

et al., 2018; Owens, Reardon, & Jencks, 2016).

For example, the results from Boterman et al. (2020) on Amsterdam reveal higher but declining rates of ethnic segregation and lower but increasing rates of socioeconomic segregation. Still, in our case, the levels of ethnic segregation were lower compared to income segregation and only slightly decreased. The history of immigration might explain this difference. Finland is along with Italy and Spain a “new immigration country” (see Azzolini, Schnell, & Palmer, 2012) where the first large waves of immigrants arrived in the 1990s and non-native population has increased significantly during the 2000s and 2010s. First, this might mean that Finland is only approaching the higher rates of ethnic segregation already present in some other countries and strong decreasing trends may appear later on. Second, the previous literature indicates that the estimates of dissimilarity index might be upwardly biased in cases of small areal units and population groups (Napierala & Denton, 2017). Although we minimize this risk by adjusting the indexes using a bootstrap correction, our indexes of ethnic segregation for the year 2000 might have some upward bias, especially in the smaller cities where we observed decreases in ethnic segregation. Thus, these decreases might be a statistical construct rather than substantive result. Another confounding factor might be varying trends for different ethnic groups as we know that there are differences between regions in the ethnic composition of immigrants (Andersson et al., 2010). We see a more nuanced analysis of different ethnic groups as one promising direction for future research, including the interplay between ethnicity and socioeconomic position (Andersson & Kährik, 2015). Particularly, in an age of increasing migration across Europe, it might be of relevance for future work to examine how increasing diversity impacts residential segregation, focusing more on mixings of peoples than ethnicity as such.

Our multiscalar comparisons on socioeconomic segregation indicate that our main result of increasing socioeconomic segregation in cities of all sizes holds regardless of the area unit utilized. We still show that the overall levels of neighbourhood segregation vary by the scale of analysis. There are also some interesting tendencies between the analysis unit and city size: for the grid size of 250 m × 250 m, there is a weak negative correlation between index value and city size, meaning larger cities have smaller values. Conversely, for zip code areas, there is a weak positive correlation, indicating that larger cities have higher values. The 1 km × 1 km grid and our residential classification fall between these two. These results align with those of Krupka (2007) as he finds that analyses based on census data might rank larger cities higher because they have more neighbourhoods that can individually fill up entire census tracts. And the zip code areas that we utilize are closer to census tracts than individual grid cells. Thus, when interpreting the absolute values of segregation indexes, the values are dependent on the scale and shape in which the index values are calculated. In our analysis, smaller neighbourhood units resulted in higher values of dissimilarity, as expected, even if they are adjusted for bias. This highlights the importance of a multiscalar or nearest neighbour approaches that take this variation into account (e.g., Clark et al., 2015; Östh et al., 2015). Finally, the multiscalar approach implies that comparison of residential segregation between cities is challenging also nationally (Krupka, 2007) and not only internationally, as is more often emphasized in the literature. Therefore, we join the calls for more advanced research designs to achieve reliable longitudinal and intercity comparisons (Haandrikman et al., 2023).

To understand the sociospatial disadvantage in more granular level, we added more fine-grained analysis of three indicators in different residential area classes and cities, which is one of the key benefits of using residential area classification (Ala-Mantila et al., 2023). E.g. Malmberg et al. (2018) have recognized the importance of also seeing segregation as a variation in the concentration of the studied groups while the dissimilarity index is based only on unevenness definition of segregation. Our results highlight a general trend in the segregation of Finnish cities: the concentration of disadvantage and ethnic minorities to suburbs built in 1960s and 1970s, and also later in 1980s and 1990s. The relative proportion of low-income households and residents with only primary education has also increased in these residential area types. At the same time, the relative average shares have slightly decreased in city centres. Lower shares are observed in newly built residential mid- and high-rise areas, and especially in low-rise areas. Most studies on spatiosocial disadvantage only focus, for example, on neighbourhoods from post-World War II decades (Baldwin Hess, Tammaru, & van Ham, 2018), but our results show that also newer developments are potentially in a declining trajectory. In contrast to these older mid-rise areas, households that are better off in the light of socioeconomic indicators form higher proportions of residents in more attractive residential area types, including city centres, new mid- and high-rise areas, and low-rise areas, particularly the new ones This trend of suburbanization of more educated and higher income households has been observed historically in the US (Nijman, 2015) and Europe (Hesse & Siedentop, 2018), and been discussed much in the context of post-socialist countries in Eastern Europe (E.g., Brade, Herfert, & Wiest, 2009; Kontuly & Tammaru, 2006). The Finnish case shares similarities with broader trends of suburbanization and urban sprawl. One key factor contributing to these trends in Finland may be the competition between municipalities for high-income taxpayers, which has been identified as a driver for city development in previous research (Vaattovaara et al., 2018).

