Beyond Spatial Proximity: Understanding Segregation and Job Accessibility among Racial and Low-Income Population in Chattanooga City

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ABSTRACT

In many cities across the United States, racial minorities and low-income households predominantly reside within the urban core. This pattern, a legacy of historic segregative practices such as restrictive deeds and redlining, remains despite laws and regulations designed to eliminate racial residential segregation. Surprisingly, many transportation accessibility studies suggest that low-income and disproportionately black and brown communities, despite their marginalized status, are not necessarily disadvantaged in their ability to access job opportunities because their central urban locations often position them favorably in relation to the wide distribution of employment opportunities across metropolitan areas. However, methods of job accessibility diverge across different racial, ethnic, and socioeconomic, and understanding this complex issue requires more nuanced exploration. To provide clearer insight into this multifaceted issue, our research employed a blend of spatial and statistical analysis, visualization of segregation indices, and measuring accessibility to jobs by different modes of transportation such as walking, driving, and public transit in Chattanooga, Tennessee using a gravity model approach. Our findings reveal that while a majority of racial minorities and low-income individuals possess an advantage in job accessibility due to their central locations, a substantial proportion remain seriously disadvantaged. Moreover, our analyses of various socioeconomic and housing variables further underscore the intricate dynamics at play. Therefore, it becomes apparent that while central urban locations may provide a degree of accessibility, the reality is multifaceted and deeply intertwined with historic and systemic disparities which necessitates a comprehensive understanding and remediation of these underlying issues.

Keywords: Accessibility, Gravity Model, Segregation, Transportation, Spatial Analysis

INTRODUCTION

In the field of transportation studies, accessibility involves the ability of individuals to reach necessary or preferred activities through diverse transportation modes (1). This concept is a critical factor when assessing the effectiveness of transport policies (2) and is a significant contributor to the quality of urbanization in metropolitan areas (3). However, when viewed through the lens of traditionally disadvantaged communities, the interplay between segregation and accessibility presents a more nuanced picture. As part of the broader discussion around this topic, it's worth revisiting the spatial mismatch hypothesis introduced by Ihlanfeldt (4). This theory suggests that economic restructuring and housing market discrimination have led to a spatial disconnect between job opportunities, which are often located in suburbs, and the residences of low-income and minority groups, typically in urban centers (4).

However, in contradiction to this theory, disadvantaged communities, including African Americans and low-income individuals, often reside in urban cores that offer high transportation accessibility to numerous jobs. Nevertheless, these communities continue to grapple with significant socioeconomic challenges such as poverty, low income, and low educational attainment (5). One of the key paradoxes in the literature is the 'skill mismatch,' whereby the jobs available, particularly in sectors like finance and technology, do not align with the skills or qualifications of the urban residents (6,7). Beyond spatial accessibility, systemic barriers like discriminatory hiring practices (8,9) and the lack of affordable childcare can prevent these communities from gaining or maintaining employment (10,11).

Further, education system disparities are prevalent in these segregated neighborhoods, often characterized by lower funding, fewer resources, and lower quality of education than wealthier, predominantly white neighborhoods. Such disparities lead to lower educational attainment, which in turn hampers access to higher-paying jobs, perpetuating a cycle of poverty (12–14). Most blacks are advantaged by virtue of the central location, but a substantial share of blacks is extremely disadvantaged because of the disproportionately low rate of car ownership among blacks. People without cars are deprived of good accessibility even if they live in the central city, where automobile accessibility is among the highest in the region. Blacks and poor people are disproportionately without cars in a city deliberately designed for cars (5).

Transportation accessibility can be understood and measured through several components or dimensions such as infrastructure-based, location-based, person-based, and utility-based measures (15). Infrastructure-based measures predominantly focus on transport service levels, while person-based and utility-based measures emphasize individual accessibility. Location-based measures facilitate macro-level accessibility analysis within different zones of the study area, typically stratified by various population groups (15).

Location-based measures are often utilized to investigate accessibility inequality. Several studies focusing on service deprivation and inequality have utilized location-based accessibility measures such as the travel time or distance to the nearest opportunity (16,17), cumulative access to multiple opportunities (18,19), and factors creating transportation challenges such as distance traveled and road networks available (20,21). When seeking to understand accessibility in a city or community, these multiple measurement dimensions are important because they reflect the complexity of transportation systems. For example, despite being intuitive and easy to communicate, measures focusing solely on the travel time or distance to the nearest opportunity do not effectively represent the connectivity of a given location to multiple other locations and opportunities.

