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SUM
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MODELLING SCENARIOS OF HOUSEHOLD RESIDENTIAL DECISIONS AND MOBILITY PATTERNS

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Modelling scenarios of household residential decisions and mobility patterns

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- **Previous research has shown how segregation can emerge from the uncoordinated residential preferences and choices of individual households, even when segregation is not an intended outcome.**

- Simulations in the Helsinki Metropolitan Area support these findings, showing how patterns of segregation can change significantly through the self-organisation of individual households. Unexpectedly however, **it is the most highly educated households which become the most isolated in the simulations, clustering particularly in the dense urban centre of Helsinki.** This result challenges previous conceptions of the position of the highly educated in the region.

- Classical Schelling-type simulations are demonstrated here as one method of exploring the complex and understudied relationship between individual household residential decisions and the macro population structure of a city, and how one may shape the other.

Household residential choices and segregation

The goal of limiting differentiation between neighbourhoods features prominently in recent city strategies within the Helsinki Metropolitan Area (HMA). As the population distribution of a region ultimately results from the residential mobility of its households, the basis on which this mobility occurs is key to understanding segregation processes. Households are seldom unconstrained in their residential choices. Macro factors such as the structure and supply of housing, competitive real estate markets and legal and institutional forms of housing discrimination can all reduce choice and may act to encourage or facilitate segregation. **However, even in the absence of these factors, segregation has been shown to arise through the self-organisation of individual households who make decisions about where to live.** Using simple theoretical models, economist Thomas Schelling (1971) demonstrated how these seemingly insignificant individual residential choices may lead to unexpected segregation in a city, even if this is not an intended outcome for anyone.

Schelling's model of segregation

Nobel laureate Thomas Schelling's (1971) classic model of residential segregation was one of the first applications of individual-based modelling to social science. Schelling's model considers the interactions of two groups of 'agents', representing households, who make decisions about where to live in a simulated world. The model begins with a random allocation of agents from the two groups to spaces on a rectangular grid. Agents are then given the opportunity to relocate to any empty space. Each agent aims to reside in a 'neighbourhood', defined as the surrounding eight grid cells, where the proportion of neighbours from the same group is sufficiently high. Several different preference thresholds (e.g. 30% of neighbours from the same group) are explored in the simulations. Each agent in turn considers whether to remain in its current location, or to relocate to a suitable position on the board by comparing the current neighbourhood composition with their prescribed preference threshold. When repeated over several cycles, the population becomes highly segregated, even when preference levels are quite low.

Social distance and spatial sorting

Schelling's models investigate the spatial outcomes of social homophily or social distance dynamics in residential sorting patterns. Theories of homophily (McPherson et al, 2001) and social distance (Park, 1926) consider that people are more likely to associate with others who are similar to themselves (low social distance), and that those with a high social distance are more likely to display avoidance behaviour. Research has shown how social distance can manifest spatially when households relocate in response to social distance, and similar households sort into the same neighbourhoods (e.g. Musterd et al, 2016, van Gent et al, 2019). Households may find benefits or support from living with others who share similar cultural values, needs, languages or lifestyles, which may also facilitate shared services and facilities (Van Ham et al, 2018). The ability of households to act upon such homophilious residential preferences, is constrained at least by the state of supply of the housing market and the agent's economic resources.

Households with more resources therefore are more advantaged when competing for housing and desirable neighbourhoods. Unsurprisingly, it is the highest social strata which has been found to be the most segregated in European cities (Marcińczak et al, 2016).

Socio-cultural factors in residential sorting

The majority of segregation modelling has focussed on ethnic segregation, particularly in the context of the United States. In Europe, socio-economic drivers have been considered more important, however recent work has highlighted increasing cultural fragmentation and socio-cultural attributes as factors in residential sorting (e.g. Boterman et al, 2020; van Gent et al, 2019). On this basis, the theoretical simulations presented here consider cultural capital, represented using educational attainment, as a potential factor in residential sorting.

The complex nature of urban segregation

Segregation processes exhibit many of the characteristics of complex systems:

- Interdependence: Interdependence exists between the many independent elements (e.g. households) that comprise the system. An action taken by a single household can thus propagate throughout the system, influencing all related parts.

- Self-organisation: Rather than being centrally controlled, the system is organised through the local interactions of the individual components.

- Emergence: Global system properties arise from the aggregate behaviour of local interactions. An apparently simple global condition, such as a segregated urban region, can thus emerge from relatively complex lower-level processes between individuals.

- Nonlinearity: The interconnectivity and feedback present in the system means that changes in the local properties are not correlated in a linear fashion with macro outcomes. Small changes at the local context (e.g. one household changing neighbourhood) may have unexpected impacts on the global behaviour and population structure of a region.

- Path dependence: The social composition of today's cities is the product of many years of historical residential mobility actions. Historic patterns continue to influence residential choices today, and actions which occur now may influence future interactions in unknown ways.