Concerning these results, we underline that the neighbourhood effects on adults and children are very small in the Finnish context (Kauppinen, 2008; Tarkiainen, Kemppainen, Lahtinen, Bernelius, & Martikainen, 2024). This implies that the selection into neighbourhoods has much larger importance in the deprivation of certain residential area types as opposed to the deprivation that these areas cause to their residents. Thus, the most likely explanation for increasing socioeconomic segregation is the increased selection to neighbourhoods through multiple mechanisms such as increasing economic inequalities or cultural preferences. Especially in the case of socioeconomic segregation measured by education the in-situ changes, unrelated to neighbourhood as such, might matter as well as the educational composition is changing in Finland as a whole. The more detailed analysis of whether in-situ changes or residential mobility contribute to trends in segregation would be one promising research direction as studies from other Nordic countries have given varying answers to the question (Bailey, van Gent, & Musterd, 2017; Boje-Kovacs, Egsgaard-Pedersen, & Weatherall, 2021; Vogiazides & Mondani, 2023).

In terms of foreign language speaking households, we see that their proportion has been very low in all residential area classes and cities in 2000. Still, the shares have gradually increased during the study period. The relative proportions of foreign language speaking residents are particularly high in the mid-rise suburbs built from 1960s to 1990s. In the mid-rise suburbs built in the 1960s and 1970s, there has also been an increasing trend in the share of foreign language speakers. While in the mid-rise suburbs built in the 1980s and 1990s, the city-wise developments are more varied and result in decreased relative average share of foreign language speakers. In larger cities, we also see relatively high proportions in city centres and new mid- and high-rise areas. Again, the shares are the lowest in residential low-rise areas, particularly in the new ones. Our results show that dissimilarity index may decrease even though the share of foreign language speakers notably increases. Thus, to understand the real nature of the development, segregation in cities should be observed with multiple indicators. Many studies also emphasize the varying rates of heritage language retention or loss between the first and second generations. When using the registered mother tongue as a proxy for ethnicity, the results may not accurately capture the situation in areas with a large second-generation population from certain ethnic groups, as only one language can be recorded in the population registry.

As a whole, our results provide an indication of increasing socioeconomic residential segregation in Finland. In contexts with less generous welfare state, more income inequality, or more pronounced intergenerational inequalities we would expect the increases in socioeconomic segregation to be even greater, as the trend towards increasing segregation appears to be global. Whether the driving force is ultimately increasing economic inequalities or something else, it is inducing increases in socioeconomic segregation even in the relatively equal national context of Finland. To date, our research is the first to study residential segregation in a wide range of Finnish cities. This provides fruitful grounds for further studies, for example, to recognize how different policy measures across various cities have affected residential segregation.

Residential areas can differentiate in several ways: either well-off areas increase their relative status, or disadvantaged regions weaken, or these both occur simultaneously. Our results provide useful indications of past developments but do not reveal the complete dynamics behind the observed patterns of segregation. It remains an open question whether we should always worry about increasing segregation or, to a certain extent, accept it as one of the externalities of urban growth that can, of course, take various forms and levels depending on the institutional and structural contexts in which it takes place. That is, the story is different if residential segregation increases through growing deprivation vs. agglomerations of prosperous households. Still, the equality of the residents in different regions and neighbourhoods, and avoiding threats, such as eroding trust between different population groups (Uslaner, 2012) and decreased social mobility between generations (Chetty, Hendren, Kline, & Saez, 2014), are important values in societies. The fact that we observe rising levels of socioeconomic segregation even in the equal context of Finland indicates that there are strong underlying mechanisms producing segregation. In comparison to increasing levels of segregation in the US, Europe, and Asia, Finland is no exception. There is a need to consider how to mitigate or avoid the negative consequences of residential segregation. To do so, the identification of types of residential areas experiencing rising levels of disadvantaged residents is very important and provides a solid basis for targeting expedient policy measures.