To measure factors creating challenges to transportation, the gravity-based model, initially proposed by Hansen (22), is used. The gravity-based model uses a distance-decay function which weighs the relative significance of the time or cost of travel against the attractiveness of the activities. This function incorporates an exponent that signifies the willingness to travel, suggesting that a higher exponent results in greater friction or impedance imposed by space and transport systems on human movement. Consequently, the gravity-based accessibility measure is one of the most commonly used metrics in urban studies, frequently associated with various social indicators to estimate different social groups' access levels to opportunities (15,23,24).

The goal of this study was to scrutinize factors that influence transit accessibility and to explore methods of measuring accessibility that are more sensitive to the community contexts.

METHOD

Study Setting

Chattanooga, nestled on the Tennessee River and neighboring Georgia to the south, serves as a hub and county seat of Hamilton County in the United States. Housing a population of 181,099 as of 2020, this city is recognized as Tennessee's fourth largest and one of the two main cities in East Tennessee, alongside Knoxville. Chattanooga anchors the fourth-largest metropolitan statistical area in Tennessee and plays a pivotal role in the expansive tri-state area that includes Southeast Tennessee, Northwest Georgia, and Northeast Alabama. This mid-size city in eastern Tennessee is frequently seen as a gateway to the Deep South, Midwest, and Northeast for travelers from Alabama, Florida, and Georgia, making its transportation infrastructure crucial.

Often compared with cities of similar size, Chattanooga experiences some of the worst traffic congestion, thereby highlighting the need for efficient transportation systems. Its diverse population is composed of various communities, each characterized by unique cultural, socioeconomic, and accessibility profiles. The city's history and continued experience of racial segregation, heavily influenced by redlining, have notably impacted its social and economic landscape, as well as accessibility patterns across the city. Redlining, a discriminatory practice from the 1930s, involved marking neighborhoods deemed "risky" for investment, primarily affecting communities of color. In Chattanooga, like many other American cities, this practice led to systemic disinvestment in Black neighborhoods, furthering socioeconomic disparities and limiting access to key resources and services. The remnants of these past injustices persist today, substantially influencing current accessibility patterns throughout the city.

The color-coded map displayed in **Figure 1** highlights the redlining practices implemented throughout Chattanooga during the 20th century. This visual representation provides critical context to understanding the racially discriminatory lending and investment strategies that targeted the city's neighborhoods, predominantly those occupied by Black residents.

Red-shaded areas on the map signify neighborhoods labeled as 'hazardous,' due to the redlining practices. These predominantly Black neighborhoods were systematically denied equal access to housing loans and mortgages, leading to significant socioeconomic disparities and hindered urban development. Conversely, the map's yellow and blue regions, mostly occupied by white residents, were deemed as 'definitely declining' and 'still desirable,' respectively, and did not face the same extent of redlining adversity, thus experiencing comparatively more substantial investment and growth.

The green zones, designated as 'best,' were the most privileged areas receiving the majority of investment, resulting in higher property values and advanced development. By comparing this historical redlining map with contemporary socioeconomic and accessibility maps of Chattanooga, the continuing impact of past discriminatory policies on the city's current disparities in wealth distribution and accessibility becomes evident.

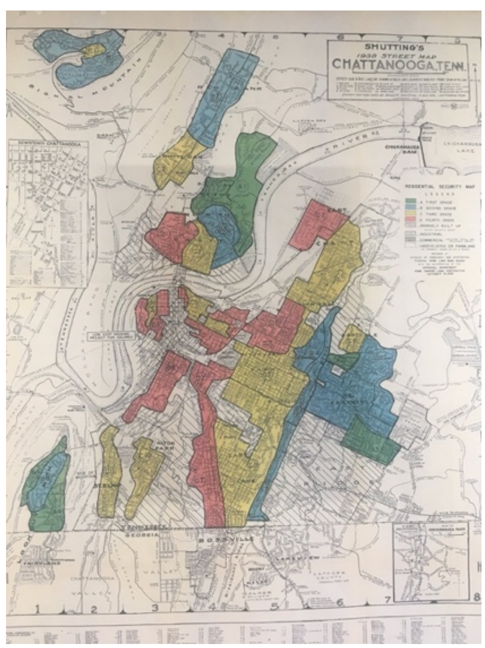

Figure 1.Chattanooga Historic Redlining

Segregation Indices

In this study, segregation within the studied region was assessed using three different indices: the Isolation Index, Dissimilarity Index, and Exposure Index. These indices were calculated on the Census tract level, allowing us to capture localized patterns of segregation, which may otherwise be obscured in broader analyses. Our decision to use census tracts for mapping these indices was primarily guided by the aim to depict diversity more accurately. Census tracts, generally home to 2,500 to 8,000 people, offer a level of detail that is granular enough to showcase variations within the county while still being large enough to ensure statistical reliability.

