Segregation in Urban Areas:
A Literature Review

Marcos Demetry*
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Abstract: This literature review outlines research on how individual preferences can lead to segregation, even in the absence of discriminatory policy and other constraints. From Schelling’s (1971) Spatial Proximity model comes the theoretical conclusion that moderate preferences for own-group neighbors (e.g. immigrants or natives) may lead to complete segregation between the two groups over time. Schelling’s Bounded Neighborhood model provides the theoretical conclusion that the stable equilibrium reached (e.g. an ‘all immigrant’ or ‘all native’ neighborhood) ultimately depends on the initial distribution of agents and their relative speeds of movement. This is because in the unstable, integrated, equilibrium an apparently insignificant event can set in motion an irreversible process toward segregation by tipping the distribution one way or another. Both models highlight how well-intentioned individual preferences may result in undesirable aggregate outcomes, whereby good intentions and some level tolerance toward others are not enough to prevent the self-segregation mechanism. The review also covers several key empirical applications and limitations in research in this field.

Keywords: Neighborhoods, Segregation, Schelling model, Urban Area
JEL-codes: J15, O15, P25, R23

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Introduction

Segregation exists in many forms. Segregation is often defined as "the non-random allocation of people who belong to different groups into social positions and the associated social and physical distances between groups" (Bruch and Mare, 2008). It carries with it certain socially desirable as well as undesirable outcomes. For example, a neighborhood predominantly comprised of immigrants may be better suited to help newly arrived immigrants solve immediate, short-term, issues such as finding a job for themselves or applying to schools for their children. On the other hand, living in isolation from the rest of society may mean being less incentivized to assimilate, e.g. finding that everything is available to you in your own mother tongue doesn’t make learning the host country’s language a necessity.¹

Throughout history and in many parts of the world today, there may be discriminatory policy, structural racism, oppressive authoritarian regimes and similar structural, "top-down", mechanisms which have forced societies to segregate residentially. Segregation may be along the lines of ethnic, racial, religious or gender belonging. However, for the sake of arguing, assume that immigrants willingly and with perfect information choose to settle down in neighborhoods with a noticeable share of immigrants. Since homophily is not forbidden, who is to prohibit an individual from making such a choice, and with what authority?² This poses an interesting question then; in the absence of all such constraints, can segregation still arise solely due to individual preferences?

This literature review focuses on precisely that. The idea that social distance dynamics and individual preferences would be at least as important as the role of policy and discrimination is still debatable (Fossett, 2006, p.187). Some prominent sociologists argue that the role of individual preferences in understanding segregation is not important (see e.g. Massey and Denton, 1988; Yinger, 1995) while others believe that it is very important (e.g. Thomas Schelling and William A.V. Clark). Ahead of presenting his models of segregation, Schelling (1978, p.138) explicitly stated that “at least two main processes of segregation are outside this analysis. One is organized action- legal or illegal, coercive or merely exclusionary, subtle or flagrant, open or covert, kindly or malicious, moralistic or pragmatic. The other is the process, largely but not entirely economic, by which the poor get separated from the rich, the less educated from the more educated, the unskilled from the skilled… in where they work and live and eat and play…” [Italics added] As previously mentioned, this restriction is important to keep in mind for the remainder of this paper. In his concluding remarks, Clark (1992, p.463) wrote that “although a study of preferences cannot answer all the questions about ethnic and racial separation in a city, preferences clearly are relevant in generating and maintaining separate ethnic residential areas”.

The remainder of the paper is structured as follows. In Section II, we will examine the set-up, outcomes and implications of two theoretical models of segregation, as well as introduce the concept of agent-based modelling. Section III will present what empirical challenges researchers face in applying the models. This section will discuss the pros and cons of different types of data, the different measurements of neighborhood and segregation as well as how ethnicity is defined. Section IV will discuss recent

¹ See e.g. Borjas (2014, pp.202–211) for a discussion on the effect of “ethnic capital” (defined as the “overall quality of the ethnic environment in which parents make their investments”) on second-generation immigrants’ economic performance. Ethnic capital is also described as a type of “social capital” formed by the ethnic neighborhood, e.g. the level of education and economic achievements of the ethnic group in the neighborhood (Borjas, 2016, p.122)

² See Nordström Skans and Åslund (2010, p.70) for a discussion on whether segregation is problematic, and if so, under what circumstances is an intervention justified.
developments in the empirical research by presenting three interesting empirical studies. Section V will briefly mention criticism of agent-based modelling. Finally, the paper concludes with a short summary and repetition of the most important conclusions of this literature review.

**Theoretical Models**

Thomas Schelling\(^3\) wanted to understand and analyse the effect of own-race preferences in generating segregated neighborhoods. In a series of publications, Schelling (1969, 1971, 1978) demonstrated how well-intentioned individual preferences, “micromotives”, may lead to undesirable aggregate change, “macrobehavior”. Schelling does so by describing two models: The Spatial Proximity model (also known as the Checkerboard model) and the Bounded Neighborhood Model (also known as the Tipping Point model). We shall examine each of the models in turn.

**The Spatial Proximity Model**

In its simplest form, the Spatial Proximity Model is set up as follows (Schelling, 2006, pp.137–155; Clark and Fossett, 2008). There are two groups in a society (e.g. natives and immigrants). The distinction between the groups is twofold, exhaustive and recognizable, i.e. any given individual should be able to be classified as belonging to one of the two groups. An individual, also known as an agent, has \( n \) neighbors. The different locations in the society are either occupied by a native, an immigrant or are left vacant. Individuals in this society have preferences for a certain share of own-group individuals in their neighborhood. This can also be explained as a tolerance level for the share of the other group in the neighborhood.

In every period, an agent chosen at random must evaluate whether their preferences are fulfilled or not. If an agent’s preferences are fulfilled, he or she is satisfied and does not move from their location. However, if an agent’s preferences are not fulfilled, he or she is dissatisfied and must move to a different location. These rules can also be expressed as agents making residential mobility decisions based on the desire to maximize their utility, which is a function of their preferences. This process repeats until an equilibrium is reached. A stable equilibrium is one where all agents are satisfied and do not wish to move.

