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Summary. A variety of segregation measures have been proposed in the literature with the dissimilarity index and its variants being the most widely applied. While these measures provide a quick means of comparing segregation patterns across space and time, they are not linked to the processes that generate and maintain segregative patterns. This paper proposes a new method for measuring segregation. The method is based on comparative evaluations of neighbourhood characteristics as a determinant of spatial behaviour in cities. The proposed approach moves away from a purely geometric interpretation of segregation by anchoring the measurement of segregation into the actual urban setting. The method's main advantages are its responsiveness to changes in urban characteristics (e.g. spatial variations in rent increases), and changes in preference structures (e.g. a declining importance of distance as an impediment to relocation). A numerical example is used to demonstrate the behaviour of the proposed method against traditional segregation measures. The results indicate that the segregation experiences of minorities may be more severe than previously thought.

1. Introduction

Residential relocation is the behavioural mechanism altering racial and ethnic segregation in urban areas. Thus the forces contributing to segregation—i.e. racial differences in preferences, economic disparities between racial groups, information biases and discriminatory constraints on access to housing (Galster, 1987; Clark, 1986, 1989 and 1991), affect relocation behaviour and consequently the observed segregation pattern. Although recent research (Huff and Waldorf, 1988; Waldorf, 1990) has emphasised these linkages, they have not been utilised to improve the measurement of segregation.

The measurement of segregation is a central theme of segregation research. Over the years, a variety of segregation measures have been proposed (Elgie, 1979; Jakubs, 1979; Lieberson, 1981; Thomas, 1981; Morgan, 1983a; White, 1983) with the dissimilarity index (Duncan and Duncan, 1955) and its variants being the most widely applied. Yet, the lack of a theoretical basis for these methods continues to be a topic of concern. The resulting dissatisfaction is evidenced by recent attempts to utilise several measures to describe the segregration experience of minorities (Massey and Denton, 1989) and by continued efforts to modify and improve existing measures (for example, Morrill, 1991). Interestingly, these methodological advancements pay most attention to the geometric and topological characteristics of segregation

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patterns, while ties to segregation forces and processes and the urban context are not sufficiently explored.

This paper proposes to redirect attention towards the processes and forces operating in a specific urban context by developing a relocation-based segregation index as a new method to measure segregation. On a formal level, the method is an extension of the distance-based segregation index (Jakubs, 1981; Morgan, 1983b). On a theoretical level, the method is innovative in that it is based on behavioural processes leading to segregation and the characteristics of the urban area in which segregation takes place. Thus, the proposed method links two major areas of segregation research: (a) research that deals with the description and measurement of segregative patterns, and (b) research that deals with modelling segregation processes. Moreover, with its emphasis on the specific metropolitan context and urban transformation, the paper links directly to research on the urban underclass (Wilson, 1987; Hughes, 1989). As such, the approach clearly moves away from a purely geometric and topological interpretation of segregated patterns.

The paper is organised into five sections. Following this introduction, the second section provides a critical discussion of two segregation measures that form the basis of this study: the traditional dissimilarity index and its distance-based derivative. In the third section, the relocation-based method of measuring segregation is developed. The fourth section provides a series of simulations in which the performance of the new method is compared with those of traditional segregation indices. The paper concludes with a critical discussion of the relocation-based segregation index and future research directions.

2. Measures of Segregation

Dissimilarity Index

Among the variety of segregation measures, the dissimilarity index developed by Duncan and Duncan (1955) has received the most attention. It compares the distributions of two population groups over discrete spatial units of an urban area. The dissimilarity index may be formulated as:

$$DI = \frac{\sum_{k=1}^{n} T_k \, |p_k - p|}{2T\, p\,(1-p)}$$

where T is the total population size in city; T_k the total population size in unit k; p the proportion of minority in city; and p_k the proportion of minority in unit k.

In this formulation, the numerator expresses the number of relocations necessary to transform the observed distributions of minority and majority into uniform distributions. A uniform distribution is achieved if each spatial unit k has the same proportion of minority residents as the city as a whole—i.e. $p_k = p$ for all k. The denominator refers to the hypothetical case of complete segregation that is $p_k = 0$ or $p_k = 1$ for all k. Hence, it expresses the number of relocations necessary to transform a distribution of complete segregation into a uniform distribution. Based on this interpretation, the dissimilarity index is referred to as a "ratio of efforts to achieve desegregation" (Jakubs, 1981; Morgan, 1983b). The ratio approaches 1 if the observed distribution represents a totally segregated pattern. The ratio is close to 0 if the observed distribution resembles a uniform distribution.