Isolation Index (P): The Isolation Index encapsulates the degree to which members of a specific minority group, for instance, the Black population, are likely to interact only with members of the same group. This index is especially relevant for understanding the experiences of minority group members in terms of isolation or clustering. Its mathematical formulation is given by:

$$P^* = \Sigma [(b_i / B) * (b_i / T_i)]$$

Here, b_i represents the minority population within a specific tract (i), B is the total minority population within the entire region of study (such as a city or a broader region), and T_i is the total population within the tract (i). The Isolation Index ranges between 0 and 1, with higher values indicating a greater likelihood of intra-group interactions and thus, higher segregation levels.

Dissimilarity Index (D): The Dissimilarity Index quantifies the relative distribution of two distinct groups across different tracts within a larger area. It essentially captures the degree to which the two groups are evenly spread out across the geographical expanse. It is computed as follows:

$$D = 0.5 * \Sigma [| (a_i / A) - (b_i / B) |]$$

Here, a_i refers to the population of Group A in tract i, and A denotes the total population of Group A in the larger area. Similarly, b_i and B represent the corresponding values for Group B. Like the Isolation Index, the Dissimilarity Index also ranges from 0 to 1, with higher values suggesting greater segregation.

Exposure Index (E): The Exposure Index is indicative of the potential contact or interaction between members of two distinct groups. It offers insights into the daily experiences of different group members, especially regarding their exposure to diversity. The mathematical expression for the Exposure Index is:

$$E = \Sigma [(a_i / A) * (b_i / T_i)]$$

Here, a_i, A, b_i, and T_i have the same definitions as above.

Gravity Model Formulation

In this study, we employed ArcGIS and Network Analysis to implement the Gravity Model, aiming to evaluate job accessibility within all census block groups. The decision to use the block group level (housing between 600 to 3,000 individuals), a smaller geographic unit compared to census tracts, was guided by the consideration that job accessibility can dramatically fluctuate over short distances and the fact that block groups provide a more granular perspective on these patterns.

To this end, we constructed a network dataset incorporating both the General Transit Feed Specification (GTFS) database for the public transit network of buses and OpenStreetMap (OSM) data. This dataset considered various commuting-influencing factors such as road lengths, hierarchy, and speed limits, thereby enabling a more realistic representation of the commuting experience.

Using the Network Analysis module, we calculated the travel times (C_{ij} in the Gravity Model) between each block group. This process generated a matrix of travel times, capturing the time-based distance between all pairs of origins (block groups) and destinations (job locations). Subsequently, the Gravity Model was applied to this matrix to compute an accessibility score for each block group. The accessibility score for each block group hence encapsulated the number of job opportunities accessible from that block group, discounted by both travel time and the competition for those jobs. The model is mathematically formulated as follows:

$$Ai = \sum (Oi / Cij^\beta)$$

Here, A_i represents the accessibility of opportunities (jobs) from a particular block group, designated as 'i'. Oi corresponds to the number of jobs available at another location, 'j'. Cij stands for the travel time from block group 'i' to job location 'j'. The symbol 'β' is the decay parameter, reflecting the rate at which the accessibility of job opportunities diminishes with increasing travel time.

This Gravity Model for public transit (bus) was applied to each block group within a 400-meter radius of a bus stop, highlighting the significance of public transit in job accessibility. The walking restriction was not used for walking and driving modes of transit.

Spatial and Statistical Analysis

Once the accessibility scores and segregation indices were calculated, spatial analysis was performed using Geographic Information Systems (GIS). This involved mapping the segregation indices and job accessibility based on public transit, walking, and driving across Chattanooga. For statistical analysis, a correlation analysis was performed to examine relationships between the accessibility scores, and socio-economic, demographic, and housing characteristics. This analysis provided insights into potential disparities and significant relationships in job accessibility across different areas and transportation modes.