The Spatial Proximity model is informally titled the checkerboard model because it could be illustrated as a two-dimensional checkerboard, as in *Figure 1* below. The figures (Schelling, 1971, pp.155 & 157) demonstrate how a group of O’s and a group of #’s start off in an integrated society (left) but eventually, with preferences for \( \frac{1}{2} \) of one’s neighbors to be of the same group, become a rather segregated society (right). In the figure to the right, the different clusters of O’s and #’s are outlined in order to emphasize their groupings.

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\(^3\) Thomas C. Schelling is an economist and Nobel Laurette, famous for several important contributions to the fields of game theory, foreign policy and national security. For further reading on Schelling, see e.g. Klein, Cowen and Kuran (2005).
Figure 1: An illustration of the Spatial Proximity model as seen in Schelling, 1971, p. 155 & 157. The checkerboard on the left shows the initial conditions, where O and # live in an integrated society. The checkerboard on the right shows that after each agent has made his or her residential mobility decision based on preferences of at least ½ own group in the neighborhood the society is relatively segregated.

The results of the Spatial Proximity model are somewhat counter-intuitive and striking. Even with mild preferences, what some would call “integrationist”, such as 50% of the neighborhood being of the agent’s own group, noticeable segregation may arise.

At this point, the reader may believe that the model is overly simplistic. When applying additional elements of mathematical rigor as well as an increased complexity, to my knowledge, there is not one extension, modification or restriction to the model which changes its qualitative conclusions. For example, letting vacancy rates be an endogenous variable (determined by housing prices driven by market mechanisms), allowing agents to swap locations (instead of simply filling vacant locations; Clark and Fossett, 2008), restricting dissatisfied agents to move only to the nearest vacant location or allowing dissatisfied agents to move to a random vacant location, allowing natives to have preferences to reside with a majority of natives while immigrants have neutral preferences (Clark, 1991), changing the network shape from a grid to either random, scale free or fractal (Banos, 2012), changing the functional form from threshold (step function) to continuous (Bruch and Mare, 2006, 2009; Van de Rijt, Siegel and Macy, 2009) and many more modifications of the model do not alter its main conclusion that micromotives of well-intentioned agents (such as integrationist preferences) may lead to collectively undesirable macrobehavior (such as a segregated society).

A critique of the Spatial Proximity model is that it does not allow each individual to have their own level of ethnic preferences. This is somewhat resolved in Schelling’s other model, the Bounded Neighborhood model.

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4 The phenomena described by the Spatial Proximity model is not unique to humans and human interaction, it has far reaching implications in subjects ranging from marketing to physics and epidemiology.
The Bounded Neighborhood Model

The Bounded Neighborhood model is set up as follows (based on Schelling, 1969, 1971, pp.167–183, 2006, pp.155–166; Clark and Fossett, 2008). As before, there are two groups in a society. Individuals are concerned about the own-group ratio within the neighborhood. Every individual has a “tolerance” level (an “upper limit”) for the ratio of the other group within the neighborhood. Every individual’s tolerance level is plotted, going from left to right, from the most tolerant individual to the least tolerant individual (we assume, for simplicity, that this creates a linear tolerant schedule). In Figure 2 to the left, we see that if there are 100 white households (top), the most tolerant individual is willing to tolerate a ratio of 2:1 Blacks to Whites, i.e. being in a 1/3rd minority. The least tolerant individual does not tolerate any Black household in the neighborhood. Similarly, if there are 50 black households (middle), the most tolerant individual is willing to tolerate 2:1 Whites to Blacks. The least tolerant individual does not tolerate any White household in the neighborhood. These tolerance schedules can be translated into absolute numbers yielding parabolic curves (bottom). The curves are to be read such that, “at least that many whites tolerate this many blacks.” For example, 50 whites can tolerate the same number of blacks (50), whereas 75 whites can tolerate 0.5 times their own number (37.5).

If an individual’s tolerance level within the neighborhood is exceeded, he or she is unsatisfied and must move somewhere else (irrespective of where). If an individual’s tolerance level within the neighborhood is not exceeded, he or she is satisfied and must remain in the neighborhood. Visually, any individual residing outside their curve is dissatisfied. We assume there is perfect information at any given moment, but individuals cannot know others’ intentions nor predict future turnover. Lastly, it is assumed that the most dissatisfied (those with the lowest tolerance levels) leave first.

Following this rule, there are certain dynamics that play out in the model. As seen in Figure 3 below, the area jointly under the White curve and Black curve is the mixture of whites and blacks that are satisfied living in the same neighborhood. The dynamics of the model are such that, there is a mixture of blacks and whites where 1) all blacks and whites are satisfied- the number of blacks and whites increases, 2) All whites but not all blacks are satisfied- the number of whites increases within the white

Figure 2: an illustration of the Bounded Neighborhood model as seen in Clark (1991, p.6)

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5 Note that the use of “blacks” and “whites” in this example is simply to facilitate the explanation of the model, keeping it in line with the works of Schelling and Clark. However, the more relevant dichotomy is still natives and immigrants.

6 Notice that the Bounded Neighborhood model has only one neighborhood with clear borders known to all agents, which are either in the neighborhood or not in the neighborhood. The Spatial Proximity model has several neighborhoods, because each agent evaluates his or her respective neighborhood.
parabola, 3) All blacks but not all whites are satisfied - the number of blacks increases within the black parabola, 4) neither all the blacks nor all the whites are satisfied, whereby the number of both blacks and whites are decreasing.

Following this line of thinking, an individual’s residential mobility decision is based either on his or her desire to move into a neighborhood (also known as tipping-in or tipping genesis) or move out from a neighborhood (also known as tipping-out or tipping exodus).

The model then predicts that there are three equilibria, of which two are stable and one is unstable. The stable equilibria are reached in neighborhoods with only whites or only blacks (in Figure 3 above, that is the point where the White curve intersects the x-axis at 100 and the point where the Black curve intersects the y-axis at 50). The unstable equilibrium is the one in which there is a mixed neighborhood. Which of the two stable equilibria we reach depends on “where the process starts and, perhaps, the relative speeds of white and black movement” (Schelling, 1978, p.160).

In the version of the model presented above, notice that there are half as many black individuals as white. There are however alternative versions with different group populations and different steepness of the tolerance schedules. For example, assume the number of blacks and whites are equal (100 each) and the tolerance schedules are slightly steeper, such that the most tolerant individual accepts a ratio of 5:1. This results in the parabolic curves illustrated in Figure 4 to the right. These populations and tolerance levels give the model three stable equilibria; the two equilibria that give complete segregation and an additional equilibrium at 80 blacks and 80 whites. Schelling (1971, pp.171–186) experiments with several other modifications and extensions.