Discussion. The index of dissimilarity is attractive because it has minimal data requirements, is easy to calculate and has clearly defined upper and lower boundaries. However, the literature has repeatedly alluded to several weaknesses of the dissimilarity index such as its reliance on the uniform rather than Poisson distribution to characterise the absence of segregation (Winship, 1977; Falk *et al.*, 1978; Kestenbaum, 1980); its reliance on proportions rather than absolute population sizes (Peach, 1981; Lieberson, 1981); and its insensitivity to the exchange principle (Winship, 1979). From a

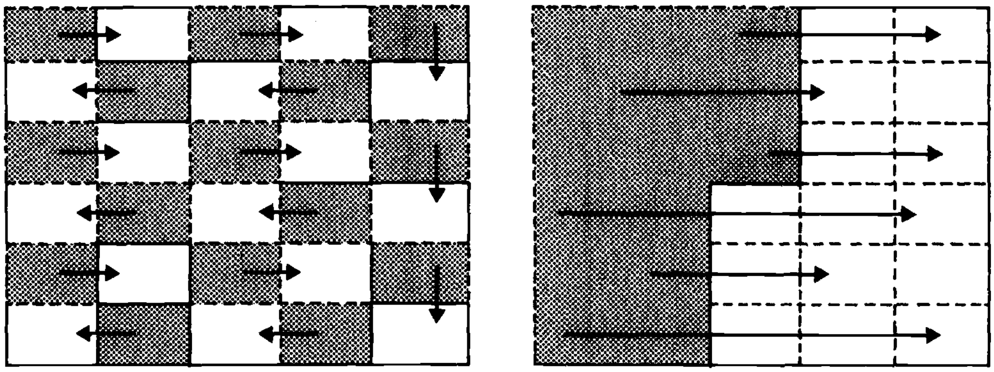

Figure 1. Relocation schemes for a segregated pattern: with a low degree of clustering (left); and with a high degree of clustering (right).

geographers' point of view, the most disturbing shortcoming of the dissimilarity index is its insensitivity to the arrangement of spatial units. A chequer-board pattern of high and low minority proportions (negative spatial autocorrelation) yields the same value for the dissimilarity index as a clustered pattern (positive spatial autocorrelation).

Distance-based Dissimilarity Index

In response to the criticism of the dissimilarity index as an aspatial measure, Jakubs (1981) and Morgan (1983b) developed a distance-based index of segregation. While they maintain the formal structure as a ratio of efforts, they incorporate a distance function so as to differentiate segregative patterns with varying degrees of spatial clustering. Using the distance function, the desegregation effort is expressed as total relocation distance as opposed to the number of relocations. More formally, the distance-based segregation index, DBDI, takes on the form:

$$DBDI = \frac{\min D_{obs}}{min\ D_{ext}}$$

where min D_{obs} is the minimised total relocation distance necessary to transform the observed distribution into a uniform distribution, and min D_{ext} is the minimised total relocation distance necesary to transform the extreme of a completely segregated pattern into a uniform distribution.

Two observations are noteworthy. First relocation distances tend to be small for a segregative pattern with a low degree of clustering (Figure 1). Consequently, the numerator in the distance-based segregation index will indicate a small desegregation effort. In contrast, long-distance relocations are typical for segregative patterns with positive spatial autocorrelation (Figure 1), yielding a greater desegregation effort than in the case of negative spatial autocorrelation.

Secondly, the definition of the extreme case—i.e. complete segregation—is an important issue if relocation distances rather than the number of relocations are used to measure segregation. For example, min D_{ext} will be smaller if the minority is clustered in and around the city centre as opposed to the periphery (Figure 2).

The minimised total relocation distances in the numerator and the denominator are the solutions of a linear programming problem of the following form. The spatial units are categorised as either sending or receiving units. Sending units have a higher than expected minority proportion while receiving units have a lower than expected minority proportion as compared to the city wide proportion, p. Thus:

$p_i > p$ *for all* $i = 1, \ldots, s$ sending units.
$p_j < p$ for all $j = 1, \ldots, r$ receiving units.

The number of minority members that have

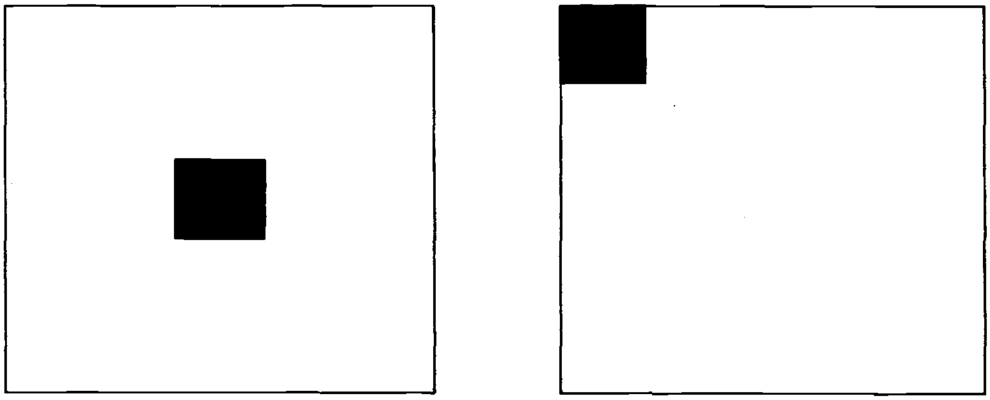

Figure 2. Definition of complete segregation: central location (left); and peripheral location (right).