Simulating residential mobility in the Helsinki Metropolitan Area

A geospatial agent-based model of the HMA was used to explore population dynamics arising from theoretical residential sorting scenarios. Approximately 100,000 representative agents (i.e. households with an educational status) were created using population data from Statistics Finland (2019) and initially located in accordance with the existing urban structure and population distribution of the region. At each cycle, agents evaluate the composition of their neighbourhood, defined using a 500-metre radius, and decide whether to stay or move by comparing the actual composition with their prescribed preference levels. If an agent's preference for similar neighbours is not achieved, it will move to a new location, otherwise it will remain in its current location. (Figure 1). Agents can move anywhere within the region, as long as there is vacant housing available. Vacancy within each grid cell was set using empirical vacancy rates for the region.

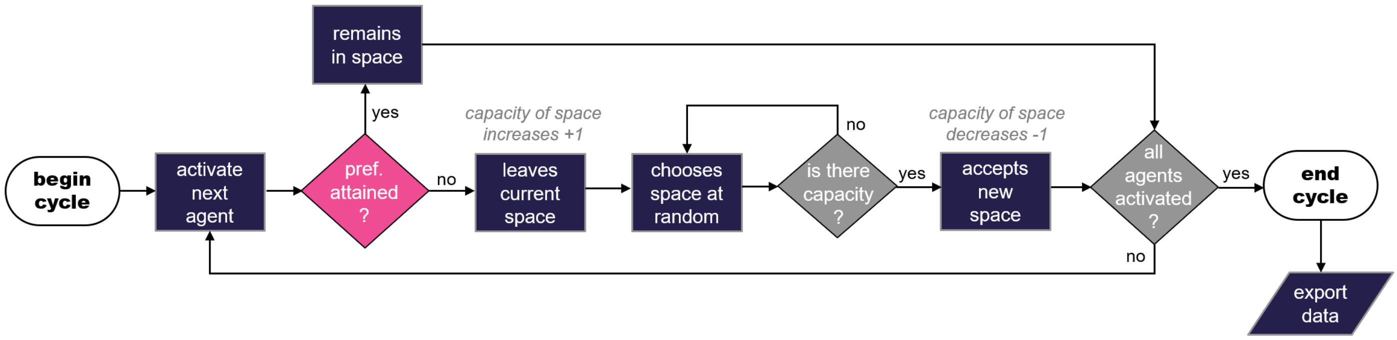


Figure 1. Process diagram for each simulation cycle. An agent will relocate if its current neighbourhood (defined using a 500 metre radius from the agents position) does not meet the prescribed preference for similar neighbours. The two simulation scenarios presented here consider two different preference thresholds. All other parameters are held constant in the simulations.

Preference thresholds

The key modifiable parameter in the simulations is the preference level for similar neighbours. All other parameters have been held constant. In all simulations, preferences have been assumed to be consistent within each group.

Two theoretical scenarios will be presented here:

Scenario A: Agents prefer 30% of their neighbours to be of the same education level as themselves.
Scenario B: Agents prefer 50% of their neighbours to be of the same education level as themselves.

In both scenarios, agents are thus happy to live in mixed neighbourhoods, provided that their preference for a minimum percentage of neighbours of the same educational background is met. In the first scenario the agents are content with being a minority group in the neighbourhood, whilst the second scenario suggests that they desire a simple majority. These preferences of 30% and 50% may seem high, however within the HMA, both secondary-educated and tertiary educated residents exceed a 30% share (21% basic education, 43% secondary education, 36% tertiary education). At the smallest areal unit of measurement, the 250 metre grid cell, over one-third of those with a tertiary degree already live in an area where other highly educated individuals represent 50% or greater (almost two-thirds in Kauniainen) (Statistics Finland, 2019). The model is thus exploring the potential cumulative outcomes if existing household behaviour is generalised and projected into the future.

Baseline – Educational attainment in the Helsinki Metropolitan Area

In order to track changes in the population structure throughout the simulation, a spatial isolation index (Q_m) has been calculated for each of the three education levels, and decomposed to visualise the local contributions of each areal unit (grid cell) to the global measure (see Page, 2021, pp. 43-48 for full description). The spatial isolation index represents the average proportion of a given group in the locality of each member of the same group, reflecting the likelihood of encountering others of the same education level as oneself at the place of residence (Feitosa et al, 2017). As this is affected by the relative group sizes (see above), direct comparison between groups is not possible, however by comparing the results to the baseline measure we can track the development of segregation throughout the simulations.