6. Conclusion

In this paper, we have studied the development of residential socioeconomic and ethnic segregation using reliable individual and household level register data across the 20 cities in Finland, which is one of the most equal states in the world. To do so, we analysed two cross-sections of time, namely years 2000 and 2018 with a multiscalar research strategy. Instead of relying on a single city-level indicator, we also zoomed into different residential area types and illustrated the development of their socioeconomic and ethnic structure.

Based on the results we conclude that:

- The socioeconomic segregation has significantly increased in all studied cities and scales.
- The results for ethnic segregation are more diverse showing increases in some cities but decreases in others. On average, ethnic segregation has slightly decreased in the 20 largest cities, although ethnic minorities are still overrepresented in the socioeconomically disadvantaged residential areas.
- Our multiscalar approach established that using smaller areal definitions generally produced higher rates of segregation but, at the same time, development trends of segregation were similar at all scales of analysis.
- The residential area classification, based on the dominating building type, and construction year of the housing stock, seemed the most balanced level of analysis producing results between administrative zip-code level and small-scale grid levels
- The increasing levels of segregation are linked to the relative deprivation of residential mid-rise areas built from the 1960s until the 1990s and to the increasing positive selection by income and education in the residential low-rise areas built after the year 2000.

Overall, our research highlights that even strong welfare policies combined with urban policies such as social mixing have not been able to dam the increases in socioeconomic segregation in Finland. Likely working theoretical mechanisms relate to the past increases in income and wealth inequalities combined with relative decreases in the production of state subsidized rental housing.

Relating to the theoretical and empirical discussion of housing estates (e.g., Hess et al., 2018), we show that not only the traditional housing estates built in the 1960s and 1970s, but also later mid-rise estates from 1980s and 1990s have experienced socioeconomic deprivation in the recent decades. This calls for widening the theoretical scope of housing estates studies.

For future work, it would be useful to analyze further how the residential area classification fits for cities of different sizes, shapes and local contexts, and how those qualities affect the segregation measurements. Concerning ethnic segregation, a separate analysis of different ethnic groups would increase our understanding of the state of segregation in Finnish cities. From a methodological standpoint, it is essential to acknowledge the limitations of index-based approaches for future research. Johnston, Forrest, and Siciliano (2021) highlight these limitations, particularly in measuring residential segregation, and emphasize the need for caution when interpreting results derived from such indices—especially when comparing groups of differing population sizes. Their critique suggests that alternative methods should be explored to gain a more comprehensive and nuanced understanding of residential segregation. In addition to the methods discussed in this paper, Jones, Johnston, Manley, Owen, and Charlton (2015) offer valuable insights for future research by introducing a novel approach to measuring ethnic residential segregation. Unlike traditional descriptive indices, their method employs formal modeling techniques that can accommodate multigroup populations and analyze data across multiple spatial scales, providing a promising multi-level framework for future investigations in this area.

CRediT authorship contribution statement

Antti Kurvinen: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Aleksi Karhula:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sanna Ala-Mantila:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

