
# EVALUATING TRANSIT EQUITY AND ACCESSIBILITY TO AFFORDABLE HOUSING IN TENNESSEE

## RES 2021-08

Research Final Report from University of Tennessee, Knoxville | Jing Guo, Ashley Hightower, Christopher Cherry, Candace Brakewood | August 31, 2022

Sponsored by Tennessee Department of Transportation, Long Range Planning

Research Office & Federal Highway Administration

# DISCLAIMER

This research was funded through the State Planning and Research (SPR) Program by the Tennessee Department of Transportation and the Federal Highway Administration under ***RES #: 2021-08 Research Project Title: Evaluating Transit Equity and Accessibility to Affordable Housing in Tennessee.***

# Technical Report Documentation Page

| | | |
|---|---|---|
| 1. Report No.<br>RES 2021-08 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>*Evaluating Transit Equity and Accessibility to Affordable Housing in Tennessee* | | 5. Report Date<br>August 31, 2022<br>6. Performing Organization Code |
| 7. Author(s)<br>Jing Guo, Graduate Research Assistant<br>Ashley Hightower, Undergraduate Research Assistant<br>Christopher Cherry, PhD, Co-Principal Investigator<br>Candace Brakewood, PhD, Principal Investigator | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>University of Tennessee, Knoxville<br>851 Neyland Drive<br>Knoxville, TN 37996 | | 10. Work Unit No. (TRAIS)<br>11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address<br>Tennessee Department of Transportation<br>505 Deaderick Street, Suite 900<br>Nashville, TN 37243 | | 13. Type of Report and Period Covered<br>14. Sponsoring Agency Code |

15. Supplementary Notes

Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

Over the last decade, urban areas throughout the country have experienced significant economic growth and gentrification, including those in Tennessee. With increasing gentrification and higher housing prices, some low-income households have had to make trade-offs between housing affordability and transit accessibility. This is because transit services tend to be more frequent and widespread in downtown areas where the housing prices are normally higher than in suburban areas. Thus, this report aims to critically assess the interrelated issues of transit access to jobs, affordable housing locations, and displaced populations in the major metropolitan regions of Tennessee. Transit accessibility to jobs from affordable housing units were measured using an accessibility software from Conveyal. Next, affordable housing locations that have limited transit access to jobs were identified, and potential modifications to transit service that could increase access were proposed. Then, maps were created to visualize the spatial distribution of displaced low-income households, which revealed that, on average from 2010 to 2019, Davidson County lost the greatest number of low-income households and had the highest displacement rate among the four counties, followed in order by Knox, Shelby, and finally Hamilton County. Lastly, maps that compared affordable housing locations, the transit network, and displacement suggested that the relationship between transit accessibility, affordable housing, and displacement differed across the four metropolitan regions. In general, transit accessibility and housing affordability are important to reduce or prevent the displacement of low-income households. Therefore, it is important for transit agencies and housing authorities to consider policies and practices that facilitate coordination of transit planning and affordable housing development in the future.

| | | | |
|---|---|---|---|
| 17. Key Words<br>**PUBLIC TRANSIT, JOB ACCESSIBILITY, LOW-INCOME HOUSEHOLDS, AFFORDABLE HOUSING, TRANSIT EQUITY** | 18. Distribution Statement | | |
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>56 | 22. Price |

# Acknowledgements

We are very grateful to the Tennessee Department of Transportation staff who provided input on this research project, particularly Emily Duchac, Melanie Murphy, and Jennifer Marshall from the Research Office. Thanks to Anson Stewart from Conveyal for providing guidance on the analysis of transit accessibility. Lastly, we would also like to recognize University of Tennessee graduate student Cassidy Crossland, who assisted with the preparatory work for this project.

An important part of research is dissemination of the methods and results to other researchers and practitioners. The following is a list of research products that are associated with this project. Additional venues for dissemination of the research findings will be added in the future as appropriate.

