An Analysis of Public Transportation and Residential Segregation

A Thesis Submitted to the Department of Urban Planning and Design,

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by

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Abstract:

Segregation is a complex social phenomenon that occurs across various socio-spatial domains and operates on multiple levels. Past research indicates that segregated residential areas can lead to social and economic exclusion. This study aims to investigate whether bus networks address present spatial inequities or if they perpetuate the inherent segregation in our metropolitan areas. This is achieved through quantitative analysis of two geographies, ZIP Code Tabulation Areas (ZCTAS) and Transit Route Service Areas (TRSAs), in four metropolitan regions (Boston, Chicago, Dallas, Los Angeles). Indexes of dissimilarity and isolation are employed to measure and compare the degree of racial segregation in the respective geographies. Analysis shows that TRSAs indicate less segregation than ZCTAs, that is bus networks demonstrate less segregation.

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Introduction:

The causes of inequality and its impact on society, as well as the tradeoffs linked with economic growth, remain a topic of contention. It has been posited that income inequality results in unequal access to resources and opportunities, which decreases the chances of escaping poverty and restricts upward mobility (Mishel, Bivens, Gould, & Shierholz, 2012). Similarly, there is debate around the role of public transportation in society and is one aspect of urban inequality that has recently garnered significant attention, especially the role of public transportation in the lives of those with limited economic means who live in dense urban cities (Garrett & Taylor, 1999). Numerous demands have been placed on public transit to solve issues such as congestion, emissions, climate intensification as well as societal inequities. Public transportation plays a pivotal role in shaping cities. Urban areas offer advantages that offset the drawbacks: clustering reduces transportation expenses, fosters exchange of ideas and goods, and benefits economies by situating consumers and workers in proximity (Glaeser, 1998).

Moreover, it has been observed that individuals with limited economic resources rely more heavily on public transportation since they are disproportionately poorer than those who own a personal vehicle (Brian Taylor & Morris, 2015) – the assumption being that public transportation is more affordable than owning and operating a personal vehicle. Despite this, the poor quality of public transportation in most US cities has been identified as a hindrance to improved quality of life by academics who have focused on the lack of vehicle ownership as a barrier (Wachs, 2010). While previous studies have suggested that historical urban planning policies have been crucial in perpetuating levels of racial segregation, spatial inequality, and transportation inequities that exist in the US today, we are currently in a situation where it fails

to operate as a public good or public service and does not provide a sufficient alternative to driving (Gössling, 2016).

Public transportation has long been a central issue in the fight for social equality. The Montgomery bus boycott in 1955 and the Freedom Riders campaign in 1961 are significant historical events in the US Civil Rights movement. Today, there is a growing interest in addressing past injustices by moving beyond removing barriers to achieve a level playing field and implementing reparations (Coates, 2004). Segregation is a complex social phenomenon that occurs across various socio-spatial domains, and it operates on multiple levels. To comprehensively understand the impact of segregation, analyses need to incorporate the perspectives of people, place, and mobility flow. As a student with a keen interest in the intersection of transportation, mobility, and housing, I am intrigued by the manifestation of inequalities in metropolitan areas and how transportation interacts with these inequalities. My research builds on prior work on residential segregation and spatial mismatch, while also examining how segregation exists outside of residential spaces. I aim to contribute to the broader theory that public transportation can serve as a comprehensive service that aids in promoting social change. Sustainable communities should provide access to critical amenities such as markets, employment, health services, and education. Access becomes especially crucial in regions with high racial and ethnic segregation.

As research has shown that segregated residential areas can lead to social and economic exclusion, reducing access, opportunity, and upward economic mobility. I set out test the relationship between public transportation, access, and opportunity empirically. This study aims to investigate what role public transportation has in social and economic exclusion.

Several key questions have guided my research, the main one being: If we are to assume that public transportation is the only means of mobility for an individual, does the region that an individual can access by way of public transportation mimic the segregation that exists where that individual resides, or does that transportation option deliver a less segregated geography? Answering this central guiding question leads to subsequent question around the policy and planning response to this finding.

This line of question is apt. There is indication that having access to efficient public transportation is crucial in mitigating employment disparities in urban areas. In large US metropolitan areas approximately 7.5 million households are zero-vehicle households, and 60 percent of these households are low income (Tomer et al. 2011); the poor are overwhelmingly dependent on public transit as their primary mode of transportation (Covington, 2018). My findings point to public transportation acting as a mechanism to lessen the impact of residential segregation, which is measured by the index of dissimilarity and index of isolation. To explore this dynamic, I will recommend policies that promote integration in the United States.

Background:

Numerous scholarly studies have documented the impact of government policies and institutions on the racial isolation of white communities from Blacks and other minority groups (Rothstein, 2017). The discussion is stems from three seminal works: Douglas Massey's American Apartheid (1993) and Richard Rothstein's The Color of Law (2017) and Andrea Gibbons City of Segregation: 100 Years of Struggle for Housing in Los Angeles (2018). Massey's account provides a comprehensive statistical analysis of the history, formation, and

consequences of the American ghetto, where Black minorities reside in racial isolation and poverty. He attributes much of the ghettoization to public policy. Rothstein's observations on segregation in America reveal how government legislation has contributed to the problem. He contends that "until the last quarter of the twentieth century, racially explicit policies of federal, state, and local governments defined where whites and African Americans should live" (Rothstein, 2017). Urban geographer Andrea Gibbons further explored the phenomenon of exclusion and how it manifests. Gibbons found that government regulations that enforced segregation in the mid-1900s increased violence, inequality, voter apathy, and discrimination. Furthermore, she found that segregation led to apathy among white voters to vote for policies that would have reduced inequality (Gibbons, 2018). These works demonstrate the profound influence of government policies such as restrictive covenants, racial zoning, public housing, and redlining in shaping the highly segregated America that persists to this day and its consequence.

Restrictive Covenants:

The establishment of restrictive covenants was closely linked to the formation of neighborhood improvement associations in the early 20th century. These associations, which were predominantly composed of white residents, utilized zoning restrictions and public investment strategies to achieve segregation by driving up property values and pricing out Black residents. The most significant tool employed by improvement associations was the enforcement of restrictive covenants. As defined by Massey, restrictive covenants were "contractual agreements among property owners stating they would not permit a Black to own,

occupy, or lease their property" (Massey, 1993). Such covenants were typically valid for 20 years, with legal action taken against homeowners or their descendants who violated the agreement, thereby legally preserving all-white communities for several decades. Generic covenants specified that "no part of said property or any portion thereof shall be…occupied by any person not of the Caucasian race" (Zenou & Boccard). Government at all levels actively promoted and supported the implementation of restrictive covenants. Notably, the US Supreme Court upheld restrictive covenants as legal private contracts, representing a significant endorsement of this practice (Rothstein, 2017). The use of restrictive covenants is indicative of how segregation evolved from informal community values to a federally supported and institutionally accepted practice.

Discriminatory Zoning:

Discriminatory zoning, also known as racial zoning, was another significant legislative tool employed at the local government level to enforce segregation in the United States. In the early 20th century, local governments passed zoning ordinances that explicitly prohibited Black residents from moving into predominantly white neighborhoods. Although the Supreme Court overturned such discriminatory zoning laws in 1917, the ruling was frequently disregarded, and federal and local governments devised stringent single-use zoning codes to circumvent it (Rothstein, 2017). These codes effectively excluded affordable multi-family apartments from white neighborhoods, forcing Black families away from such areas due to the pronounced racial-income divide. Throughout the 20th century, implicit racial discrimination in zoning laws

played a significant role in legally segregating America and creating insular white communities (Rothstein, 2017).