RESULTS

Segregation

Our findings utilize several indices to illustrate the patterns of racial segregation in Hamilton County, Tennessee, which includes the city of Chattanooga. These indices, detailed below, were mapped at the census tract level using GIS to reveal the geographic distribution of these patterns.

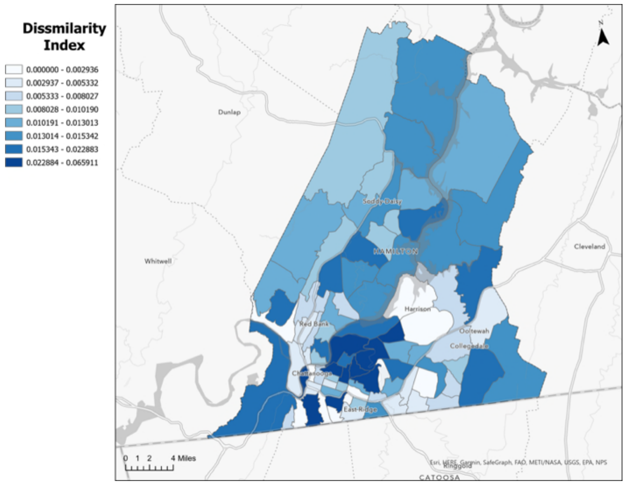

Figure 2. Dissimilarity Index: Racial Segregation in Hamilton County

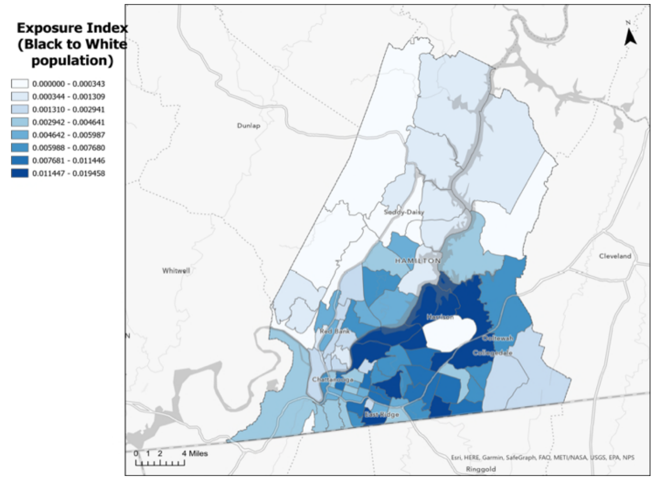

Figure 3. Exposure Index: Black-White Interaction in Hamilton County

Figure 2 illustrates the Dissimilarity Index, a commonly used measure to represent residential segregation between two racial groups - in this case, Black and White residents. The map shows varied dissimilarity indices across the city, providing insights into patterns of residential segregation. **Figure 3** depicts the Exposure Index for Black to White populations. This measure gives an idea of the average racial composition of the neighborhood for a typical Black resident, indicating the degree of potential contact or exposure between racial groups. The map reveals that the exposure of Black residents to White residents varies across the city, with center areas demonstrating higher levels of exposure compared to suburbs.

The Isolation Indices for White and Black populations are shown in **Figures 4 and 5**, respectively. A higher isolation index suggests that members of a racial group predominantly live around others from the same group.

Figure 4 demonstrates that the isolation index of White residents tends to be higher as we move further away from the city center. In contrast, **Figure 5** shows that the isolation index for the Black population is higher around the city center. These figures suggest a pattern of racial segregation, where White residents are more isolated in the outskirts, while Black residents are more isolated around the city's central areas.