**Presentations:**

1. "Evaluating Transit Equity and Accessibility to Affordable Housing in Tennessee," presented at the Transportation Research Board (TRB) Conference on Advancing Transportation Equity, Virtual Conference, September 13, 2021.
2. "Transit Accessibility, Housing Affordability and the Displacement of Low-Income Households in Tennessee," presented at the 101st Annual Meeting of the Transportation Research Board (TRB) in Washington, DC, January 11, 2022.

**Papers:**

1. "Transit Accessibility, Housing Affordability and the Displacement of Low-Income Households in Tennessee," submitted to *Case Studies on Transport Policy*, Under Review.
2. "Evaluating Equity: A Method for Analyzing Transit Accessibility of Affordable Housing Units," submitted to the *Journal of Transport Geography*, Under Review.

# Executive Summary

Over the last decade, urban areas throughout the country have experienced substantial economic growth and revitalization, particularly in downtown areas. This has been accompanied by increased housing prices and changing demographics in the urban core of many metropolitan areas, including those here in Tennessee. While these changes have many positive societal outcomes, they can negatively affect low-income groups who historically have resided in dense urban areas. With increasing gentrification and higher housing prices, some low-income residents have begun to move to lower density, suburban areas where housing prices are more affordable. The displacement of low-income populations to lower density areas has led to transportation challenges. Low-income populations often rely on public transit for their transportation needs; however, transit services tend to be most frequent and have the most coverage in dense, urban areas. By moving to suburban and exurban areas, low-income populations may no longer have the level of transit access that they once had in downtown areas, potentially imposing significant mobility challenges on these disadvantaged populations. This report aims to critically assess the interrelated issues of transit access to jobs, affordable housing locations, and displaced populations in the major metropolitan regions of Tennessee.

To do this, five research objectives were set forth, which are as follows:

- **Objective 1:** Review new literature and compile case studies of similar southern metropolitan regions that have conducted research or successfully implemented policies to address displacement, transit access, and affordable housing.
- **Objective 2:** Analyze transit access to jobs from affordable housing units in the four major cities of Tennessee (Nashville, Memphis, Knoxville, and Chattanooga) and create maps that visualize transit accessibility from affordable housing developments.
- **Objective 3:** Identify affordable housing locations that have limited transit access to jobs and propose and evaluate modifications to transit service that could increase access.
- **Objective 4:** Develop measures to identify displaced populations, particularly low-income groups, and create maps showing the results.
- **Objective 5:** Share the tools to evaluate transit access to jobs, affordable housing locations, and displaced populations with key stakeholders in the region to facilitate future equity-related analyses.

## *Key Findings*

To fulfill these objectives, a four-part method was applied, and the key findings are briefly described in the following paragraphs.

1. **Results of the literature review and case studies**

   The body of literature reviewed could be broadly classified into the following topics: 1) *gentrification and displacement*, 2) *transit accessibility*, and 3) *coordination between affordable housing locations and transit services*. The literature on *gentrification and displacemen*t revealed that displacement could occur when residents involuntarily move to the suburbs due to unaffordable housing prices. A measure of displacement could be the change in population composition over time using public data from the U.S. census. Previous research has shown that a

decrease in the number of low-income households over time could be used as an estimate to measure displacement, and the data required for this method could be obtained from the publicly available U.S. Decennial Census and American Community Survey.

Second, the literature on *transit accessibility* suggested that an opportunity-denominated measure, which counts the number of opportunities people can reach in a given threshold of time or cost, could be used to quantify the number of jobs accessible via transit from affordable housing units. The literature on transit accessibility measures also discussed the data needed to be collected and tools that could be used in measuring transit accessibility. General Transit Feed Specification (GTFS) data from four regional transit agencies were used for transit service information. The Longitudinal Employer-Household Dynamics (LEHD) data, a public database providing job locations in the United States, were used to obtain the job information in the four study areas. The tool for measuring transit accessibility was the Conveyal Analysis platform, which is a web-based geographic information system built on open-source software. Conveyal's Analysis software utilizes an opportunity-denominated measure to assess transit accessibility, GTFS data were used to build the transit network, and LEHD data were used to create the destinations layer.