Public Housing:

Public housing served to further exacerbate racial separation in the United States. The New Deal implemented the first-ever public housing program, which frequently featured separate developments for white and Black Americans (Rothstein, 2017). In 1937, the US Housing Authority (USHA), which was responsible for providing funding to local governments for housing projects, sustained residential segregation by actively discouraging state and local governments from placing public housing intended for whites "in areas now occupied by Negroes" (Rothstein, 23). When World War II began, Congress passed the Lanham Act to construct housing for workers in the military industry due to the housing shortage. However, like past governmental bodies, the projects built under the Act were fully segregated (Rothstein, 2017). To this day, public housing is mainly located in low-income and minority-dominant neighborhoods (Labov, 2017). The persistence of racial segregation in public housing represents the acceptance and even adoption of racial segregation by the government, ultimately leading to white isolation.

Redlining:

The practice of redlining – the discriminatory practice of banks and other institutions not investing in areas based on the demographics of the community – is one of the most impactful causes of modern-day residential segregation. The Home Owners' Loan Corporation

(HOLC) established four categories of neighborhoods and color-coded maps to determine loan eligibility. The lowest rating, marked in red, was rarely granted mortgages. HOLC assumed Black homebuyers would be unable to pay off loans and as a result, “Black areas were invariably rated as fourth grade and ‘redlined’” (Massey, 1993). Central city neighborhoods that were ethnically mixed or predominantly Black received no funding from HOLC. In the 1930s, the FHA provided generous mortgage insurance, which made the ability to purchase a house widespread. However, the FHA utilized redlining maps to determine loan offers, thereby reserving this privilege exclusively for white Americans. The FHA manual, published in 1939, stated that "if a neighborhood is to retain stability, it is necessary that properties shall continue to be occupied by the same social and racial classes" (Massey, 54). While the Civil Rights Act of 1968 eventually outlawed redlining, the practice led to the isolation of white suburban communities that persist to this day (Marciano et al., 2010).

Segregation Today:

Although residential segregation was outlawed in 1968, it did not reverse the consequences of the policies from the previous 50 years, and contribute to a substantial economic divide (Rothstein, 2017). Minorities were denied access to white suburban houses that appreciated significantly in value, generating wealth opportunities that were not available to them (Rothstein, 2017). Moreover, the lack of loans to inner-city minority neighborhoods resulted in a smaller tax base and depreciated services, which, in turn, led to a Black-white achievement gap in education, where poorly funded and segregated schools mirrored the segregation and disinvestment of their neighborhoods. Currently, all levels of government

continue to implicitly reinforce segregation. Developers of low-income housing use government tax credits to build in lower income communities, perpetuating racial separation (Rothstein, 2017). These factors contribute to the entrenchment of social, political, and economic realities that make the issue of segregation more intractable.

The absence of policies that actively promote integration underlies these factors. Although the US Constitution states that policies cannot reverse individual preferences that segregate neighborhoods, many believe that residential segregation resulted from a wide array of factors, such as private prejudice, personal choice, real estate industry discrimination, and income differences. As a result, there has been little political action to address segregation despite the role of governmental policies in creating the current state of extreme residential separation. A study by the Stanford Center on Poverty and Inequality (2016) found a clear concentration of U.S. minority populations in major metropolitan areas, the South, and along states bordering the Atlantic and Pacific where redlining, restrictive covenants and other segregating practices were common.

Nexus – Housing and Transportation:

While segregation was eventually outlawed, society is saturated with the consequences. Segregation has contributed to wealth inequality, gaps in educational achievement, and stymied the creation of beneficial social networks. It is still (albeit mostly implicitly) reinforced at all levels of government. This makes segregation very intractable. I define these negative outcomes – wealth inequality, gaps in educational achievement, and the inability to create a robust network – as lack of access to opportunity. The intractable nature of residential

segregation produces a need for a multifaceted solution. I hold that one solution is public transportation. Minority populations have been confined to areas without access to opportunity through explicit government housing and land use policy and implicit practices. In this way inequality continues to grow to this day. Social isolation and fragmentation that are inherent in our environments can be remedied through access and mobility. Those with greater interaction with people of a different race and class are more tolerant and more likely to care about issues that affect other people, a phenomenon that can be induced by transportation. This theory was exemplified in an analysis of several large cities' public transport systems in Sweden that revealed the use of public transport contributed to greater community integration and increased levels of equality among all residents (Stjernborg, 2016). While these issues cannot be fully addressed by public transportation, they can be minimized by providing access to opportunity (e.g., economic, education, healthcare, etc.) and expanding interaction among people of different races and classes.

This assertion is supported by Heather Allen, who at the International Association for Public Transportation, has sought to cast public transportation as a "useful social actor" rather than just a provider of mobility (Allen H., 2008). Allen has argued that to build resilient and sustainable communities, communities must be easily connected to "markets, employment, health services, and education" (Allen H., 2008). Manville et. al (2018) build on Allen's position by centering how access becomes much more relevant in areas highly segregated by income and race. They find segregation can be addressed through an expansion of mobility and access, to and within the metropolitan regions.

The fragmentation of US communities has led to an erosion of inclusive values as well as further segregated low-income and minorities from the rest of society by creating a barrier between them and public goods easily accessed by those in a higher income bracket and whites. One can extrapolate these observations and find nexus in housing and transportation. Inefficient transportation systems contribute to social and economic exclusion, and as such, enhancing access to opportunity through transportation is an apt means to address exclusion, isolation, and segregation.

Literature Review:

Transportation represents the cost or an individual's willingness to utilize transportation to pursue a purpose. While that "purpose" is wide ranging it is for the benefit and overall agency of the individual. Transportation is a vessel for mobility, which provides access to achieve that purpose. How easily accessibility the process to achieve or pursue that purpose represents the relationship between transportation and opportunity. In this way, social and economic exclusion are, in part, a result of inefficient transportation systems. This literature review aims to analyze the scholarly research on the social and political implications of residing in racially/ethnically isolated versus integrated communities; highlight scholarly research on segregation, transportation, housing, while underscoring their interaction and nexus; and, finally, explore accessibility while demonstrating the specific role transportation can play in enhancing access to opportunity.

Accessibility:

Accessibility is defined and operationalized in several ways, and thus has taken on a variety of meanings (Geurs and Wee, 2003). Definitions encompass the potential for opportunities for social engagement, as described by Hansen in 1959, the convenience of accessing various land-use activities using a specific transportation system, as outlined by Dalvi and Martin in 1976, the liberty of individuals to choose their level of participation in diverse activities (Burns 1979), and the advantages that arise from a transportation and land-use system (Ben-Akiva and Lerman, 1979). Accessibility measures are considered as markers to gauge the effects of land-use and transportation policies and developments on the overall functioning of society. This implies that accessibility should be connected to the function of land-use and transportation systems in society, providing people or groups of people with the ability to participate in activities across different areas. In the case of passenger transportation, accessibility can be defined as the degree to which land-use and transportation systems allow individuals or groups to access activities or destinations through transit. Additionally, the terms "access" and "accessibility" are sometimes used interchangeably in literature. Within the context of this research, access is utilized when analyzing an individual-based perspective in realizing opportunity, whereas accessibility alludes to the mechanisms (transportation, land-use, etc.) that allow for opportunity to be realized.

Spatial Mismatch:

Spatial mismatch was coined by John Kain when, in 1968, he conducted a seminal study in Chicago and Detroit, drawing three key conclusions from his analysis and defining this phenomenon as spatial mismatch. Kain found that Black individuals were less likely to find

employment in areas where the share of Black residents was low. Kain argued that if housing segregation was reduced, Black employment opportunities would improve considerably. Finally, Kain observed that between 1950 and 1960, jobs had shifted from central city areas to suburban areas, which, combined with residential segregation of Black individuals in central city areas, further lowered Black employment prospects. Limitation on residential choice combined with suburbanization of employment negatively affected the economic outcomes of Black and low-income residents. Segregation and lack of mobility and subsequent access to opportunity are central to these findings.