Appendix A

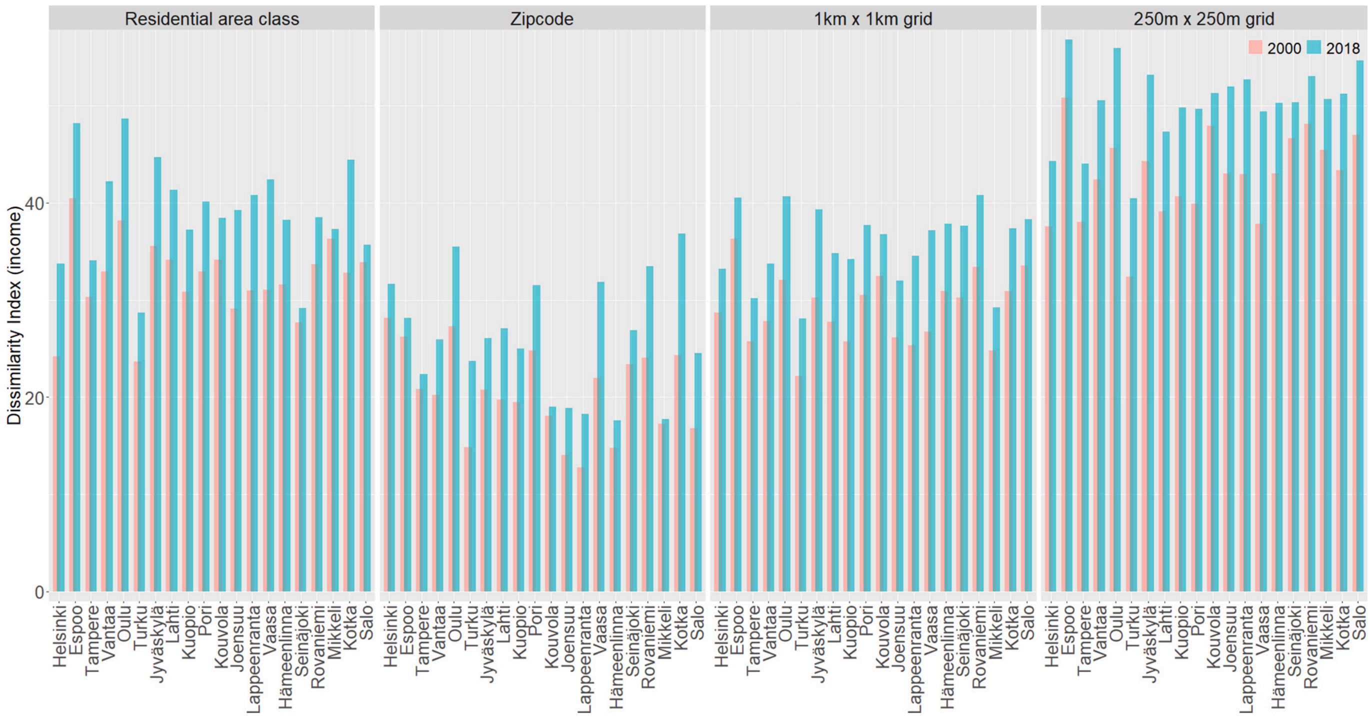

Fig. A.1. Dissimilarity index to measure segregation between low- and high-income households.

Table A.1
Bias adjusted estimates for dissimilarity index to measure segregation between low- and high-income households.

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Espoo	0.40	0.48	0.26	0.28	0.36	0.41	0.51	0.57
Helsinki	0.24	0.34	0.28	0.32	0.29	0.33	0.38	0.44
Vantaa	0.33	0.42	0.20	0.26	0.28	0.34	0.42	0.51
Hämeenlinna	0.32	0.38	0.15	0.18	0.31	0.38	0.43	0.50
Joensuu	0.29	0.39	0.14	0.19	0.26	0.32	0.43	0.52
Jyväskylä	0.36	0.45	0.21	0.26	0.30	0.39	0.44	0.53
Kotka	0.33	0.44	0.24	0.37	0.31	0.37	0.43	0.51
Kouvola	0.34	0.38	0.18	0.19	0.32	0.37	0.48	0.51
Kuopio	0.31	0.37	0.20	0.25	0.26	0.34	0.41	0.50
Lahti	0.34	0.41	0.20	0.27	0.28	0.35	0.39	0.47
Lappeenranta	0.31	0.41	0.13	0.18	0.25	0.35	0.43	0.53
Mikkeli	0.36	0.37	0.17	0.18	0.25	0.29	0.45	0.51
Oulu	0.38	0.49	0.27	0.35	0.32	0.41	0.46	0.56
Pori	0.33	0.40	0.25	0.32	0.31	0.38	0.40	0.50
Rovaniemi	0.34	0.39	0.24	0.33	0.33	0.41	0.48	0.53
Salo	0.34	0.36	0.17	0.25	0.34	0.38	0.47	0.55
Seinäjoki	0.28	0.29	0.23	0.27	0.30	0.38	0.47	0.50
Tampere	0.30	0.34	0.21	0.22	0.26	0.30	0.38	0.44
Turku	0.24	0.29	0.15	0.24	0.22	0.28	0.32	0.40
Vaasa	0.31	0.42	0.22	0.32	0.27	0.37	0.38	0.49

Table A.2
Bootstrap bias estimates for index values in Table A.1.

