URBAN RACIAL SEGREGATION MEASURES COMPARISON

A Thesis

by

JAMIL DJONIE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF URBAN PLANNING

December 2009

Major Subject: Urban and Regional Planning

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ABSTRACT

Urban Racial Segregation Measures Comparison. (December 2009)

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Urban racial segregation has been a problem to many U.S. cities. Many researchers have interested on the urban segregation issues since long time ago. To understand and plan a better community, urban planners needs to know how to measure the segregation and interpret the results. However, over the past several decades, many scientists have proposed many types of urban segregation measures. Although a few of them are commonly used nowadays, this doesn't mean the other measures are not appropriate. Disregarding the fact that some of the measures are mostly used or easily calculated this paper attempts to gather many of the proposed and the most discussed measures for comparison.

The results of the comparison were categorized in one group measure, two group measure, and multi group measure. They are also divided in to the five dimensions of segregation such as the evenness, exposure, concentration, clustering, and centralization. Two U.S. metropolitan cities that are different in racial proportion, Houston, TX and Philadelphia, PA, were selected for the comparison. All the selected measures are evaluated in several criteria such as the scale, level of measures, data required, level of complexity, and tendencies of using different census data.

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1. INTRODUCTION

Racial segregation is crucial to understand and explain the existence of American urban underclass. Understanding the racial segregation enable us to identify the cause of segregation as well as the impact generated by a segregated neighborhood. It helps us to determine the pattern of segregation in the society. It also helps to discover the vulnerability of the segregated community in a wealthy society.

There are many types of neighborhoods in metropolitan areas. Some have large houses and some have small houses. Some live in prosperous populated area and magnificent homes. Some live in isolated residential areas. Different racial compositions occur in different neighborhood such as urban core or central city, suburban ring, older cities, and types of economics. In certain types of neighborhoods, most residents are African American while in the other types they are Whites. According to Massey (1990), when a high distribution of minority population occurs within a racial segregated area, this created power to transform rapidly the socioeconomic environment of the poor minority family. He showed that the black and white neighborhood poverty disparity increases as racial segregation rises. And when racial segregation concentrates poverty in urban space, it focuses and increases any change in economic status. In segregated society, the change in economic will cause downward shift in minority income distribution and will only increase the poverty rate as a group and increase the geographic concentration of poverty. Racial segregation was the key factor for the social

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This thesis follows the style of *Population Research and Policy Review.*

transformation of the black community and the concentration of poverty during the 1970s. Racial segregation acts to undermine the socioeconomic environment faced by poor blacks who live in their communities extremely vulnerable to downturn of economy. The shifting in black poverty rates during the 1970s had the power to transform the poor black neighborhoods very rapidly.

1.1. The Purpose of Research

There have been many developments of segregation measures. Some evolved and some remained unchanged. Some are widely used and some are hardly being seen. Some capture small scale, while others capture larger scale. There are measures that can be calculated easily, while others need complicated formulas and they are time consuming. Each measure has its own advantages and disadvantages.

This paper will compare several useful methods used to measure urban segregation. These include the indices of dissimilarity (D), the indices by dimension of segregation, spatial indices of dissimilarity, multi group indices, and a lacunarity-based measure. These measures are selected because they are widely used and are mostly discussed. Each of the selected measures will be assessed for their measuring capabilities and their weaknesses. These are based on criteria formed by the overall capabilities such as the degree of scales, the data requirement, the dimension of captures, the level of measures, number of groups being measured, the spatial attributes, etc.

The first step towards comparing the measures is to gather information as much as possible from literature review. Each of the measures will be reviewed through the previous discussions. The critiques and support will be used to compare the measures. After having compared the measures from the reading materials, empirical data from two metro areas will be calculated and compared. These urban areas are selected to provide a contrast in socioeconomic characteristics.

Each measure will be used to measure the same area of the location. The results of the empirical analysis will be compared along each criteria. By comparing the different results, any interested researchers, practitioners, sociologists, or planners can choose the best fit measuring tools to be applied in their area of interest and further as a base of decision making.

1.2. Cause of Segregation

Urban segregation in society has been a concern of many researchers for the past 50 years. One of the important issues in urban planning is residential segregation. Residential segregation has to be taken into account for a planning to be successful. Planners must understand any urban constraints, problems, and the relations between communities as well as the impact of urban planning on the people or individuals that are living in planned communities. There are several causes of residential segregation. The focus in this work is the one determined by race.

The racial residential segregation occurred in natural society pattern influenced by many conditions. Human's basic ethnocentric behavior, which means the tendency to live with the same group or race, is the core of the reality. Ethnocentrism is a way of seeing other groups from its own point of view. It is to judge other culture by its own standards. If one believes their group or their way of living is superior to others, whether they are the majority or minority, their group can be ethnocentric. This ethnocentric behavior prevents a person from understanding the world as it is experienced by others. Therefore, this may lead to narrow minded conclusions about the other groups, and about the worth of diverse cultures (Andersen, M. L., Taylor, H. F., 2005).

Many might argue that the ability to afford housing in certain desired area was the main cause of separation. Or one would say that it was the intention of the authority. Others believe it was the result of discrimination. The further a vulnerable minority becomes segregated and isolated, the faster it grows larger and lower opportunity to perceive amenities. There are many layers of conditions contributing to the segregation. Unveiling all the layers, the last one would be the natural human behavior that is grown by the social determinism.

Social determinism is a doctrine that every decision, event, or act is a consequence of genetic and environmental influences which means that human has no free will. The following action or the conducted event is obligated to natural laws. It means that human think and act according to their social background rather than a freedom of choice (Koons, 2002). Everyone went through a subliminal process which unconsciously influenced by social norms and biased doctrines.

In the U.S., segregation mostly reflects separation of the dominant group which is whites and minority group which is composed of African Americans, Hispanics, Native Americans, and Asians. According to the history, blacks have experienced higher discrimination over the others. There have been many arguments to the result of racial residential segregation. Two of them are contrasting to each other. The first, suggested that the segregation is not a racial issue, it is the result of different income that leads to different choice of housing. Second, the segregation is more of individual preferences.

Wilson (1978) suggested that the segregation is based on racial issues. In accordance with Wilson, the result of poverty was not due to racial discrimination only, even if all racial discrimination were eliminated today, the situation of poor blacks will not be substantially improved unless something is done to remove the structural barriers. Some previous research showed that when equalize income, wealth, and education will make the changes to reduce segregation. However, a simulation model using general equilibrium model eliminating differences in incomes or education will lead to a significant increase in segregation (Bayer, P. J., McMillan, R., Rueben, K. S., 2004). Zenou and Nicholas (1999) also used equilibrium model to test two segregated communities (black and white) with two categories, employed and unemployed and the result again showed separation by either opportunity or employment status. Blacks were either segregated from the job center or have less opportunity to find job from their living locations.

1.3. Segregation Impacts

What happen when segregation occurs? What impacts does segregation have? Many sectors may be affected by the segregation such as poverty, disaster evacuation, education, etc. There is a famous term called “white flight” which prejudiced the White population refused to live with the African American and moved out to the suburbs or the outer rings of the cities.

During the Hurricane Katrina in New Orleans, the segregated poor society, mainly black people, was left out from the pre-disaster evacuation effort. After the disaster, there was still a large population of poor black people trapped in the Ninth Ward. There are many more similar pattern of segregation in American cities such as the North Philadelphia, New York City, etc. Gordon (2005) suggested that only integrated neighborhoods can create the kinds of opportunities – good schools, good jobs, and safe communities – necessary for people to escape the devastating cycle of poverty.

In education, the segregated minority schools are facing a significant inequality. Currently, U.S. schools have 41 percent non white and the majority of them are attending schools that are substantially segregated (Orfield and Lee, 2005). Since the 1980, the segregation of black and Latino students are increasing. The scores are strongly related to the racial composition and the experienced teachers. The concentrated minority high schools in big cities show high dropout problem. There have been some arguments whether to desegregate the schools composition or to keep them “separate but equal”, as reaching the educational success by deepening segregation. However, in larger scale, there is a very little evidence of success in creating the “separate but equal” results (Orfield and Lee, 2005). Educational inequality is caused by multidimensional segregation and race is deeply and systematically related to many forms of inequality in background, treatment, expectations and opportunities (Orfield and Lee, 2005).

1.4. Measuring Segregation

Measures of segregation help us examine many issues such as the above mentioned. By studying the measure of segregation, we can identify the segregation patterns. The results will be useful to provide a framework for analyzing the outcomes in decisions making process and policy effectiveness. The distribution of population varies in different places, it is apparent that some areas have higher proportion of minorities. Different proportion of population groups may have influence on the quality of education at certain schools (Hutchens, 2006). Racial segregation has strongly concentrated poverty and created underclass. Poverty increased when residential segregation got higher (Massey, 1990). By measuring the segregation, we can understand the fundamental impact of segregation.

Finding the right measurements have been debated over the past several decades. The first proposed measure by Duncan and Duncan in 1955 which was the index of dissimilarity that became widely adapted. However, it has been criticized for not being useful in randomness (Duncan and Duncan, 1955). Then a variety of indices were introduced and the debate continued until Massey and Denton in 1988 proposed five measures for different dimensions of segregation. The five dimensions were the evenness, exposure, clustering, concentration, and centralization (Massey and Denton, 1988). Since 1991, a series of publications explained major deficiency of the dissimilarity indices. It was opposed mainly because the indices did not capture the potential interaction between different groups across areal unit boundaries; Morrill in 1991 modified the dissimilarity index (Morrill, 1991). Then Wong in 1993 found that the boundary length affected the value and introduced another modified dissimilarity index (Wong, 1993). Further studying the indices, Wong modified the index to capture boundary shape (Wu and Sui, 2001).

Today, with the development of computer software, researchers have started to use a newer tool of measuring segregation using Geographic Information System (GIS). GIS is a powerful tool in capturing many dimension of segregation. Moreover, it captures all together and even further to boundary less and multiple scale. Many new measures were introduced with the use of ArcGIS such as agent-based measure, lacunarity-based measure, spatial statistics based, and numerical based.

1.5. Problem Statement

There are many urban segregation measures that capture a variety of scope. They differ in many different ways. Massey and Denton (1988) has categorized them by dimensions of segregation. Wong (1993) suggested the measures to have spatial attributes. In the advanced of GIS, the method to measure the ‘gappiness’ of an image is used to measure the urban segregation. The purpose of this different segregation measurement comparison is to understand the differences in segregation methods and provide detailed scope of segregation indices.

2. LITERATURE REVIEW

Although there are a few segregation measures that are well known and commonly used, the new measures are occurring and many have used new technology especially in computer sciences such as the use of GIS. The new indices are typically more complicated than the previous ones. These new ones enable researchers to capture more features and are categorized according to their capabilities in different dimensions.

Looking at the development of segregation measures, each of the new ones were proposed for the purpose of capturing more detail results. Everyone attempts to find a better measure for segregation. After a certain period of debate, one measure would be used over the others. Even so, there would be some critiques and the debate continued for another period of time until some measures were proposed again. The latest discussion is the spatial attribute for the measurement with the use of GIS.

2.1. History of Segregation Measure

Racial segregation has been one of the central issues in social science and population studies. Lee described that the racial and ethnic residential segregation can be traced back to 1926 when Robert Park stated his dictum of spatial patterns reflect social relations and Ernest Burgess in 1928 published his first landmark study (Lee, 2008). Since then, the measures of segregation debate had been flowing around for several decades. Otis Dudley Duncan and Beverly Duncan in 1955 proposed a famous index of dissimilarity to measure segregation between two groups. The index of dissimilarity D has dominated the population and racial segregation studies for several decades. This index is simple and easy to compute. In 1965, Taeuber and Taeuber reaffirmed this measure (Massey and Denton, 1988).

The first critique was stated by Charles Cortese and his colleagues, Falk and Cohen, in 1976. Their work had ushered debate for over 20 years. However, this paper did not create a serious impact on the measurement. Practitioners did not take the criticism serious enough. Since then, many new measures were introduced. At this time, the segregation study was in a state of theoretical and methodological disarray with different researchers suggesting different segregation measures. Not to mention many researchers had used inconsistent measures. James and Taeuber (1985) considered only five measures and used a sample of schools, not cities. White in 1986 used more indices, but still excluded major potential indices and he only examined 21 metropolitan areas (Massey and Denton, 1988).

In 1988, Douglas Massey and Nancy Denton undertook a systematic analysis of 20 segregation indices from a review of the extant literature. They classified the indices conceptually and explained how each corresponded to one of the five basic dimensions of spatial variation. The indices are computed to measure the segregation in three minority groups from non-Hispanic to whites in 60 metropolitan areas. They argued that residential segregation should be measured not with one index, but with several. They also stated that segregation is a global construct that subsumes five underlying dimensions of measurement, each corresponding to a different aspect of spatial variation: evenness, exposure, concentration, centralization, and clustering.

The different dimension of segregation has different social and behavioral implications. Some of them overlap, but they are conceptually distinct to one another. The racial groups may be separated in many different ways corresponding to the pattern of the five characteristics of dimension. If a racial group is segregated in one dimension, it tends to be segregated on other dimensions (Massey and Denton, 1988). The five dimensions of segregation with their measures (the measures can be found on Appendix A) are described as follows:

Evenness, refers to the differential distribution of two social groups among areal units in a city. It is scaled relative to some other group. There are several measures: Segregation Index (IS – Appendix A: A.1), Dissimilarity Index (ID – Appendix A: B.1, C.1), Gini Index (G – Appendix A: A.5, C.3), Entropy Index (H – Appendix A: A.6, C.4), Atkinson Index (ATK – Appendix A: A.7).

Exposure, refers to the degree of potential contact or interaction between minority and majority in an area. Beside measuring segregation as departure from abstract ideal of evenness, exposure measures the experience of segregation by the average minority or majority member. It is measured by: Interaction Index (xPy – Appendix A: B.6), Isolation Index (xPx – Appendix A: A.8), and Correlation Ratio (V – Appendix A: A.9).

Concentration, refers to relative amount of physical space occupied by a minority group in the urban environment. The smaller a group occupies an area, the more it is concentrated. In comparison, two cities that have the same proportion of majority and minority will be considered the smaller city to be more segregated by observers. This is measured by: Duncan's Delta (DEL – Appendix A: A.10), Absolute Concentration Index (ACO – Appendix A: A.11), Relative Concentration Index (RCO – Appendix A: B.7).

Clustering, refers to the degree of spatial clustering exhibited by a minority group to the extent of which areal units inhabited by minority members adjoin one another, or cluster, in space. This is measured by: Absolute Clustering Index (ACL – Appendix A: A.12), Index Of Spatial Proximity (SP - Appendix A: B.10), Relative Clustering Index (RCL - Appendix A: B.11), Distance-Decay xPx (DPxx - Appendix A: A.15), and Distance-Decay xPy (DPxy - Appendix A: B.12).

Centralization, refers to the degree to which a group is spatially located near the center of an urban area. The closer to the center tends to be spatially concentrated. This is measured by: Proportion In Central City (PCC – Appendix A: A.16), Absolute Centralization Index (ACE – Appendix A: A.17), and Relative Centralization Index (RCE).

After comparing the results, Massey concluded that each dimension has its advantaged measurements which best describe and more desirable. For the Evenness: index of dissimilarity (D), Exposure: the P indices, Concentration: RCO, Centralization: ACE, and Clustering: SP. The five dimensions of measures described by Massey are shown in **Figure 1**.

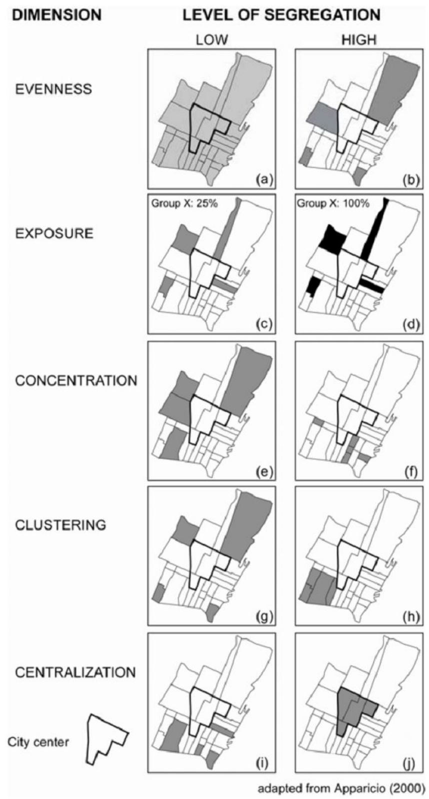

Figure 1: The five dimensions of segregation.