Spatial mismatch has continued to evolve. Subsequent work has focused on the degree to which mobility influence opportunity and outcomes as well as how various demographics experience spatial mismatch. Blumenberg and Pierce find that improved access to public transit is positively associated with maintaining employment (Blumenberg & Pierce, 2014). Paul and Morris, when conducting a re-examination of spatial mismatch in the United States in the 2000s and 2010s, produced findings that suggest that spatial mismatch is present in both Black and Hispanic individuals (Paul & Morris, 2022). Furthermore, they found a lack of sufficient access to places that offer job opportunities, essential services, and recreational activities can negatively impact an individual's economic, health, and social well-being. A significant portion of the existing research emphasizes the role of transportation challenges in limiting access to employment opportunities. Some scholars argue that low-income residents in inner-city areas are not necessarily experiencing the traditional spatial mismatch. Instead, they are subject to a modal mismatch, where there is a significant disparity in the benefits between individuals who have access to cars and those who do not (Blumenberg& Ong, 2001).

Much of spatial mismatch literature highlights the connection between employment, residential locations, and transportation. In this circumstance employment acts as a proxy to opportunity. Drawing on this theoretical underpinning of residential location, transportation, and opportunity is an apt method to understand transportation's impact on inequity. Increasingly, there is a focus on the impact that social determinants of place, such as the availability of transportation options, have on the quality of life and the prospects of individuals in those regions. Chetty and Hendren's Equality of Opportunity Project (2015) highlighted how the likelihood of a child growing up in a low-income household to eventually achieve higher income levels varies considerably based on the location in which they grow up. The quality of the environment in which children are raised is determined by a range of factors, including segregation, family structure, income inequality, local school quality, and social capital.

Opportunity:

Are there specific characteristics of regions with observably high levels of mobility? According to Chetty these regions often poses four systematic characteristics: lower rates of poverty, more stable family structure, higher levels of social capital, and are places with high quality education. Of those characteristics one sticks out as something that can be influenced by transportation, and nests within precedent study – social capital.

Chetty et al. (2022a) argue that social capital and particularly the socioeconomic status (SES) of friends in your network is a strong predictor of upward income mobility; subsequently from Chetty et al. (2022b) that "the lowest-SES individuals make about four-times as large a share of their friends in their neighborhoods (residential ZIP codes) as the highest-SES

individuals do." It could follow that if a transportation network of a particular region, positively influenced social capital then policy and planning choices around transportation could drive or inhibit upward mobility, especially for lower-SES individuals who would feel the effects the most given their reliance on the neighborhood as a place to make connections.

The impact of social interactions on economic and labor market outcomes is crucial, especially regarding access to job opportunities, connections, and recommendations. Recent studies have suggested that public transportation can help in preserving and building social connections between individuals residing in different areas of the same city. Research demonstrates that social networks and social capital hold relationships to economic participation and interaction. For example, Barwick et al. (2019) conducted a study where they observed a strong correlation between phone call volumes and worker flows. This correlation suggests that social contacts provide valuable information that can affect one's performance in the labor market. Similarly, Schmutte (2015) found that job referral networks play a crucial role in professional network building. Furthermore, research suggests that public transit can help facilitate the maintenance and formation of social links across individuals living in geographically distant parts of the same city (Bailey et al., 2020).

Bailey et al. (2020) further find geographies that are more similar along demographic lines such as race, education, and income tend to be more socially connected, which aligns with earlier research demonstrating that social connections are more prevalent between similar individuals and regions (Bailey et al., 2018b; 2018a). Analysis by Bailey et al., 2020 indicate that public transit not only fosters social ties between distant zip codes but also plays a crucial role in connecting zip codes with different demographics. Furthermore, Bailey et al. (2020) provides

evidence of the significant role of transportation infrastructure in forming and maintaining urban social connections by demonstrating that social networks are distributed along public transportation routes and that social connectedness between locations diminishes more significantly in travel time than in physical distance. Commuting patterns are stronger between socially connected areas, indicating that social networks play a vital role in shaping economic interactions. They also find locations with better public transit access exhibiting less geographically concentrated social networks.

Methodology:

A central claim underpins this work is that the United States is a land of immense opportunities, yet is characterized by a complex interplay of policy, planning, and design that creates significant barriers to accessing this opportunity for many individuals. This methodology intends to examine public transportation's role in providing opportunity for increased mobility, which drives accessibility, which drives opportunity. I am interested in how inequities manifest in metropolitan regions, and I explore this idea of inequities through the lens of segregation and further explore how transportation can act as a potential method to address segregation. Throughout my time as a planning student an idea of a sustainable community has always been presented as a goal for us to strive towards. I hold that one means to achieve this goal is to increase access to opportunity, whether that be employment, health services, education, or merely to hold and maintain relationships with individuals that live in different regions.

Research Design:

Summary of Methodology:

Spatial and statistical analyses were conducted using the Geographic Information Systems (GIS) software RStudio version 2022.07.2+576. Data were imported into RStudio, and all statistical tests were performed using the appropriate R packages. Demographic information and US Census geographies were garnered from the 2010 US Decennial Census Survey. Bus networks were garnered from publicly available General Transit Feed Specification (GTFS) data.

Framework:

I define segregation as spatially uneven distributions and relationships – spatial arrangements, patterning, and spatial interactions – between people belonging to different populations (Yao et al., 2019). This research methodology is informed by multiple fields of segregation research, residential segregation, and activity space segregation, and how segregation impacts social outcomes, spatial mismatch. I have employed methodologies from the more established literature concerning residential segregation and spatial mismatch, which present strategies for measuring segregation and the broader implications in the relationship between segregation and access to opportunity. I gained inspiration the burgeoning field of activity space segregation, in particular employing established methodologies in geographic vessel that capture how segregation interfaces with mobility.

The activity space approach is being increasingly utilized in spatial segregation research to broaden the scope of research from residential neighborhoods and into other socio-spatial contexts (Massey and Denton, 1988; Tammaru et al., 2015). I define socio-spatial contexts as

environments where individuals or groups live their everyday lives. Given that residential spaces are not the only contexts that people exist in, and that significant amount of time is spent outside of residential spaces it is important to understand how segregation manifests. While this work does not analyze segregation in socio-spatial contexts beyond residential it does attempt to understand how residential spaces are influence by and interact with an individual's potential activity space or the areas that individuals have access to.

As discussed in the *Background* chapter of this work, residential segregation was explicitly and implicitly pursued by government sponsored policy. In this way, residential segregation transcends the physical and exists more broadly in all spaces. This research engages with research that has captured segregation beyond residential neighborhoods, across individuals, multiple activity locations, and mobility broadly, but is not classified as activity space research. My approach works to expand the definition of a neighborhood to extend beyond one's residential space and into the areas one has access to, the individuals and groups I might interact with.

Review of Methodology:

Several methods and measures have been proposed, tested, developed, to turn the more abstract concepts underpinning segregation into measurable observations. There are three central perspectives that can be addressed when examining segregation – place, people, and movement flows. Central questions to address these themes are – "how segregated are neighborhoods?", "how segregated are individuals' mobility spaces?", and "how segregated are potential mobility flow patterns between locations?" Future research should bring place- and

people-based methods together as well as flow-based perspectives. This thesis will tackle segregation across place while incorporating transit service, which will reflect how mobility relates to segregation and ultimately access.

My approach to understanding segregation is inspired by the activity space segregation (Wong and Shaw, 2011; Palmer, 2013) and spatial mismatch research (Blumenberg & Ong, 1998). The concept of activity spaces (Golledge and Stimson, 1997) proposes that segregation is produced and reproduced across all locations that a person visits and routes and areas the person travels through. This highlights the importance of both activity locations and spatial mobility and residential segregation in shaping people's segregation experiences and access to opportunity. While this approach to measuring segregation is valuable the methodology to complete this research is very complex and resource intensive. Spatial mismatch provides an apt theoretical framework that demonstrates the gap between where the jobs are and where people live. Spatial inequities and the lack of mobility will impact access to opportunity. Mobility is crucial for understanding the intersection between segregation in residential neighborhoods, schools, workplaces, and leisure time. The purpose of transit is to increase mobility and drive access. However, I am interested in understanding if this is the reality, do bus networks address the spatial inequities present, or do they perpetuate the segregation that is inherent in our metropolitan areas?