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Espoo	0.002	0.003	0.001	0.001	0.005	0.003	0.016	0.010
Helsinki	0.001	0.001	0.001	0.001	0.001	0.002	0.008	0.005
Vantaa	0.002	0.002	0.001	0.001	0.004	0.002	0.018	0.010
Hämeenlinna	0.010	0.007	0.003	0.001	0.015	0.010	0.034	0.027

(continued on next page)

Table A.2 (*continued*)

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Joensuu	0.006	0.004	0.005	0.003	0.011	0.009	0.026	0.018
Jyväskylä	0.005	0.004	0.002	0.001	0.006	0.003	0.022	0.015
Kotka	0.002	0.003	0.005	0.001	0.006	0.005	0.026	0.022
Kouvola	0.010	0.009	0.003	0.002	0.015	0.012	0.035	0.034
Kuopio	0.004	0.006	0.003	0.002	0.007	0.009	0.021	0.014
Lahti	0.003	0.003	0.002	0.001	0.005	0.003	0.023	0.014
Lappeenranta	0.008	0.006	0.004	0.005	0.014	0.008	0.030	0.022
Mikkeli	0.009	0.009	0.004	0.005	0.012	0.014	0.029	0.026
Oulu	0.003	0.003	0.002	0.000	0.009	0.005	0.026	0.015
Pori	0.004	0.004	0.002	0.002	0.011	0.009	0.036	0.025
Rovaniemi	0.007	0.007	0.003	0.002	0.011	0.009	0.030	0.024
Salo	0.017	0.017	0.006	0.006	0.023	0.020	0.044	0.037
Seinäjoki	0.008	0.008	0.003	0.002	0.015	0.011	0.038	0.031
Tampere	0.003	0.002	0.000	0.001	0.004	0.003	0.014	0.010
Turku	0.001	0.002	0.001	0.000	0.003	0.003	0.018	0.014
Vaasa	0.003	0.003	0.002	0.001	0.009	0.005	0.029	0.016

Table B.1
Bias adjusted estimates for dissimilarity index to measure segregation between persons with primary school or less and persons with post-secondary education.

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Espoo	0.19	0.27	0.15	0.17	0.21	0.24	0.28	0.34
Helsinki	0.23	0.30	0.23	0.28	0.24	0.29	0.30	0.35
Vantaa	0.14	0.23	0.12	0.17	0.14	0.21	0.22	0.30
Hämeenlinna	0.20	0.24	0.16	0.14	0.22	0.25	0.28	0.33
Joensuu	0.20	0.24	0.19	0.22	0.21	0.27	0.27	0.34
Jyväskylä	0.18	0.26	0.15	0.17	0.21	0.25	0.29	0.33
Kotka	0.16	0.19	0.15	0.18	0.17	0.21	0.27	0.30
Kouvola	0.19	0.23	0.14	0.13	0.20	0.22	0.30	0.32
Kuopio	0.25	0.28	0.20	0.20	0.21	0.25	0.30	0.36
Lahti	0.17	0.21	0.11	0.17	0.16	0.19	0.27	0.30
Lappeenranta	0.15	0.20	0.13	0.13	0.19	0.21	0.27	0.31
Mikkeli	0.21	0.24	0.14	0.15	0.18	0.21	0.29	0.34
Oulu	0.15	0.24	0.17	0.17	0.21	0.25	0.28	0.33
Pori	0.16	0.21	0.14	0.17	0.20	0.23	0.27	0.32
Rovaniemi	0.18	0.21	0.15	0.15	0.22	0.21	0.30	0.32
Salo	0.23	0.26	0.14	0.19	0.25	0.27	0.32	0.36
Seinäjoki	0.18	0.23	0.19	0.21	0.22	0.25	0.29	0.34
Tampere	0.18	0.24	0.14	0.15	0.19	0.22	0.26	0.30
Turku	0.20	0.28	0.17	0.26	0.20	0.29	0.26	0.35
Vaasa	0.15	0.21	0.12	0.16	0.17	0.22	0.24	0.31

Table B.2
Bootstrap bias estimates for index values in Table B.1.