They are proposed by Massey and Denton in 1988. Source: (Apparicio, Petkevitch, and Charron, 2008)

Almost a decade after several spatial measures for segregation were introduced, they had not been used properly and extensively. The reason could be that the popular indices were simple and were easy to calculate (Wong, 2002). Another reason was the availability of data (Wu and Sui, 2000). However, due to the limitation of traditional measures, the modified indices were proposed such as D(adj) with consideration of spatial adjacency of areal units (Morrill, 1991), D(w) with the length of the boundary of areal units using weight matrix (Wong, 1993), and D(s) that incorporated shape factor of area and perimeter of areal units (Wong, 1993). After the advanced of GIS, many researchers realized its spatial analytical capability. GIS is useful to analyze attribute data without incorporating any geographic characteristic of the features, analyze only the geographic information without referencing to the attribute data, and analyze the spatial features by combining the geographical information and attribute data (Goodchild, 1987; Laurini and Thompson, 1992; in (Wong, 2003). To measure urban segregation, spatial information is needed to improve traditional measures. Both population data and its spatial characteristics are needed (Wong, 2003).

2.2. The Use of GIS for Segregation Measures

In the beginning of the development of GIS, the implementation of spatial segregation measures were succeeded by Wong and Chong in 1998 with integrating GIS (ArcInfo) with statistics software (S-plus). ArcInfo was used to calculate spatial data and S-plus was used to compute the population data. Wong (2002) introduced a spatial measure using statistics tool in GIS software which is similar to today's spatial statistics. Now, with the current state of GIS, this same calculation can be done completely with GIS alone.

Before Wong, Plotnick et al in 1993 introduced lacunarity based measure (Wu and Sui, 2000). All of the previously used measures are based on vector data structures, this lead to a MAUP (Modified Area Unit Problems) which effected by different scales. A lacunarity index is a multi scale segregation measure. It measures the deviation of a geometric form by the 'gappiness' of a structure. The lacunarity curve is produced by plotting varying box sizes on an landscape image at different scales. The results of lacunarity measure are not limited to the boundaries but sensitive to scale. It has been used in several ecological and remote sensing studies to quantify spatial heterogeneity and domains of the spatial scale (Wu and Sui, 2000).

Another spatial segregation measure was pioneered by Schelling (1971). It started from a simple model of 2-dimensional checkerboard model of simple logic how segregation could occur (Schelling, 1971). Each square can represent different social classes, racial groups, etc. The model was created in a way the agent (the square) decides to move or not with certain criteria such as preference of having same type of neighbors like itself. This model is best known as the 'agent-based' model. This Schelling's model later inspired researchers into new phenomena (Crook, 2008). A research done by Bruch and Mare in 2005 showed that most people are unwilling to live in a neighborhood where their own racial group is the minority. The limitation from the simulation was that not everyone has the ability to move and people are not initially distributed randomly in a city in comparison to the model.

Many researchers have extended the Schelling's model to integrate other factors rather than just social or racial groups, for example, Fosset and Senft in 2004 included neighborhood status, housing quality, and different level of socio-economic inequality. Bruch in 2006 combined the racial ethnic and income, and how the both interacted to produce and maintain segregation in Los Angeles. Researchers in Tel Aviv University, Israel, are active in using Agent-Based Model to simulate residential segregation dynamics form real-world samples (Omer and Benenson, 2002).

2.3. Categories and Types of Measures

There are a variety of many different measures of segregation: the dissimilarity index proposed by Duncan and Duncan (1955), the five dimension measures by Massey and Denton (1988), the modified D to include spatial features across boundary related by Morrill (1991), the modified D for boundary length by Wong (1993), the modified D for area shape and parameter by Wong (1993), the multi group D by Morgan (1975) and Sakoda (1981), the measures uses spatial map and GIS which is lacunarity analysis tool. Most of the measures can be categorized into three major categories: one group measure, two group measure, and multi group measure.

The only measures that do not require cartographic data are the original index of dissimilarity, the isolation index for exposure, the Gini index, the entropy index, Atkinson, and correlation ratio index. The remaining requires cartographic or feature data to describe the geographical and geometrical characteristics. Usually, GIS software is required to compute these measures. Computing these measures uses both population data and cartographic data.

2.3.1. One Group Measures (Appendix A: A)

The one group measures are the measurements that only capture the indices for one racial group only over the total population in the study area. These indices include the five dimensions of measures mentioned by Massey and Denton (1988).

1. **Segregation Index IS (Appendix A: A.1) – Duncan and Duncan, 1955**

   The famous and commonly used is Index of Dissimilarity proposed by Duncan (1955). This index is easy to compute and has intuitive interpretations favored by many sociologists and population researchers. Therefore, it has been used extensively in the past several decades (Wong, 2003). It is often used to measure the segregation between two population (black and white segregation patterns) and ethnic, racial, or other groups. For one group measures, it is used as IS (Index of Segregation). The values are between 0 – 1 where 0 is evenly distributed and 1 means totally separated.

2. **Segregation Index with Boundary access IS(adj) (Appendix A: A.2) – Morrill, 1991**

   Massey and Denton proposed their five dimensions of segregation, there had been several publications that revealed a major deficiency of the dissimilarity index. The D is effective only capturing the evenness of population, but only to the extent where spatial arrangement of a population is not measured. When each area unit in the study area is dominated by one group or the other, the index will be 1. If there are some different groups in the adjacent units, the result will still be 1 as it was not calculated. In other words, population groups in different adjacent units are not accounted to have interaction across unit boundaries to lower the level of segregation (Wong, 2003). There is an obvious interaction of individual across boundaries of study area. Morill in 1991 introduced D(adj) to capture potential interaction between different groups across areal unit boundaries. The D(adj) is the original dissimilarity index by Duncan and Duncan (1955) minus the amount of potential interaction between different group across areal unit boundaries.

3. **Segregation Index with Boundary Length IS(w) (Appendix A: A.3) – Wong, 1993**

The above IS(adj) measures only across boundary, while the actual interactions are not only based upon adjacency. The boundary of study area which the interaction shared has length. Wong in 1993 defined a component of length to the interaction across areal units. Wong modified slightly the D(adj) to incorporate a boundary length component. Then the index D(w) was introduced where the shared boundary between areal units divided by the total length of the boundary for areal unit. This is shown in **Figure 2**.

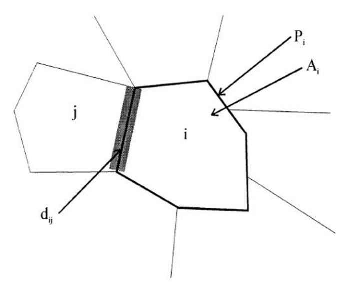

Figure 2: Geographical elements – boundary length.

Geography feature used by Wong for spatial segregation indices. Area unit *i* and *j* share boundary-length of d_{ij} with P_i as perimeter for area unit *i* and A_i as the area of area unit *i*. Source: **(Wong, 2002)**.

4. **Segregation Index with Perimeter Ratio IS(s) (Appendix A: A.4) – Wong, 1993**

   Not only Wong (1993) argued the interactions are shared by the length of boundaries, but two different areas that share boundary have two different size and shape. Wong (1993) also added a compactness measure based on perimeter area ratio. He further modified the D to capture the perimeter-area ratio divided by the maximum perimeter-area ratio among all of the area units in the study region. Therefore, Wong introduced D(s) to incorporate the geometric characteristics of areal units into the segregation index.

5. **Gini Index G (Appendix A: A.5) – Duncan and Duncan, 1955**

   The Gini index was developed by Corrado Gini and is mostly used for measuring the inequality of income and wealth. This measure was derived from the Lorenz curve, which is a distribution function of a probability distribution developed by Max O. Lorenz in 1905. The Gini Index is located in the area between the segregation curve and the diagonal (Gastwirth, 1972). The Gini coefficient for measuring segregation, proposed by Duncan and Duncan (1955), is the mean of absolute differences between minority proportions weighted across all pairs of areal units. It is shown as a proportion of the maximum weighted mean differences which occurs when minority and majority share no area in common. The values are between 0 – 1 where 0 is evenly distributed and 1 means totally separated.

6. **Entropy Index H (Appendix A: A.6) – Theil, 1972; Theil and Finezza, 1971**

   This is also called the information index, originally proposed by Theil (1972) and Theil and Finezza (1971) as a measure for school segregation. It is also called as the information index. It was later extended to racial evenness segregation measure for the city. The city's entropy is the extent of its racial diversity. If there are two groups, it will reach a maximum of 50-50 division. This entropy index was the weighted average deviation of each unit's entropy from the city wide entropy. The values are between 0 – 1 where 0 is evenly distributed and 1 means totally separated.

7. **Atkinson Index ATK (Appendix A: A.7) – Atkinson, 1970**

   This was proposed by Atkinson (1970) which resembles the Gini coefficient. Unlike the Gini, this measure allows researchers decide how heavily to weight areal units at different points over the city wide minority proportion. When computing the Atkinson index, researchers must decide whether the segregation index should take greater account of differences among areas of over or under represented. The values are between 0 – 1 where 0 is evenly distributed and 1 means totally separated.

8. **Isolation Index xPx (Appendix A: A.8) – Bell, 1954**

   This index is derived from interaction index (xPy) in two group category and categorized by Massey and Denton (1988) as an exposure index. It measures the extent to which minority members are exposed to only their own group. It is calculated as the minority weighted average of each unit's minority proportion. The values are between 0 – 1 where 0 is no exposure at all and 1 means highly exposed. The less the value, the more segregated the racial group.

9. **Correlation Ratio Eta^2 (Appendix A: A.9) – Bell, 1954; White, 1986**

   This measure is the interaction index with the asymmetric relation removed. It represents an independent dimension of segregation (Stearns and Logan, 1986). The values are between 0 – 1 where 0 is no exposure at all and 1 means highly exposed. The less the value, the more segregated the racial group.

10. **Delta Index DEL (Appendix A: A.10) – Hoover, 1941; Duncan, Cuzzort, and Duncan, 1961**

    Massey and Denton have grouped this measure under the dimension of concentration. This was originally from Hoover (1941) and later used by Duncan, Cuzzort, and Duncan (1961). It computes the proportion of X members residing in areal units with above average density of X members. It can be interpreted as the share of minority that would have to move to achieve uniform density. The value varies between 0 to 1, where 0 means minimum concentration and 1 means maximum concentration.

11. **Absolute Concentration Index ACO (Appendix A: A.11) – Massey and Denton, 1988**

    This is also grouped by Massey and Denton (1988) as the concentration dimension index. It is by computing the total area inhabited by a group, and compared to the minimum and maximum possible areas that could be inhabited by that group in a given city. The value varies between 0 to 1, where 0 means minimum concentration and 1 means maximum concentration.

12. **Absolute Clustering Index ACL (Appendix A: A.12) – Massey and Denton, 1988**

    Absolute clustering index was derived from Dacey (1968) and Geary (1954). This measure calculates the absolute clustering in urban space. It is first obtained by creating centroid coordinates for areal units in urban areas and then represents a distance function between areas. The value varies between 0 and 1, where 0 means non-contiguous and 1 means contiguous.

13. **Mean Proximity between Members of Group X (Pxx) (Appendix A: A.13) – White, 1986**

    This was proposed by White (1986) called the index of spatial proximity. It calculates by estimating the average proximity between members of the same group, and between members of different groups. The Pxx calculates the average proximity between group X. The value varies from 0 to ∞, where 1 means no differential clustering, less than 1 means X and Y resided closer to each other than other from the same group, and greater than 1 means they live closer to their own group than different groups.

14. **Mean Proximity between Members of Group X (exp): (Pxx_{exp}) (Appendix A: A.14) – White, 1986**

    This is the same as the Pxx, but it is multiplied by the exponential. The value varies from 0 to ∞, where 1 means no differential clustering, less than 1 means X and Y resided closer to each other than other from the same group, and greater than 1 means they live closer to their own group than different groups.

15. **Distance decay Isolation Index DPxx (Appendix A: A.15) – Morgan, 1983**

    This was proposed by Morgan (1983) and categorized as the clustering dimension index by Massey and Denton (1988). Morgan suggested the distance-decay P* index to reflect the two countervailing forces. The probability of meeting a member of another group decreases as a function of distance. The value varies between 0 to 1, where 0 means no isolation and 1 means maximum isolation.

16. **Proportion in Central City PCC (Appendix A: A.16) – Massey and Denton, 1988**

    This is proposed by Massey and Denton (1988) as an index for dimension of centralization. It is to express the proportion of group X living within the boundaries of the central city.

17. **Absolute Centralization Index ACE (Appendix A: A.17) – Massey and Denton, 1988**

    This is also proposed by Massey and Denton (1988) for the dimension of centralization. It measures a group's spatial distribution compared to the distribution of land area around the city center. The index varies between -1 and 1 with positive values means X members are located closer to the city center than Y members. For one group measures, it means the X members to their own groups.

2.3.2. Two Group Measures (Appendix A)

The two group measures provide the indices between two different racial groups in a study area. It is usually conducted with one group as the minority and the other group as the majority. However, any racial group of any races can be selected to get the result of the segregation indices within any two racial groups. The indices are as follows:

1. **Index of Dissimilarity D (Appendix A: B.1) – Duncan and Duncan (1955)**

   This is the same as the segregation index. For two groups, it uses the majority population as the comparison.

2. **Dissimilarity Index with Boundary Access: D(adj) (Appendix A: B.2) – Morrill, 1991**

   This is the same as the one group which has been described above. The only difference is used for two groups.

3. **Dissimilarity Index with Boundary Length Components D(w) (Appendix A: B.3) – Wong, 1993**

   This is the same as the one group which has been described above. The only difference is used for two groups.

4. **Dissimilarity Index with Perimeter Ratio D(s) (Appendix A: B.4) – Wong, 1993**

   This is the same as the one group which has been described above. The only difference is used for two groups.

5. **Deviational Ellipse Index S (Appendix A: B.5) – Wong, 1999**

   This measure was proposed by Wong (1999) and based on Centro graphic analysis. It represents the ratio between the intersection and the union of deviational ellipses of n – 1 population groups.

6. **Interaction Index xPy (Appendix A: B.6) – Bell, 1954**

   This index is an exposure index which captures the one of dimension of segregation proposed by Massey and Denton (1988). This was noted early by Bell (1954) and reintroduced later by Lieberson (1981). This measure captures to what extend a minority group X are exposed to a majority group Y. The values are between 0 – 1 where 0 is no exposure at all and 1 means highly exposed. The less the value, the more segregated the racial group.

7. **Relative Concentration Index RCO (Appendix A: B.7) – Massey and Denton, 1988**

   The same as the RCO for one group, but it is measured for 2 groups.

8. **Mean Proximity between Members of Group X and Y (Pxy) (Appendix A: B.8) – White, 1986**

   The same as one group, but it is measured for 2 groups.

9. **Mean Proximity between Members of Group X and Y (exp): (Pxy_{exp}) (Appendix A: B.9) – White, 1986**

   The same as one group, but it is measured for 2 groups.

10. **Spatial Proximity Index SP (Appendix A: B.10) – White, 1986**

    The same as one group, but it is measured for 2 groups.

11. **Relative Clustering Index RCL (Appendix A: B.11) – White, 1986**

    The same as one group, but it is measured for 2 groups.

12. **Distance Decay Interaction Index DPxy (Appendix A: B.12) – Morgan, 1983**

    The same as one group, but it is measured for 2 groups.

13. **Relative Centralization Index RCE (Appendix A: B.13) – Duncan and Duncan, 1955**

    It is derived from proportion in central city index and for one group measure. The central cities are changing by incorporating suburbs. Therefore, Duncan and Duncan in 1955 proposed to make use of spatial data and formulated an ordered increasing distance from central business district.

2.3.3. Multi Group Measures (Appendix A)

All the above indices of dissimilarity only measure interaction within its own group or between two groups. The following measurements capture more than two groups all in the same study area. Some of them are the same measures as the previously mentioned ones, but they were modified to capture multi group.

1. **Dissimilarity Index for Multi Group D (Appendix A: C.1) – Morgan, 1975; Sakoda, 1981**

   Although some said that for multiple groups measure one can use the D by pairing two groups one at a time, but this is not satisfactory. Then the D was modified for multi groups by Morgan (1975) and Sakoda (1981). This D(m) can measure more than two groups, but again, has the same limitation as the original dissimilarity index which is non-spatial and rearranging populations among area units will not change the level of segregation. The interpretation is the same as the original index of dissimilarity.