to be relocated from the sending unit i is:

$$S_i = T_i(p_i - p).$$

The number of minority members that have to move into receiving unit j is:

$$R_j = T_j(p - p_j).$$

Thus, the objective function takes on the form:

$$\min \sum_{i=1}^{s} \sum_{j=1}^{r} X_{ij}\, d_j$$

where X_{ij} is the number of people relocating from i to j, and d_{ij} is the distance between i and j.

The minimisation is subject to the following constraints:

$$\sum_{j=1}^{r} X_{ij} = S_i \ \forall i = 1, \ldots, s$$

$$\sum_{i=1}^{s} X_{ij} = R_j \ \forall j = 1, \ldots, r$$

$$\sum_{i=1}^{s} S_i = \sum_{j=1}^{r} R_j$$

Discussion. Incorporating a distance function into the dissimilarity index is a significant improvement over the original formulation by Duncan and Duncan (1955). The distance-based index not only measures the unevenness of two spatial distributions but responds also to the degree of clustering. From a descriptive point of view, the distance-based index is therefore much more desirable than the dissimilarity index.

From a theoretical point of view, however, the distance-based index reveals several shortcomings. First, the effect of distance is assumed to be a simple linear function. This assumption, however, is in contrast to our understanding of distance as impediment to spatial interaction. Distance-decay effects of interaction are commonly expressed as exponential or second-order functions (Fotheringham and O'Kelly, 1989). Thus, we expect a non-linear relationship between the moving distance and relocation effort.

Secondly, the distance-based index assumes that distance between a sending and a receiving unit is the only attribute that defines the ease of relocation. Other characteristics, such as housing price and quality differences, are not considered. This simplification implies that the distance-based index is insensitive to the specific urban context in which segregation takes place. It is also insensitive to changes in urban structure such as urban renewal or the deindustrialisation of the central city.

Thirdly, desegregation efforts via relocations are described without accounting for group-specific biases in relocation behaviour. The relocation scheme derived from the distance-based index is such that the effort to relocate a minority member from i to j equals the effort to relocate a majority member from j to i. However, if population groups have dissimilar distance-decay functions then relocation efforts might differ significantly.

In the following section, a new method of measuring segregation is developed that allows for non-linear distance-decay effects, housing price differentials and other attributes that influence relocation behaviour, and group-specific biases in the relocation process.

3. A Relocation-based Segregation Index

The relocation-based segregation index retains the notion of expressing the degree of segregation as a ratio of relocation efforts needed to obtain a desegregated distribution. However, unlike the traditional formulation and subsequent distance-based modifications, the specification of the index is closely tied to our knowledge of segregation and relocation behaviour in urban space. The derivation will proceed in two steps. In the first step, the effort associated with a relocation will be specified. Secondly, this effort function will be used to define the relocation-based segregation index and the optimal desegregation scheme.

Relocation Effort

The traditional dissimilarity index considers relocation effort as a binary variable. Effort is either present (= 1) if a relocation takes place, or absent (= 0) if a relocation does not take place. Thus, if there are n relocations then the aggregate efforts equals n as well. For the distance-based dissimilarity index, relocation effort is equated with relocation distance. Thus, if there are n relocations from i to j then the aggregate relocation effort equals n times the distance between i and j.

In this paper, relocation effort is specified indirectly via the observed number of relocations. A small number of households moving from i to j is indicative of obstacles to re-location, and hence signals substantial adjustment and relocation efforts. On the other hand, a large number of relocations between i and j manifests the desirability of the destination, the lack of obstacles and, consequently, little relocation effort.

Formally, let M_{ij} be the number of moves from i to j, and E_{ij} the effort associated with a relocation from i to j. Then the inverse relationship may be expressed as:

$$E_{ij} \sim \frac{1}{M_{ij}}$$

Now assume that the number of relocations from i to j is specified in a multiplicative model[1] of the form:

$$M_{ij} = \alpha \prod_{k=1}^{K} A_{ijk}^{\beta_k}$$

where α and $(\beta_k)_{k=1,\ldots,K}$ are parameters and A_{ijk} is the k-th variable describing the origin-destination pair i, j.