Differences and similarities between the two models
The two models were initially presented as independent of one another, but in a sense, they are two ways of describing the same phenomenon and are to a large degree integrated. In fact, somewhat confusingly, several articles simply refer to “the Schelling model of segregation” when referencing one or the other, or an integrated version of both. However, as Zhang (2011, pp.169–173) notes, there are some differences between the Spatial Proximity (henceforth, SP) model and the Bounded Neighborhood (henceforth, BN) model worth highlighting.

The SP model is simulated whereas the BN model is purely analytical. In the SP model, the entire group is said to have a tolerance level whereas the BN model allows for each individual within the group to have his or her own tolerance level. While the SP model does not require any external event for its mechanisms to be set in motion, in the BN model, events that trigger tipping are assumed to be exogenous (e.g. an immigrant moving into a neighborhood). The key insight from the SP model is that
mild preferences for like-neighbors may lead to segregation. The key insight from the BN model is that “seemingly unimportant events trigger the movement of a system from one equilibrium to another” (Zhang, 2011, p.172). The SP model has several neighborhoods, specifically, each agent defines his or her own neighborhood as the locations in their immediate surrounding. The BN model has only one neighborhood, similarly defined and known by all agents. The SP model specifies where an agent moves to if dissatisfied and where they have moved from, allowing residential segregation to arise endogenously. The BN model does not specify where an agent moves to once they tip out of the neighborhood nor where the agent has moved from. Being able to specify and follow the movements of the agents from one neighborhood to another gives the SP model a “flavor” of a general equilibrium model. On the other hand, focusing only on one neighborhood and its tipping to either of the two possible stable segregated equilibria, completely disregarding the evolution of other neighborhoods, makes the BN model a partial equilibrium model.

The SP model has inspired less literature than the BN model. The SP model has inspired literature that looks into how area characteristics (such as the ethnic mix of neighborhoods) affects residential mobility (and vice versa). The BN model has inspired literature that looks into identifying the neighborhood tipping points and its effects on neighborhood ethnic mix.

“Tipping occurs in this checkerboard model in the sense that the accumulation of low-probability random events perturb an equilibrium residential pattern and trigger the move into a completely different equilibrium residential pattern. Indeed, segregation emerges and persists precisely because tipping tends to occur to integrated residential patterns but not to completely segregated ones... Tipping away from segregation is difficult because the first step involves some [immigrants] moving into predominantly [native] neighborhoods or some [natives] moving into predominantly [immigrant] or both. If people really dislike being isolated in a neighborhood of the opposite color, as survey data seem to suggest, they will not take the first step even though they really like ‘half black, half white’ neighborhoods. Thus, they get stuck with segregation.”

- (Zhang, 2011, p.189)

Implication: Dynamic Model
One must take into account feedback effects in order to capture the (movement) dynamics of the models. A major implication of both models is therefore that in order to examine how residential mobility decisions affect the degree of segregation of neighborhoods it is not enough to apply static models. Agents decisions in the first period affect the information on which agents tomorrow will make their decisions. In other words, residential mobility of individuals today affects the neighborhood characteristics (e.g. ethnic mix) both of the neighborhood they move into and the neighborhood they move out of. The new neighborhood characteristics in turn affect the decisions of individuals tomorrow.
Implication: The Paradox of Weak Minority Preferences

We want to explain how residential mobility decisions based on preferences affect the degree of segregation in a neighborhood, and we have established that there are feedback effects making our models dynamic. It is interesting to understand just how (in)tolerant individual preferences “should” be in order for the model to predict complete segregation. By considering feedback effects, even weak minority preferences (high tolerance) can have amplified effects over a “sufficient” number of periods. This means that supposedly “integration-promoting” preferences are in fact “segregation-promoting” if they exceed the population distribution (Fossett, 2006, p.201; Clark and Fossett, 2008, p.4111). For example, a minority preference of 50-50 (simply not wanting to be in a minority in the neighborhood) may bring about segregation if the population distribution is 20% immigrants and 80% natives. A too tolerant majority could overwhelm a minority and bring about segregation. As Fossett (2006, p.203) eloquently summarizes it, “integration is strictly contingent on a city’s ethnic demographic structure.”

A simple mental exercise could clarify this astounding result. Assume that we are in the Spatial Proximity model, in its simplest form as presented earlier where the initial placement of agents is random. On the one extreme, assume that tolerance levels for both groups are exceptionally low (0%), i.e. individuals only accept being in a majority in the neighborhood comprising 100% of the neighborhood population. Following the rules of residential mobility established earlier, each agent will evaluate their immediate neighborhood, feel dissatisfied and move to a random vacant location. This agent, and all agents, continue to do this indefinitely. This implies that agents are constantly on the move and society does not settle with segregated patterns. On the other extreme, assume that tolerance levels for both groups are exceptionally high (100%), i.e. individuals accept being an extreme minority in the neighborhood comprising 0% of the neighborhood population. Again, following the rules of residential mobility established earlier, each agent will evaluate their immediate neighborhood, feel completely satisfied and decide not to move. This agent, and all agents, are satisfied with where they are and do not move. This implies that society immediately reaches an equilibrium which is integrated. However, at some interval of weak minority preferences (say, between 30%-70%), a dissatisfied agent could potentially find a neighborhood that satisfies his or her needs and decides to move there. If enough previously dissatisfied agents find a neighborhood that satisfies them and move there, one starts to see clusters of one group or the other. This is the paradox! Seemingly weak minority preferences bring about segregation, whereas extreme preferences bring about integration.