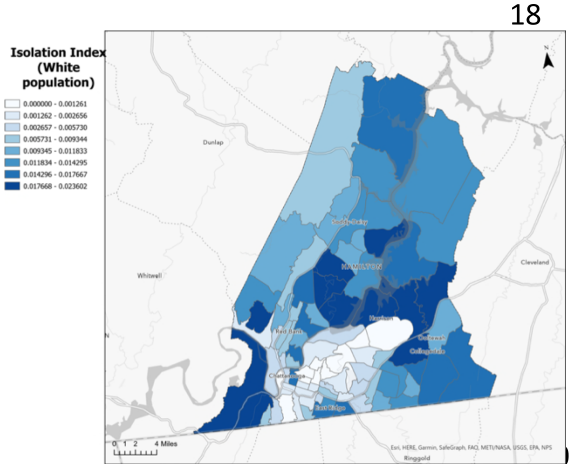

Figure 4. White Isolation Index: White Community Clusters in Hamilton County

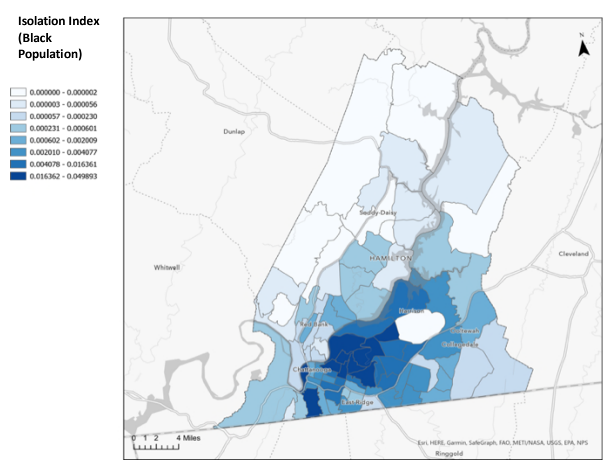

Figure 5. Black Isolation Index: Black Community Clusters in Hamilton County

Dissimilarity Index of approximately 0.56, which indicates a moderate level of racial segregation across Hamilton County, suggesting that more than half of either African American and Black or White residents would need to move to achieve racial balance across the county. The Isolation Index of 0.80 for White residents is significantly higher than for Black residents (0.45), indicating that White residents in Hamilton County are more likely to live in areas where they only encounter other White residents. The Exposure Index of 0.47 for Black residents to White residents is higher than the Exposure Index for White residents to Black residents (0.12). This indicates that Black residents are more likely to encounter White residents in their local area than vice versa. The Exposure Indices also show that both Black (0.45) and White (0.80) residents are most likely to encounter residents of their own race.

Accessibility

The results depicted in **Figures 6, 7, and 8** visually represent the accessibility to jobs within the city of Chattanooga using the gravity model, across three modes of transportation - driving, public transit, and walking, respectively. The gravity model effectively calculates the potential interaction between two places, considering the distance between them and the number of opportunities at the destination. Here, it has been utilized to assess job accessibility within the city.

Figure 6 displays the driving accessibility to jobs, illustrating the highest levels of accessibility concentrated within the city center. As the distance from the city center increases, accessibility progressively decreases. This pattern signifies those areas closer to the heart of the city present higher job opportunities for individuals relying on driving as their primary means of transportation.

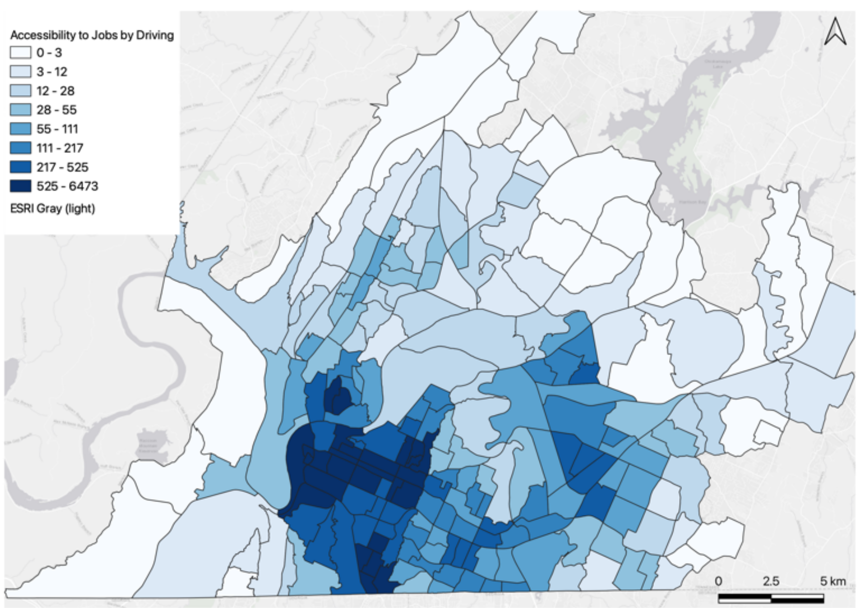

Figure 6. Access to Jobs via Driving Using Gravity Model Approach in Chattanooga

Figure 7 reveals the accessibility to jobs via public transit, namely buses. While the trend of decreasing accessibility with increasing distance from the city center remains consistent, the overall accessibility scores for public transit are lower than that of driving. Despite this, the central areas still provide relatively reasonable job accessibility for those using public transportation.