The baseline scenario is presented below. A Q_m value of 0 indicates low isolation, whilst 1 indicates maximum isolation. A quick visual analysis indicates the presence of clusters of tertiary-educated residents in the city centre of Helsinki and in some parts of Espoo, whilst those with only basic education appear to be more dispersed, with a few clusters in the east of the region. Around 60% of those aged 25 years or over with a tertiary education in the HMA live in Helsinki, and whilst Espoo currently has a higher share of highly educated residents (45% compared to 42% in Helsinki), the share of tertiary-educated individuals has been growing at a faster rate in Helsinki than in Espoo in recent years (OSF, 2021).

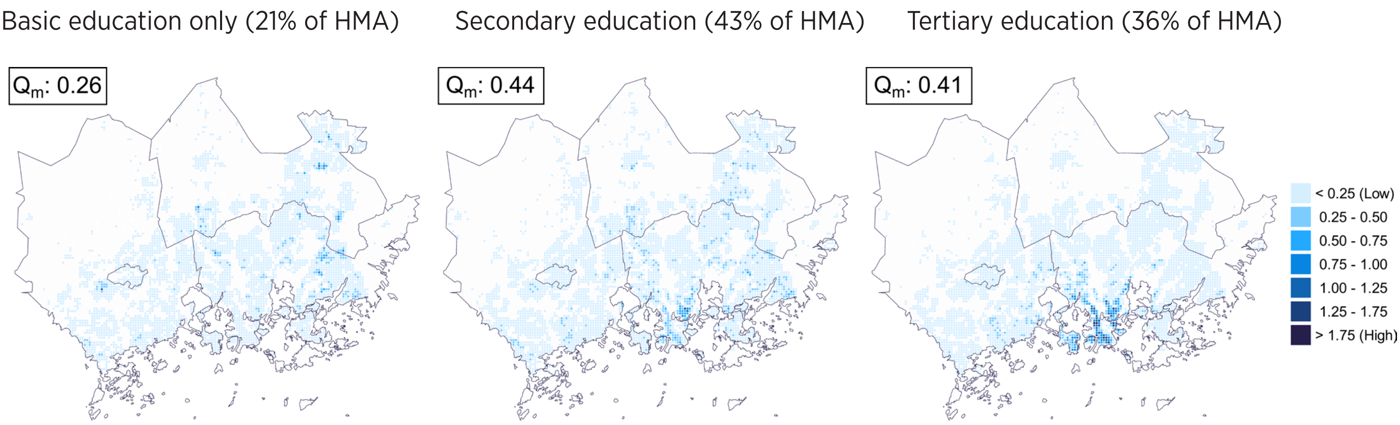


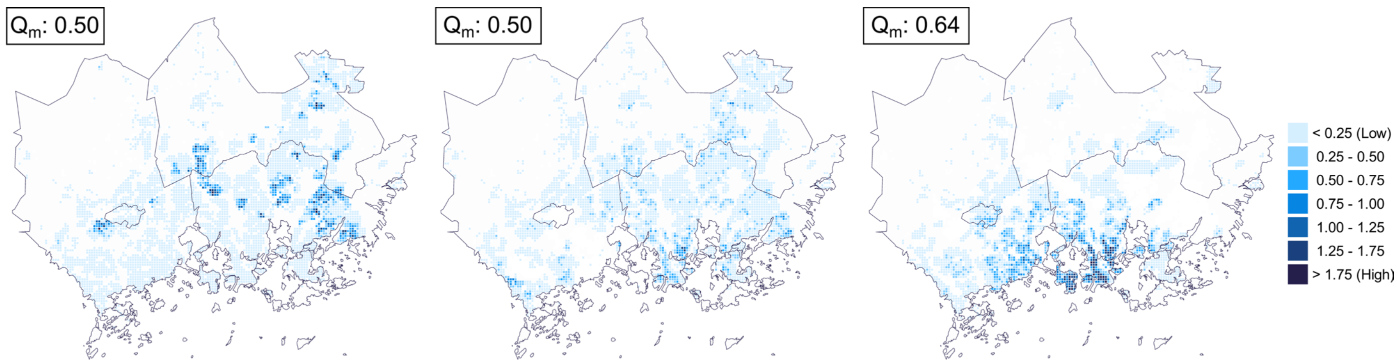
Figure 2. Spatial isolation index (Q_m) at baseline (31 December 2018). The global Q_m value is indicated above the figures, and local decompositions are mapped. Local values in the legend are multiplied by 1000 for legibility. (Data: Statistics Finland, 2019)

Unexpected outcomes

The following maps present the simulated outcomes of the model, under the theoretical conditions described above. All results are the aggregate mean values of 10 separate simulations run with identical parameters in order to account for the stochasticity of the agents' mobility decisions. All simulations were terminated after 20 cycles, which can be considered 20 years, if one imagines that households contemplate moving once every year. For further background on the reported figures, see Page (2021).