Throughout review of relevant literature, an underlying finding became apparent when looking at the relationship between opportunity and public transportation. There is less opportunity to develop robust social capital in regions with high residential segregation. The theory being that in areas of high segregation those residing near one another are of a similar

race and/or hold a similar socioeconomic status. Similarly, there is less opportunity if there are limits to the transportation options available to maintain relationships that exist beyond your immediate residential space. Further, if the present transportation options only provide access to geographies that are similar in a demographic or socioeconomic sense, this does little to improve opportunity. Put simply, the distribution of people and exposure to people influences social capital and subsequent opportunity. This finding highlighted a nexus between literature review and methodological review that directly informed how segregation could be quantified for my research.

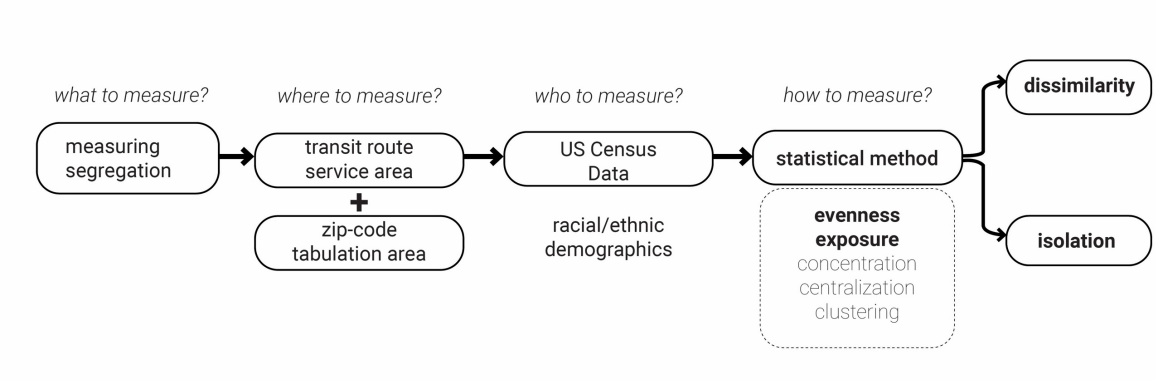


Figure 1: Methodology framework

Methodology – Measuring Where:

How do I empirically test this? First, I found two geographies to act as vessels to measure segregation – one having a relation to bus networks. I began by creating a geography that I designate as a Transit Route Service Area (TRSA). I did this by identifying the most frequent bus route associated with a Census block and subsequently combining each Census block that had the same most frequent bus route. After performing this step, I compare the service areas with

a Census geography that had a similar number within the metropolitan area that was being analyzed. This turned out to be Zip-Code Tabulation Areas (ZCTA).

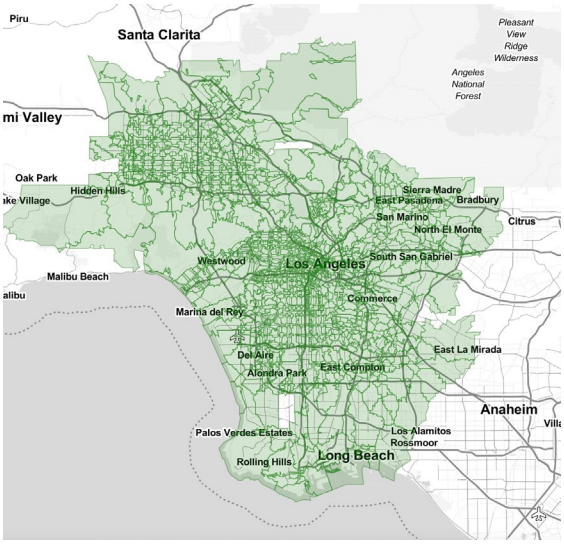


Figure 2: Transit Route Service Area (TRSA)

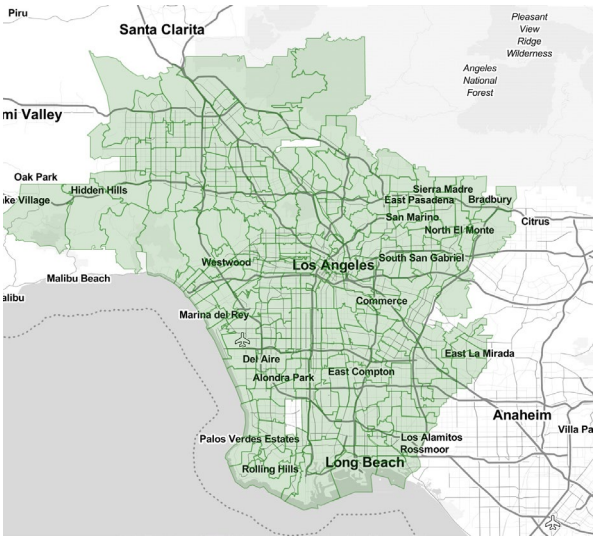


Figure 3: Zip-Code Tabulation Area (ZCTA)

Methodology – Measuring Who:

Racial and ethnic data was pulled from the US Census and included a majority population or white (non-Hispanic), and minority populations or Black (non-Hispanic), Asian (non-Hispanic), Hispanic. These demographics were used as variables when measuring segregation with white population acting as the majority and the other racial demographics acting as the minority individually.

Methodology – Measuring How:

Next, I had to determine how to measure segregation. To measure segregation, I turned to the US Census which employs the findings of Massey and Denton 1988 study in which they conducted an in-depth search of relevant literature and utilized cluster analysis to distinguish

20 segregation indexes and group them into five main segregation dimensions. The dimensions include evenness, which pertains to how the population is distributed differentially; exposure, which measures the potential for interaction between different groups; concentration, which refers to the amount of physical space occupied by a group; centralization, which gauges the proximity of a group to the center of an urban area; and clustering, which measures the extent to which minority group members reside in contiguous areas at a higher rate than expected. As cited earlier in this chapter, in the context of this research I am interested in how evenly racial and ethnic populations are distributed and the degree of exposure. I measure segregation through the index of dissimilarity which measures evenness and the index of isolation which measures exposure.

The index of dissimilarity measures the distribution minority residents throughout the geography they are being measured in (in this case Transit Route Service Areas and Zip-Codes) and then determines how closely it aligns with the minority distribution throughout the whole study region. So as an example, if all of Los Angeles has an Asian population of 20%, and we are analyzing Asian dissimilarity in Zip-Codes, the dissimilarity index will tell us how closely the average of all Zip-Codes matches the overall Asian population. If the dissimilarity score is close to 1 then the Asian population is not evenly distributed, whereas if it is close to 0 it is evenly distributed.

The index of isolation measures the extent to which minority members are exposed only to one another in the geography that they are being measured in. As an example, if an Asian resident lives in a Transit Route Service Area that is 90% Asian, they will have an isolation score close to 1 because they are exposed to a lot of Asians. If they live in a Transit Route Service Area

that is 10% Asian, they will have a score closer to 0 because they are not exposed to a lot of Asians.

In a basic sense, evenness involves the differential distribution of the subject population, exposure measures potential contact – and exposure measures depend on the relative sizes of the two groups being compared, while evenness measures do not.
The index of dissimilarity measures how different two groups are from each other. On the other hand, the index of isolation measures how much two groups of people interact with each other.

One point I would like to get across is that while I chose these two measures of segregation, I could have chosen to use a handful of the other 20 indexes. What is novel about my research is not how I am measuring segregation, this method for measuring segregation is a precedent. What is novel is the vessel through which I am conducting these measurements, the construction of the Transit Route Service Area is a new way to analyze segregation and something that I am contributing.