2. **Spatial Dissimilarity Index SD (Appendix A: C.2) – Wong, 1998**

   This was proposed by Wong (1998). It uses a binary contiguous matrix between spatial units of the urban area.

3. **Gini Coefficient for Multi Group G (Appendix A: C.3) – Reardon, 1998**

   This was modified by Reardon (1998) from the original Gini to captured multi group.

4. **Entropy Index for Multi Group H (Appendix A: C.4) – Theil, 1972; Theil and Finezza, 1971**

   This is the same from the one group entropy, but modified for multi group by Theil and Finezza (1971).

5. **Squared Coefficient for Variation C (Appendix A: C.5) – Reardon and Firebaugh, 2002**

   The coefficient for variation is a normalized measure of dispersion of a probability distribution. It is the standard deviation to the mean of normal distribution.

6. **Deviational Ellipse Index for Multi Group S (Appendix A: C.6) – Wong, 1999**

   The same as the two group measure with the modified formula to capture multi group.

7. **Normalized Exposure P (Appendix A: C.7) – James, 1986**

   This is one of the two multi group measures that measure the dimension of exposure, others measure the evenness. This measure was proposed by James (1986) and derived from the P* exposure by Bell (1954). It is a simple weighted average of the normalized exposure of each group to all other groups.

8. **Relative Diversity R (Appendix A: C.8) – Carlson, 1992; Goodman and Kruskal, 1954; Rearton, 1988**

   This measure was proposed by Carlson (1992), Goodman and Kruskal (1954), and Reardon (1998). It was derived from the diversity index and interpreted as 1 minus the ratio of the probability of two individual from the same unit are members of different groups to the probability that any two individuals are members of different groups.

2.3.4. GIS based Measures: Lacunarity

Traditional measures of segregation use only population data for the calculation. The use of spreadsheet is sufficient enough for the calculation. However, the interaction of population groups in the real world is in space and distance. As the development of computer technology, many models using computer computation were introduced. The famous common approach is the use of GIS (Geographic Information System) to measure spatial segregation of a designated area of any landscape. With the advance of GIS, this type of analysis can provide detailed spatial information for the computation process (Wong, 2000). But the vector based data has to be dealt carefully because there could be issue with Modified Area Unit Problem (MAUP). There are several new measures occurred in the last decade, such as the agent-based model, correlation GIS to other Statistic model, and Lacunarity-based model.

The agent-based model was introduced by Crooks (2008) as an improvement from Schilling's model (2006) by linking vector based GIS and agent-based modeling

(Crooks, 2008). It transforms the basic form of real world into points, lines, and polygons. This can be applied as housing and roads in urban environment. This system is based on each individual's interaction with the environment. It creates an algorithmic movement to interact with spatial area and result in measurement values.

Combining the spatial data from GIS with statistical tools is often used. All the results from GIS spatial measures are later processed by additional statistical software. The newer version of GIS has more analysis tools such as Spatial Analysis and Spatial Statistics (Wong, 2000). These can be used in some extend.

Lacunarity-based model is a new measure that uses spatial scale. Spatial scale is important in many fields. Lacunarity-based model captures the distribution of gaps within a set at multiple scales. It captures also the 5 dimensions of segregation explained above. It is a scale dependent measure of spatial heterogeneity measuring the deviation of a geometric structure from translational invariance of a geometric structure (Wu and Sui, 2001). Lacunarity literally means *gappiness*. There are various meanings derived from it: visual texture, inhomogeneity, translational and rotational invariance, etc.

3. ANALYTICAL APPROACH/METHODS

This study compared the most widely used and popular measures of residential segregation over the past decades. All selected structural measures and spatial measures will be identified by several criteria described in the following section.

The purpose is to gain a deep understanding of each selected measurement and the phenomena of residential segregation; it is decided to use a case study of an urban area. The chosen city will have a mixed racial distribution consisting four major racial ethnic groups: white, black, Asian, and Hispanic. Besides the demographic data, the spatial data and cartographic data will be collected for the spatial measures.

The basic measures such as the dissimilarity index, Gini, entropy, Atkinson, isolation, and the correlation ratio are the result of the minority population and the majority population of a study area, there are no other variables. These can be simply calculated by spread sheet without any additional tools. Other measures needs a binary contiguous matrix from spatial units, such as Wong's multi group indices, IS(adj), D(adj), and SD. Again, the IS(w) and ID(w) require boundary lengths matrix. Then the IS(s) and ID(s) require vectors of area polygons and perimeters. The concentration indices such as the Delta (DEL), absolute concentration (ACO), and relative concentration (RCO) require one area vector. Furthermore, the centralization and clustering indices (ACL and RCL) require a distance matrix or a binary contiguous matrix and center gravity polygon. Moreover, the spatial segregation index by Wong (S) requires Centro graphic analysis to compute the result. And lastly, the lacunarity measure needs to have raster image of cartographic map and GIS software.

Two cities were chosen to apply the measures to. These cities are large metropolitan cities in the United States. The first one is Houston, being one of the ten largest population cities in the U.S., Houston is very diverse in ethnicity. From the 2008 population count, it has 25.3% African American, 30.8% white, 37.4% Hispanic, and 4.5% Asian. It can be considered to have a balanced proportion of African American, white, and Hispanic. This city has a large Hispanic population in the United States, especially the immigrants from Mexico. The African American population has been there for many decades in the city area. The foreign Asian Americans have made up a great number, such as the Chinese, Vietnamese, Thai, and Indian. The west side of the city has a high population of Vietnamese and Chinese. There are two Chinatowns in Houston, located in downtown and along west Bellaire Boulevard. The diversity of this city will be very interesting to be used for segregation measures comparison.

The second city is Philadelphia. Philadelphia has been considered as “black and white” city. There are many cities in the United States that have large populations of African American and Non Hispanic White American. Norfolk, VA and Baton Rouge, LA both have a balanced proportion of the two races. However, Philadelphia has a larger population; it is the sixth largest population in the United States. Although there are some Asian, Hispanic, and other races which make up the 14% of the remaining population, the proportion of African American and Whites are still the majority. The other races are not that significant to the interaction. This city can be used to measure segregation for two group measurements.

3.1. Measures

This study included several most commonly used segregation measures and spatial segregation measures for one group, two groups, and multi groups which were described in earlier section. These measures also consist of the five dimensions proposed by Massey and Denton (1988). The formulas for each measure are described and shown on **Appendix A**.

All of the structural measures can be processed by using an application called Segregation Analyzer created by Apparicio, Petkevitch, and Charron (2008). This application does not require any GIS software such as ArcInfo or MapInfo to calculate the spatial attributes. This application does not include data, therefore must be prepared by the user. It is developed in C# language that works with the Microsoft.Net platform (Apparicio, Petkevitch, and Charron, 2008). The calculation contains three steps:

1. Creating a data table, which contains population of each group in urban area.
2. Apply the formula of indices.
3. Export the results to output files (text file such as *.txt)

The below figure show the process of Segregation Analyzer works (**Figure 3**) and the sample of its menu bar on computer screen (**Figure 4**).

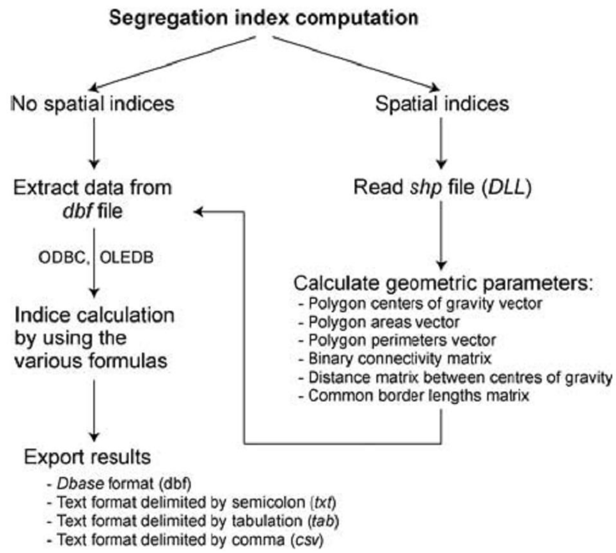

Figure 3: The process of Segregation Analyzer. Source: Apparicio, 2008.

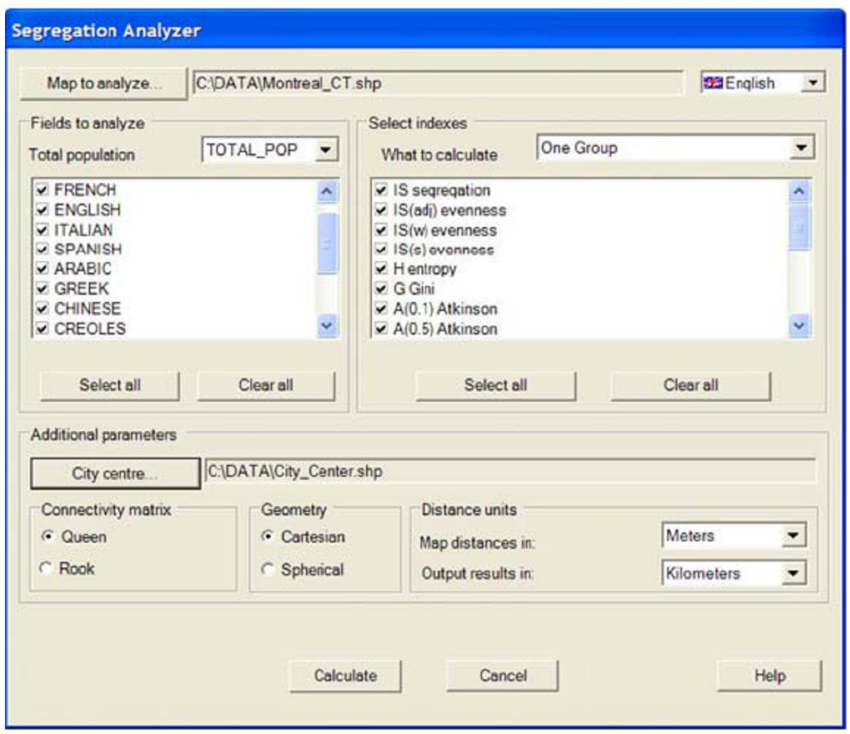

Figure 4: Segregation Analyzer interface. Source: Apparicio, 2008.

Spatial scale is important in many fields. Lacunarity-based model captures the distribution of gaps within a set at multiple scales. It captures also the 5 dimensions of segregation explained above. It is a scale dependent measure of spatial heterogeneity measuring the deviation of a geometric structure from translational invariance of a geometric structure (Wu and Sui, 2001). Lacunarity literally means *gappiness*. There are various meanings derived from it: visual texture, inhomogeneity, translational and rotational invariance, etc. The symbol is usually denoted as Λ or λ. The formula is as follows:

$$\Lambda(r) = \frac{\sum_{M} M^2 Q(M,r)}{[\sum_{M} M Q(M,r)]^2}$$

It uses a gliding box algorithm for lacunarity estimation. The r is the radius of a box gliding on a lattice overlaid on the set. The probability function Q(M,r) is obtained by dividing n(M,r) by the total number of the boxes, when the n(M,r) is the number of gliding boxes with radius r and mass M. The lacunarity scale of r is defined by the mean square deviation of the fluctuation of mass distribution probability Q(M,r) divided by its square mean (Allain and Cloitre, 1991).

Lacunarity is increasingly being used for multi scale modeling of spatial patterns. The concept of lacunarity was introduced in 1982 by Mandelbrot to differentiate texture patterns that may look the same but appear to be surprisingly different. This tool is created by using Visual Basic 6.0 and integrated with ESRI (Environmental Systems

Research Institute)'s ArcObject 9.2 to provide better result on the existing spatial analysis tool in GIS (Dong, 2009). The flowchart for Lacunarity Analysis Extension process in GIS is shown in **Figure 5**.

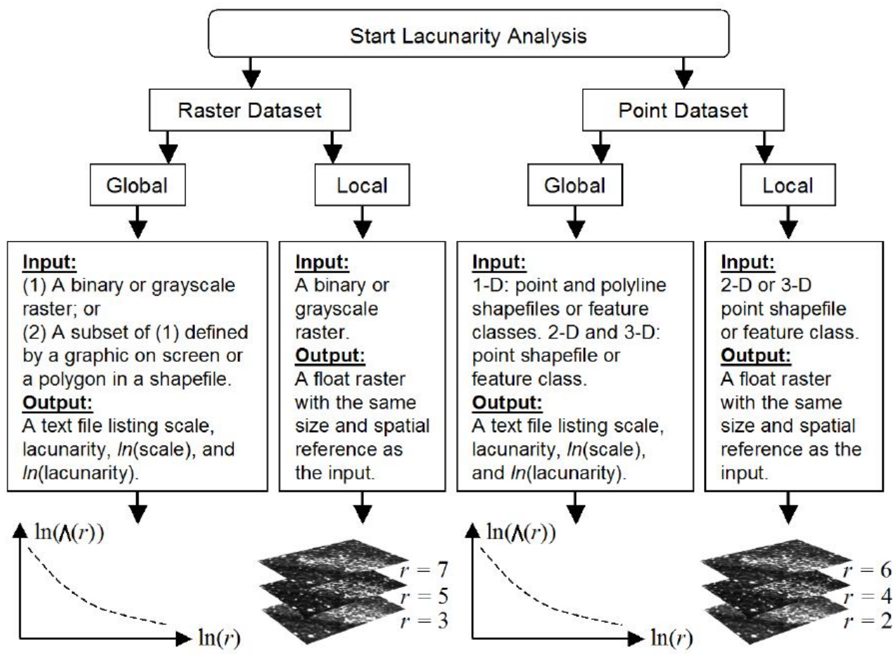

Figure 5: Lacunarity analysis flowchart. Source: Dong, 2009.

3.2. Data

There are two types of data needed to conduct the research. The first is the population demographic data and the second is the geographic data.

a. Demographic data.

The Census data provides a variety range of information on the individuals: race, age, educational attainment, incomes, household size, occupation, etc. The summary file 1 (SF1), that has all the credential information, can be downloaded from American Census Website. In this study, the demographic data is from the American Census 2000.

b. Geographic data.

The geographic data is downloaded from the same year as the demographic data, which is 2000. The shape files containing geographic and cartographic information can also be downloaded from U.S. Census website called TIGER/Line shape files. These shape files which contains the area vectors can be used to calculate the spatial attributes needed for some of the measures such as the area and perimeter, binary matrix, distance matrix, boundary length, center of gravity vector and deviational ellipse. The raster image for lacunarity analysis can be produced by importing the result of cartographic map and demographic data.

3.3. Criteria

The outcomes of this study will provide a comparison of the selected measures for urban segregation. All of the selected measurements will be assessed with several criteria such as the flexibility of scale, data requirements, complicatedness, and currency responsiveness. These criteria have important roles for the measures.

1. Flexibility of scale.

Most of the measures have the result of single value for each racial group in one study area or the metropolitan city. However, these measures are calculated from both the total population and the smaller racial units which may be using the census tracts, census block groups, and census blocks. Many of the measures used the census tracts rather than the smaller scale, the census blocks. Depending on different scale, large or small, the result is expected to show significant differences.

a. Small scale (census blocks, households, or individual)
b. Medium scale (census block groups)
c. Large scale (census tracts, counties, etc.)

2. Data requirements.

This criterion shows what kind of data is required to compute a measure. By listing the needed data for computation, researchers may choose measures according to the availability of the data. On the other hand, researchers may also select a certain measure and gather the appropriate data accordingly. Different types of measure will require different specific data such as:

a. population by racial groups in area unit (census blocks, block group, or tract)
b. Total population in study area (city, metropolitan, county, etc.)
c. Area vector of the unit,
d. Perimeter of the unit,
e. Binary Matrix of the population,
f. Distance Matrix from each unit,
g. Boundary Length of any adjacent unit,
h. Center of Gravity Vector for area unit,

i. Deviational Ellipse,

j. Raster Image

3. **Currency responsiveness.**

Some of the measures are easily found on any institution or website providing a certain metropolitan profiles. The currency indicates the relation of the measures to the general usage and how common they are being used.