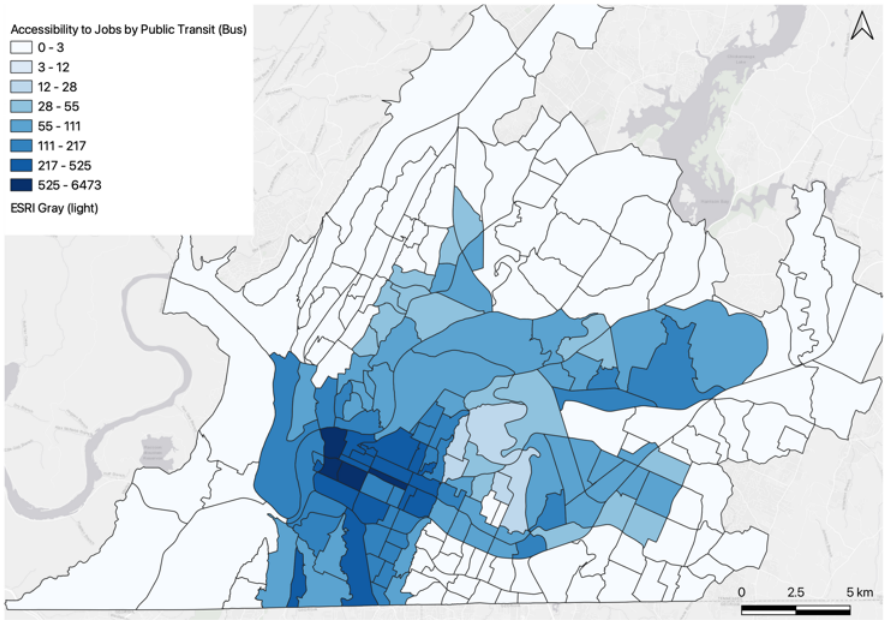

Figure 7. Access to Jobs via Public Transit (Bus) Using Gravity Model Approach in Chattanooga

Figure 8 demonstrates job accessibility via walking. Here, the trend of decreasing accessibility with increasing distance from the city center is even more prominent, with significantly lower accessibility scores compared to driving and public transit. The map confirms that the job opportunities accessible by walking are primarily confined to the city center, emphasizing the influence of geographical proximity on job accessibility for pedestrians.

Overall, these maps corroborate that the city center of Chattanooga offers the highest job accessibility across all three modes of transportation, with driving providing the greatest accessibility followed by public transit and walking.

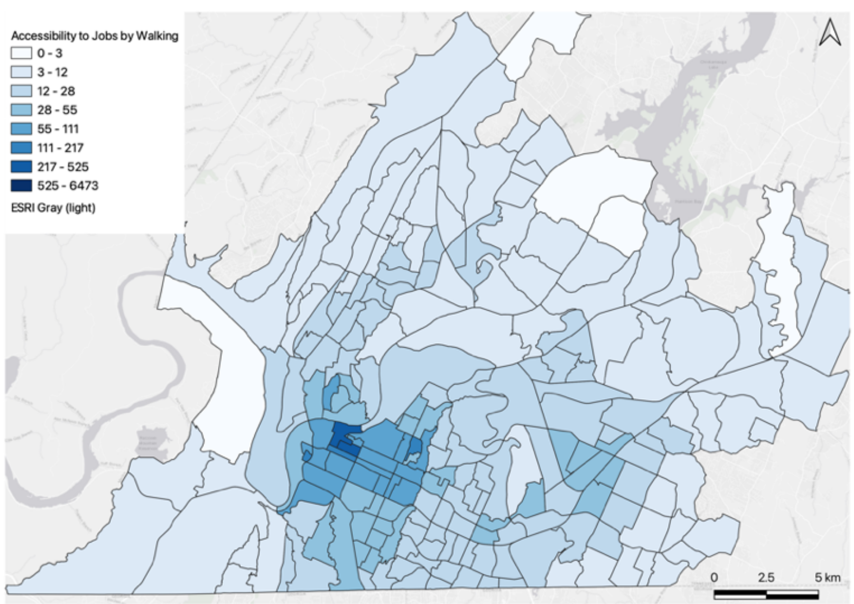

Figure 8. Access to Jobs via Walking Using Gravity Model Approach in Chattanooga

Correlation

The investigation reveals various significant correlations in the context of accessibility, education, income, employment, and housing situation concerning the percentages of White and Black populations **(Table 1)**.