Implication: Tipping point

The final steady state reached in the Bounded Neighborhood model depends on the initial distribution of agents and their relative speeds of movement, an apparently insignificant event could set in motion an irreversible process toward segregation simply by tipping the distribution one way or another. The model is most vulnerable for tipping near the tipping point. As a result, the Bounded Neighborhood model provides the basic theoretical framework for the White Flight and White Avoidance literature. Gladwell (2000, p. 7-9) eloquently summarized the characteristics of tipping points as follows: Individual behavior is interdependent (contagious), the accumulation of small changes has significant consequences and dynamics accelerate once a threshold is reached. (Zhang, 2011, p. 171)

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7 This is particularly true with specific measurements of segregation such as the Index of Dissimilarity, which we will discuss momentarily.
Empirical Applications

There are certain crucial decisions to be made when attempting to apply the Schelling model empirically, such as what type of data and method to use. The analyst needs to appropriately define key variables, such as ethnicity and neighborhood as well as the preferences. There are several measurements of segregation; which is most suitable with regards to the research question? Lastly, the analyst also needs econometric methods for evaluating how residential mobility affects neighborhood characteristics (and vice versa).

Measuring Segregation

There needs to be some formal method of measuring segregation as an outcome in order for researchers to systematically evaluate segregation in urban areas. Segregation in urban areas may be measured qualitatively and quantitatively. The qualitative measures are often in the form of geographic maps overlapped with densities for each group. An example of this is illustrated in Figure 5 below, as seen in Clark et al. (2015, p.1270). The strength of using a qualitative measure is that it is intuitive to understand. On the other hand, it is more difficult to accurately compare “levels” of segregation in different areas.

Figure 5: a color-coded illustration of population clusters in Los Angeles, California, USA, as seen in Clark et al. (2015, p. 1270)
However, complementary to illustrating segregation visually, the quantitative measurements can be categorized as follows. There are measures of **evenness** (e.g. Index of Dissimilarity), **exposure** (e.g. Index of Isolation), **concentration**, **centralization** and **clustering**.

The Index of Dissimilarity compares the ethnic mix of the neighborhood to the ethnic mix of a greater region (such as the nation). The resulting index is a number from zero to one, where one is complete segregation. The index is interpreted as “the share of the immigrant group that would have to move to produce a distribution equal to that of the native population within the municipality” (Aldén, Hammarstedt and Neuman, 2015, p.42).  

The Index of Isolation calculates the “extent to which minority members are exposed only to one another” (Massey and Denton, 1988, p.288). An index value of one means that the minority group in the neighborhood in question is completely isolated from the majority group.

Concentration indices measure “the relative amount of physical space occupied”, centralization indices “indicate the degree to which a group is located near the center of an urban area” and finally, cluster indices measure “the degree to which minority group members live disproportionately in contiguous areas.” (Iceland and Weinberg, 2002, p.119)

“Measurements of residential segregation say something, but far from everything, about whom a person might reasonably be expected to interact with on a daily basis, since few persons spend all their time in the immediate vicinity of their dwelling. There are considerable variations in this regard with respect to age and life situation in general. Adults, as a rule, spend less time in their neighborhood than children, as do those employed in comparison with the unemployed.” – Bråmå (2006, p.21)

**Defining ethnicity**

Much of the previous empirical literature is set in the context of housing segregation in the United States, whereby the relevant “race-ethnic” groups are African-Americans, Asians, Hispanics and Whites (see e.g. Clark, 1991; Mare and Bruch, 2003; Clark et al., 2015). Similarly, many studies examine racial and ethnic segregation in urban areas between “whites” and “blacks”, much like the theoretical work by Schelling presented earlier. However, this classification is less relevant in a Swedish context. What is relevant to study in a Swedish context is the ethnic segregation in urban areas between natives and immigrants (Nordström Skans and Åslund, 2010, pp.10–11). Definitions of “native” vary, but a Swedish native is defined as either being born in Sweden irrespectively of where the parents are born, as being born in Sweden and having both parents Swedish-born, or as being born in Sweden with at least one

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8 The dissimilarity index may be calculated as follows: \( D = \frac{1}{2} \sum_{k=1}^{K} \left| \frac{i_k}{I} - \frac{n_k}{N} \right| \), where \( i_k \) is the immigrant share in the \( k^{th} \) neighborhood, \( I \) is the immigrant share in the municipality (or larger region), \( n_k \) is the native share in the \( k^{th} \) neighborhood and \( N \) is the native share in the municipality (or larger region), for all neighborhoods \( 1 \) to \( K \). (See also Fossett, 2006; Hedström, 2015; Mare and Bruch, 2003 for different versions of the Index of Dissimilarity)

9 The isolation index may be calculated as follows: \( I = \sum_{i=1}^{n} \left( \frac{x_i}{X} \right) \left( \frac{t_i}{T} \right) \), where \( x_i \) is the number of immigrants in neighborhood \( i \), \( X \) is the total population of immigrants, \( n \) is the total number of neighborhoods in the larger region being studied, and \( t_i \) is the total population (immigrants plus natives) in neighborhood \( i \). With only two groups, the isolation index sums to 1.0, but it can be extended to analyzing several groups. See also the Correlation index that corrects for different population weights.

10 The US Census Bureau published a report in 2002 evaluating and measuring the degree of segregation experienced by different ethnic groups in the United States of America using several different measures (Iceland and Weinberg, 2002). For more on the evaluation of different measurements, see e.g. Duncan and Duncan (1955)
parent being born abroad, or simply as individuals born in Sweden (see Aldén, Hammarstedt and Neuman, 2015, p.39).

Depending on research question and quality of data, researchers either have very broad categories of immigrants (e.g. European vs Non-European, ibid.) or they examine specific immigration countries. In any case, the idea of ethnicity is rather abstract. As pointed out by (Nordström Skans and Åslund, 2010, p.19), subtleties such as how individuals define themselves and to which ethnicity they feel themselves as belonging to, are beyond the scope of empirical studies of segregation in urban areas. This may present methodological problems when estimating the degree of assimilation among second and third generation immigrants, if each successive generation is less likely to identify themselves with their ancestry. This problem is a type of “ethnic self-selection”. (Borjas, 2016, pp.119–121, 2014, p.201)

Defining neighborhood

In order to say anything about segregation in urban areas with the Schelling model as a theoretical framework, one must be clear about what information an agent has and does not have. This includes how the agents define their neighborhoods when taking a residential decision. **Vision** is the technical word for how large of a neighborhood an agent evaluates when making their residential mobility decision. Given the same preferences, a broader vision may lead to greater segregation than a narrow vision. To the left, **Figure 6** shows just how important the role of vision is (Laurie and Jaggi, 2003, p.2697). With preferences of 0.5 (right), increased vision means increased segregation. Most previous literature defines a neighborhood in one of the following three ways. Either it is 

**i)** **border** based (such as census tracts and SAMS, discussed below), 

**ii)** defined using a fixed **radius** from certain midpoints or 

**iii)** defined as the **k-nearest** neighbor of each individual. Following is a brief summarizing explanation and evaluation of each measure in order to highlight the strengths and weaknesses of each definition, respectively.