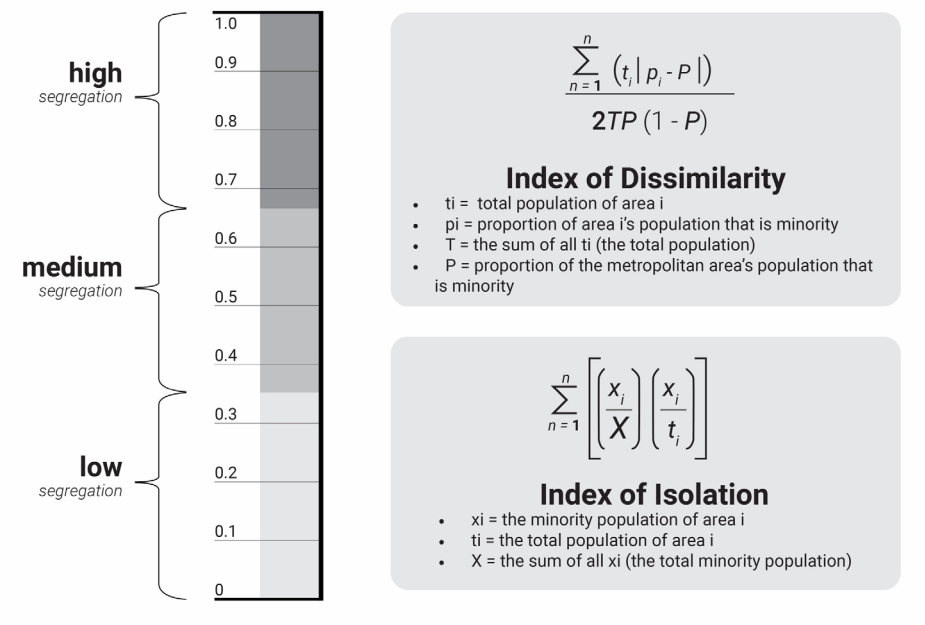


Figure 4: Indexes of Dissimilarity and Isolation

Methodology – Measuring Where (cont.):

To strengthen my research and provide another layer of analysis, I have extended my research to include the four most populous regions in each of the Census Divisions, with the exception of the Northeast. I elected to exclude New York as it is an outlier in transportation research within the US context. Analysis of just New York would prove an interesting avenue for future study. Each of the geographies created for this research are associated with the service of the major transportation agency in region. More specifically, the bus service of each major transportation agency. These boundaries do not follow the same geographic bounds of a formal Metropolitan Statistical Area (MSA). While they do closely align, they are themselves distinct. All the regions that I have chosen to have a long history of segregation on the basis of race and ethnicity – the explicit and implicit manner in which this occurred is described in the background section of this work. The Northeast Census division metropolitan area chosen for analysis was Boston, and bus network data was garnered from the Massachusetts Bay Transit Authority (MBTA); the Midwest Census division metropolitan area chosen for analysis was Chicago, and bus network data was garnered from Chicago Transit Authority (CTA); the South Census division metropolitan area chosen for analysis was Dallas, and bus network data was garnered from the Dallas Area Rapid Transit (DART); finally, the West Census division metropolitan area chosen for analysis was Los Angeles, and bus network data was garnered from Los Angeles County Metropolitan Transit Authority (LA Metro).

The indexes of dissimilarity and isolation measure race and ethnicity in the respective ZCTAs and TRSAs for each Metropolitan Transit Service Region. The results of this spatial and statistical analysis are then compared, revealing the impact bus networks have on segregation –

if TRSAs or ZCTAs suggest less or greater segregation. Because these indexes operate in a binary sense, indexes for race and ethnicity are calculated against non-Hispanic whites (white), which act as the majority for these measurements. Non-Hispanic Black (Black), non-Hispanic Asian (Asian), and Hispanic act as minority populations and are then individually compared to the majority. I examine segregation in terms of race and ethnicity – as opposed to income or nativity – as race and ethnicity are the most appropriate demographic to measure segregation that could be directly gathered from Census data at the scale of the Census block.

Results:

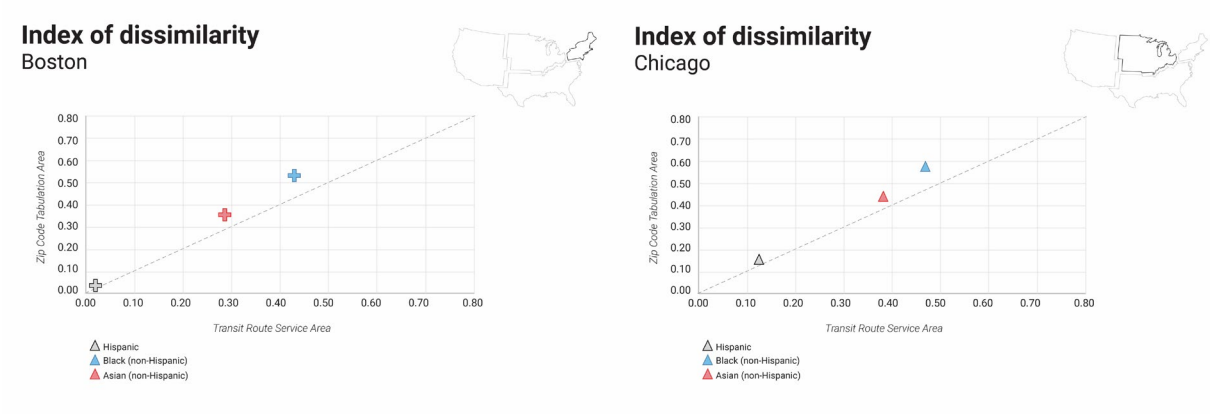
I directly compare the score of dissimilarity and isolation respectively for both ZCTAs and TRSAs (figure x). When presenting my findings and results I will use the score of dissimilarity and isolation in ZCTAs as the base and compare the scores of those same indexes in TRSAs against ZCTAs. Results from these calculations are summarized below and can be found in the appendix section of this study.

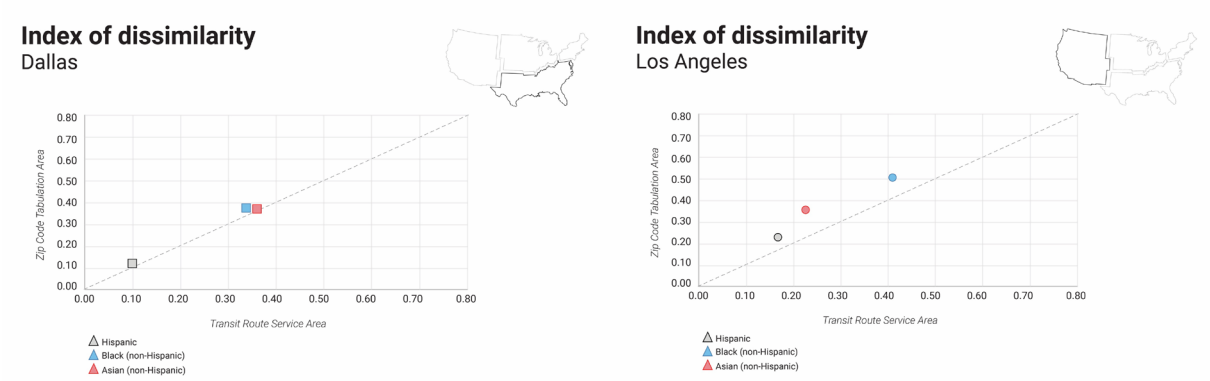
In all metropolitan regions, TRSAs demonstrated less segregation than ZCTAs as represented by a score of both dissimilarity and isolation. When comparing metropolitan areas there is significant variation in levels of segregation and which populations (Hispanic, Black, Asian) were segregated to a higher degree when comparing them against one another.