Last, the literature review also included a recent report that conducted a national survey of 51 American transit agencies on the coordination of public transit and affordable housing. The report indicated the importance of improving transit accessibility to affordable housing and the lack of cooperation between most transit agencies and affordable housing authorities. The report also suggested that more research is needed to examine the transit accessibility of affordable housing programs and to develop methods to improve coordination between affordable housing planning and transit network design. More findings from the literature review can be found in Chapter 2: Literature Review and Appendix 1.

Case studies were also conducted on southern cities that have implemented policies or are engaged in projects to address public transit equity issues, particularly pertaining to affordable housing and/or displaced populations. The case studies are in Appendix 2.

2. **Results of the transit accessibility analysis of affordable housing locations and proposed transit modifications**

Next, transit accessibility levels of affordable housing locations in the four major Tennessee cities (Nashville, Memphis, Knoxville, and Chattanooga) were analyzed in Conveyal's Analysis software. The results generally showed that Nashville and Memphis had higher transit-inequity levels (as compared to Knoxville and Chattanooga) because of the presence of greater numbers of affordable housing units with limited transit access. The ratio of the percentage of affordable housing units to the percentage of jobs accessible by transit was calculated for each affordable housing location and sorted in descending order. For affordable housing locations with a higher ratio value (high number of affordable housing units and limited transit supply), specific transit service modifications were proposed. The types of transit service modifications considered include reroutes, added trip patterns, and increased frequency. The detailed evaluations can be found in Chapter 4.

3. **Results of the displacement analysis**

Displacement was measured by the loss of low-income households from 2010 to 2019 in four counties (Davidson County, Shelby County, Knox County, and Hamilton County). This was visualized using spatial distribution maps of displaced low-income households. The count of

displaced blocks showed that 37% of the blocks in the four counties experienced displacement between 2010 and 2019. Looking at each county individually, over half of the blocks in Davidson County experienced displacement, while the other three counties had fewer census blocks that lost low-income households. The spatial distribution of displaced low-income households revealed that many of the displaced areas were often located in places with less affordable housing and higher transit accessibility, although there were differences across the four metropolitan regions. More information on the displacement analysis can be found in Chapter 4.

4. **Results of the comparison of affordable housing, displaced populations, and transit accessibility**

   The relationship between affordable housing locations, displaced populations, and transit accessibility was then explored by creating a series of maps overlaying displacement, affordable housing locations, and the transit network. These maps revealed which areas in each of the four major metropolitan regions in Tennessee could benefit from future affordable housing and/or transit modifications, and the results suggest that the relationship between transit accessibility, affordable housing, and displacement differs across regions. More information can be found in Chapter 4.

5. **Results of the stakeholder engagement**

   Last, zoom calls were conducted with transit agency and planning organization stakeholders from the four major metropolitan regions to share and discuss the results of this project. Detailed suggestions from stakeholders are incorporated into the results found in Chapter 4.

## *Key Recommendations*

Based on the key findings discussed above, the following recommendations were made.

1. **Consider specific modifications to the fixed route transit network for affordable housing units with low transit accessibility levels**

   Specific recommendations for modifications to the fixed route transit network were provided for locations with low transit accessibility and higher numbers of affordable housing units. The recommendations for each affordable housing location were made by considering the existing fixed route transit network and the nearby street network. Proposed recommendations to the fixed route transit network were put into three categories: reroutes, added trip patterns, and increased frequency. In some areas with very limited access to fixed route service, transit agencies could consider providing demand-response transportation services to affordable housing units; however, new demand-response services were not evaluated in this report.