![Figure 6: an illustration of different simulation outcomes of the Spatial Proximity model based on combinations of preferences (rho) and vision (R), as seen in Laurie and Jaggi, 2003, p. 2697](image)
Borders

Much of the previous literature in a U.S. context has defined neighborhoods as census tracts (see e.g. Mare and Bruch, 2003; Clark, Andersson and Malmberg, 2017). Census tracts have populations between 1,200 and 8,000, with an optimum level of 4,000. A similar Swedish measure of what constitutes a neighborhood is Small Areas for Market Statistics (abbreviated as SAMS). Sweden is divided up in approximately 9,200 SAMS, with an average of 1,000 individuals per SAMS (Amcoff, 2012, p.103). It is argued that the SAMS areas are rather homogenous with respect to the inhabitants’ socioeconomic level (Aldén, Hammarstedt and Neuman, 2015, p. 47). However, one major problem with using fixed borders in this fashion is the Modifiable Area Unit Problem, MAUP, (Moberg et al., 2014, pp.11–12).

The MAUP can be divided into three distinct problems: scale, aggregation and reference area. The scale problem concerns the fact that depending on the number of units into which the data are aggregated, one may detect completely different levels of segregation, as the top three illustrations of Figure 7 show. The aggregation problem concerns the fact that the manner in which borders between units are drawn may have an effect on the detected levels of segregation, as the middle three illustrations of Figure 7 show.

Lastly, the reference area problem is concerned with the fact that keeping the “same areal unit but different areas of reference” yields different levels of segregation, as the bottom three illustrations of Figure 7 show. (Hennerdal and Nielsen, 2017) This final problem is a type of error that arises from choosing the “wrong” base rate.

The differences in degrees of segregation measured empirically that result from defining different references areas is quite striking. For example, the degree of segregation measured for the Hispanic population of neighborhoods in Los Angeles, California depends highly on whether the reference area was Los Angeles County, the state of California or the contiguous United States. This is best illustrated visually in Figure 8 below. As you can see, with the contiguous United States as a reference area (right), Los Angeles has an extraordinary high share of Hispanics (dark red). However, from a regional perspective, with Los Angeles County as a reference area (left), there seems to be some clusters of the Hispanic population and other neighborhoods with very few Hispanics.

11 For more on U.S. census tracts, see https://www.census.gov/geo/reference/gtc/gtc_ct.html
12 It should be noted however that the variance is quite large. Approximately 300 SAMS have no inhabitants, whereas the largest SAMS has 58,000 inhabitants.
One way of attempting to solve for MAUP is by defining an agent’s neighborhood as a fixed radius (in km or miles) with the agent as the midpoint, as illustrated in Figure 9 to the left. Because a neighborhood is a set radius from an agent, it can neither be scaled differently, the neighborhood can’t be scaled the same way borders can. Also, once a neighborhood is defined as a fixed radius, one avoids the aggregation problems described above. The third, and last, problem of MAUP regarding the area of reference remains however. If one were to try solve the problem by having the area of reference also be a fixed radius, what midpoint should it have?

An additional problem with using the fixed radius approach is that several interesting statistical measurements of distribution such as variance and average are not as consistently reliable across fixed radius neighborhoods, and therefore one is to be extra careful when interpreting conclusions drawn from them. (Moberg et al., 2014, p.13)

**K-nearest neighbor: a multiscalar approach**

Can an agent evaluate several neighborhoods? Assume a much more realistic and complex model, if an agent has the choice to move into a municipality that fulfills his or her preferences but the only vacant housing unit is one in which the agent will find themselves as an extreme minority. Will the agent move
into the housing unit because he or she is satisfied with the municipality? Or will the agent not move into the housing unit because he or she is dissatisfied with the municipality? The more general question is, can we model the rules so that agents evaluate different scales of neighborhood?

With the traditional definition of neighborhoods as borders (Census tracts/SAMS), an implicit assumption is that an agent’s next door neighbor and the furthest neighbor from him or her are both as important to the agent when he or she evaluates a neighborhood (Wong, 2016, p.80). However, it is not unreasonable to assume, as Clark and Coulter (2015, p.1262) do, that agents “consider residential context at different geographical scales when they evaluate a certain location.” An agent may ask themselves, “am I satisfied with the ethnic mix in this apartment building?”, as well as “am I satisfied with the ethnic mix in this municipality?” The one does not exclude the other, and there is no reason we should have to choose between the two.

A multiscalar approach of measuring neighborhoods does just that. By using population instead of radius, this approach overcomes the problems of MAUP discussed above. This approach assigns each agent bespoke neighborhoods with several population scales where they are the mid-point and each scale encompasses the \( k \)-nearest neighbors to the agent. These populations are e.g. 12, 25, 50, 100, up to 12 800 nearest neighbors\(^{13}\). One way of thinking about the different scales in the multiscalar approach is that each population scale corresponds to the following (Moberg et al., 2014, p.15):

<table>
<thead>
<tr>
<th>( K )-nearest neighbor</th>
<th>Corresponds to</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Shares staircase with you</td>
</tr>
<tr>
<td>25</td>
<td>Lives in the same apartment building</td>
</tr>
<tr>
<td>50</td>
<td>Shares washing room, bike storage room and garbage room with you</td>
</tr>
<tr>
<td>100</td>
<td>Lives in the same block</td>
</tr>
<tr>
<td>200</td>
<td>Shares the same bus stop</td>
</tr>
<tr>
<td>400</td>
<td>Familiar with the physical surrounding, knows all the neighbors</td>
</tr>
<tr>
<td>800</td>
<td>Shares football field and parks, dog-owners greet each other</td>
</tr>
<tr>
<td>1 600</td>
<td>Local grocery store that serves the area</td>
</tr>
<tr>
<td>3 200</td>
<td>Kindergarten and primary school</td>
</tr>
<tr>
<td>6 400</td>
<td>District square and dentist</td>
</tr>
<tr>
<td>12 800</td>
<td>Highschool, marketplace, sports center, associations and religious communities</td>
</tr>
</tbody>
</table>

\(^{13}\) Östh, Malmberg & Andersson (2015) use bespoke neighborhoods sized 13 to 1 600, while (Clark et al., 2015) use 100, 6 400, 51 200 and 409 600.