Scenario A: Preference for 30% of neighbours with same educational background

Basic education only (21% of HMA) Secondary education (43% of HMA) Tertiary education (36% of HMA)



Scenario B: Preference for 50% of neighbours with same educational background

Basic education only (21% of HMA) Secondary education (43% of HMA) Tertiary education (36% of HMA)

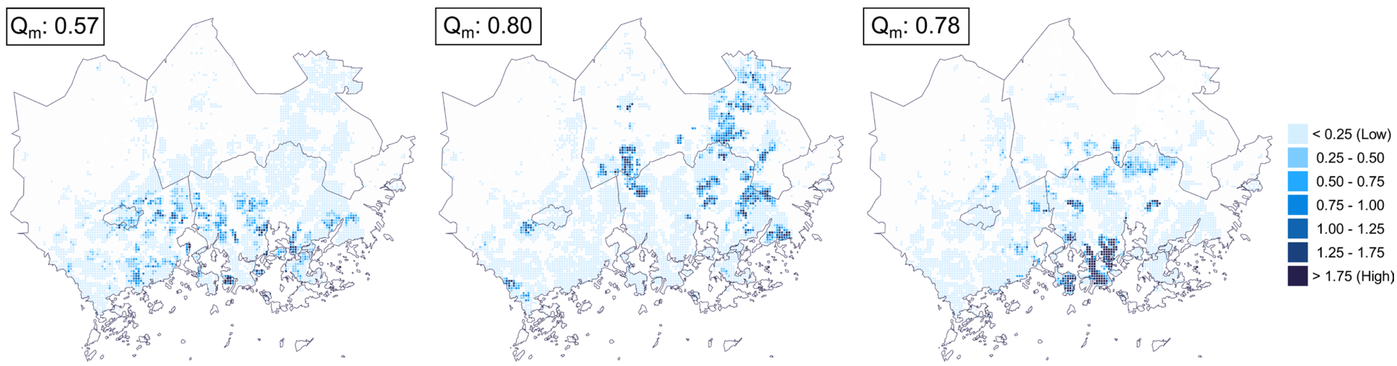


Figure 3. Spatial isolation index (Q_m) after 20 cycles. The global Q_m value is indicated above the figures, and local decompositions are mapped. Local values in the legend are multiplied by 1000 for legibility.

Emerging spatial divisions

In both scenarios, all three education groups become increasingly isolated. Despite their regional proportion being lower than those with only secondary education, tertiary educated residents become the most isolated (highest Q_m) under the 30% preference scenario. This isolation is most notable within the dense city centre of Helsinki, and even more so under the 50% preference scenario. Whilst such an outcome contrasts with the historic idea of Espoo as the home of the highly educated in the region, it would be consistent with observations from many European and international cities.

Education and cultural capital as a differentiating feature in social relations has been well documented (e.g. Bourdieu, 1984). Savage et al. (2018) highlight increasing cultural divides in European cities and the accumulation of those with emerging cultural capital in urban centres. Residents seeking cultural consumption and a means to demonstrate distinction may locate close to the urban centre where the majority of cultural amenities and services are often located (Allen, 2008, Bridge, 2006, Van Gent et al, 2019).

The clustering of highly-educated individuals has been evidenced at least since the 1990's in the HMA (Vaattovaara, 1998; Vaattovaara & Kortteinen, 2003). Whilst the simulations have produced unexpected patterns, as discussed previously, in many parts of the region, those with a tertiary education are already clustered with shares greater than the two preference thresholds prescribed in the simulations.

Limitations

Any model is necessarily a simplification of the system which it is seeking to explore, and should be interpreted as such. Whilst the model is representative of the geographic housing and population structure, density, and empirical vacancy rates of the HMA, many other housing characteristics and urban qualities are not factored in (see Page, 2021 for a detailed discussion of limitations and modelling assumptions). Under the modelled theoretical conditions, all agents have absolute freedom in their residential choices, are not subject to competitive real estate markets, discrimination or other macro conditions which may limit their choices. In reality, choices are constrained at least by the state of supply in the housing market and the agent's resources. As education often corresponds with income, the highly educated are likely more capable of sorting into their preferred neighbourhoods. Such a process driven by the choices of the highest social strata has been noted in other Nordic cities where the "...movement patterns of the wealthiest and most advantaged groups play the largest role in shaping the housing market and demographic distribution..." (Tunström & Wang, 2019).

Social systems are inherently complex and involve many interconnected processes. Models such as that employed in this study go some way to acknowledging this complexity. By isolating certain system properties we are able to explore hypothetical what-if scenarios and test theoretical behaviour and outcomes. In doing so we can gain an increased understanding of segregation as a collective process and these complex social dynamics which can produce unexpected outcomes.

Acknowledgments

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Page, M. (2021). Agent-based models as a tool for exploring complex segregation processes. Simulating scenarios of residential segregation in the Helsinki Metropolitan Area. [Master's thesis, University of Helsinki]. http://hdl.handle.net/10138/331731

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