   Recommendations for fixed route transit service modifications were provided to the local transit agencies during stakeholder engagement. One of these recommendations for each city is shown as an example in Chapter 4. The analysis for additional affordable housing units in Nashville, Memphis, Knoxville, and Chattanooga are not included in this report but are available from the authors upon request.

2. **Implement policies to reduce or mitigate displacement in specific areas**

   This report provides a series of maps that show the spatial distribution of the loss of low-income households from 2010 to 2019. These maps can be used to help identify the trends in the displacement of low-income households in each county. Because there were substantial

differences across the four counties, it is recommended that planning and policy changes to address displacement be tailored to the local context. Policy recommendations should focus on reducing or preventing further displacement of low-income households in the areas of concern; for example, local housing authorities may provide rental subsidies to low-income households in these areas, and local transit agencies could offer free or discounted fare programs to encourage low-income households to take transit. However, additional research is also recommended in the future to further assess displacement; this could include conducting a survey that tracks displacement both spatially and temporally and investigates the causes driving displacement.

3. **Coordinate new affordable housing development and transit service planning**

This report presents an analysis of the relationship between affordable housing, displacement, and transit accessibility that was accomplished by creating a series of maps that included the locations of existing affordable housing units, the spatial distribution of fixed route transit networks, and the spatial distribution of the loss of low-income households from 2010 to 2019. These maps suggest that there is a complex relationship between transit accessibility, affordable housing, and displacement. Due to this complexity and differences across regions, it is generally recommended that local transit agencies and housing authorities coordinate transit planning and affordable housing development. For example, housing authorities should consider placing new affordable housing buildings in areas with higher transit access; additionally, transit agencies could offer discounted fare programs to encourage these residents to take transit. Other planning and policy options could also be considered in the future to facilitate coordination between affordable housing and transit service.

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# Glossary of Key Terms and Acronyms

- ACS: American Community Survey
- CARTA: Chattanooga Area Regional Transportation Authority
- GIS: Geographic Information System
- GTFS: General Transit Feed Specification
- KAT: Knoxville Area Transit
- LEHD: Longitudinal Employer-Household Dynamics
- LIHTC: Low-income Housing Tax Credit
- MATA: Memphis Area Transit Authority
- MPO: Metropolitan Planning Organization
- Multifamily: Multifamily Subsidized Housing
- PH: Public Housing
- WeGo: WeGo Public Transit (Nashville)

# Chapter 1 Introduction

## 1.1 Background

Over the last decade, urban areas throughout the country have experienced substantial economic growth and gentrification, particularly in downtown areas (Freeman, 2005). Gentrification has been accompanied by increasing housing prices and changing demographics in the center of many metropolitan areas, including those in Tennessee (Cappellano & Spisto, 2014; Immergluck, 2009; Jones & Ley, 2016; Kahn, 2007; Rayle, 2015). Even though these changes have had many positive societal outcomes, they can negatively affect some groups, particularly low-income populations. Low-income groups have historically resided in dense urban areas, but with increasing rates of gentrification and higher housing prices, some of these populations have begun to move to lower density suburban and exurban areas where housing is more affordable (McKenzie, 2013). This phenomenon can be defined as *gentrification-induced displacement*, which may result in transportation challenges.

Many low-income populations are dependent on transit for their transportation needs (Taylor & Morris, 2014); however, transit services tend to be more frequent and widespread in downtown areas (Kawabata & Shen, 2006). When moving to suburban and exurban areas, low-income populations may lose the level of transit access that they had in downtown areas, leading to potential mobility challenges. This report aims to critically assess the interrelated issues of transit access to jobs, affordable housing locations, and displaced populations in the major metropolitan regions of Tennessee.