4. **Level of measures.**

The level of measures evaluates what is the smaller scale a measure is able to compute. The results of each measure represent different level of population such as:

a. City or Metropolitan area,

b. Census tract,

c. Census block group,

d. Census block,

5. **Ease of use.**

After getting all required data, each measure will have different method and time to be processed. Some would be easy and fast, some would be difficult and time consuming. This criterion indicates how easy or hard a measure is. However, this criteria can be subjective.

6. **Number of groups measured.**

Some of the measures only capture two population groups while others are able to examine multi groups.

7. Dimension of measurement.

The five dimensions of measures proposed by Massey and Denton (1988) are used to capture the different population distribution in the study area. This will categorize the measure for the different dimensions as follows:

a. Dimension of Evenness.

b. Dimension of Exposure.

c. Dimension of Concentration.

d. Dimension of Centralization.

e. Dimension of Clustering.

8. Spatial Attributes.

a. Boundary Accessibility.

This measures the interaction of individual across boundaries.

b. Boundary-length Consideration.

The length of boundary lines will affect the interaction.

c. Perimeter Ratio

Boundary size and shape.

d. Area

The area sizes of each racial group are located.

e. Binary Matrix

To be used for defining surrounding spatial units in each groups.

f. Distance Matrix

The distance from population groups to the central urban area.

g. Center of Gravity Vector

The center of each population unit.

h. Deviational Ellipse.

The distribution of each population groups in a whole city.

4. RESULTS

This paper discussed only conceptual and empirical issues on the most used segregation measures. As stated by Massey and Denton (1988), segregation is a multidimensional concept and therefore it should be measured not with one index, but with several (Massey and Denton, 1988). After having completed all of the measures with two metro areas[1], which are Harris county and Philadelphia county, the measurements are analyzed according to the number of groups being measured. There are measurements for one racial group - which only measure the chosen population group in certain census tract, block group, or block; for two racial group – which measure in pair where a first racial group compared to a second racial group or a minority population to a majority population; and for the multi group – which measure more than two racial groups all together in a study area.

The results are compared within different units, the census tract, block groups, or blocks. Next, they are compared by the racial groups to see how these different measures ranked the segregated racial groups. Finally, these measures are compared between racial groups themselves.

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[1] The metro areas are only the counties, not the full metropolitan areas of Houston and Philadelphia. The full Houston Metropolitan area has 10 surrounding counties (Harris County, Fort Bend County, Montgomery County, Brazoria County, Galveston County, Liberty County, Waller County, Chambers County, Austin County, and San Jacinto County). The Philadelphia Metropolitan area has 13 counties from 4 different states (Delaware State: New Castle County; Maryland State: Cecil County; New Jersey State: Burlington County, Camden County, Cumberland County, Gloucester County, and Salem County, Pennsylvania State: Berks County, Bucks County, Chester County, Delaware County, Montgomery County, and Philadelphia County)

Unfortunately, there were some unexpected problems encountered when processing the measures. There are eleven measures which were unable to be processed in block level for one group and two groups which due to the data being calculated were too large (more than 17,000 data for Philadelphia and more than 38,000 data for Houston). In one group measures, they are the IS(w), IS(s), Pxx, Pxx(exp), and DPxx. In two group measures, they are the D(w), D(s), Pxy, SP, RCL, and DPxy. The data were meant to be calculated with each of the unit's area and perimeter boundaries. However, by looking at the results in other levels the unprocessed result can be predicted and the conclusion can be made. The twelve measures for the block level can be analyzed by looking at the tract and block group level. Many of them have similar patterns. There were only three that could not be processed at all levels from all 39 measures. The three measures are the centralization measures which are not commonly used and do not have a significant impact on the analysis.

4.1 Calculation and Getting the Results

Most of the basic indices defined in Appendix A, such as the Segregation Index (IS), Dissimilarity Index (ID), Entropy (H), Gini Coeffisien (G), Atkinson index (Atk), Squared Coefficient of Variation (C), Isolation Index (xPx), Interaction Index (xPy), Normalized Exposure (P), Relative Diversity (R), and Proportion in Central City (PCC) are easily calculated manually (**Figure 6**, **Figure 7**, **Figure 8**, **Figure 9**, and **Figure 10)**. These indices only need the total population in the study area and the racial group population in smaller area units such as the census block, block group, or tract. Usually these indices are calculated with the area unit in census tract and the city population as the total population.

Software such as the Segregation Analyzer is able to produce results all at once and saving a huge amount of time. Other modified indices or those that need spatial attributes are not easy to calculate. The required spatial attributes are area vector, perimeter, binary matrix, distance matrix, boundary length, center of gravity vector, deviational ellipse, and Central Business District boundary.

This Segregation Analyzer still has limitations. The model can only be processed by selecting one shape file at a time which means you can only compute on one level. This means the software can only compute the results of the indices with census tract data. To compute other results such as the census block or block group, a researcher needs to input the appropriate shape file.

Another issue is when it computes a very large amount of data such as those of census block. The IS(w), IS(s), Pxx, Pxx(exp), and DPxx would be hard to get the result due to the intensity of the calculation with binary matrices, distance matrices, and center of gravity vectors. Calculation such matrices need a large amount of memory to process because all of the census blocks have to form a large n x n matrix to multiply. However, with some of those indices missing, a researcher may still manage to analyze the results by having other data of different level such as the census tracts and census block groups.

Table 1: Segregation measures comparison for evenness dimension

Dimension:		EVENNESS					
Criteria		**Segregation Index**	**Segregation Index Boundary Access**	**Segregation Index Boundary Length**	**Segregation Index Parameter Ratio**	**Entropy Index**	**Gini Coef**
Symbol		IS/ID	IS/ID(adj)	IS/ID(w)	IS/ID(s)	H	G
Scale		Small/ Large	Small/ Large	Small/ Large	Small/ Large	Small/ Large	Small/ Large
Scale Tendency		Higher on small scale	Higher on small scale	Higher on small scale	Higher on small scale	Higher on small scale	Higher on small scale
Data:	Group	X	X	X	X	X	X
	Total Population	X	X	X	X	X	X
	Area vector	-	-	-	X	-	-
	Perimeter	-	-	-	X	-	-
	Binary Matrix	-	X	X	X		-
	Distance Matrix	-	-	-	-	-	-
	Boundary Length	-	-	X	X	-	-
	Center of Gravity Vector	-	-	-	-	-	-
	Deviational Ellipse	-	-	-	-	-	-
Usage		Very Common	Less Common	Less Common	Less Common	Very Common	Very Common
Level		City	City	City	City	City	City
Easy (manually)		Easy	Very Hard	Very Hard	Very Hard	Easy	Easy
Easy (software)		Easy	Easy	Easy	Easy	Easy	Easy
Group		1, 2	1, 2	1, 2	1, 2	1, M	1, M

Dimension:		EVENNESS (CONTINUED)				
Criteria		**Atkinson**	**Multigroup Dissimilarity Index**	**Spatial Dissimilarity**	**Squarred coefficient of variation**	**Deviational Ellipse**
Symbol		Atk	D	SD	C	S
Scale		Small/ Large	Small/ Large	Small/ Large	Small/ Large	Small/ Large
Scale Tendency		Higher on small scale	Higher on small scale	Higher on small scale	Higher on small scale	Similar
Data:	Group	X	X	X	X	X
	Total Population	X	X	X	X	X
	Area vector	-	-	-	-	-
	Perimeter	-	-	-	-	-
	Binary Matrix	-	-	X	-	-
	Distance Matrix	-	-	-	-	-
	Boundary Length	-	-	-	-	-
	Center of Gravity Vector	-	-	-	-	X
	Deviational Ellipse	-	-	-	-	X
Usage		Very Common	Not Common	Not Common	Not Common	Less Common
Level		City				City
Easy (manually)		Easy	Very Hard	Very Hard	Very Hard	Very Hard
Easy (software)		Easy	Easy	Easy	Easy	Easy
Group		1	M	M	M	2, M

Table 2: Segregation measures comparison for exposure dimension

Dimension:		EXPOSURE				
Criteria		**Isolation**	**Interaction**	**Correlation Ratio**	**Normalized Exposure**	**Relative Diversity**
Symbol		xPx	xPy	Eta	P	R
Scale		Small/ Large	Small/ Large	Small/ Large	Small/ Large	Small/ Large
Scale Tendency		Higher on small scale	Higher on small scale	Higher on small scale	Higher on small scale	Higher on small scale
Data:	Group	X	X	X	X	X
	Total Population	X	X	X	X	X
	Area vector	-	-	-	-	-
	Perimeter	-	-	-	-	-
	Binary Matrix	-	-	-	-	-
	Distance Matrix	-	-	-	-	-
	Boundary Length	-	-	-	-	-
	Center of Gravity Vector	-	-	-	-	-
	Deviational Ellipse	-	-	-	-	-
Usage		Very Common	Very Common	Less Common	Not Common	Not Common
Level		City	City	City		
Easy (manually)		Easy	Easy	Easy	Very Hard	Very Hard
Easy (software)		Easy	Easy	Easy	Easy	Easy
Group		1	2	1	M	M

Table 3: Segregation measures comparison for concentration dimension

Dimension:		CONCENTRATION		
Criteria		**Delta Index**	**Absolute Concentration Index**	**Relative Concentration Index**
Symbol		DEL	ACO	RCO
Scale		Small/ Large	Small/ Large	Small/ Large
Scale Tendency		Higher on small scale	Higher on small scale	Higher on small scale
Data:	Group	X	X	X
	Total Population	X	X	X
	Area vector	X	X	X
	Perimeter	-	-	-
	Binary Matrix	-	-	-
	Distance Matrix	-	-	-
	Boundary Length	-	-	-
	Center of Gravity Vector	-	-	-
	Deviational Ellipse	-	-	-
Usage		Less Common	Less Common	Not Common
Level		City	City	
Easy (manually)		Very Hard	Very Hard	Very Hard
Easy (software)		Easy	Easy	Easy
Group		1	1	2

Table 4: Segregation measures comparison for clustering dimension

Dimension:		CLUSTERING				
Criteria		**Mean Proximity group X**	**Mean Proximity group X(exp)**	**Mean Proximity group X**	**Mean Proximity group X(exp)**	**Absolute Clustering Index**
Symbol		Pxx	Pxx(exp)	Pxy	Pxy(exp)	ACL
Scale		Small/ Large	Small/ Large	Small/ Large	Small/ Large	Small/ Large
Scale Tendency		Similar	Higher on small scale	Varies	Varies	Higher on small scale
Data:	Group	X	X	X	X	X
	Total Population	X	X	X	X	X
	Area vector	-	-	-	-	-
	Perimeter	-	-	-	-	-
	Binary Matrix	-	-	-	-	X
	Distance Matrix	X	X	X	X	-
	Boundary Length	-	-	-	-	-
	Center of Gravity Vector	X	X	X	X	-
	Deviational Ellipse	-	-	-	-	-
Usage		Less Common	Less Common	Less Common	Less Common	Less Common
Level		City	City	City	City	City
Easy (manually)		Medium	Medium	Medium	Medium	Very Hard
Easy (software)		Easy	Easy	Easy	Easy	Easy
Group		1	1	2	2	1

Dimension:		CLUSTERING (CONTINUED)			
Criteria		**Spatial Proximity Index**	**Relative Clustering Index**	**Distance Decay**	**Distance Decay**
Symbol		SP	RCL	DPxx	DPxy
Scale		Small/ Large	Small/ Large	Small/ Large	Small/ Large
Scale Tendency		Similar	Lower on small scale	Varies	Varies
Data:	Group	X	X	X	X
	Total Population	X	X	X	X
	Area vector	-	-	-	-
	Perimeter	-	-	-	-
	Binary Matrix	-	X	-	-
	Distance Matrix	X	X	X	X
	Boundary Length	-	-	-	-
	Center of Gravity Vector	X	X	X	X
	Deviational Ellipse	-	-	-	-
Usage		Less Common	Less Common	Less Common	Less Common
Level		City	City	City	City
Easy (manually)		Very Hard	Very Hard	Medium	Medium
Easy (software)		Easy	Easy	Easy	Easy
Group		2	2	1	2

Table 5: Segregation measures comparison for centralization dimension and lacunarity

Dimension:		CENTRALIZATION			
Criteria		**Proportion in Central City**	**Absolute Centralization Index**	**Relative Centralization Index**	**Lacunarity**
Symbol		PCC	ACE	RCE	-
Scale		Small/ Large	Small/ Large	Small/ Large	Multi Scale
Scale Tendency		Same result	Same result	Same result	Varies
Data:	Group	X	X	X	X
	Total Population	X	X	X	X
	Area vector	-	-	-	X
	Perimeter	-	-	-	X
	Binary Matrix	-	-	-	-
	Distance Matrix	-	X	X	-
	Boundary Length	-	-	-	-
	Center of Gravity Vector	-	X	X	-
	Deviational Ellipse	-	-	-	-
	Usage	Not Common	Not Common	Not Common	Not Common
Level		City	City	City	block-tract
Easy (manually)		Very Hard	Very Hard	Very Hard	Unmeasured
Easy (software)		Easy	Easy	Easy	Very Hard
Group		1	1	2	M

The lacunarity analysis captures all the scale and dimension of the other indices at the same time by computing a raster image. The Lacunarity Analysis software by Dong (2009) used in this research uses a grayscale raster image to produce the result. Several attempts have been conducted for this paper. The computation would fail when a large resolution image was used. For this research, all of the raster images used are 800 x 554 pixels. The zooming in ArcView affects the result slightly. Therefore, it is suggested to use the same zoom when running more than one model for comparison. The time taken for each model of racial groups in one scale was around 90 minutes.

4.2 Comparison

The comparison is analyzed in three different categories. First, between different scales of blocks, block groups, and tracts. Second, compare between the four selected racial groups: Asians, blacks, Hispanics, and whites. And third, compare the results between the two study areas, Houston and Philadelphia (Harris County and Philadelphia County). The tables of comparison with the criteria are shown in **Table 1**, **Table 2**, **Table 3**, **Table 4**, and **Table 5**.

4.2.1. Scale (Block, Block Group, and Tract)

In one group segregation indices, the tract level, block group level, and block level experienced a slightly increase from larger to smaller area. In Houston, the indices increased by 0.01 – 0.05 from tract to block group, and 0.05 – 0.1 higher from block group to block. The two group measures only show the indices between the minority and majority. This means that black, Asian, and Hispanics are measured separately with the white population. But again, the indices show the similar pattern as in one group. At the multi groups, the indices increase from tract to block level (**Figure 6**). This indicates that for the evenness measures, the value increases when the scale is smaller.

The charts in **Figure 6** and **Figure 7** shows that the indices for one group measures, specifically for the evenness indices, vary differently with high and low value. But the highest segregation can be seen on the black racial groups for Houston and Philadelphia. The modified indices such as the IS(adj), IS(s), and IS(w) or for the two group D(adj), D(s), and D(w) decreased slightly when the boundary access and perimeter were applied to the indices.

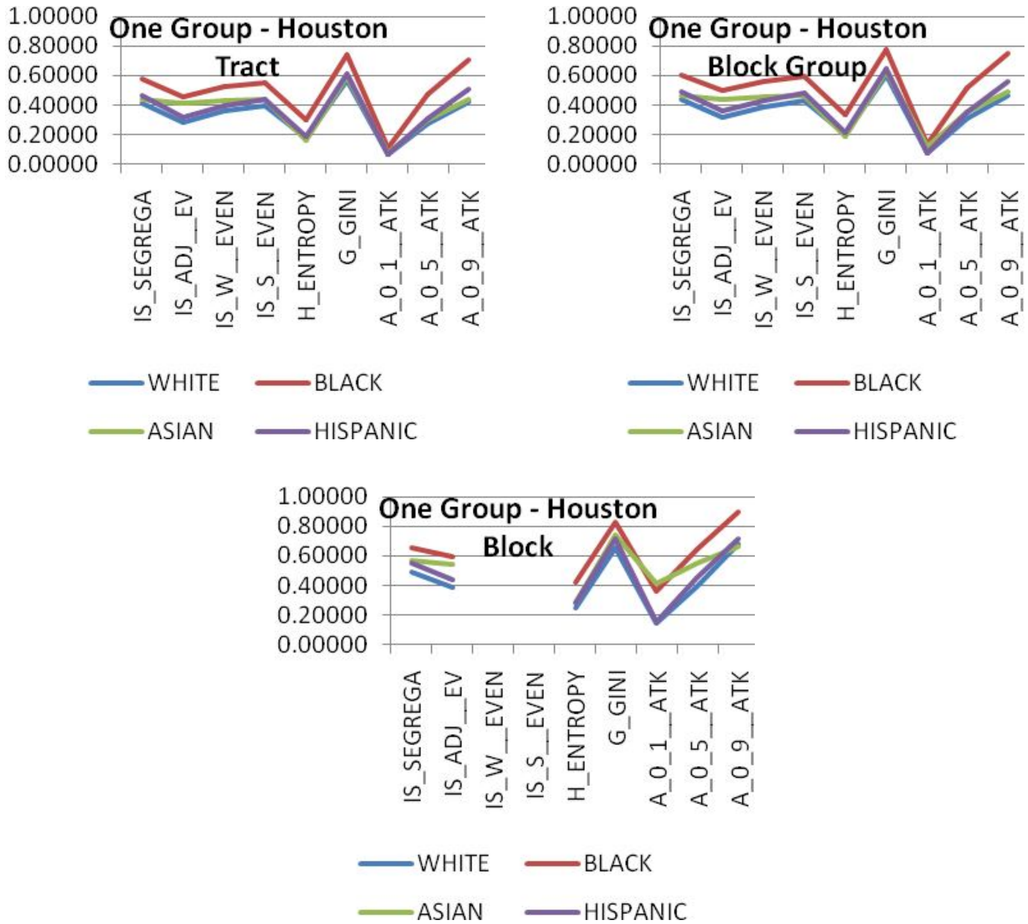

Figure 6: One group measures for evenness in Houston.