Combining the two equations above yields the formal specification of the relocation efforts as:

$$E_{ij} \sim \alpha^{-1} \prod_{k=1}^{K} A_{ijk}^{-\beta_k}$$

The above specified effort function is simple in structure and easy to handle from an operational point of view. In particular, the parameters can be obtained via OLS estimation of the linearised relocation model. The most crucial aspect for the specification of the effort function is the selection of co-variates. Research on intra-urban mobility (Waldorf, 1990) suggests that the co-variates should reflect the comparative evaluation of neighbourhood and housing attributes in origin and destination neighbourhoods. Thus, differentials in price, quality, density and access to employment are salient co-variates. In addition, research on segregation alludes to the importance of variables measuring racial/ethnic composition (Schelling, 1971; Clark, 1991), discriminatory access constraints (Darden, 1987) and information biases (Huff and Waldorf, 1988).

To assess differences between minority and majority households, relocation efforts should be estimated separately for each racial/ethnic group. Differences, if they exist, will be manifested in the parameters α and β_k. For example, assume that the proportion of black residents is included in the set of salient co-variates. If whites avoid black neighbourhoods then the associated parameter will be negative. In contrast, if blacks have a tendency towards self-segregation then the parameter will be positive.

Relocation-based segregation index and desegregation scheme. With the above definitions, the relocation-based dissimilarity index is specified as a ratio of aggregate efforts. The numerator is the minimised total relocation effort necessary to transform the observed pattern into a desegregated pattern. The denominator expresses the aggregate relocation-effort associated with transforming a totally segregated pattern into a desegregated distribution.

Let E_{ij} and e_{ij} be the efforts of relocating from i to j for majority and minority households, respectively. Then the relocation-based indices for minority and majority population are specified as:

$$RDI_{minority} = \frac{\min \sum_{i=1}^{s} \sum_{j=1}^{r} x_{ij}\, e_{ij}}{\min \sum_{i=1}^{s'} \sum_{j=1}^{r'} y_{ij}\, e_{ij}}$$

$$RDI_{majority} = \frac{\min \sum_{j=1}^{r} \sum_{i=1}^{s} X_{ji}\, E_{ji}}{\min \sum_{j=1}^{r'} \sum_{i=1}^{s'} Y_{ji}\, E_{ji}}$$

where x_{ij} expresses the number of minority households moving from a sending neighbourhood i to a receiving neighbourhood j. Sending and receiving units are defined with respect to the minority population. X_{ji} is the number of majority households moving from j to i. Similarly, Y_{ji} and y_{ij} are defined as the number of majority and minority households relocating between i and j to transform the totally segregated pattern into a desegregated distribution.

The desegregation schemes X_{ij}, x_{ij}, Y_{ij} and y_{ij} that minimise total efforts are the solutions to linear optimisation problems subject to the same type of constraints specified for the distance-based dissimilarity index. Unlike for the distance-based index, however, the optimal relocation schemes for minority and majority may not be complementary. That is, the number of minority households moving from i to j, x_{ij}, may not equal the number of majority households moving from j to i, X_{ji}.

By design, the relocation-based dissimilarity index takes on values between 0 and 1. The index is close to 1 for a highly segregated pattern. In contrast, a value of 0 indicates complete desegregation. The separately specified indices for minority and majority can be combined in a composite measure that takes the respective population proportions into account:

$$RDI_{composite} = (1 - p)\, RDI_{majority} + p\, RDI_{minority}$$

Thus, $RDI_{composite}$ is the weighted ratio of efforts experienced when translating the observed distribution of the two population groups into a desegregated distribution.

Discussion. The formal structure of the relocation-based index is similar to that of the distance-based index. However, the relocation-based index is strongly preferred from a theoretical point of view for several reasons.

First, the relocation-based index is anchored in a theoretical model of intra-urban relocation, the prime behavioural mechanism generating and maintaining patterns of spatial segregation. The relocation model connects a set of salient variables with observed behaviour and indirectly with relocation efforts. The choice of co-variates is driven by our understanding of spatial mobility and segregation. Thus, since segregagation is most often attributed to four principal forces —income, information, preference and discrimination—the measurement of relocation effort should take into account variables referring to housing prices, relocation distance, racial/ethnic composition and discriminatory access constraints. Prices respond to the consistently low economic power and housing consumption of minorities which prevent minority households from choosing more expensive housing. The relocation distance captures information biases due to constrained communication and interaction networks. The racial composition picks up voluntary self-segregation most likely in the form of white flight and avoidance. Finally, discriminatory access constraints in the housing market are the most direct form of dis- crimination leading to residential segregation.

Secondly, the relocation-based index allows to account explicitly for racial/ethnic differences in the evaluation of neighbourhoods. These differences will be documented in the parameters of the relocation function. For example, if white households consistently avoid moving into predominantly black neighbourhoods, then the parameter associated with a measure of neighbourhood composition will reflect whites' preference for white neighbourhoods.