## 1.2 Objectives

The overarching objective of this research project is to critically assess the interrelated issues of transit access to opportunities, affordable housing locations, and displaced populations in the major metropolitan regions of Tennessee. The specific objectives are as follows:

- **Objective 1:** Review new literature and compile case studies of similar southern metropolitan regions that have conducted research or successfully implemented policies to address displacement, transit access, and affordable housing.
- **Objective 2:** Analyze access to opportunities via transit from affordable housing locations in the four major metropolitan regions of Tennessee and create maps that visualize transit travel times from affordable housing developments.
- **Objective 3:** Identify affordable housing locations that have limited access to opportunities via transit and evaluate potential modifications to transit service that could increase access.
- **Objective 4:** Develop measures to identify displaced populations, particularly low-income groups, and create maps showing the results.
- **Objective 5:** Share the tools to evaluate access via transit to jobs, affordable housing locations, and displaced populations with key stakeholders in the region to facilitate future equity-related analyses.

## *1.3 Scope of Work*

The scope of work was divided into seven primary tasks, which are briefly described below. Additional details are presented in the Research Methodology section in Chapter 3.

- **Part 1: Review new literature and compile case studies of southern cities**

  First, a detailed literature review of prior studies pertaining to transit accessibility, displaced populations, and affordable housing was conducted. Additionally, case studies of comparable southern cities were conducted to identify policies and practices aimed at providing better transit access to affordable housing and displaced populations. A comprehensive literature review is presented in Chapter 2. Case studies are included in Appendix 2.

- **Part 2: Collect relevant data on affordable housing, transit service, and demographics in Tennessee metro regions**

  Next, recent data on (1) the locations of affordable housing; (2) transit services; (3) the locations of jobs; and (4) relevant demographic data were collected. Those datasets were used in the following analyses focusing on the four largest metropolitan regions in Tennessee: Chattanooga, Knoxville, Nashville, and Memphis.

- **Part 3: Analyze accessibility of affordable housing locations and propose transit modifications**

  Next, an analysis of transit access to jobs from affordable housing locations in the four largest cities of Tennessee was conducted using a cutting-edge software tool developed by the company Conveyal. Conveyal's "Analysis" platform is a web-based geographic information system built on open-source software that maps transit accessibility using isochrones and analyzes regionwide accessibility impacts of transit system changes (e.g., new bus stop locations). The results of this analysis included a series of maps that identify the locations of affordable housing units that have low transit accessibility, and specific recommendations to improve transit service were suggested for these locations.

- **Part 4: Develop measures and create maps of displaced populations**

  Specific measures were developed to identify census blocks with displaced populations; for example, population changes of low-income households were analyzed over time. Then, a GIS-based analysis of relevant demographic data for the four counties of Tennessee was conducted. The results include a series of maps that identify locations with greater numbers of displaced populations in each county.

- **Part 5: Compare affordable housing, displaced populations, and transit access**

  Next, the results of Part 3 on transit accessibility of affordable housing and Part 4 on the locations of displaced populations were compared. This was used to identify specific areas of concern, such as areas with larger numbers of displaced populations with limited transit accessibility. The results include a series of maps showing specific areas of concern that could benefit from future affordable housing and/or transit modifications.

- **Part 6: Engage key stakeholders and conduct technology transfer**

A key component of the project was engaging local stakeholders from transit agencies and planning organizations. Stakeholders from each of the four major metropolitan areas were engaged via Zoom calls to (1) disseminate methods of mapping transit accessibility, e.g., with Conveyal's Analysis tool, and (2) get structured feedback on the results of Part 3 through Part 5.

- **Part 7: Write recommendations and the final report**

  The final part of this project was to list the specific areas that are recommended for transit service modifications, which can be found in Chapter 4. These findings, as well as findings from the previous parts, were compiled into this final report.

## *1.4 Structure of the Report*

This report is organized as follows. Chapter 2 provides a comprehensive literature review on displacement and transit accessibility. Chapter 3 presents the method and data used to measure transit accessibility and displacement. Chapter 4 discusses the results of the analysis of transit accessibility of affordable housing and potential transit service modifications, the results of the displacement analysis, and the comparison between transit accessibility, affordable housing locations, and displacement. Chapter 5 includes conclusions, areas for future research, and recommendations. Additional information is included in the Appendices.