Results – Index of Dissimilarity:

In Boston, Black residents score highest for dissimilarity in both ZCTAs and TRSAs (0.510 and 0.453), followed by Asian residents (0.348 and 0.293), and finally Hispanic residents (0.050 and 0.037). In Chicago, Black residents score highest for dissimilarity in both ZCTAs and TRSAs

(0.551 and 0.466), followed by Asian residents (0.449 and 0.386), and finally Hispanic residents (0.146 and 0.110). In Dallas, Black residents score highest for dissimilarity in both ZCTAs but not TRSAs (0.393 and 0.349), Asian residents score follow Black residents in ZCTAs but score higher in TRSAs (0.376 and 0.372), and finally Hispanic residents score lowest (0.122 and 0.107). In Los Angeles, Black residents score highest for dissimilarity in both ZCTAs and TRSAs (0.515 and 0.407), followed by Asian residents (0.371 and 0.257), and finally Hispanic residents (0.223 and 0.151).





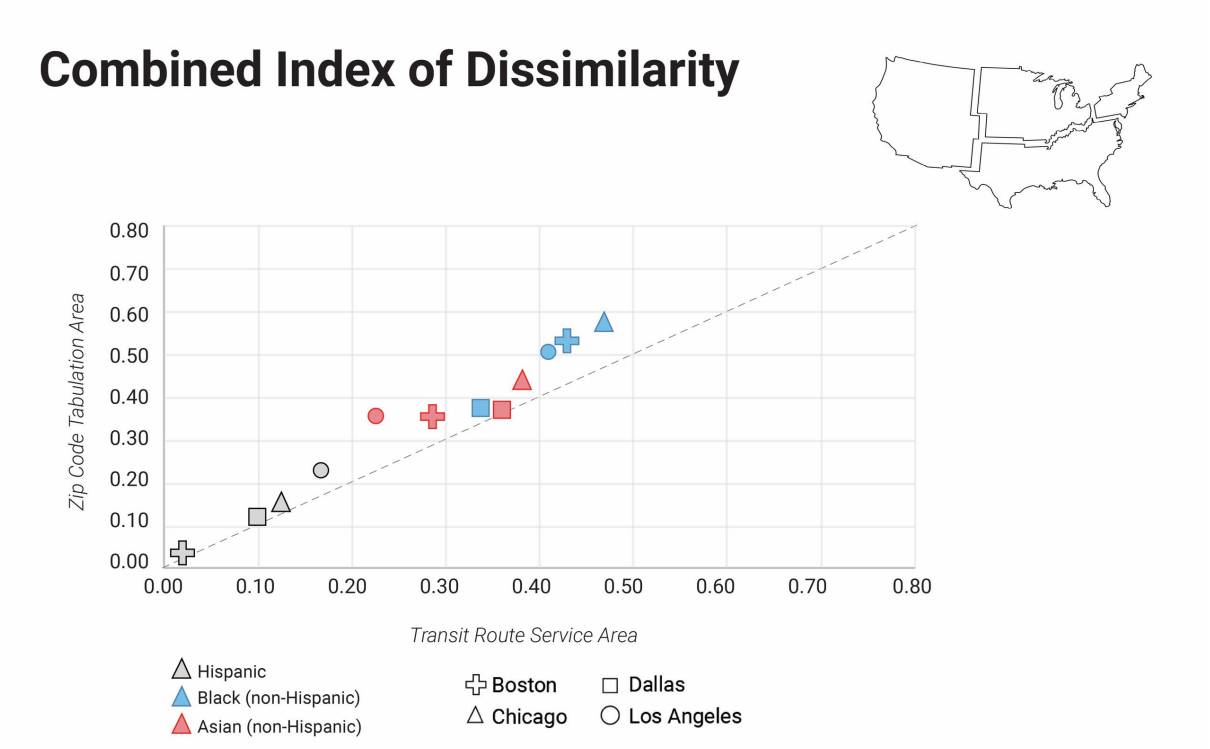
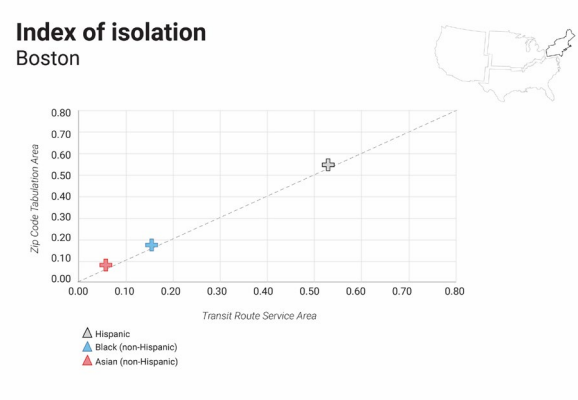
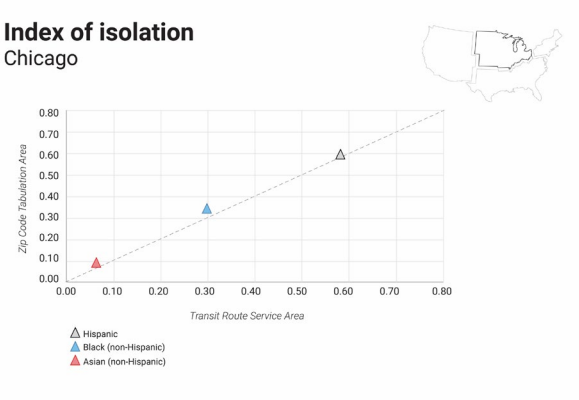


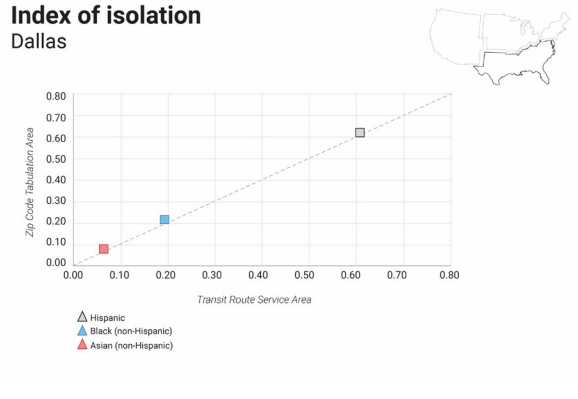
Figure 5, 6, 7, 8, 9: Scores for Index of Dissimilarity

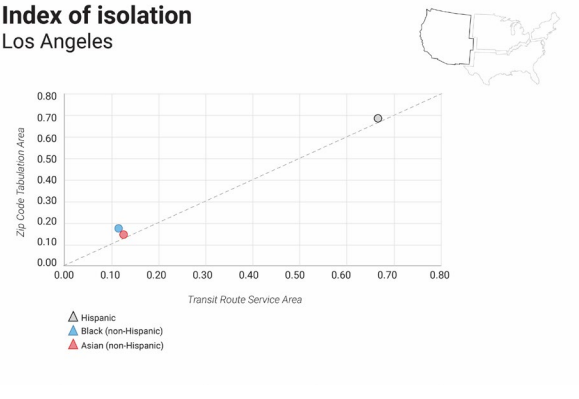
Results Index of Isolation:

In Boston, Hispanic residents scored highest for isolation in both ZCTAs and TRSAs (0.536 and 0.535), followed by Black residents (0.168 and 0.149), and finally Asian residents (0.073 and 0.062). In Chicago, Hispanic residents scored highest for isolation in both ZCTAs and TRSAs (0.596 and 0.590), followed by Black residents (0.348 and 0.293), and finally Asian residents (0.085 and 0.068). In Dallas, Hispanic residents scored highest for isolation in both ZCTAs and TRSAs (0.611 and 0.610), followed by Black residents (0.215 and 0.195), and finally Asian residents (0.076 and 0.068). In Los Angeles, Hispanic residents scored highest for isolation in both ZCTAs and TRSAs (0.684 and 0.673), followed by Black residents (0.178 and 0.123), and finally Asian residents (0.371 and 0.257).