The Gini indices for all levels show higher than the others. On the other hand, the H entropies are low on all results. The Atkinson indices also follow the same patterns where the Atkinson 1 are low on all results, Atkinson 5 are moderate, and Atkinson 9 are high. Disregard to the value differences, all of them showed that black is the highest segregated for the evenness.

For the dimension of exposure, most of the indices for one group showed that the Asian is the least exposed to other racial groups. The reason can be that the Asian population is low compared to the white and black population. These results occurred also in Philadelphia, the Hispanic is ranked second after the Asian. Both Asian and Hispanic population are very low compared to their other counterparts.

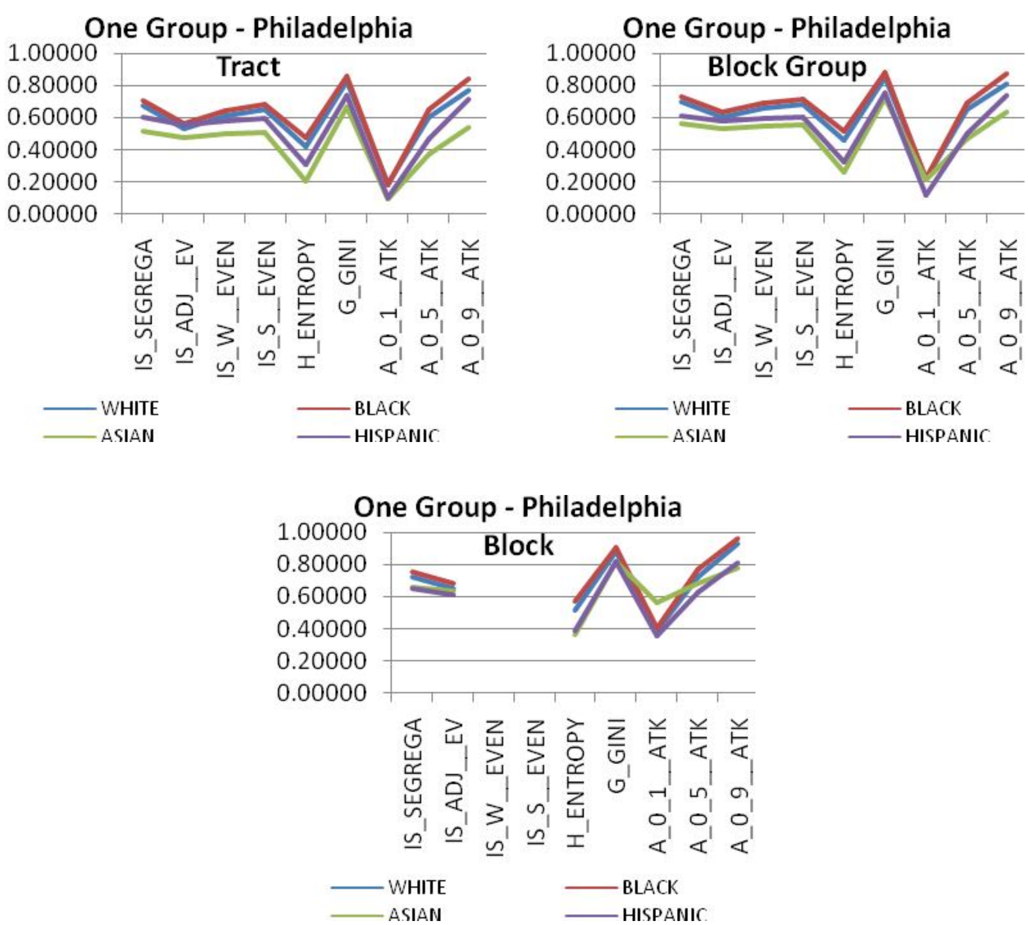

Figure 7: One group measures for evenness in Philadelphia.

Most of the clustering indices for block levels are not computed due to the difficulty in data processing. From only the two levels (census tract and census block groups), the indices increases from tract level to block group level. This indicates that the smaller the scale, the indices increase slightly.

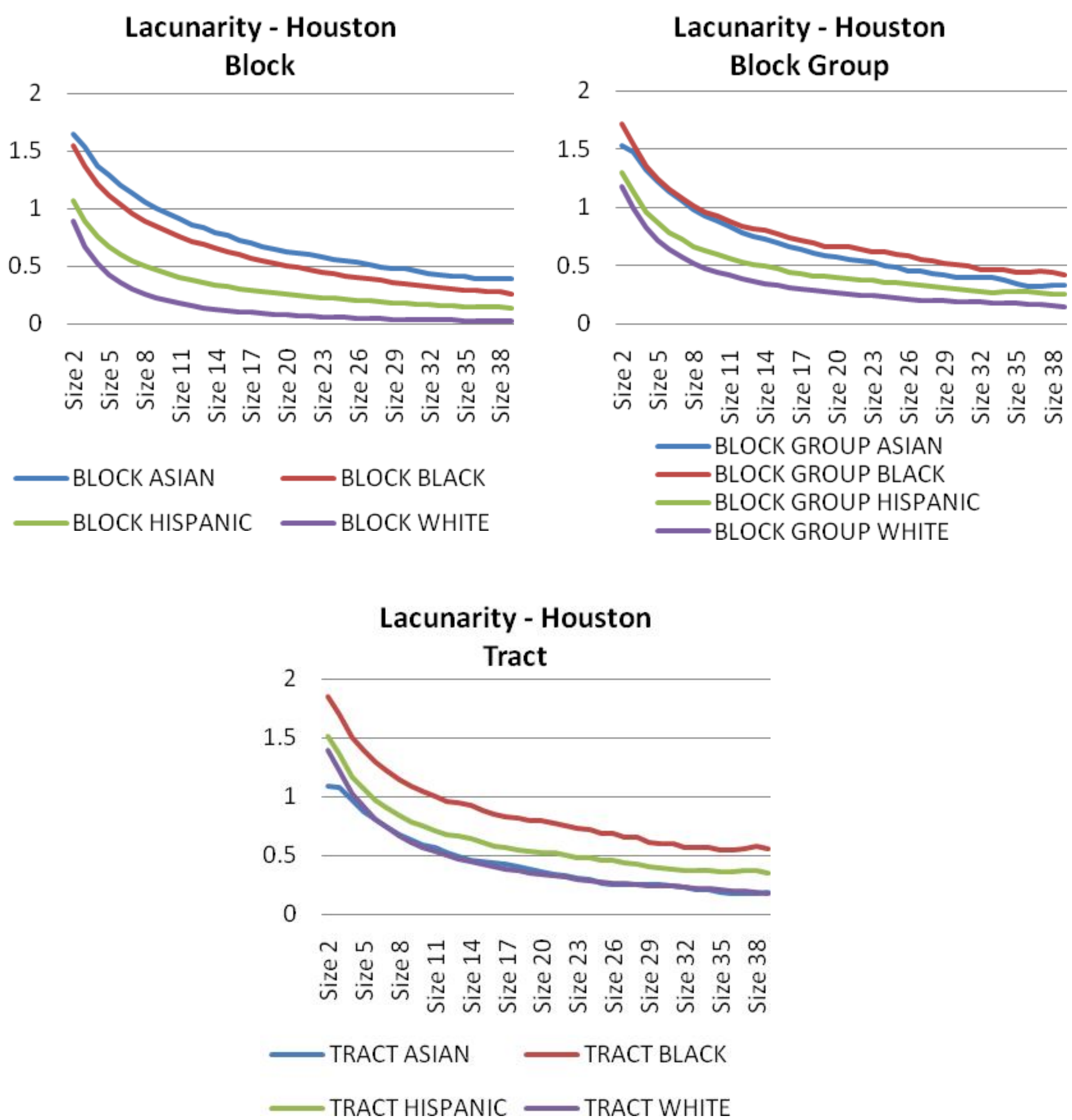

Figure 8: Lacunarity results for Houston.

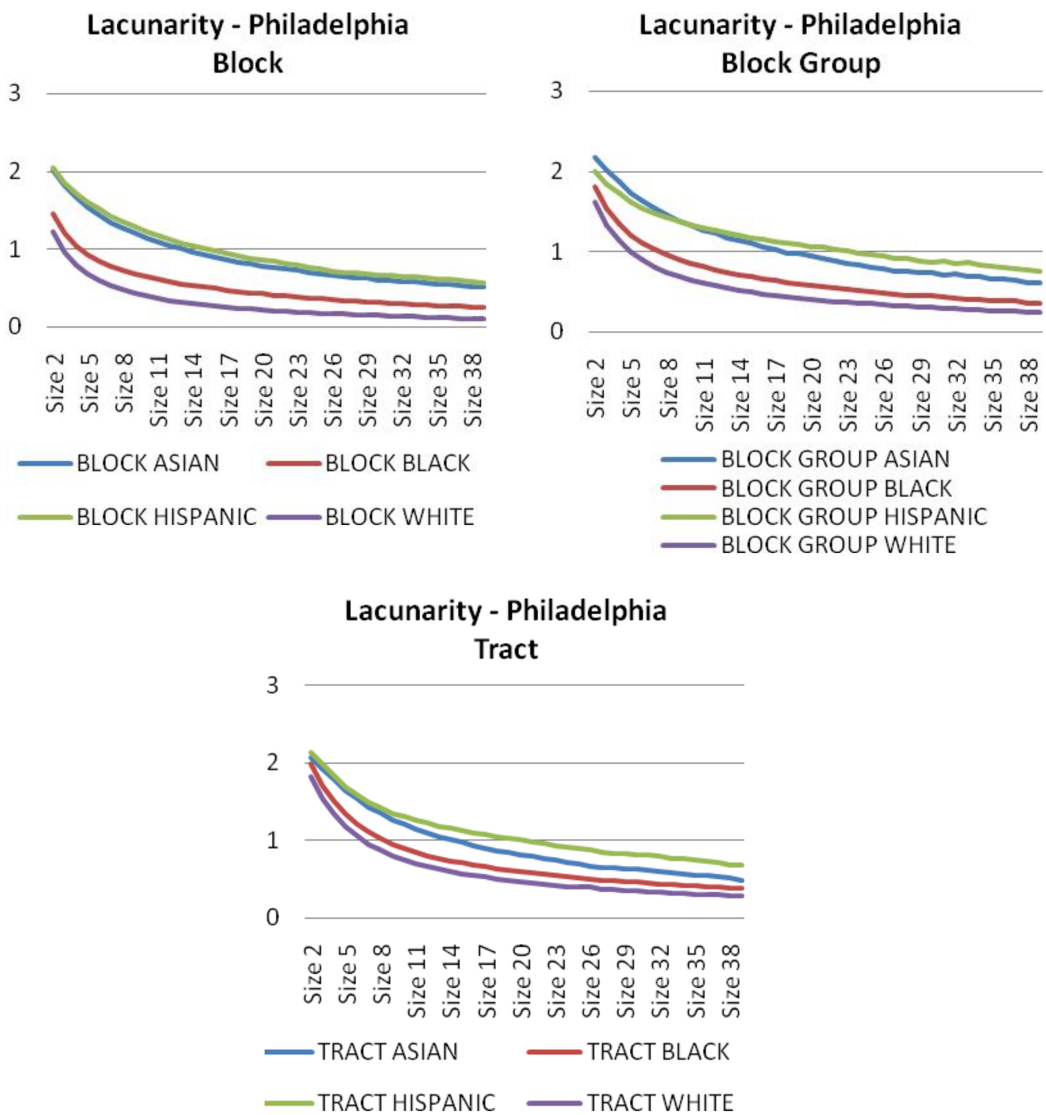

Figure 9: Lacunarity analysis for Philadelphia.

The lacunarity results showed some differences in the ranks of the racial groups. In Houston, instead of Black, the Asian is the highest segregated in census block level. But when in tract level, the results showed similarity with the other indices, black is the most segregated. This can be seen on **Figure 8** and **Figure 9**. In Philadelphia, Hispanic ranked the highest, followed by Asian, black, and white. However, the larger the scale the higher the values, this follows the similar pattern as the other indices. The census tract has higher values in lacunarity analysis. Moreover, when the scale (gliding boxes) gets larger, the values drop.

4.2.2. Racial Groups

The order of the segregated groups for one group measures is very similar in both Houston and Philadelphia. In Houston, the most segregated for one group is black and follow up by Hispanic or Asian interchangeably. In Philadelphia, black is also the most segregated and the second is the white population. When going down to census block level, there is a slight change only in DEL indices. The block results showed the Asian as the highest followed by Hispanic, unlike the block results, the tract and block groups have the Hispanic as the highest followed by Asian. These can be seen on Table 6 and Table 7. The Atkinson 1 index has the Asians as the most segregated in Houston, and black the second. Although the value varies from 0.1 – 0.9 for the highest segregation indices, the order of the racial groups being segregated are still showing the black as the most segregated for all levels and in both cities. The Atkinson indices with b=1 showed different in both cities. It did not follow the pattern as the others; for the one group block measures the highest is the Asian, while tract and block group have the highest indices for black. In two group measures, the Atkinson b=1 also showed the Asian as the highest while the tract and block group placed white as the highest. This could be the result of the population proportion. Black and white has a huge number in census block group and tract. The Asian has a very small proportion that it is not captured in census block group and tract level, but it showed some differences when calculating in smaller area such as the census block. These are shown in **Table 6** and **Table 7**.

For two group measures that compared minority groups to white population, Houston and Philadelphia both placed black-white pair as the most segregated, Asian-white came second, and Hispanic-white is placed third. This is shown on **Table 8** and **Table 9**. Both study area shows black as the highest among other racial groups. All the different indices in two group measures have the same order for all racial groups in both cities.