# Chapter 2 Literature Review

First, literature on the following three topics were reviewed: 1) gentrification and displacement, 2) transit accessibility, 3) coordination between affordable housing locations and transit services. The primary search engine used to conduct this review was Google Scholar. Several key terms were used to find relevant journal articles, including gentrification, displacement, transit accessibility, job accessibility, affordable housing, Conveyal, and Longitudinal Employer-Household Dynamics (LEHD). The selection was narrowed down further by only selecting papers published after 2000, since the characteristics of residential mobility and transit network before 2000 may be different than the current situation. Only sources that analyzed gentrification and/or displacement in the United States were selected since these will be the most relevant to the study areas in Tennessee.

## *2.1 Gentrification and Displacement*

### 2.1.1 Define and measure gentrification

The influx of relative affluence over the past decade has triggered economic growth and gentrification in urban areas (Freeman, 2005). According to Freeman, gentrification is a dynamic process, and changes in the characteristics of neighborhoods over time are important factors to determine gentrifying areas. Neighborhoods that have experienced gentrification are 1) initially located in the central city; 2) initially populated by low-income households whose median income is lower than the regional average; 3) experienced disinvestment (mostly older housing stock); 4) experienced an influx of relative affluence (an increase in education level which is greater than the median increase in regional education level); 5) experienced an increase in housing prices (increase in investment) (Freeman, 2005). Those neighborhoods that meet the first three conditions can be considered as gentrification-eligible or potentially gentrifying. The last two conditions refer to the process of gentrification. Based on the above criteria, Freeman concluded that in the United States, 41% of gentrification-eligible tracts gentrified in the 1980s and 31% of gentrification-eligible tracts gentrified in the 1990s. Another study using more recent 2009-2013 American Community Survey data found that around 20% of gentrification-eligible tracts had gentrified since 2000 (Maciag, 2015). In a more recent study, Landis measured gentrifying tracts by using only the change in income from 1990 to 2010 and found that 21% of gentrification-eligible tracts in 70 metropolitan areas in the United States gentrified in the 1990s and 2000s (Landis, 2015). According to a literature review published in 2019, the top four most frequently used indicators to reflect gentrification are household income, race, education level, and housing price (Padeiro et al., 2019).

Gentrification (*Freeman, 2005)*:

- initially located in the central city;
- initially populated by low-income households;
- experienced disinvestment;
- experienced an influx of relative affluence;
- experienced an increase in housing prices.

### 2.1.2 Define and measure displacement

While the increasing housing prices, demographic changes, and gentrification in the urban core of metropolitan areas may have positive societal outcomes, some groups may be negatively affected, particularly disadvantaged populations. With increasing gentrification and higher housing prices, some low-income populations who have historically resided in dense urban areas have begun to

move to lower density, suburban areas where housing prices are more affordable. This phenomenon can be defined as gentrification-induced displacement.

*1) Define displacement*

As originally proposed by Grier and Grier (Grier & Grier, 1978) and cited by many studies (Carlson, 2020; Chapple et al., 2017; Zuk et al., 2017), displacement could occur when any household is forced to move from its residence by conditions that affect the dwelling or its immediate surroundings and that: 1) are beyond the household's reasonable ability to control or prevent; 2) occur despite the household's having met all previously-imposed conditions of occupancy; 3) make continued occupancy by that household impossible, hazardous, or unaffordable. In this study, we will focus on the displacement induced by gentrification; that is, the displacement that occurs when current residents involuntarily move to the suburbs due to unaffordable housing in the gentrifying neighborhoods.