Thirdly, since the definition of relocation efforts takes neighbourhood attributes into account, changes in these characteristics will affect the relocation effort and consequently the degree of segregation. For example, if housing prices increase disproportionately in predominantly white neighbourhoods then the effort to relocate a minority household into a white neighbourhood will rise as well. These shifts in relocation efforts due to changes in housing prices will influence the relocation-based index even if the observed distribution of the minority population remains constant. This explicit consideration of neighbourhood attributes allows to trace the impact of the transformation of inner cities and the creation of impacted ghettos (Hughes, 1989) on the segregation experience of minorities. In this case, the effort function should include indicators of neighbourhood deprivation as, for example, proposed by Hughes (1989, 1990). Thus, the measurement of segregation via the relocation-based index is not simply a function of the spatial distribution of minorities across neighbourhoods *per se*, but also a function of neighbourhood characteristics, urban structure and metropolitan change. Note that neither the distance-based nor the traditional dissimilarity index will reflect changes in segregation experience due to metropolitan transformations.

Fourthly, the relocation-based index enables assessment of the impacts on desegregation efforts due to changes in the relative importance of segregative forces. For example, an enhanced preference for suburban locations will be reflected in a changing parameter β_k and consequently will affect the relocation efforts. Similarly, as the relative strength of segregative forces such as avoidance of minority-dominated neighbourhoods is altered the corresponding parameter on a neighbourhood composition variable will be modified. Thus, the relocation-based index not only accounts for the geometry of the spatial distribution but also the relative importance of segregative forces.

Fifthly, since separate parameter vectors are used for minority and majority populations it is possible to capture the asymmetry in relocation efforts. An effort-minimising relocation scheme derived for the minority may well be suboptimal for the majority population. Thus, simple locational exchanges between minority and majority households may not be adequate to measure the desegregation effort. The relocation-based index allows for more complicated relocation schemes where a vacancy created by a minority moving to neighbourhood j is not necessarily filled by a majority household originating in neighbourhood j.

Finally, it should be mentioned that the quality of the relocation-based dissimilarity index depends by and large on the degree to which the relocation model responds to the prime causes of segregation.

4. A Numerical Example

In this section, the behaviour of the relocation-based dissimilarity index and its advantages over the traditional formulations are discussed in the context of a simulated numerical example. The example is based on a hypothetical urban area with 10 neighbourhoods and a division of the population into 2000 black households and 3000 white households. Black and white households are unevenly distributed across the neighbourhoods with black households being

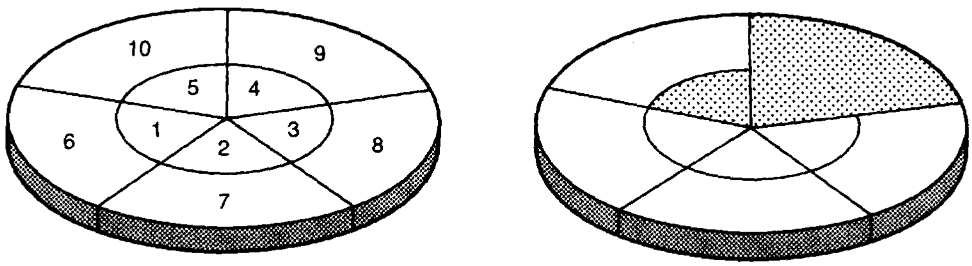

Figure 3. Spatial layout of a hypothetical city (left); in the stippled area (right), the proportion of black population is greater than the citywide proportion; elsewhere it is smaller.

overrepresented in neighbourhoods 4, 5 and 9 (Figure 3).

The characteristics assigned to the hypothetical city and its 10 neighbourhoods are summarised in Table 1. In total, four neighbourhood characteristics are considered: the racial composition as measured via the proportion of black households; the average housing price; a variable capturing the size and quality of the housing stock; and, finally, a discrimination measure that represents such features as racial steering and racial prejudice. For example, neighbourhood 4 is a predominantly (98 per cent) black neighbourhood with low housing prices and small houses of poor quality. In contrast, neighbourhood 7 is a white neighbourhood that scores high on the discrimination variable. Its housing stock consists of expensive, high-quality housing.

Table 2 shows the variables and their associated parameters describing black and white relocation behaviour within the hypothetical city. It is assumed that households' behaviour is influenced by relocation distance, as well as origin–destination differentials in racial composition, housing price, size/quality of the housing stock and discrimination. In Table 2, the third column displays the parameters of black relocation behaviour, and the last column includes the parameters of white relocation behaviour. Differences in parameters express racial differences in relocation behaviour. For example, distance is assumed to be a stronger impediment for blacks than for whites. Other racial differences are attributed to housing price differentials—blacks are assumed to be more price sensitive; discrimination—for white households discrimination is assumed to be irrelevant; and racial neighbourhood composition—whites avoid moving into neighbourhoods with a stronger black representation than their current neighbourhood.