Table 6: One group – Houston

	TRACT				BLOCK GROUP				BLOCK			
MEASURES	WHITE	BLACK	ASIAN	HISP	WHITE	BLACK	ASIAN	HISP	WHITE	BLACK	ASIAN	HISP
IS_Evenness	0.417	0.574	0.441	0.461	0.440	0.606	0.469	0.492	0.491	0.651	0.566	0.549
IS(Adj) Even	0.282	0.455	0.412	0.321	0.316	0.503	0.440	0.360	0.384	0.590	0.540	0.445
IS(w) Even	0.358	0.523	0.428	0.399	0.384	0.560	0.456	0.433	-	-	-	-
IS(s) Even	0.395	0.555	0.436	0.437	0.431	0.598	0.467	0.482	-	-	-	-
H – Entropy	0.183	0.302	0.162	0.189	0.205	0.338	0.186	0.216	0.246	0.417	0.279	0.286
G – Gini	0.571	0.740	0.595	0.612	0.599	0.772	0.629	0.647	0.661	0.827	0.738	0.716
A_0_1__ATK	0.068	0.114	0.079	0.068	0.078	0.134	0.121	0.078	0.143	0.359	0.406	0.157
A_0_5__ATK	0.277	0.472	0.302	0.310	0.307	0.520	0.349	0.349	0.399	0.649	0.550	0.455
A_0_9__ATK	0.422	0.703	0.441	0.504	0.462	0.751	0.494	0.556	0.684	0.897	0.659	0.712
XPX Exposure	0.689	0.477	0.122	0.512	0.699	0.508	0.139	0.534	0.722	0.559	0.193	0.581
ETA2 Exposure	0.245	0.359	0.074	0.272	0.270	0.396	0.093	0.305	0.326	0.459	0.149	0.375
DEL – Concent	0.466	0.648	0.643	0.590	0.518	0.689	0.678	0.630	0.653	0.797	0.807	0.745
ACO – Concent	0.307	0.805	0.899	0.753	0.291	0.844	0.908	0.769	0.350	0.815	0.922	0.731
ACL – Cluster	0.373	0.240	0.069	0.264	0.444	0.293	0.084	0.291	0.569	0.400	0.129	0.497
PXX – Cluster	32.95	24.990	26.733	26.014	30.184	23.061	24.672	23.754	-	-	-	-
PXX_EXP__D	0.002	0.003	0.004	0.003	0.002	0.005	0.006	0.004	-	-	-	-
DPXX – Cluster	0.667	0.371	0.092	0.434	0.665	0.381	0.095	0.448	-	-	-	-
PCC_Central	0.002	0.004	0.001	0.001	0.002	0.004	0.001	0.001	0.002	0.004	0.001	0.001
ACC_Central	0.290	0.557	0.341	0.546	0.292	0.560	0.342	0.547	0.292	0.560	0.341	0.548

Notes: The shaded color shows the most and the second most segregated values in each measurement. The dark gray: the most segregated, light gray: the second most segregated.

Table 7: One group – Philadelphia

MEASURES	TRACT WHITE	TRACT BLACK	TRACT ASIAN	TRACT HISP	BLOCK GROUP WHITE	BLOCK GROUP BLACK	BLOCK GROUP ASIAN	BLOCK GROUP HISP	BLOCK WHITE	BLOCK BLACK	BLOCK ASIAN	BLOCK HISP
IS_Evenness	0.676	0.705	0.512	0.599	0.700	0.731	0.559	0.610	0.723	0.757	0.660	0.647
IS(Adj) Even	0.532	0.562	0.475	0.556	0.601	0.632	0.529	0.575	0.649	0.686	0.632	0.607
IS(w) Even	0.614	0.645	0.496	0.581	0.656	0.687	0.545	0.594	-	-	-	-
IS(s) Even	0.652	0.681	0.505	0.592	0.685	0.716	0.554	0.604	-	-	-	-
H – Entropy	0.418	0.473	0.205	0.304	0.455	0.514	0.256	0.324	0.512	0.569	0.360	0.385
G – Gini	0.827	0.856	0.663	0.734	0.850	0.878	0.723	0.756	0.879	0.905	0.822	0.819
A_0_1__ATK	0.185	0.180	0.094	0.103	0.216	0.216	0.208	0.119	0.389	0.401	0.562	0.359
A_0_5__ATK	0.606	0.649	0.368	0.467	0.650	0.693	0.469	0.497	0.725	0.769	0.680	0.627
A_0_9__ATK	0.769	0.843	0.536	0.715	0.807	0.874	0.631	0.740	0.931	0.962	0.778	0.807
XPX Exposure	0.741	0.762	0.137	0.364	0.759	0.782	0.174	0.381	0.782	0.804	0.232	0.411
ETA2	0.528	0.581	0.097	0.305	0.562	0.616	0.135	0.323	0.603	0.654	0.196	0.357
DEL –	0.494	0.608	0.615	0.656	0.541	0.639	0.670	0.678	0.641	0.720	0.805	0.772
ACO –	0.307	0.732	0.782	0.771	0.315	0.743	0.882	0.892	0.409	0.659	0.931	0.917
ACL – Cluster	0.540	0.586	0.070	0.293	0.634	0.570	0.105	0.302	0.667	0.653	0.155	0.301
PXX – Cluster	10.884	7.908	9.904	5.860	10.877	7.919	9.912	5.850	-	-	-	-
PXX_EXP__D	0.020	0.032	0.034	0.065	0.024	0.035	0.041	0.077	-	-	-	-
DPXX –	0.642	0.643	0.064	0.219	0.620	0.673	0.067	0.237	-	-	-	-
PCC_Central	0.057	0.006	0.074	0.014	0.057	0.006	0.074	0.014	0.057	0.006	0.074	0.014
ACC_Central	-0.010	0.299	0.259	0.269	-0.009	0.300	0.258	0.268	-0.008	0.301	0.259	0.269

Notes: The shaded color shows the most and the second most segregated values in each measurement. The dark gray: the most segregated, light gray: the second most segregated.

In lacunarity analysis (see **Figure 8** and **Figure 9**), the highly segregated racial groups are the Asian, black, and Hispanic. Black and Asian are in Houston and Hispanic and Asian in Philadelphia. These are shown on all level of measures, from census block, block group, to tract. The nature of lacunarity analysis is to measure the gappiness on given maps. The smaller the unit of analysis, the more detail it captures. The high value for the Asian and Hispanic in Philadelphia is the result of the small populations which in small scale they are distributed in small clustering while the larger populations are distributed more evenly.

Table 8: Two groups – Houston

	HOUSTON - TRACT			HOUSTON - BLOCK GROUP			HOUSTON - BLOCK		
MEASURES	**B to W**	**H to W**	**A to W**	**B to W**	**H to W**	**A to W**	**B to W**	**H to W**	**A to W**
D - Dissimilarity	0.621	0.400	0.442	0.651	0.420	0.469	0.693	0.455	0.564
D(adj) - Evenness	0.487	0.265	0.307	0.527	0.296	0.345	0.587	0.349	0.457
D(w) - Evenness	0.562	0.341	0.382	0.595	0.364	0.413	-	-	-
D(s) - Evenness	0.600	0.378	0.420	0.642	0.411	0.460	-	-	-
S - Centographic	0.789	0.701	0.858	0.793	0.700	0.858	0.793	0.700	0.858
xPy - Exposure	0.325	0.542	0.560	0.302	0.539	0.553	0.269	0.533	0.520
RCO - Relative Conc	0.353	0.419	0.353	0.442	0.456	0.254	0.246	0.310	0.190
Pxy - Clustering	29.771	30.089	31.472	27.360	27.526	28.877	-	-	-
SP - Clustering	1.332	1.136	1.095	1.344	1.146	1.101	-	-	-
RCL - Clustering	1.188	0.903	1.428	1.175	0.861	1.439	-	-	-
Dpxy - Interaction	0.404	0.548	0.578	0.394	0.556	0.562	-	-	-
RCE - Centralization	0.300	0.293	0.015	0.302	0.294	0.015	0.302	0.294	0.015

Notes: The shaded color shows the most and the second most segregated values in each measurement. The dark gray: the most segregated, light gray: the second most segregated.

Table 9: Two groups – Philadelphia

	HOUSTON - TRACT			HOUSTON - BLOCK GROUP			HOUSTON - BLOCK		
MEASURES	**B to W**	**H to W**	**A to W**	**B to W**	**H to W**	**A to W**	**B to W**	**H to W**	**A to W**
D - Dissimilarity	0.751	0.614	0.486	0.775	0.633	0.537	0.800	0.666	0.633
D(adj) - Evenness	0.607	0.470	0.341	0.676	0.534	0.438	0.726	0.592	0.558
D(w) - Evenness	0.689	0.552	0.423	0.731	0.589	0.493	-	-	-
D(s) - Evenness	0.727	0.590	0.461	0.760	0.618	0.522	-	-	-
S - Centographic	0.926	0.847	0.837	0.926	0.848	0.835	0.927	0.847	0.835
xPy - Exposure	0.154	0.387	0.504	0.138	0.383	0.486	0.121	0.377	0.455
RCO - Relative Conc	0.521	0.312	0.222	0.566	0.508	0.307	0.372	0.451	0.301
Pxy - Clustering	11.183	0.312	0.222	11.186	9.181	10.925	-	-	-
SP - Clustering	1.433	1.316	1.050	1.457	1.336	1.062	-	-	-
RCL - Clustering	0.554	2.204	0.667	0.491	2.274	0.735	-	-	-
Dpxy - Interaction	0.266	0.443	0.508	0.233	0.422	0.487	-	-	-
RCE - Centralization	0.284	0.254	0.249	0.284	0.255	0.248	0.284	0.255	0.249

Notes: The shaded color shows the most and the second most segregated values in each measurement. The dark gray: the most segregated, light gray: the second most segregated.

4.2.3. Houston vs. Philadelphia

The indices are higher in Philadelphia than in Houston for all one group, two groups, or multi group indices. Whenever the value is very high in Houston, the same measure in Philadelphia is significantly higher. The multi group results are shown in **Table 10**. Also, when it is low for Houston, Philadelphia would have a low result but a bit higher. Interestingly, the indices for multi group Deviational ellipse measure (S – Centro graphic) in Philadelphia have the maximum value, which is 1. This means that Philadelphia has all the racial groups totally separated each other.

Table 10: Multi group

	Philadelphia			Houston		
MEASURES	Block	Block Group	Tract	Block	Block Group	Tract
D - Dissimilarity	0.7226	0.6912	0.6664	0.5519	0.4971	0.4692
G - Gini	0.8775	0.8406	0.8156	0.7228	0.6565	0.6246
H - Information theory	0.5418	0.4796	0.4425	0.3610	0.2876	0.2576
P - Normalized exposure	0.5930	0.5527	0.5189	0.4074	0.3369	0.3038
R - Relative diversity	0.5638	0.5237	0.4909	0.3596	0.2973	0.2674
C - Squared variation	0.4055	0.3612	0.3306	0.3006	0.2422	0.2155
SD - Spatial	0.6904	0.6442	0.5977	0.4976	0.4296	0.3916
S - Centrographic	1.0000	1.0000	1.0000	0.7667	0.7679	0.7678

Notes: The shaded color shows the most and the second most segregated values in each measurement. The dark gray: the most segregated, light gray: the second most segregated.

For concentration dimension, the indices for the racial groups vary differently for Houston and Philadelphia. In one group measures, black and Hispanic have higher values in Houston while in Philadelphia the Asian is higher. In two group measures, Hispanics is the highest in Houston but white in Philadelphia. These indices show that Houston and Philadelphia has different distribution in concentration dimension.

5. CONCLUSION

Computing the segregation indices using different scales (census tracts, census block groups, and census blocks) gives slightly different values, but follows the same order. The smaller the scale, the indices also somewhat increases. For examples, all the multi groups indices varies differently from 0.2 – 0.8 (multi group dissimilarity index, gini index, entropy index, normalized index, relatives diversity index, squared variation index, spatial index, and Centro graphic index). Changing the scale from tract to block group or block will increase the indices slightly from 0.4 – 1.0 (**Figure 10**).

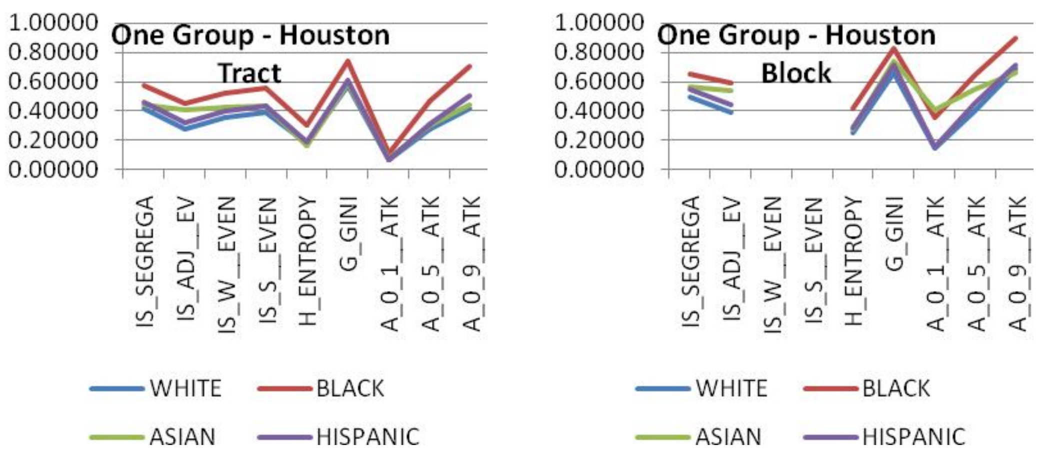

Figure 10: Multi group indices in different scales, block and tract.

Note: The lines do not cross each other. The differences in scales change the indices nearly proportionally. The indices from block to tract show decreases.

All indices follow the similar patterns. When the scales decrease, the indices increase significantly. When using different measures, the rank orders of racial groups do not change much. Only for a few indices that the rank orders change, these indices can be found in Clustering and Concentration dimension. Calculating the index of dissimilarity is the easiest among all other indices. There is no need to use the spatial data, only the census data and the total population of the designated area. But due to the certain type of segregations, the five dimensions of segregation or other spatial methods are used to capture more attributes.

Hopefully, these results will provide researchers and interested individuals, who are conducting urban segregation measures, to choose a method or model according to their area of interest and the data availability. Some might want to conduct a segregation measure based on the minimum data such as the racial group population number in each unit area and the total population of the designated study area. This can be done by using the Segregation Index IS only. It is very simple and easy to calculate, doesn't take a long time. It doesn't need any additional software. Using only a calculator will do the job. However, these basic measures only produce the segregation index by the proportion of the population. They don't consider how the populations of the different racial groups are distributed in a city.

Researchers may choose the method to use from their gathered data or they can choose which result they expected with their data. With all of the data they have, they will have several options to choose from according to what they need and what type of dimension they think is more suitable for their analysis.

They can use more than one measure and analyze the result. The more measures researchers use, the more convincing they can be. When there are many results having the similar patterns, there may be signs that the results are aiming to one direction and can be significant. If there are some significant unusual results from many measures, it may need further investigation.

Knowing the advantage and disadvantages of each measure is very helpful for decision making. By using only one or two segregation measures researchers might not find a close representation of the urban racial segregation level. Sometimes those findings could mislead and create wrong assumptions. Many of the segregation measures used today are the basic Segregation Indices IS and Dissimilarity Indices ID. These two measures are easy and fast to calculate. There are also no standard or indicator to justify which ones of the available measures are the best and capture the closest level of segregation. With the advance of science and technology, many new measures have been proposed to get the better result. Many aspects have been introduced such as the spatial attributes with binary contiguous matrix, boundary length, area, perimeter, area vector, center gravity polygon, central graphic analysis, and cartographic maps. All of the new measures that use spatial attributes have a wider capturing of segregation. Researchers and planners are suggested to use the new measures for urban racial segregation or use both the simple Dissimilarity Indices ID with new measures for better analysis.