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Espoo	0.001	0.002	0.001	0.001	0.002	0.003	0.014	0.011
Helsinki	0.001	0.001	0.001	0.000	0.001	0.001	0.005	0.004
Vantaa	0.002	0.002	0.000	0.001	0.005	0.003	0.017	0.011
Hämeenlinna	0.006	0.007	0.001	0.002	0.009	0.010	0.027	0.025
Joensuu	0.005	0.006	0.001	0.000	0.008	0.008	0.025	0.024
Jyväskylä	0.004	0.006	0.001	0.001	0.006	0.007	0.021	0.023
Kotka	0.002	0.004	0.002	0.003	0.007	0.006	0.025	0.025
Kouvola	0.006	0.008	0.002	0.003	0.010	0.013	0.031	0.034
Kuopio	0.004	0.006	0.002	0.001	0.007	0.008	0.017	0.018
Lahti	0.003	0.003	0.003	0.001	0.005	0.005	0.019	0.017
Lappeenranta	0.007	0.007	0.001	0.001	0.007	0.008	0.025	0.026
Mikkeli	0.007	0.010	0.001	0.003	0.012	0.012	0.028	0.029
Oulu	0.002	0.003	0.001	0.002	0.005	0.005	0.021	0.024
Pori	0.004	0.005	0.002	0.002	0.007	0.010	0.029	0.029
Rovaniemi	0.005	0.006	0.001	0.001	0.009	0.012	0.028	0.032
Salo	0.010	0.014	0.005	0.002	0.014	0.017	0.037	0.038
Seinäjoki	0.005	0.007	0.001	0.001	0.009	0.009	0.033	0.033
Tampere	0.002	0.002	0.001	0.001	0.001	0.002	0.012	0.012
Turku	0.002	0.002	0.000	0.000	0.003	0.002	0.013	0.011
Vaasa	0.003	0.003	0.001	0.000	0.006	0.005	0.023	0.022

Table C.1
Bias adjusted estimates for dissimilarity index to measure segregation between persons speaking foreign and domestic languages.

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Espoo	0.21	0.27	0.19	0.20	0.23	0.26	0.32	0.34
Helsinki	0.20	0.26	0.18	0.25	0.19	0.25	0.29	0.31
Vantaa	0.28	0.26	0.21	0.19	0.29	0.24	0.40	0.33
Hämeenlinna	0.41	0.27	0.27	0.16	0.41	0.30	0.56	0.41
Joensuu	0.22	0.26	0.34	0.29	0.36	0.32	0.50	0.41
Jyväskylä	0.30	0.33	0.28	0.30	0.31	0.32	0.44	0.39
Kotka	0.29	0.29	0.24	0.22	0.28	0.24	0.45	0.35
Kouvola	0.35	0.30	0.26	0.24	0.35	0.30	0.53	0.41
Kuopio	0.27	0.27	0.20	0.24	0.30	0.28	0.41	0.36
Lahti	0.24	0.19	0.19	0.16	0.23	0.18	0.38	0.29
Lappeenranta	0.33	0.34	0.26	0.29	0.34	0.32	0.46	0.42
Mikkeli	0.44	0.33	0.29	0.17	0.39	0.30	0.53	0.47
Oulu	0.32	0.31	0.30	0.28	0.30	0.32	0.45	0.40
Pori	0.32	0.24	0.27	0.20	0.35	0.26	0.56	0.37
Rovaniemi	0.28	0.26	0.25	0.18	0.31	0.26	0.51	0.41
Salo	0.34	0.27	0.29	0.20	0.37	0.28	0.58	0.46
Seinäjoki	0.13	0.19	0.17	0.17	0.33	0.25	0.64	0.42
Tampere	0.29	0.31	0.23	0.26	0.27	0.28	0.35	0.35
Turku	0.33	0.35	0.32	0.35	0.39	0.39	0.46	0.43
Vaasa	0.28	0.30	0.14	0.16	0.27	0.31	0.46	0.45

Table C.2
Bootstrap bias estimates for index values in Table C.1.