The above information is sufficient to calculate the three versions of the dissimilarity index discussed in this paper. The results, summarised in Table 3, indicate that the efforts necessary to achieve a desegregated pattern are underestimated if measured via the traditional or the distance-based dissimilarity index. The traditional and the distance-based dissimilarity indices estimate that—compared to the worst-case scenario of complete segregation—the effort to achieve a desegregated pattern of black and white households amounts to 67.5 per cent and 64.9 per cent, respectively. In contrast, according to the relocation-based index it is estimated that the relative efforts necessary to achieve desegregation amount to 84.92 per cent for the black population and 90.64 per cent for the white population, yielding a composite index of 88.35 per cent. Thus, the traditional and distance-based formulations of the dissimilarity index potentially underestimate the actual degree of segregation experienced by the black population. Furthermore, neither the traditional nor the distance-based index is capable of distinguishing between efforts necessary by white households and efforts provided by the black population. In this example, it turns out that

Table 1. Neighbourhood characteristics

Neighbourhood	Blacks	Whites	Price	Quality	Discrimination
1	100	400	200	50	2.0
2	50	450	250	40	3.0
3	50	450	220	45	3.0
4	490	10	50	20	1.0
5	450	50	100	30	1.0
6	100	100	170	60	4.0
7	50	450	210	70	5.0
8	60	460	190	65	5.0
9	470	30	90	38	1.0
10	180	320	130	43	1.5

Table 2. Variables and parameters describing relocation behaviour

Variable	Definition	β (black)	β (white)
$DIST_{ij}$	Distance between i and j	−2.5	−1.5
P_{ij}	Ratio of price in j to price in i	−1.5	−0.5
Q_{ij}	Ratio of quality in j to quality in i	1.6	1.5
$Disc_{ij}$	Ratio of discrimination in j versus i	−2.1	0.0
M_{ij}	Ratio of minority proportion in j versus i	1.1	−2.0

Table 3. Comparison of dissimilarity indices

		Relocation-based		
Traditional	Distance-based	Black	White	Composite
0.675	0.650	0.849	0.906	0.884

the desegregation efforts of white households exceed those of black households.

Figure 4 displays the major flows of desegregating relocation schemes derived from the distance-based and the relocation-based disssimilarity indices. Two observations are noteworthy. First, in the distance-minimising relocation scheme, movements of blacks and whites (not shown) are identical except for the direction of flows—i.e. the index implies simple exchanges between black and white households with a black household moving from i to j being replaced by a white household moving from j to i. In contrast, the schemes derived from the relocation-based index go beyond simple exchanges. For example, 100 black households leave neighbourhood 9 and move into neighbourhood 1. However, only 10 of the created vacancies are filled with white households from neighbourhood 1 (the remaining 90 vacancies are filled by whites from neighbourhood 6).

Secondly, as expected, the distance minimising scheme emphasises short-distance moves. Interestingly, in the competing scheme derived from the relocation-based index, the average moving distance is equally low for black households due to the strong distance-deterrence parameter. In contrast, for white households the average moving distance is 4.4 per cent higher than in the distance minimising scheme. Alternatively, the relocation schemes may be compared using the total (or average) effort as defined via relocation behaviour. For black households, the total effort of the distance-based scheme is 25.8 per cent higher than in the