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APPENDIX

APPENDIX A

A. One Group Measures

1. **Segregation Index IS (Duncan and Duncan, 1955)**

$$IS = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{t_i - x_i}{T - X}\right|$$

2. **Segregation Index with Boundary access IS(adj) – Morrill, 1991**

$$IS(adj) = IS - \left(\sum_{i=1}^{n}\sum_{j=1}^{n}\left|c_{ij}\left(\frac{x_i}{t_i} - \frac{x_j}{t_j}\right)\right| / \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\right)$$

3. **Segregation Index with Boundary Length IS(w) – Wong, 1993**

$$IS(w) = IS - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\left|w_{ij}\left(\frac{x_i}{t_i} - \frac{x_j}{t_j}\right)\right| \text{ with } w_{ij} = b_{ij} / \sum_{j=1}^{n} b_{ij}$$

4. **Segregation Index with Perimeter Ratio IS(s) – Wong, 1993**

$$IS(s) = IS - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\left\{\frac{w_{ij}\left|\frac{x_i}{t_i} - \frac{x_j}{t_j}\right|}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\frac{1}{2}\left[(P_i / A_i) + (P_j / A_j)\right]}{MAX\ (P / A)}\right\}$$

5. **Gini Index (G)**

$$G = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[t_i t_j \left|p_i - p_j\right| / 2T^2 P(1 - P)\right]$$

6. **Entropy Index (H)**

$$H = \sum_{i=1}^{n}\left[t_i(E - E_i) / ET\right] \text{ with}$$

$$E = (P)\ln[1/P] + (1-P)\ln[1/(1-P)] \text{ and } E_i = (p_i)\ln[1/p_i] + (1-p_i)\ln[1/(1-p_i)]$$

7. **Atkinson Index (ATK)**

$$A = 1 - [P/(1-P)]\left|\sum_{i=1}^{n}\left[(1-p_i)^{1-b} p_i^{b} t_i / PT\right]\right|^{1/(1-b)}$$

8. **Isolation Index (xPx)**

$${}_xP_x = \sum_{i=1}^{n}[x_i / X][x_i / t_i]$$

9. **Correlation Ratio (Eta^2)**

$$Eta^2 = [({}_xP_x - P)/(1-P)]$$

10. **Delta Index (DEL)**

$$DEL = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{A_i}{A}\right|$$

11. **Absolute Concentration Index (ACO)**

$$ACO = 1 - \left\{[\sum_{i=1}^{n}(x_i A_i / X) - \sum_{i=1}^{n_1}(t_i A_i / T_1)] / [\sum_{i=n_2}^{n}(t_i A_i / T_2) - \sum_{i=1}^{n_1}(t_i A_i / T_1)]\right\}$$

12. **Absolute Clustering Index (ACL)**

$$ACL = \left\{[\sum_{i=1}^{n}(x_i / X)\sum_{j=1}^{n}(c_{ij}x_j)] - [X / n^2 \sum_{i=1}^{n}\sum_{j=1}^{n}c_{ij}]\right\} / \left\{[\sum_{i=1}^{n}(x_i / X)\sum_{j=1}^{n}(c_{ij}t_j)] - [X / n^2 \sum_{i=1}^{n}\sum_{j=1}^{n}c_{ij}]\right\}$$

13. **Mean Proximity Between Members of group X (Pxx)**

$$P_{xx} = \frac{1}{X^2}\sum_{i=1}^{n}\sum_{j=1}^{n}x_i x_j d_{ij}$$

14. **Mean Proximity Between Members of group X (exp) – (Pxx_{exp})**

$$P_{xx_{exp}} = \frac{1}{X^2}\sum_{i=1}^{n}\sum_{j=1}^{n}x_i x_j e^{-d_{ij}}$$

15. **Distance decay Isolation Index (DPxx)**

$$DP_{xx} = \sum_{i=1}^{n}x_i / X \sum_{j=1}^{n}k_{ij}x_j / t_j \text{ with } k_{ij} = t_j e^{-d_{ij}} / \sum_{i=1}^{n}t_i e^{-d_{ij}}$$

16. **Proportion in Central City**

$$PCC = X_{cc} / X$$

17. **Absolute Centralization Index (ACE)**

$$ACE = (\sum_{i=1}^{n}X_{i-1}S_i) - (\sum_{i=1}^{n}X_i S_{i-1})$$

The units are sorted in ascending order by the distance to the central city.

The notations for all the one group measures are as follows:

A_i : Area of spatial unit *i*
A_j : Area of spatial unit *j*
A : Area of urban area
b : Shape parameter varies between 0 and 1
b_{ij} : Length of the common boundary of spatial units *i* and *j*
c_{ij} : Cell value of the binary contiguity matrix, 1 for *i* and *j* contiguous, 0 otherwise.
d_{ij} : Distance between the centroids of spatial units *i* and *j*
Max(P/A) : Maximum perimeter-area ratio in the metropolitan area

n : Number of spatial units in the urban area (census blocks, block groups, or tracts)
n_1 : Rank of spatial unit where the sum of all t_i equals X (from 1 to n_1)
n_2 : Rank of spatial unit where the sum of all t_i equals X (from n to n_2)
P : Proportion of group in the urban area (X/T)
p_i : Proportion of group in spatial unit i (x_i/t_i)
p_j : Proportion of group in spatial unit j (x_j/t_j)
P_i : Perimeter of spatial unit i
P_j : Perimeter of spatial unit j
S_i : Cumulative proportion of area of spatial unit i (from 1 to i)
T : Total population in the urban area
T_1 : Sum of all t_i in spatial unit 1 to spatial unit n_1
T_2 : Sum of all t_i in spatial unit n_2 to spatial unit n
t_i : Total population in spatial unit i
t_j : Total population in spatial unit j
X : Total population of group X in metropolitan area
X_{cc} : Total population of group X in city center
x_i : Total population of group X in spatial unit i
x_j : Total population of group X in spatial unit j
X_{i-1} : Cumulative proportion of group X in spatial unit i (from 1 to i)

B. Two Group Measures

1. **Index of Dissimilarity (D)or (ID) by Duncan and Duncan (1955)**

$$ID = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{y_i}{Y}\right|$$

2. **Dissimilarity Index with Boundary Access – D(adj) or ID(adj)**

$$ID(adj) = ID - \left(\sum_{i=1}^{n}\sum_{j=1}^{n}\left|c_{ij}\left(\frac{x_i}{t_i} - \frac{x_j}{t_j}\right)\right| / \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\right)$$

3. **Dissimilarity Index with Boundary Length Components – D(w)**

$$ID(w) = ID - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\left|w_{ij}\left(\frac{x_i}{t_i} - \frac{x_j}{t_j}\right)\right| \text{ with } w_{ij} = b_{ij} / \sum_{j=1}^{n} b_{ij}$$

4. **Dissimilarity Index with Perimeter Ratio – D(s)**

$$ID(s) = ID - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\left\{\frac{w_{ij}\left|\frac{x_i}{t_i} - \frac{x_j}{t_j}\right|}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\frac{1}{2}\left[(P_i / A_i) + (P_j / A_j)\right]}{MAX\ (P / A)}\right\}$$

5. **Deviational Ellipse Index (S)**

$$S = 1 - \frac{E_1 \bigcap E_2 \bigcap E_3 \bigcap \ldots E_n}{E_1 \bigcup E_2 \bigcup E_3 \bigcup \ldots E_n}$$

6. **Interaction Index (xPy)**

$${}_xP_y = \sum_{i=1}^{n}[x_i / X][y_i / t_i]$$

7. **Relative Concentration Index (RCO)**

$$RCO = \left\{[\sum_{i=1}^{n}(x_i A_i / X)] / [\sum_{i=1}^{n}(y_i A_i / Y)] - 1\right\} / \left\{[\sum_{i=1}^{n_1}(t_i A_i / T_1)] / [\sum_{i=n_2}^{n}(t_i A_i / T_2)] - 1\right\}$$

8. **Mean Proximity between Members of group X and Y (Pxy)**

$$P_{xy} = \frac{1}{XY}\sum_{i=1}^{n}\sum_{j=1}^{n} x_i y_j d_{ij}$$

9. **Mean Proximity between Members of group X and Y (exp) – (Pxy_{exp})**

$$P_{xy_{exp}} = \frac{1}{XY}\sum_{i=1}^{n}\sum_{j=1}^{n} x_i y_j e^{-d_{ij}}$$

10. **Spatial Proximity Index (SP)**

$$SP = (XP_{xx_{exp}} + YP_{yy_{exp}}) / (X+Y) P_{00_{exp}} \quad \text{with}$$

$$P_{00_{exp}} = \frac{1}{XY} \sum_{i=1}^{n} \sum_{j=1}^{n} e^{-d_{ij}} (x_i + y_i)(x_j + y_j)$$

11. **Relative Clustering Index (RCL)**

$$RCL = P_{xx_{exp}} / P_{yy_{exp}} - 1$$

12. **Distance Decay Interaction Index (DPxy)**

$$DP_{xy} = \sum_{i=1}^{n} x_i / X \sum_{j=1}^{n} k_{ij} y_j / t_j \quad \text{with} \quad k_{ij} = t_j e^{-d_{ij}} / \sum_{i=1}^{n} t_i e^{-d_{ij}}$$

13. **Relative Centralization Index (RCE) – Duncan and Duncan, 1955**

$$RCE = (\sum_{i=1}^{n} X_{i-1} Y_i) - (\sum_{i=1}^{n} X_i Y_{i-1})$$

The units are sorted in ascending order by the distance to the central city.

Notation for all two group measures:

A_i : Area of spatial unit *i*
A_j : Area of spatial unit *j*
A : Area of urban area
b : Shape parameter varies between 0 and 1
b_{ij} : Length of the common boundary of spatial units *i* and *j*
c_{ij} : Cell value of the binary contiguity matrix, 1 for *i* and *j* contiguous, 0 otherwise.
d_{ij} : Distance between the centroids of spatial units *i* and *j*
Max(P/A) : Maximum perimeter-area ratio in the metropolitan area
E_i : Deviational ellipse describing the distribution of population group *i*
n : Number of spatial units in the urban area (census blocks, block groups, or tracts)
n_1 : Rank of spatial unit where the sum of all t_i equals X (from 1 to n_1)
n_2 : Rank of spatial unit where the sum of all t_i equals X (from n to n_2)
P : Proportion of group in the urban area (X/T)
p_i : Proportion of group in spatial unit *i* (x_i/t_i)
p_j : Proportion of group in spatial unit *j* (x_j/t_j)
P_i : Perimeter of spatial unit *i*
P_j : Perimeter of spatial unit *j*
S_i : Cumulative proportion of area of spatial unit *i* (from 1 to *i*)
T : Total population in the urban area
T_1 : Sum of all t_i in spatial unit 1 to spatial unit n_1
T_2 : Sum of all t_i in spatial unit n_2 to spatial unit *n*
t_i : Total population in spatial unit *i*
t_j : Total population in spatial unit *j*
X : Total population of group X in metropolitan area

X_{cc} : Total population of group X in city center
x_i : Total population of group X in spatial unit *i*
x_j : Total population of group X in spatial unit *j*
X_{i-1} : Cumulative proportions of group X in spatial unit *i* (from 1 to *i*)
y_i : Total population of group Y in spatial unit *i*
y_j : Total population of group Y in spatial unit *j*
Y_{i-1} : Cumulative proportions of group Y in spatial unit *i* (from 1 to *i*)

C. Multi Group Measures

1. **Dissimilarity Index for Multi Group (D)**

$$D = (\frac{1}{2TI})\sum_{m=1}^{M}\sum_{j=1}^{J} t_j \left|\pi_{jm} - \pi_m\right|$$

2. **Spatial Dissimilarity Index (SD)**

$$SD = (1/2)(\sum_{i=1}^{n}\sum_{j=1}^{m}\left|CN_{ij} - CE_{ij}\right| / \sum_{j=1}^{m} CN \times CP_j(1-CP_j) \text{ with}$$

$$CE_{ij} = (CN_{i.} - CN_{.j}) / CN \text{ and } CN_{ij} = \sum_{k=1}^{n} d(N_{kj})$$

3. **Gini Coefficient for Multi Group (G)**

$$G = (\frac{1}{2T^2 I})\sum_{m=1}^{M}\sum_{i=1}^{I}\sum_{j=1}^{J} t_i t_j \left|\pi_{im} - \pi_{jm}\right|$$

4. **Entropy Index for Multi Group (H) or Information Theory**

$$H = (\frac{1}{TE})\sum_{m=1}^{M}\sum_{j=1}^{J} t_j \pi_{jm} \ln\left[\pi_{jm} / \pi_m\right]$$

5. **Squared Coefficient for Variation (C)**

$$C = \frac{1}{T(M-1)}\sum_{m=1}^{M}\sum_{j=1}^{J} t_j(\pi_{jm} - \pi_m)^2 / \pi_m$$

6. **Deviational Ellipse Index for Multi Group (S)**

$$S = 1 - (Ell_1 \cap Ell_2 \cap Ell_3 \cap \ldots Ell_n) / (Ell_1 \cup Ell_2 \cup Ell_3 \cup \ldots Ell_n)$$

7. **Normalized Exposure (P)**

$$P = \frac{1}{T}\sum_{m=1}^{M}\sum_{j=1}^{J} t_j(\pi_{jm} - \pi_m)^2 / (1 - \pi_{jm})$$

8. **Relative Diversity (R)**

$$R = \frac{1}{TI}\sum_{m=1}^{M}\sum_{j=1}^{J} t_j(\pi_{jm} - \pi_m)^2$$

Notation for all of the multi group measures:

CN_{ij} : Composite population count of ethnic group *j* in spatial unit *i*

d() : Function defining surrounding spatial units *i* and *k*
CN_i : Total composite population count in spatial unit *i*
CN_j : Total composite population count of ethnic group *j*
CN : Total population in the city
CP_j : Proportion of population in ethnic group *j*

$$I = \sum_{m=1}^{M} \pi_m (1 - \pi_m)$$
: Simpson's interaction index (Liberson, 1969; White, 1986)

$$E = \sum_{m=1}^{M} \pi_m \ln(1/\pi_m)$$
: Theil's entropy index (Theil, 1972)

M : Number of groups
t_j : Total population in spatial unit *j*
T : Total population in the city (sum of all t_j)