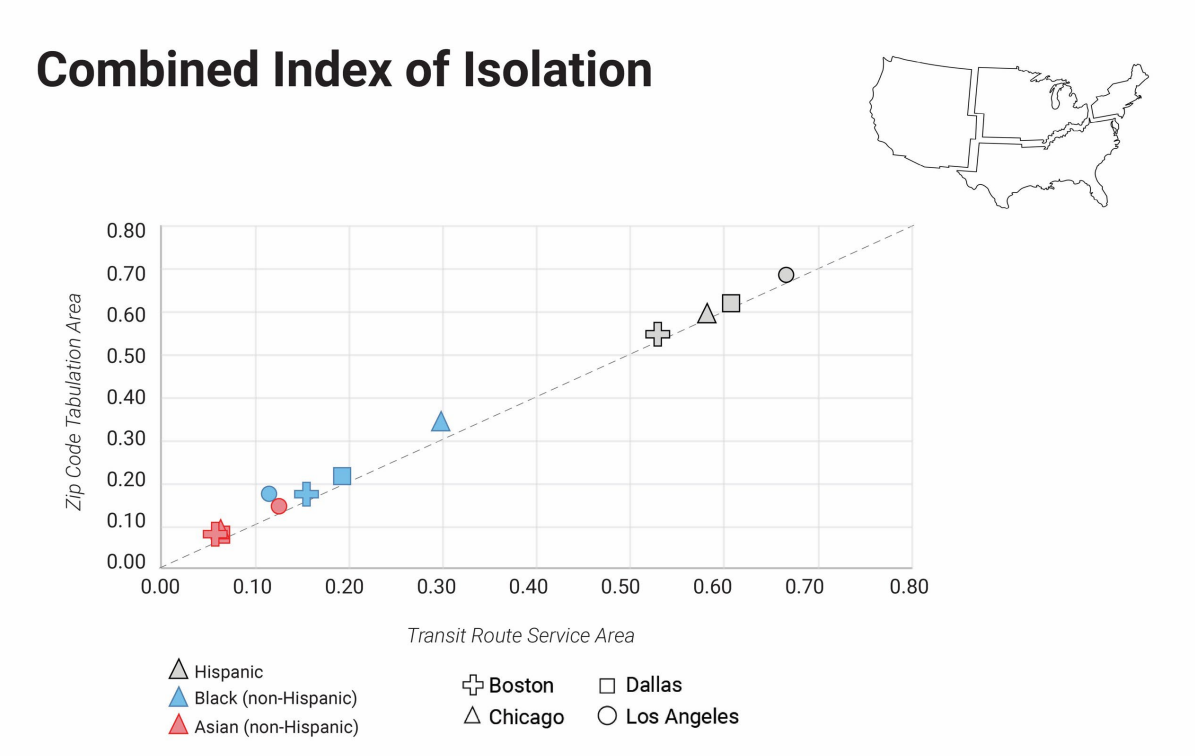


Figure 10, 11, 12, 13, 14: Scores for Index of Isolation

Discussion:

Explanation of Limitations:

Before discussion the implications of these findings, it is necessary to outline the limitation of this study. This thesis is limited in the scope of segregation that is being measured. It measures residential segregation in both TRSAs and ZCTAs. This is different from the activity space approach, which is an extremely data intensive and complex method that measures segregation outside of residential spaces. Another limitation to this method is the number of TRSAs do not numerically match another geography. When developing this study, I found that ZCTAs are the most appropriate geography for this analysis as there are a similar number of each TRSAs to ZCTAs in each respective region.

Analysis:

As cited previously, evenness – as measured by the index of dissimilarity – measures of segregation compare the spatial distributions of different groups among units in a metropolitan area. In the context of my research this metric highlights how similar or different the racial composition of each geography is. Exposure – as measured by the index of isolation – measures the degree of potential contact or possibility of interaction between minority and majority group members. Exposure depends on the extent to which two groups share common residential areas and on the degree to which the average minority group member "experiences" segregation. Massey and Denton (1988) point out, indexes of evenness and exposure are correlated but measure different things: exposure measures depend on the relative sizes of the two groups being compared, while evenness measures do not.

When employing evenness (index of dissimilarity) as an indicator for segregation, Black populations demonstrate the most segregation, followed by Asian populations, followed by the Hispanic populations. This is an interesting pattern that held in all the regions studied. This pattern did not hold when analyzing segregation through the lens of exposure (index of isolation). Hispanic populations scored highest, followed by Black populations, followed by Asian populations. Dissimilarity measures the percentage of a group's population that would have to change residence for each geography to have the same percentage of that group as the metropolitan area overall. It can be understood that Black residents would have to change residence to a higher degree than Asian and Hispanic populations to achieve less segregation. On the other hand, exposure is a measure of the level of potential contact or interaction between members of minority and majority groups (Massey & Denton, 1988). This measure is

dependent on the extent to which both groups share residential areas. Under the context of isolation as a measure for segregation, one can interpret that Hispanic populations interact with other Hispanic people less than other minority groups interact with one another.

When taken together, these findings paint an interesting picture of transportation's role in addressing dissimilarity and isolation of minority populations, especially given *that TRSAs indicate less segregation than ZCTAs, that is bus networks alleviate the segregation that is inherent in these metropolitan regions*. This resonates with the work by Bailey et al. (2020), which indicates public transportation's role in not only fosters social ties between distant zip codes but acting as a crucial connection between geographies different demographics. Bus networks in these study areas demonstrate evidence of the significant role that transportation can play in forming and maintaining a potential infrastructure of social connections and networks. As cited by Blumenberg & Manville (2004) it would be ideal for policy discussions pertaining to economic inequality and transportation consider previous reasoning of the spatial mismatch hypothesis and incorporate additional conceptions of spatial barriers to opportunity. Likewise, while bus networks are not a sole solution to inequity there is evidence that bus networks are not given enough credit for the role that they play in society as a public good. They are a factor and can be a part of a portfolio of solutions to create positive outcomes.

Currently, there is increasing debate around the duty public transportation should hold. Often this debate is broken down into two distinct camps. One being that public transportation should move people throughout a region as efficiently as possible and the other being public transportations' function should be to act as a public good that addresses inequity. Distilling these perspectives down to their core highlights that the debate centers around maximizing

mobility versus mobility driving access and driving opportunity. Accounting for this argument my study indicates that public transportation can assist in building and maintaining social connections, which as cited by Chetty et al. (2022), is a strong predictor of opportunity. In this way, it can be argued that bus networks can provide frequent and efficient service and exist as a public good. Bus networks are a prime means to be a testing ground that straddles these two ideologies. They are intrinsically flexible and can be altered with relatively low capital cost, unlike rail transportation, and have the potential to cover wide swaths of existing right-of-way, something that metropolitan regions in the US have no shortage of.

Future Research:

While this study is limited in scope and only analyzes segregation on the basis of race/ethnicity one strength is that it is extremely replicable and can include a variety of demographic information to include other metrics for analysis. The limiting factor is the scale of geography used to construct a TRSA, which is a Census block. One example of future research that would fit nicely into the existing literature would be income. In particular, an analysis that included income would be an apt means to engage with Raj Chetty's on opportunity and social capital. Chetty's Opportunity Atlas, a public website that allows users to explore data on economic outcomes from the scale of the entire nation to the block where they grew up. This powerful tool could be incorporated and produce unique analysis that further explores the nexus of transportation and opportunity.

Future study is not limited to any geography so long as there is publicly available GTFS data and relevant Census data. This opens the door to a longitudinal component that could

analyze change in segregation over time. As the debate around the role of transportation in addressing inequity, public transit agencies have moved to incorporate equitable planning practices, such as in bus network redesign. Transit planning could utilize this methodology as one step in understanding the degree to which segregation in TRSAs has changed over time in tandem with bus networks.

Additional study could work to understand the specific role that a particular bus route plays within the broader network. One could systematically exclude a route from the analysis to understand the "weight" that route holds in comparison to other routes within the system. This could then highlight strategies to assist a particular line such as priority bus lanes, robust infrastructure that supports bus operation, etc.

Recommendations:

Racial and ethnic enclaves, defined as residential areas with a high concentration of individuals from the same ethnic or racial group, have been a subject of academic inquiry for decades. Although enclaves are often associated with poverty and social exclusion, there is a growing body of research that highlights the benefits of these communities.