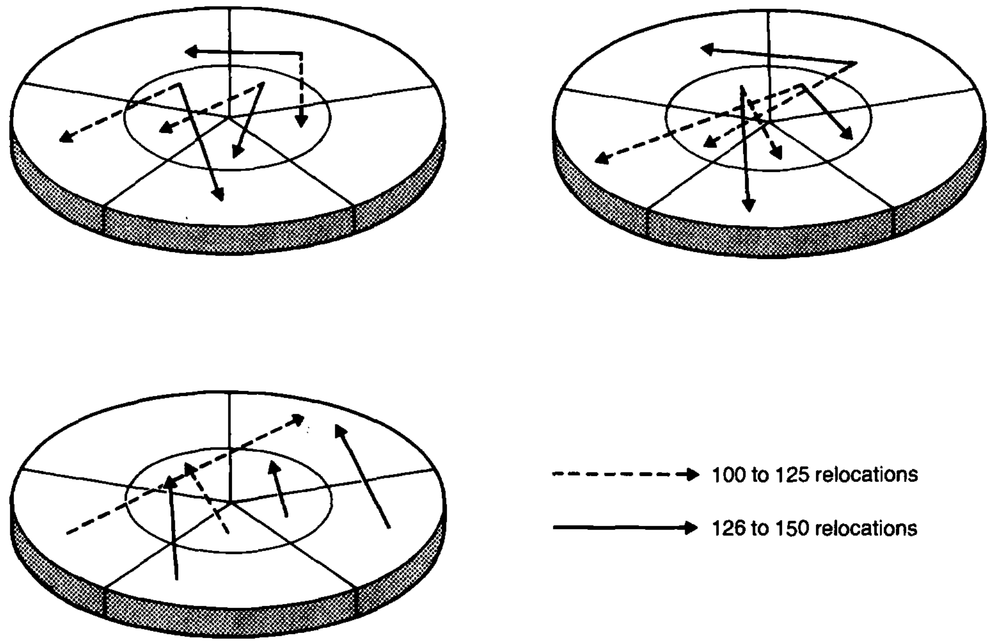

Figure 4. Above: optimal relocation schemes for blacks derived from RDI (major flows only): distance-minimising (left) and relocation-based (right). Below: an optimal relocation-based scheme for whites derived from RDI (major flows only).

Table 4. Impact of change in neighbourhood 1 on black relocation efforts

Scenario	Impact on black relocation effort (percentage)
10 per cent price increase	+ 1.06
25 per cent price increase	+ 2.75
25 per cent increase of discrimination variable	+ 4.13
100 per cent increase of discrimination variable	+ 22.7

effort minimising scheme. For whites, the equivalent figure is 8.3 per cent.

Since the relocation-based dissimilarity index defines efforts via neighbourhood attributes and their relative importance in observed relocation behaviour, the index can be used to assess the effects of changes in neighbourhood characteristics and their relative importance for neighbourhood choice. To demonstrate these capabilities, three types of simulation are performed. The first group of simulations assumes a scenario in which neighbourhood 1 experiences an increase in average housing price. These changes can be thought of, for example, as the outcome of an urban renewal programme. For black households, this price increase is expected to result in additional relocation efforts since neighbourhood 1 is a receiving neighbourhood and price differentials are associated with a negative parameter. As Table 4 shows, a 10 per cent housing price increase in neighbourhood 1 raises the total relocation effort of black households by 1.06 per cent. A 25 per cent increase produces a 2.75 per cent increase in black relocation effort. Note, however, that the changing price scenarios do not impact the traditional versions of the segregation measures.

The second set of simulations assesses the

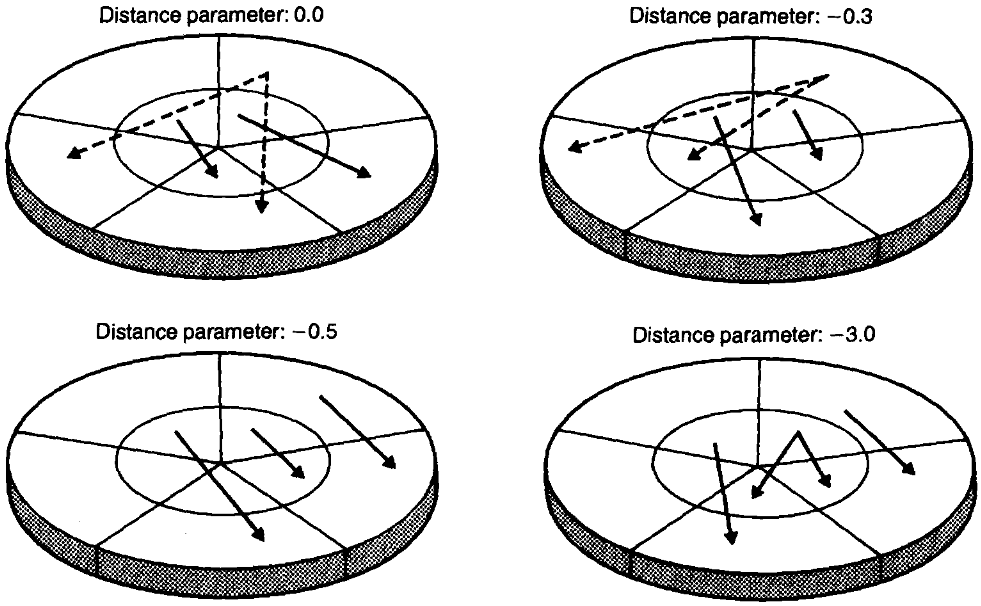

Figure 5. Impact of distance parameter on optimal relocation of black households (major flows only).

effects of increases in the discrimination variable for neighbourhood 1. As in the case of increasing housing prices, it is expected that the simulated change will result in additional relocation efforts for black households. However, as Table 4 indicates, the impacts are more drastic than in the case of changing housing prices. A 25 per cent increase in the discrimination variable results in a 4.13 per cent increase in total black relocation effort. A 100 per cent increase raises black relocation efforts by 22.7 per cent, thereby significantly heightening the segregation experience of black households. It should be noted that neither of the above simulations creates a change in the optimal relocation scheme.