The correlations concerning accessibility modes and the racial population percentages showed distinct patterns. For the White population, there were negative correlations with walking ($\beta = -0.23$; $p < .05$), driving ($\beta = -0.16$; $p < .05$), and public transit ($\beta = -0.14$; $p < .05$) accessibility. On the other hand, the Black population showed positive correlations with walking ($\beta = 0.27$; $p < .05$), driving ($\beta = 0.23$; $p < .05$), and public transit accessibility.

In terms of educational attainment, there was a slight negative correlation between individuals with no formal education completed and the percentage of White population ($\beta = -0.14$; $p < .05$). The correlation turned positive and intensified with higher educational attainment - attended college for over a year without a degree ($\beta = 0.17$; $p < .05$), Bachelor's degree ($\beta = 0.47$; $p < .05$), Master's degree ($\beta = 0.35$; $p < .05$), and Professional degree ($\beta = 0.30$; $p < .05$). In contrast, the Black population showed an inverse and significant correlation for higher degrees - Bachelor's degree ($\beta = -0.34$; $p < .05$), Master's degree ($\beta = -0.26$; $p < .05$), and Professional degree ($\beta = -0.24$; $p < .05$).

Income levels showed distinct correlations as well. The White population showed a positive correlation with median household income ($\beta = 0.53$; $p < .05$) and a moderate negative correlation with households with income below the poverty level ($\beta = -0.28$; $p < .05$). Conversely, the Black population showed a moderate negative correlation with median household income ($\beta = -0.35$; $p < .05$) and a significant positive correlation with households with income below the poverty level ($\beta = 0.38$; $p < .05$).

When it comes to employment, the employed civilian labor force positively correlated with the White ($\beta = .32$; $p < .05$) and negatively with Black ($\beta = -0.14$; $p < .05$) populations, while the unemployed civilian labor force negatively correlated with White ($\beta = -0.16$; $p < .05$) and positively with the Black ($\beta = 0.24$; $p < .05$) populations.

The housing situation also demonstrated significant correlations. For the White population, owner-occupied households ($\beta = 0.54$; $p < .05$), owner-occupied households with a vehicle ($\beta = 0.43$; $p < .05$), and renter-occupied households without a vehicle ($\beta = -0.32$; $p < .05$) showed significant correlations. In contrast, for the Black population, correlations were significant with owner-occupied households ($\beta = -0.33$; $p < .05$), renter-occupied households ($\beta = 0.45$; $p < .05$), owner-occupied households with a vehicle ($\beta = -0.26$; $p < .05$), renter-occupied households with a vehicle ($\beta = 0.26$; $p < .05$), and renter-occupied households without a vehicle ($\beta = 0.39$; $p < .05$).

Table 1. Correlation Between Accessibility, Education, Income, Employment, Housing, and Racial Composition of Chattanooga Population