APPENDIX B

Lacunarity Analysis Result - Houston

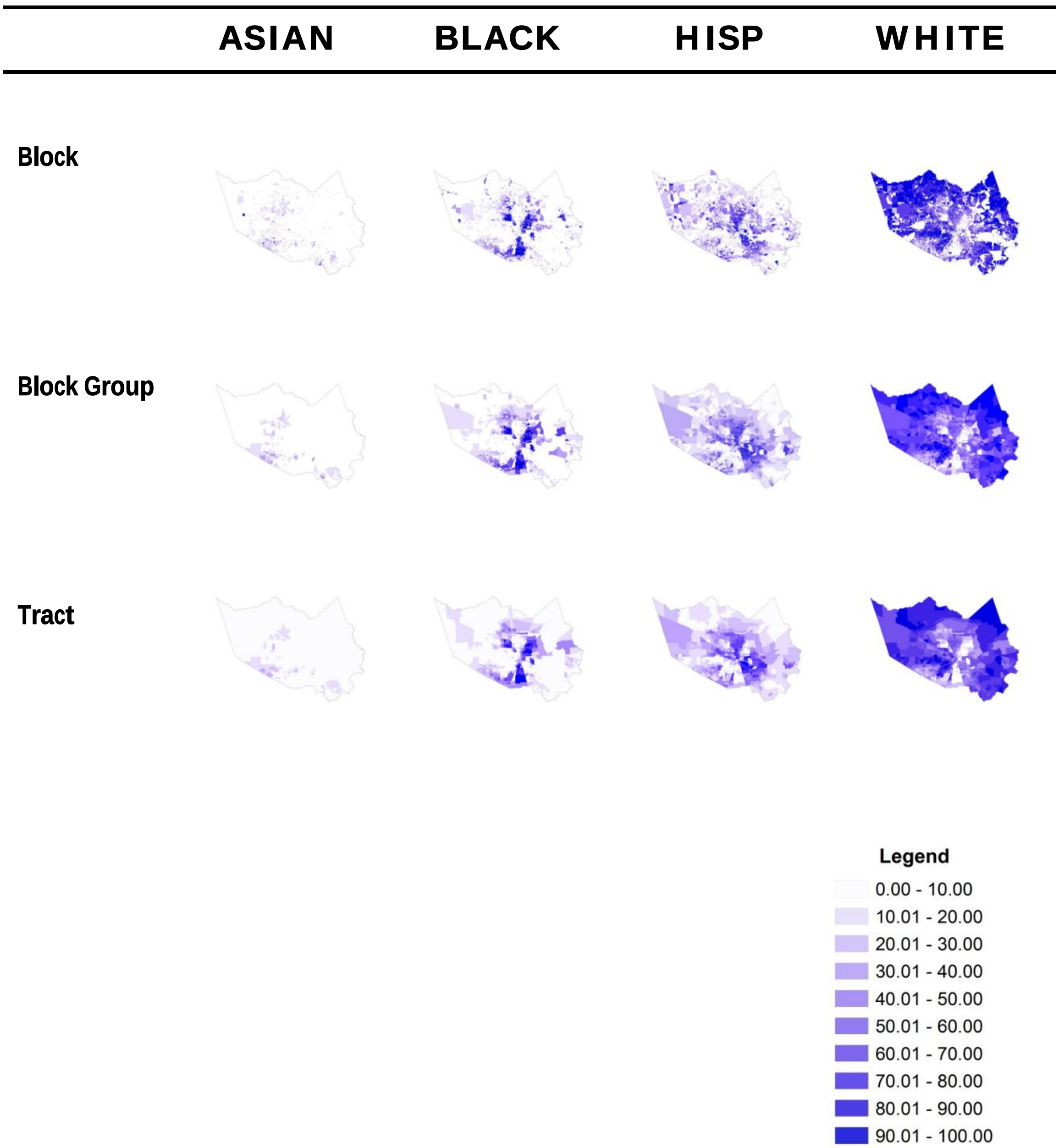
Box Size	BLOCK				BLOCK GROUP				TRACT			
	ASIAN	BLACK	HISP	WHITE	ASIAN	BLACK	HISP	WHITE	ASIAN	BLACK	HISP	WHITE
Size 2	1.6510	1.5517	1.0680	0.8917	1.5284	1.7103	1.2987	1.1744	1.0918	1.8471	1.5126	1.3929
Size 3	1.5429	1.3725	0.8874	0.6706	1.4790	1.5309	1.1324	0.9927	1.0800	1.6942	1.3570	1.2222
Size 4	1.3774	1.2163	0.7532	0.5212	1.3237	1.3459	0.9610	0.8189	0.9672	1.5012	1.1653	1.0268
Size 5	1.2924	1.1184	0.6695	0.4235	1.2250	1.2406	0.8680	0.7180	0.8784	1.3927	1.0644	0.9133
Size 6	1.2043	1.0333	0.6000	0.3514	1.1342	1.1512	0.7839	0.6334	0.8116	1.2909	0.9699	0.8130
Size 7	1.1371	0.9640	0.5475	0.2964	1.0592	1.0826	0.7253	0.5713	0.7457	1.2205	0.9056	0.7410
Size 8	1.0550	0.8954	0.4992	0.2539	0.9788	1.0108	0.6626	0.5131	0.6807	1.1387	0.8307	0.6649
Size 9	1.0056	0.8445	0.4629	0.2205	0.9311	0.9615	0.6210	0.4750	0.6396	1.0845	0.7850	0.6170
Size 10	0.9592	0.8003	0.4331	0.1957	0.8800	0.9223	0.5901	0.4398	0.5878	1.0446	0.7466	0.5751
Size 11	0.9174	0.7614	0.4055	0.1741	0.8382	0.8846	0.5548	0.4118	0.5648	1.0019	0.7081	0.5378
Size 12	0.8590	0.7193	0.3799	0.1543	0.7898	0.8420	0.5216	0.3825	0.5310	0.9579	0.6708	0.5001
Size 13	0.8316	0.6869	0.3589	0.1392	0.7538	0.8201	0.5097	0.3618	0.4961	0.9466	0.6586	0.4769
Size 14	0.7960	0.6550	0.3405	0.1251	0.7287	0.8004	0.4899	0.3429	0.4666	0.9190	0.6342	0.4527
Size 15	0.7705	0.6253	0.3229	0.1120	0.6926	0.7711	0.4675	0.3286	0.4552	0.8779	0.6054	0.4299
Size 16	0.7299	0.5991	0.3074	0.1032	0.6621	0.7398	0.4384	0.3092	0.4422	0.8453	0.5746	0.4046
Size 17	0.7002	0.5719	0.2913	0.0954	0.6402	0.7137	0.4234	0.2949	0.4244	0.8267	0.5586	0.3897
Size 18	0.6695	0.5493	0.2798	0.0879	0.6058	0.6925	0.4091	0.2844	0.4039	0.8118	0.5448	0.3746
Size 19	0.6508	0.5190	0.2663	0.0769	0.5881	0.6675	0.4047	0.2729	0.3839	0.7926	0.5344	0.3588
Size 20	0.6304	0.5060	0.2575	0.0748	0.5751	0.6589	0.3931	0.2612	0.3628	0.7901	0.5249	0.3421
Size 21	0.6154	0.4903	0.2488	0.0691	0.5499	0.6589	0.3874	0.2506	0.3410	0.7726	0.5169	0.3276
Size 22	0.5987	0.4683	0.2389	0.0637	0.5456	0.6409	0.3751	0.2426	0.3294	0.7485	0.4993	0.3203
Size 23	0.5824	0.4474	0.2263	0.0570	0.5369	0.6207	0.3667	0.2369	0.3129	0.7252	0.4800	0.3042
Size 24	0.5597	0.4365	0.2213	0.0564	0.5006	0.6179	0.3543	0.2298	0.2936	0.7204	0.4751	0.2933
Size 25	0.5445	0.4130	0.2109	0.0504	0.4929	0.5921	0.3481	0.2195	0.2707	0.6894	0.4550	0.2824
Size 26	0.5314	0.4046	0.2068	0.0499	0.4590	0.5825	0.3407	0.2107	0.2541	0.6831	0.4523	0.2722
Size 27	0.5154	0.3869	0.1996	0.0446	0.4533	0.5571	0.3323	0.2027	0.2570	0.6512	0.4308	0.2662
Size 28	0.4949	0.3765	0.1944	0.0438	0.4305	0.5457	0.3173	0.2000	0.2553	0.6463	0.4203	0.2562
Size 29	0.4835	0.3553	0.1847	0.0385	0.4203	0.5196	0.3025	0.1941	0.2527	0.6082	0.3990	0.2497
Size 30	0.4776	0.3467	0.1788	0.0383	0.4030	0.5126	0.2908	0.1920	0.2544	0.5989	0.3869	0.2505
Size 31	0.4617	0.3398	0.1721	0.0376	0.4017	0.4985	0.2807	0.1879	0.2447	0.5948	0.3821	0.2448
Size 32	0.4339	0.3191	0.1652	0.0328	0.4038	0.4682	0.2716	0.1820	0.2360	0.5597	0.3624	0.2377
Size 33	0.4288	0.3113	0.1610	0.0328	0.4042	0.4661	0.2664	0.1797	0.2152	0.5631	0.3648	0.2286
Size 34	0.4161	0.3042	0.1559	0.0325	0.3816	0.4624	0.2685	0.1764	0.2130	0.5667	0.3681	0.2202
Size 35	0.4110	0.2909	0.1470	0.0275	0.3443	0.4441	0.2742	0.1718	0.1880	0.5430	0.3549	0.2092
Size 36	0.3907	0.2870	0.1491	0.0273	0.3302	0.4474	0.2740	0.1691	0.1827	0.5470	0.3571	0.2029
Size 37	0.3923	0.2810	0.1467	0.0270	0.3257	0.4545	0.2636	0.1630	0.1788	0.5583	0.3615	0.1977
Size 38	0.3910	0.2744	0.1412	0.0269	0.3318	0.4473	0.2505	0.1554	0.1816	0.5757	0.3649	0.1885
Size 39	0.3933	0.2562	0.1353	0.0222	0.3375	0.4226	0.2539	0.1428	0.1858	0.5515	0.3450	0.1802

Lacunarity Analysis Result - Houston

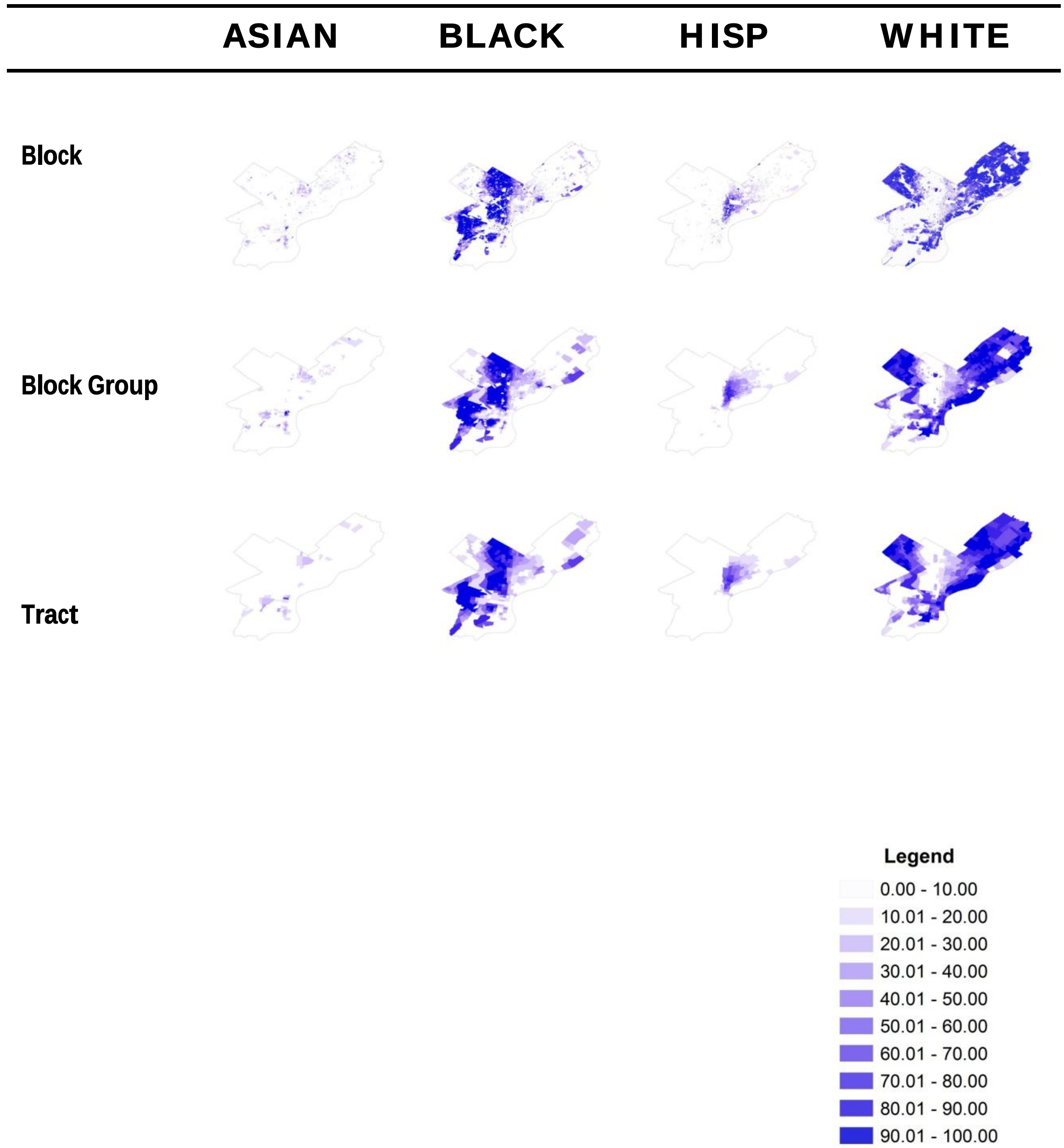
Box_Size	BLOCK				BLOCK GROUP				TRACT			
	ASIAN	BLACK	HISP	WHITE	ASIAN	BLACK	HISP	WHITE	ASIAN	BLACK	HISP	WHITE
Size 2	2.0152	1.4546	2.0433	1.2162	2.1792	1.8116	1.9926	1.6126	2.0631	1.9879	2.1316	1.8177
Size 3	1.8138	1.2013	1.8488	0.9595	2.0157	1.5374	1.8439	1.3276	1.9162	1.7105	1.9764	1.5380
Size 4	1.6751	1.0437	1.7222	0.7966	1.8759	1.3511	1.7254	1.1383	1.7822	1.5146	1.8380	1.3451
Size 5	1.5362	0.9300	1.6017	0.6811	1.7287	1.2081	1.6113	0.9936	1.6309	1.3427	1.6899	1.1779
Size 6	1.4411	0.8462	1.5140	0.5966	1.6341	1.1067	1.5428	0.8906	1.5341	1.2198	1.5930	1.0582
Size 7	1.3419	0.7766	1.4237	0.5293	1.5308	1.0217	1.4680	0.8067	1.4221	1.1100	1.4890	0.9520
Size 8	1.2740	0.7234	1.3554	0.4754	1.4611	0.9586	1.4225	0.7439	1.3493	1.0294	1.4207	0.8740
Size 9	1.2001	0.6758	1.2833	0.4314	1.3834	0.9001	1.3689	0.6883	1.2621	0.9554	1.3450	0.8042
Size 10	1.1475	0.6386	1.2313	0.3952	1.3292	0.8566	1.3346	0.6459	1.2034	0.9009	1.3011	0.7523
Size 11	1.0890	0.6020	1.1744	0.3636	1.2711	0.8103	1.2966	0.6050	1.1425	0.8480	1.2517	0.7025
Size 12	1.0453	0.5748	1.1292	0.3373	1.2269	0.7767	1.2626	0.5739	1.0946	0.8076	1.2185	0.6649
Size 13	1.0006	0.5485	1.0806	0.3146	1.1715	0.7419	1.2245	0.5447	1.0387	0.7695	1.1729	0.6285
Size 14	0.9632	0.5230	1.0437	0.2951	1.1350	0.7109	1.2014	0.5179	1.0041	0.7380	1.1489	0.5964
Size 15	0.9226	0.5031	1.0061	0.2779	1.0969	0.6863	1.1728	0.4955	0.9662	0.7095	1.1165	0.5708
Size 16	0.8922	0.4838	0.9741	0.2625	1.0630	0.6605	1.1528	0.4746	0.9293	0.6818	1.0938	0.5436
Size 17	0.8625	0.4659	0.9420	0.2505	1.0251	0.6402	1.1276	0.4575	0.8924	0.6630	1.0649	0.5266
Size 18	0.8295	0.4430	0.9057	0.2373	0.9838	0.6101	1.0987	0.4348	0.8640	0.6340	1.0366	0.5010
Size 19	0.8076	0.4308	0.8842	0.2261	0.9722	0.5971	1.0851	0.4230	0.8442	0.6195	1.0198	0.4853
Size 20	0.7815	0.4175	0.8646	0.2160	0.9428	0.5822	1.0613	0.4104	0.8123	0.6018	0.9981	0.4709
Size 21	0.7646	0.3987	0.8486	0.2061	0.9186	0.5601	1.0550	0.3919	0.7929	0.5843	0.9751	0.4545
Size 22	0.7380	0.3860	0.8199	0.1966	0.8854	0.5408	1.0290	0.3760	0.7574	0.5663	0.9552	0.4336
Size 23	0.7196	0.3711	0.7952	0.1884	0.8533	0.5231	1.0049	0.3634	0.7408	0.5463	0.9290	0.4181
Size 24	0.6918	0.3649	0.7712	0.1797	0.8411	0.5133	0.9765	0.3603	0.7171	0.5339	0.9079	0.4108
Size 25	0.6768	0.3533	0.7467	0.1742	0.8071	0.5001	0.9587	0.3506	0.6860	0.5237	0.8851	0.4044
Size 26	0.6606	0.3415	0.7239	0.1677	0.7828	0.4841	0.9405	0.3396	0.6625	0.5104	0.8666	0.3947
Size 27	0.6449	0.3270	0.7057	0.1610	0.7594	0.4643	0.9148	0.3247	0.6468	0.4937	0.8429	0.3751
Size 28	0.6336	0.3224	0.6964	0.1557	0.7489	0.4586	0.9076	0.3208	0.6404	0.4867	0.8312	0.3696
Size 29	0.6221	0.3086	0.6827	0.1491	0.7328	0.4444	0.8879	0.3074	0.6267	0.4701	0.8254	0.3545
Size 30	0.6008	0.3070	0.6744	0.1442	0.7323	0.4429	0.8712	0.3068	0.6197	0.4660	0.8083	0.3514
Size 31	0.5975	0.2959	0.6618	0.1378	0.7111	0.4322	0.8823	0.2948	0.6059	0.4503	0.8019	0.3414
Size 32	0.5795	0.2909	0.6575	0.1342	0.7157	0.4239	0.8569	0.2937	0.5857	0.4443	0.7835	0.3393
Size 33	0.5722	0.2768	0.6483	0.1293	0.6915	0.4055	0.8581	0.2787	0.5806	0.4310	0.7644	0.3274
Size 34	0.5605	0.2777	0.6394	0.1245	0.6839	0.4064	0.8415	0.2770	0.5673	0.4276	0.7551	0.3246
Size 35	0.5490	0.2639	0.6174	0.1209	0.6589	0.3886	0.8157	0.2609	0.5404	0.4144	0.7342	0.3110
Size 36	0.5453	0.2609	0.6119	0.1152	0.6508	0.3847	0.8088	0.2584	0.5359	0.4102	0.7264	0.3055
Size 37	0.5213	0.2577	0.5969	0.1101	0.6431	0.3818	0.7844	0.2579	0.5242	0.4096	0.7030	0.2993
Size 38	0.5153	0.2445	0.5774	0.1070	0.6127	0.3614	0.7742	0.2427	0.5061	0.3940	0.6820	0.2875
Size 39	0.5116	0.2417	0.5689	0.1030	0.6066	0.3565	0.7582	0.2416	0.4779	0.3875	0.6747	0.2894

APPENDIX C

Houston – Maps of the percentage population in each census track/block group/block belonging to individual racial groups in Houston.



Philadelphia – Maps of the percentage population in each census track/block group/block belonging to individual racial groups in Philadelphia.



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