Municipality	Residential area classification		Zip codes		Grid 1 km × 1 km		Grid 250 m × 250 m	
	2000	2018	2000	2018	2000	2018	2000	2018
Espoo	0.005	0.002	0.002	0.000	0.008	0.001	0.034	0.009
Helsinki	0.002	0.001	0.001	0.000	0.003	0.001	0.015	0.005
Vantaa	0.003	0.002	0.002	0.000	0.005	0.001	0.024	0.009
Hämeenlinna	0.007	0.007	0.007	0.004	0.017	0.011	0.053	0.038
Joensuu	0.016	0.007	0.002	0.001	0.012	0.007	0.050	0.034
Jyväskylä	0.009	0.007	0.002	0.001	0.014	0.007	0.051	0.027
Kotka	0.010	0.004	0.007	0.003	0.025	0.007	0.059	0.027
Kouvola	0.015	0.010	0.012	0.005	0.030	0.016	0.064	0.054
Kuopio	0.017	0.007	0.013	0.001	0.016	0.009	0.059	0.036
Lahti	0.010	0.007	0.010	0.004	0.014	0.008	0.049	0.029
Lappeenranta	0.011	0.007	0.007	0.001	0.016	0.008	0.049	0.026
Mikkeli	0.015	0.009	0.012	0.008	0.021	0.014	0.053	0.036
Oulu	0.008	0.005	0.002	0.000	0.024	0.006	0.060	0.034
Pori	0.015	0.009	0.007	0.006	0.030	0.014	0.060	0.051
Rovaniemi	0.012	0.010	0.012	0.003	0.034	0.016	0.064	0.044
Salo	0.010	0.011	0.002	0.004	0.021	0.018	0.041	0.039
Seinäjoki	0.035	0.012	0.026	0.004	0.045	0.022	0.064	0.058
Tampere	0.005	0.003	0.004	0.000	0.007	0.003	0.037	0.014
Turku	0.002	0.002	0.001	0.000	0.004	0.001	0.018	0.009
Vaasa	0.005	0.003	0.006	0.003	0.006	0.005	0.035	0.016

Table D.1
Total number of households/residents within the analysed socioeconomic categories and their statistical distributions within the different areal definitions.

2018	N	Residential area		Zip code		Grid 1 km × 1 km		Grid 250 m × 250 m	
		Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Low-income households	294,042	66	369	364	545	60	168	15	31
High-income households	294,024	46	406	354	458	45	124	11	19
Primary education	443,974	68	402	522	743	65	184	16	31
Post-secondary education	896,148	125	1191	1067	1460	126	388	29	60
Foreign language speakers	220,769	75	374	304	589	69	191	15	33
Domestic language speakers	2,101,351	240	2006	2427	3072	250	735	60	115
2000									

(continued on next page)

Table D.1 (*continued*)

2000										
	N	Residential area		Zip code		Grid 1 km × 1 km		Grid 250 m × 250 m		
		Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	
	N	Residential area		Zip code		Grid 1 km × 1 km		Grid 250 m × 250 m		
		Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	
Low-income households	233,592	70	417	293	434	47	142	13	26	
High-income households	233,557	64	483	287	377	43	114	10	18	
Primary education	590,690	119	752	704	927	85	242	22	42	
Post-secondary education	579,347	147	1181	713	968	100	283	24	45	
Foreign language speakers	54,315	40	184	88	160	27	63	7	13	
Domestic language speakers	1,882,573	342	2612	2217	2836	252	736	63	120	

Data availability

We have shared a link to the data that is openly available. Some of the data is confidential.

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Antti Kurvinen is an Assistant Professor of Real Estate Development at the Faculty of Built Environment at Tampere University. He also serves as a Visiting Scholar with the Sustainable Urban Systems Research Group at the University of Helsinki and is affiliated with the Helsinki Institute of Sustainability Science. With a strong academic foundation in construction and real estate economics, Dr. Kurvinen is dedicated to advancing evidence-based decision-making through rigorous research.

Aleksi Karhula is a Research Fellow at the INVEST flagship centre at the University of Turku and a Visiting Researcher at the Sustainable Urban Systems Research Groups at the University of Helsinki. After a master's degree in sociology at the University of Helsinki he did his doctoral studies at the University of Turku focusing on intergenerational transmission of inequalities. Dr. Karhula has a strong background in quantitative sociology and register-based research, and his research interests are wide-ranging, including different forms of intergenerational inequalities, segregation dynamics, twin models and sequence analysis methodology.

Sanna Ala-Mantila is an Assistant Professor of Sustainable Urban Systems at the Ecosystems and Environment Research Program at University of Helsinki's Faculty of Biological and Environmental Sciences. She is also affiliated with Helsinki Institute of Sustainability Science. Her research aims to understand how we can build and transform our urban systems into more sustainable ones, with a focus on ecological and social sustainability and their interconnectedness.