Firstly, ethnic enclaves offer a sense of social and cultural belonging to individuals who might feel marginalized in mainstream society. For instance, these enclaves provide a supportive environment that fosters a strong sense of community, shared culture, and traditions. This sense of belonging helps to mitigate the social isolation that can result from living in a society where one's cultural background is not represented. Secondly, enclaves can provide immigrants and minorities with access to valuable resources, including language

services, job networks, and social support networks. For instance, ethnic enclaves can be a vital source of information and assistance for individuals navigating complex bureaucratic systems, such as the healthcare or legal systems. Thirdly, ethnic enclaves can foster economic development and entrepreneurship within their respective communities. These communities can create their own economic ecosystems by providing a market for niche products or services that might not be readily available in the broader economy. This development can lead to job creation and increased economic mobility within the community. Lastly, ethnic enclaves can facilitate the preservation and transmission of cultural traditions and practices. This preservation of cultural heritage helps to ensure the continuity of cultural practices across generations and serves as a reminder of the rich diversity that exists within society.

Overall, while ethnic enclaves have historically been stigmatized, recent research has highlighted the benefits of these communities (Schüller & Chakraborty, 2022). These enclaves provide a sense of belonging, access to resources, opportunities for economic development, and cultural preservation. As such, policies that prioritize the well-being of these communities and recognize the benefits of enclaves are essential for building a more equitable and inclusive society. Policy and planning efforts to address segregation should allow people to retain the power derived from marginalization while simultaneously having the agency to access

Housing Policy Recommendations:

Incorporating inclusionary zoning laws is a viable approach to promote both racial and economic integration. These laws either incentivize or require housing developers to designate a percentage of affordable units for low or moderate-income individuals. Incentives, such as

cost deductions and permits, are often provided by the government to encourage the implementation of these laws (HUD, 2013). Although the goal of inclusionary zoning is to ensure income integration, it frequently leads to racial integration since income is often a proxy for race (Labov, 2017). Inclusionary zoning laws are a desirable departure from the exclusionary zoning laws of the early 20th century, which promoted residential segregation. Since inclusionary zoning laws mandate income integration, they are more likely to be accepted by the public than policies that mandate racial integration, which are frequently perceived as social engineering.

Housing mobility programs represent a potential policy solution to promote integration. These programs assist individuals and families who live in poverty to move to higher income neighborhoods with rent subsidies. Successful housing mobility programs have produced numerous social and economic benefits. For example, the Gautreaux program aimed to promote racial integration by placing over 7,000 families into higher income, primarily white suburbs (Roisman, 1995). A long-term study revealed better school performance and job opportunities for the relocated families. Building on Gautreaux's achievements, HUD implemented the Moving to Opportunity (MTO) program, which relocated low-income Americans to higher income neighborhoods and yielded substantial benefits for children. However, some programs have been less successful because families were relocated to neighborhoods only slightly less impoverished than their previous residence. Therefore, any policy that aims to promote integration must ensure that significant income mixing occurs.

Transportation Policy Recommendations:

Numerous cities could utilize a myriad of tactics to inform the redesign of their bus networks. Leveraging public transportation to accomplish goals that shift outcomes towards increasing opportunity are in the early stages of development. As presented in this study, segregation of residential spaces is extremely intractable, meaning untangling its web of explicit and implicit policy, planning, and design will take generations. As cited, public transportation works to increase opportunity through access. When understanding the reality that housing will largely remain segregated one can turn to public transportation as a means to allow for individuals and households to engage with neighborhoods that are different than their own.

What is interesting is strategies to increase the network efficiency of a bus system requires low capital cost and as demonstrated by this work will induce social benefits. Examples of strategies include infrastructural changes such as designated and protected bus lanes that allow buses to be excluded from congestion and mimic a rail transportation option. Transit signal priority to allow buses to change the traffic signal as they approach or provide buses with their own signal that occurs more often than signal for private vehicles. Furthermore, intentionally incorporating and integrating other modes of transportation into the bus network to increase the permeability and ease of transportation demonstrates a more comprehensive mobility approach.

Changes to fare collection policy whether that be off-board fare collection and all-door boarding to reduce the bus idle time at stops or working to eliminate fares more broadly. As this study has shown, bus networks produce a social benefit in that they connect regions in a manner that demonstrates less segregation. This is particularly relevant in a metropolitan

region like Los Angeles where unlike public transit agencies in other large cities, such as New York or Chicago, LA Metro serves mostly low-income people of color. Seventy-five percent of the agency's ridership identifies as Latinx or Black, 12.7% as white, and close to 63% of riders earn household incomes of less than $25,000 annually, with 40% subsisting on household incomes under $15,000 per year (LA Metro, 2022).

Conclusion:

It is evident that segregated residential spaces leads to unequal access to resources and opportunities, restricting upward mobility and creating societal inequities. The role of public transportation in addressing urban inequality is a topic of much debate, with demands being placed on it to address a myriad of social, economic, and environmental issues. This study demonstrates that transportation is a critical actor in shaping cities more equitable regions, a finding that can positively impact low-income and minority individuals that poses less social capital and opportunity for economic advancement, as they rely more heavily on public transportation. As such, it is important to explore the relationship between public transportation, access, opportunity, and social and economic exclusion, particularly in regions with high racial and ethnic segregation.

Despite these findings, metropolitan regions must work to address social inequities in a comprehensive manner. The implementation of inclusionary zoning policies can effectively encourage socio-economic diversity in housing. These policies may require or incentivize housing developers to designate a certain percentage of their units as affordable for moderate or low-income residents. Government agencies may offer bonuses or permits to encourage

developers to comply with such regulations. While income is the explicit target of inclusionary zoning, it is often used as a proxy for race, leading to the potential for racial integration through successful implementation. Another potential is the implementation of housing mobility programs. These programs enable low-income individuals and families to move to higher-income neighborhoods with the help of rent subsidies. By providing the means for individuals to live in neighborhoods with better access to resources and opportunities, housing mobility programs could contribute to both racial and economic integration. Finally, it is essential to enforce fair lending laws more strictly. One approach to this is to mandate that lenders provide detailed information about their customers, such as their credit score, age, and race. By gathering this information, the Department of Housing and Urban Development (HUD) could investigate lenders that are suspected of discriminatory practices.

Appendix:

	Los Angeles Index of Dissimilarity	
Race	LA ZCTA	Transit Route Service Area
Hispanic Population	0.223	0.151
Black Population	0.515	0.407
Asian Population	0.371	0.257

	Los Angeles Index of Isolation	
Race	LA ZCTA	Transit Route Service Area
Hispanic Population	0.684	0.673
Black Population	0.178	0.123
Asian Population	0.169	0.129

	Boston Index of Dissimilarity	
Race	MBTA ZCTA	Transit Route Service Area
Hispanic Population	0.050	0.037
Black Population	0.510	0.453
Asian Population	0.348	0.293

	Boston Index of Isolation	
Race	MBTA ZCTA	Transit Route Service Area
Hispanic Population	0.536	0.535
Black Population	0.168	0.149
Asian Population	0.073	0.062

	Chicago Index of Dissimilarity	
Race	CTA ZCTA	Transit Route Service Area
Hispanic Population	0.146	0.110
Black Population	0.551	0.466
Asian Population	0.449	0.386

	Chicago Index of Isolation	
Race	CTA ZCTA	Transit Route Service Area
Hispanic Population	0.596	0.590
Black Population	0.348	0.293
Asian Population	0.085	0.068

	Dallas Index of Dissimilarity	
Race	DART ZCTA	Transit Route Service Area
Hispanic Population	0.122	0.107
Black Population	0.393	0.349
Asian Population	0.376	0.372

	Dallas Index of Isolation	
Race	DART ZCTA	Transit Route Service Area
Hispanic Population	0.611	0.610
Black Population	0.215	0.195
Asian Population	0.076	0.068

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