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Walking Accessibility																				
2.Driving Accessibility	0.85*																			
3.Public Transit Accessibility	0.48*	0.39*																		
4.Percentage of White Population	-0.23*	-0.16*	-0.14*																	
5.Percentage of Black Population	0.27*	0.23*	0.11	-0.76*																
6.No Formal Education Completed	0.01	-0.01	-0.03	-0.14*	0.12															
7. Attended College (1+ Years), No Degree	-0.11	-0.14*	-0.13	0.17*	0.02	0.12														
8.Bachelor's Degree Holders	-0.23*	-0.20*	-0.09	0.47*	-0.34*	-0.11	0.43*													
9.Master's Degree Holders	-0.20*	-0.18*	-0.09	0.35*	-0.26*	-0.09	0.32*	0.63*												
10.Professional Degree Holders	-0.09	-0.10	0.07	0.30*	-0.24*	-0.06	0.12	0.46*	0.41*											
11.Median Household Income	-0.18*	-0.13	-0.11	0.53*	-0.35*	-0.09	0.20*	0.59*	0.52*	0.54*										
12.Households with Income Below Poverty Level	0.21*	0.16*	0.13	-0.28*	0.38*	0.10	0.19*	-0.09	-0.06	-0.14*	-0.39*									
13.Employed Civilian Labor Force	-0.10	-0.12	-0.06	0.32*	-0.14*	-0.00	0.64*	0.68*	0.66*	0.29*	0.33*	0.18*								
14.Unemployed Civilian Labor Force	0.08	0.02	-0.01	-0.16*	0.24*	0.25*	0.23*	0.01	0.04	-0.06	-0.13	0.32*	0.21*							
15.Percentage of Owner-Occupied Households	-0.42*	-0.33*	-0.33*	0.54*	-0.33*	-0.10	0.19*	0.46*	0.33*	0.27*	0.62*	-0.36*	0.24*	-0.14*						
16.Percentage of Renter-Occupied Households	0.37*	0.30*	0.21*	-0.24*	0.45*	0.18*	0.02	-0.29*	-0.21*	-0.19*	-0.41*	0.48*	0.01	0.25*	-0.72*					
17.Number of Owner-Occupied Households with Vehicle	-0.37*	-0.31*	-0.26*	0.43*	-0.26*	-0.06	0.53*	0.72*	0.62*	0.36*	0.49*	-0.09	0.66*	0.05	0.72*	-0.54*				
18.Number of Owner-Occupied Households with No Vehicle Available	0.02	-0.01	-0.03	0.00	0.06	-0.02	0.05	-0.04	0.01	0.01	-0.08	0.09	0.07	0.16*	0.08	-0.06	0.16*			
19.Numberof Renter-Occupied Households with Vehicle	0.20*	0.11	0.14*	-0.13	0.26*	0.12	0.38*	0.07	0.16*	-0.02	-0.24*	0.60*	0.46*	0.33*	-0.53*	0.72*	-0.15*	-0.00		
20.Number of Renter-Occupied Households with No Vehicle Available	0.32*	0.28*	0.19*	-0.32*	0.39*	-0.01	0.00	-0.17*	-0.11	-0.12	-0.28*	0.60*	-0.05	0.13	-0.42*	0.48*	-0.24*	-0.00	0.47*	

* p<.05

DISCUSSION

Our research provides nuanced insights into the ongoing debate surrounding segregation and highlights the necessity to incorporate multiple factors such as education, income, and employment into transportation accessibility studies. Though disadvantaged communities are often located in areas with high accessibility to job opportunities, systemic barriers, and mismatches in skills and qualifications persist. These obstacles hinder their ability to fully capitalize on the accessibility benefits provided by their central urban location.

The study also reaffirms the complexity of transportation accessibility and the need for multi-dimensional measures. Focusing solely on proximity or travel time to job opportunities, while easy to communicate, does not capture the complete picture. The gravity-based model employed in this study provides a more comprehensive measure of job accessibility by incorporating the interaction between two places, the cost of travel, and the number of opportunities at the destination.

Our results demonstrate significant correlations between accessibility, education, income, employment, and housing situation with respect to racial populations. For example, for the Black population, we found positive correlations with accessibility across all modes of transportation (walking, driving, and public transit), which is consistent with their residence in urban areas. However, despite the higher accessibility scores, this population exhibits negative correlations with higher levels of education and median household income and positive correlations with households with income below the poverty level. These results indicate that while they may have physical access to job opportunities, systemic barriers and disparities in education and income prevent them from fully benefiting from these opportunities.

The results also reveal the distinct housing situations between the White and Black populations, with significant correlations found with owner-occupied households with a vehicle for the White population and renter-occupied households without a vehicle for the Black population. This situation further exacerbates the accessibility challenges for Black communities, as car ownership significantly improves job accessibility, especially in a city designed for cars.

CONCLUSION

Our study offers an exploration of the factors that influence transit accessibility in Chattanooga, highlighting the intricate connections between accessibility, segregation, education, income, employment, and housing situation. Our findings provide some evidence of systemic disparities in accessibility and socioeconomic factors and shed light on the ways in which race, income, and car ownership interact with transportation accessibility.

The results underline the need to approach urban planning and transportation policy with a comprehensive lens, considering the multifaceted nature of accessibility and the unique circumstances and challenges faced by disadvantaged communities. It underscores the necessity to integrate considerations of equity and social justice into transportation planning and infrastructure development.

In the case of Chattanooga, while the city center offers the highest job accessibility across all modes of transportation, these benefits are not equally distributed or capitalized upon by all residents. Consequently, a strong case can be made for policy interventions that seek to mitigate these disparities and ensure fair access to job opportunities for all residents. Such interventions may include investment in public transit infrastructure, initiatives to enhance accessibility in peripheral regions, and social policies aimed at overcoming systemic barriers, such as discriminatory hiring practices, lack of affordable childcare, and disparities in education.

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