Table 1: an adaptation of Table 1 in the report “Segregation I Stockholmsregionen” by Regionala utvecklingsplanering för Stockholmsregionen; Moberg et al. (2014, p.15)
In their application of the multiscalar approach, Clark et al. (2015) coined the term “dynamic diversity” to illustrate that for any given agent there may be some scales of neighborhood which are more segregated (or integrated) than others. This implies that this method of measuring neighborhoods allows for heterogeneous effects of different neighborhood sizes. Knowing that choice of neighborhood scale affects outcome, one should be particularly critical of studies that poorly motivate their choice of neighborhood scale. This adds a layer of complexity to the analysis of segregation in urban areas, but also stays truer to the spirit of the Schelling model than using borders or radius.

Another useful property of the multiscalar approach is that it allows for results comparable across countries, “independent of administratively defined areal units” (Östh, Clark and Malmberg, 2015, p.35) The use of the multiscalar approach has yielded interesting studies both when used with simulated data (Laurie and Jaggi, 2003, p.2691) and using actual data (Clark et al., 2015; Hennerdal and Nielsen, 2017; Lee et al., 2008, p.768; Sampson, 2012).\(^\text{14}\)

Despite the strengths of multiscalar approach, it does not take into consideration physical obstacles such as roads and rivers that might hinder contact. “Residential areas” Bråmå (2006, p.36) claims, “also often function as formal or informal organizational units for different forms of services, e.g. schools and commercial services, and will thus influence people’s activity patterns, service utilization and consumption” and thus advocates the use of measures of neighborhoods based on borders (such as SAMS).

Another weakness of the multiscalar approach is that it is computationally demanding. With a dozen of years, a few thousand individuals and a handful of bespoke neighborhoods, the sum of the number of alternative destinations each individual evaluates can quickly reach several million. This computational problem does however have a solution. One can obtain consistent estimates with a slight modification to the discrete choice model (in the Spatial Proximity framework) by subsampling the alternatives each individual faces. (Mare and Bruch, 2003, pp.13–14; Hedström, 2015, p.30)

While using the \(k\)-nearest neighbor solves the MAUP issues discussed above, it is important to keep in mind that the reference area (e.g. in calculating the Index of Dissimilarity) does not need to be constructed with a \(k\)-nearest neighbor approach. A well-motivated reference area, depending on the research question, may be much more relevant to the study at hand than computing \(k\)-nearest neighbor by \(k\)-nearest neighbor. (Hennerdal and Nielsen, 2017, p.559)

**Data on preferences**

The agents’ preferences and constraints are not always known to the analyst. As a theorist, Schelling used simulated models to infer outcomes based on programmed preferences and constraints. Empiricists, however, would like to find empirical data on preferences and constraints. There are primarily two types of data used in the empirical applications of the Schelling model. The first is data on individuals’ stated preferences, usually in the form of survey data. The other is data on individuals’ actual moves, usually in the form of cross-sectional data, panel data or surveys. What are the strengths and weaknesses of respective type of data?

\(^{14}\) For a practical guide on the use of multiscalar neighborhoods with empirical data, see Östh’s (2014) introduction of the software EquiPop.
In the stated preferences approach, individuals are presented with alternative (fictional) vignettes of neighborhoods, with varying shares of in-group members and out-group members \((all \ else \ equal\)). For example, one neighborhood vignette may show that the neighborhood is comprised of \(\frac{3}{8}\) in-group members. Individuals are then asked to rank the different alternatives in terms of how attractive each neighborhood is to them. An example of this is illustrated in Figure 10 below, where black respondents were asked about white neighbors (Bruch and Mare, 2012, p.107).

![Figure 10: an illustration of vignettes shown to survey respondents (Bruch and Mare, 2012, p.107)](image)

This set-up allows the analyst to be in control of all other hypothetical neighborhood characteristics (in theory) as well as allowing the analyst to specify uncommon types of neighborhoods that would otherwise demand a very large sample of actual moves in order to analyze. Providing a relative ranking of neighborhoods allows the analyst to examine own-group preferences with descriptive statistics, OLS regressions and other categorical response models.

However, there are some set-backs to the stated preferences approach. When ranking the relative attractiveness of alternative neighborhoods, although not explicitly presented with any other information than group-shares, the analyst cannot know for sure whether individuals provide answers based solely on their group preferences or whether individuals’ answers have accounted for neighborhood characteristics stereotypically associated with immigrants or natives (such as schooling quality, income levels and neighborhood safety). Depending on the exact research question, this could be problematic. The analyst, doing their best to get all responders to understand the vignettes in the same way, it may still be the case that individuals interpret the vignettes differently. Related to this, individuals may provide answers that are socially desirable and not a true reflection of their actual preferences. (Bruch and Mare, 2012, pp.108, 112)

The actual moves approach has its pro’s and con’s as well. On the one hand, it allows the analyst to incorporate other rich individual- and neighborhood-level data. Actual moves are made in the desired setting, real life, as opposed to stating one’s preferences in a survey. Data on actual moves is a manifestation of individuals’ “best” (or highest) ranked neighborhood destination (subject to constraints such as income, housing unit vacancy, school quality and less tangible preferences). This allows the analyst to examine the choice of destination conditional on individual and neighborhood characteristics.

\[\text{Figure 10: an illustration of vignettes shown to survey respondents (Bruch and Mare, 2012, p.107)}\]

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15 The vignettes may be presented stylistically as a checkerboard with nine blocks where the individual is told that they occupy the middle block and that their neighborhood is comprised of the surrounding eight blocks. These eight blocks are then filled with varying degrees of in- and out-group neighbors, as in Figure 10. But the vignettes may also be presented as pictures, videos or a short text.

16 This (non-)problem is analogous to arguing which omitted variables to control for and which not to. If certain individuals have own-group preferences because of confounding factors stereotypically associated with the out-group, should one control for the confounding factors?
This also allows the analyst to examine outcomes such as the decision to move ("native flight") using logit models, demographic or the ethnic composition of neighborhoods using multinomial logit models.