The third set of simulations looks at the effects of changing sensitivities to distance. Increased distance sensitivity is reflected in a decrease of the (negative) parameter associated with the distance variable. A change in distance parameter from, say -2.5 to -3.0, raises the relocation effort between neighbourhood i and neighbourhood j by a factor of $\sqrt{DIST_{ij}}$. Since the increase is not constant for all origin–destination pairs but varies by distance, the parameter change will affect the optimal relocation scheme.

Figure 5 shows the main flows in the optimal relocation schemes for black households for various distance parameters. If the distance parameter is zero—i.e. distance is irrelevant in the relocation process—then the major flows in the optimal scheme are from neighbourhoods 4 to 8 and 5 to 2. An equal number of households leave neighbourhood 9 and move to neighbourhoods 6 and 7 (Figure 5a). As the distance parameter decreases to -0.3 the optimal pattern changes significantly. The main flows are between neighbourhoods 5 and 7, and 4 and 3 (Figure 5b). A further decrease in the distance parameter to -0.5 results in a concentration of flows out of neighbourhood 9 into neighbourhood 8 (Figure 5c). Interestingly, this pattern persists as the distance parameter is further manipulated within the range of -0.5 and -2.9. Within this range, only some minor flows are being shifted around. As the distance parameter reaches -3, a major shift occurs with flows from neighbourhood 4 being equally divided between destination neighbourhoods 2 and 3 (Figure

5d). This optimal relocation scheme remains remarkably stable as the distance parameter declines to -5.

It should be noted that neither the traditional nor the distance-based dissimilarity index is sensitive to the types of change simulated in this section. Both indices define segregation experience independent of the specific urban context and behaviour in urban space and consequently do not include variations in segregation as a response to changes in urban characteristics or spatial behaviour.

5. Summary and Conclusions

This paper suggests an innovative method of measuring the segregation experience in urban areas. The method moves away from a purely geometric interpretation of segregation. Instead, it directs attention towards the measurement of segregation experiences in an actual urban setting.

The urban setting is described by a set of salient attributes that shape the characteristics of neighbourhoods and that influence racial differences in spatial behaviour. In the presence of segregation forces, black and white households make different spatial choices within this urban context. These behavioural differences often serve to maintain or even reinforce segregative patterns. The spatial behaviour within a concrete urban context is at the core of the relocation-based dissimilarity index.

The index expresses the degree of segregation in an urban area as a ratio of efforts needed to transform the observed distribution into a desegregated distribution relative to the efforts needed to make a transition from a completely segregated to a completely desegregated pattern. On a formal level, therefore, the relocation-based index is similar to its predecessors. However, the definition of relocation effort via observed relocation behaviour provides major advantages from a theoretical point of view.

First, the relocation-based index is capable of reflecting changes in segregation experience that are due to changes in urban structure as opposed to changes in the distribution of minorities. That is, although the observed distribution of minorities remain constant, the efforts needed to achieve desegregation might increase if the neighbourhood character is altered. Secondly, the relocation-based index is sensitive to changes in the strength of segregative forces. The strength of segregative forces is reflected in the parameters of the effort function. Thirdly, measuring segregation via observed behaviour allows us to capture asymmetries between minorities and majorities with respect to relocation efforts. Consequently, effort-minimising relocation schemes go beyond simple locational exchanges between black and white households. The numerical example provides a direct comparison between the traditional formulations of the dissimilarity index and the proposed relocation-based index. This comparison demonstrates that first, segregation experiences of minorities may be more severe than the traditional measures indicate. Secondly, changes in urban structure and segregative forces have an effect on the segregation experience within a city. These effects can be measured via the relocation-based index but not via traditional formulations of the dissimilarity index.

Using the relocation-based index in future research may significantly enhance our understanding of racial and ethnic segregation. Three issues are particularly worth mentioning. First, because of its emphasis on neighbourhood characteristics and metropolitan structure, the index may be effectively utilised in research on the urban underclass and impacted ghettos. Secondly, the index is suitable to address the scale-dependent nature of segregation processes (Huff and Waldorf, 1990). If different forces are responsible for segregation at different spatial scales, then spatial behaviour at each scale may be portrayed by a scale-specific effort function. These scale-specific functions may then be used as inputs for the measurement of desegregation efforts at each spatial scale. The final issue revolves around the persistence of residential segregation patterns over time. Comparing observed relocation patterns against the desegregating relocation scheme derived from the relocation-based dissimilarity index allows us to assess the degree of persistence of existing segregative patterns. Such a comparison may also be used to estimate the amount of time needed to break up segregative patterns.

Note

1. The multiplicative model structure is simple yet frequently used in migration and mobility research. For example, it forms the basis for gravity and push-pull models. It should be noted that more sophisticated structures such as the nested multinomial logit model (Waldorf, 1990; Clark and Onaka, 1985; Onaka and Clark, 1983) may be used instead.

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