On the other hand, as mentioned earlier, actual moves are a manifestation of both revealed preferences and constraints. For any given individual, it is difficult to know which of these two components weighed the most in the actual residential mobility decision. In order to cover most (or many different) types of neighborhoods, using data on actual moves requires a very large sample. (Bruch and Mare, 2012, pp.109, 112)

Despite the drawbacks of using actual moves as a proxy for preferences, considering the fact that the analyst is able to control for several individual as well as neighborhood specific confounders (that perhaps are correlated to constraints, such as income and school quality), it seems to have a slight upper hand over stated preferences.

Irrespective of type of data, Bruch and Mare (2012) suggest using a discrete choice model as a way to formally model the agents rules of assessing the attractiveness of neighborhoods and deciding when and where to move.

**Empirical Studies**

Following is a short summarizing overview of a few empirical studies, one based on the Spatial Proximity model and two studies based on the Bounded Neighborhood model.

**Paper 1: Spatial Proximity Simulations**

Banos (2012) uses simulations to study how network shapes and cliques affect the dynamics of the spatial proximity model. The author uses four types of networks of which the first is the **regular** (grid) network originally used by Schelling, the second is a **random** network, the third is a **scale free** network and lastly, a **fractal** (Sierpinski tree) network. These networks are illustrated in Figure 11 below. By simulations, the author rather beautifully illustrates that irrespective of type of network, the results of the Spatial Proximity model hold. Besides the interesting visual outcome, Banos reaches two conclusions: i) network shapes may accelerate and reinforce the dynamics of the model and ii) segregation arises quicker in hierarchized networks (such as the fractal network) characterized by cliques (i.e. gated communities). 17

![Figure 11: an illustration of different network types and the outcome of simulations based on the Spatial Proximity model, as seen in Banos (2012, p.397). From left to right, the networks are i) Regular (grid), ii) Random, iii) Scale free and iv) Fractal (Sierpinski tree). Red and Green represent the two groups in society while White is vacant areas.](image)

17 As a side note, Banos (2012, p.404) also reaches the conclusion that "fatalism should be banned and laissez-faire should be fought: public policy and urban planning have their role to play. Limiting undesirable self-enforcement process may be possible and should be part of any ambitious urban politics."
Banos (2012, p.396) also illustrates the average levels of so-called ‘mixity’ (where low mixity = high segregation), that arise with different tolerance levels using each of the four network shapes respectively, from 1000 simulations. This is illustrated in Figure 12 below.

![Figure 12: an illustration of average levels of 'mixity' (i.e. integration or inverse segregation) arising from different tolerance levels in the four network models shown in Figure 11 above; as seen in Banos (2012, p.396).](image)

As discussed in the section about the Paradox of Weak Minority Preferences, simulations confirm the somewhat counter-intuitive fact that the least tolerant individuals (in the Spatial Proximity model) could sustain a rather integrated neighborhood (because they will continue to move until they are satisfied, but alas, will never become satisfied). The most tolerant individuals will also produce a rather integrated neighborhood, as they are satisfied with the initial (random) distribution and do not wish to move. Tolerance levels of approximately 30%-70% (i.e. an agent is satisfied so long as the other group’s share of the neighborhood population does not exceed 30%-70%) produce quite segregated outcomes.

Two interesting results to take away from this article is that the conclusions of the Spatial Proximity model are rather robust to changes in network shapes and the second is that if segregation arises quicker in networks with cliques (i.e. gated communities), then perhaps extra attention is to be given to such real life gated communities when doing other empirical work. This is perhaps more relevant in a U.S. context than a European context, but it is nonetheless worth keeping in mind.

**Paper 2: Bounded Neighborhood**

Aldén, Hammarstedt and Neuman (2015) use data of actual moves to examine where the tipping points are, what the effect of passing the tipping point is on the growth rate of neighborhoods' native population, whether the effect is driven by native flight or avoidance, and the correlation between fleeing and socioeconomic status (measured in income & education).

They attempt to identify tipping points using a method developed by Card, Mas and Rothstein (2008). The method goes as follows. First, using 2/3rd of the sample, test tipping points between 1% and 60% in the following regression:
\[ d_{i,c,t} = \alpha_c + dc1[m_{i,c,t-1} > m_{c,t-1}^*] + \varepsilon_{i,c,t} \]  

\( (1) \)

Where \( d_{i,c,t} \) is the native populations growth rate in neighborhood \( i \), municipality \( c \) in time \( t \), \( m_{i,c,t-1} \) is the base year immigrant share, \( m_{c,t-1}^* \) is the municipality specific tipping point to be tested and \( \varepsilon_{i,c,t} \) is an error term. They define a tipping point as the value of \( m_{c,t-1}^* \) that yields the highest value of \( R^2 \), given that the neighborhood growth in native population changes discontinuously. (Card, Mas and Rothstein, 2008, p.49)

Secondly, with the remaining 1/3rd of the sample, estimate the following RDD regression (i.e. a regression discontinuity design):

\[ d_{i,c,t} = \alpha_c + dc1[m_{i,c,t-1} > m_{c,t-1}^*] + h[m_{i,c,t-1} - m_{c,t-1}^*] + \mu_c + \gamma_i + \varepsilon_{i,c,t} \]  

\( (2) \)

Where \( dc1 \) is the ‘effect’ on native growth rate in the neighborhood when the share of immigrants exceeds the tipping point, \( \mu_c \) is municipality fixed effects, \( \gamma_i \) is individual level fixed effects and \( \varepsilon_{i,c,t} \) is an error term.

They identify tipping points between 3.2% - 4.1% for non-Europeans and 9.5%-9.8% for Europeans. When the non-European immigrant share in the neighborhood exceeds the municipality specific tipping point, there is a statistically significant effect on native population growth rate with -6.5% (for the years 1990-2000) and -4.5% (for the years 2000-2007). Two conclusions could be drawn from this. Firstly, tipping points for European and non-European immigrants have risen from the time period 1990-2000 to 2000-2007. Secondly, the “negative” effects on the native population growth has decreased from the time period 1990-2000 to 2000-2007. The authors interpret this result as possibly due to natives being more tolerant toward immigrants (both European and non-European) over time (Aldén, Hammarstedt and Neuman, 2015, p.54).

The authors show that the effects are driven by native flight not avoidance. Individuals with higher incomes and education are more prone to flight once tipping point is passed.

**Paper 3: Bounded Neighborhood**

Clark (1991) uses stated preferences data from telephone surveys conducted in Omaha, Kansas City, Milwaukee, Cincinnati and LA to examine the effect of own race preferences on segregation.

The author sets the assumptions just as in the Bounded Neighborhood model. Concretely, the author assume that preferences are unidirectional (reaches tipping point), that there are no minority-seeking individuals and that there is perfect information. The author tries to infer “blacks” and “whites” tolerance schedules in the five cities mentioned above, and using that to construct the parabolas used by Schelling to analyze the effect of own-race preferences on segregation.
Overall, whites seem to prefer neighborhoods with at least 80% whites (or at most 20% blacks) while blacks prefer neighborhoods with at least 50% blacks (ibid., 1991, p.9). These preferences are of course not compatible (a neighborhood cannot at once have both an 80/20 and 50/50 distribution). For example, taking the responses from Cincinnati, these preferences can be illustrated as in Figure 13 to the right. Quite noticeable is a peak in the percent of black respondents around preferring neighborhoods of 50/50, and white respondents having slightly lower tolerance levels.

Clark (1991, p.17) finds that the empirical parabolas are similar to the theoretical but are less regular and more rectangular. There are small areas of overlap (where both groups are satisfied). The differences in preferences are greater than Schelling posited.

As an example, Figure 14 to the right illustrates the empirical parabola for Cincinnati (Clark, 1991, p.14). Black preferences are bimodal, almost Z-shaped. This is mainly due to a small number of blacks that are extremely tolerant (this is seen in several other cities besides Cincinnati). It is also clear here that the area of overlap where both blacks and whites are satisfied is rather small, keeping in mind that the x-axis is chopped at around 130 in order to facilitate analyzing the model visually.

Clark (1991, p.17) draws an interesting conclusion from this empirical study. Due to the small areas of overlap, i.e. the big gap in preferences between blacks and whites, “the likelihood of [integrated] equilibria is small, if it exists at all”. This conclusion makes sense. As we’ve seen earlier, one of Schelling’s extensions in the Bounded Neighborhood model was to have an equal number of blacks and whites, as well as steeper tolerance schedules. This extension, seen in Figure 4 on page 6, creates a very large area where both parabolas overlap. In that scenario, an integrated society was also a stable equilibrium. In accordance with Schelling, Clark also argues that the two stable equilibria are the ones where there are only whites and no blacks, and only blacks and no whites.

**Criticism**

At the heart of agent-based modelling are individuals’ preferences. However, as discussed in the introduction, there are other explanatory factors for the arising and persistence of residential segregation aside from ethnic preferences.

An alternative explanation is that segregation arises due to **restrictions rather than preferences**. Around the same time that Schelling published his work on the models of segregation, researchers Rex and Moore (1967) and Pahl (1975) introduced the ‘managerialist’ approach to the study of segregation.
This approach claims that segregation arises and persists because there are ‘gate keepers’ or ‘urban managers’ that purposefully keep certain groups away from majority areas. This approach claims that certain actors such as banks, credit institutions, real estate firms and others may actively deny visible minorities access to the host society (e.g. immigrants not receiving the same care at open houses as natives). Another, closely related, perspective claims that segregation arises and persists mainly due to structural (‘institutional’) discrimination, rather than due to individual preferences or to the work of separate individuals, organisations and institutions. According to this perspective, structural discrimination exists to preserve and reproduce social and material inequality between different ethnic or racial groups in society.  

(Bråmå, 2006, pp.15–21)

There are also alternative ways of modelling the effect of individual preferences on segregation. For example, moving from micromodels to macromodels, one could use general equilibrium (GE) models or integrated Markov models.

However, as mentioned earlier, there is not one example that goes against Schelling’s main conclusions. Schelling’s models do exactly what models are supposed to do. They are concerned with an important issue, have striking results and are easy to understand and experiment with. (Zhang, 2011, p. 170)

Conclusion

This review set out to outline how individual preferences can lead to segregation, even in the absence of discriminatory policy and other constraints. From Schelling’s Spatial Proximity model came the theoretical conclusion that moderate preferences for own-group neighbors may lead to complete segregation between the two groups (this is also known as the Paradox of Weak Minority Preferences). From Schelling’s Bounded Neighborhood model came the theoretical conclusion that the stable equilibrium reached ultimately depends on the initial distribution of agents and their relative speeds of movement, because in the unstable integrated equilibrium an apparently insignificant event could set in motion an irreversible process toward segregation simply by tipping the distribution one way or another (the point in the model where this takes place is also known as the Tipping Point). The models are not identical, they have their differences but both models highlight how well-intentioned individual preferences may result in undesirable aggregate outcomes. The models also highlight the importance of analysing residential segregation in dynamic, not static, models. When applying the models empirically, a researcher must carefully weigh the pros and cons of different measurements of segregation (qualitative and quantitative), and motivate their definition of ethnicity as well as how they define neighborhoods (choosing between borders, fixed radius or the k-nearest neighbor approach). In choosing data, on the one hand, survey data (stated preferences) may not entirely reflect actual preferences but allows the researcher flexibility in defining neighborhoods exactly as they wish. On the other hand, actual moves data reflects both preferences and constraints faced by individuals which is not entirely desirable. Previous studies using simulations, stated preferences and actual moves have attempted to answer how individual preferences can lead to segregation. They have done so by posing questions such as: at what tolerance levels does segregation arise? Is segregation driven by a flight or avoidance mechanism? And what equilibrium can we expect neighborhoods to reach given its residents stated preferences? Finally, we also saw that not everyone agrees that preferences are necessary to study, but that other factors such as structural discrimination is the main explanation for why segregation arises and persists.

For an excellent and concise overview of the alternative theoretical frameworks as well as the Swedish history of research in segregation in urban areas, see Bråmå (2006)
In conclusion, because micromotives do not equal macrobehavior, even in the absence of discriminatory policy and racism, segregation may arise. Whether or not segregation is problematic is a topic for another time. If segregation is an undesirable outcome, good intentions and some tolerance toward others are not enough to prevent the self-segregation mechanism.
Bibliography