**Displacement** occurs when any household is forced to move from its residence by conditions which affect the dwelling or its immediate surroundings *(Grier and Grier, 1978).*

*2) Measure displacement*

Measuring residential displacement is a challenge (Atkinson, 2000). Some prior researchers believe residential displacement should be involuntary (Vigdor et al., 2002); thus, they measured displacement by the indicator of the number of residential moves when the reason for moving was involuntary (Carlson, 2020; Freeman, 2005). Due to the limitations of access to survey data on the reasons for movement, some studies have proposed measurement methods that utilize more readily available data. Chapple et al. proposed two indicators that can be used to measure displacement: the loss of affordable housing and the loss of low-income households (Chapple et al., 2017). The data used to measure displacement in previous studies can be classified into three types: survey data, housing data, and census data. Table IX (in Appendix 1) summarized the studies on residential displacement measurement according to the dataset used; this is briefly summarized next.

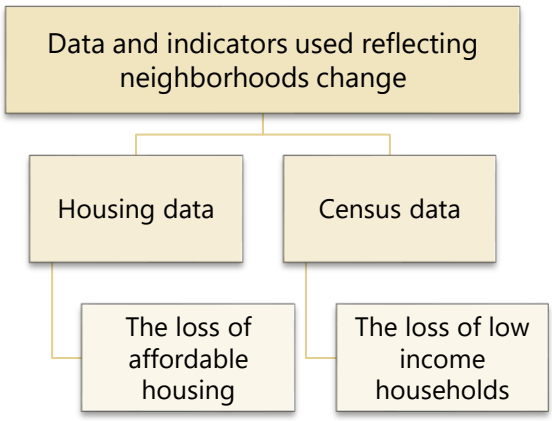
### Survey data

Survey data are commonly used in longitudinal analyses because they can reflect the changes of an object over a period of time. For displacement measurement, survey data can track the dynamic process of residential displacement and even obtain reasons for the displacement. The survey datasets used in previous studies are briefly discussed below.

- Panel Study of Income Dynamics (PSID): this is a national and longitudinal household survey in the United States that records respondent's reasons for moving. This was not used in the following analysis because the PSID data is state level.
- New York City Housing and Vacancy Survey (NYCHVS): it is a longitudinal household survey conducted in New York City. This was not used in the following analysis because it only includes data from New York City.
- Regional renters' survey: this type of data contains private survey datasets conducted in specific areas. This data was not used in the following analysis because similar data sets were not available in the study areas.
- American Housing Survey (AHS): this survey can trace longitudinal individual mobility on the housing-unit level. This was not used in the following analysis because it does not include data for Knoxville and Chattanooga.

- Confidential Census Long Form data: this data provides residents' mobility over time on an individual level, but this was not used in the following analysis because it is confidential.

### Housing data: the loss of affordable housing




According to previous studies, there are two types of indicators reflecting changes in a neighborhood: one is housing change, and the other is household demographic change. Chapple measured displacement by the *loss of affordable housing* in Los Angeles and San Francisco for which multiple affordable housing datasets exist (Chapple et al., 2017).

### Census data: the loss of low-income households

Another approach to measuring displacement is to compare the changes in household demographics. This approach was used since the required data are public and easy to obtain for Nashville, Chattanooga, Memphis, and Knoxville. The data for household changes are the US Decennial Census and American Community Survey (ACS) data. These datasets were used in displacement estimation in previous studies and can be downloaded for free. Based on Census data, low-income individuals are defined as individuals earning below 80% of the regional median income. Assuming that any neighborhood that has undergone a net loss of low-income households while staying stable in the overall population is the result of displacement, Chapple used the *loss of low-income households* as the indicator in estimating displacement in the Bay Area (Chapple et al., 2017). Applying the same methodologies in the Bay Area, the Urban Displacement Project led by UC Berkeley used US Decennial Census and ACS data to calculate the loss of low-income households for each time period to measure the risk of displacement (Chapple et al., 2021). This approach analyzes how populations compositionally change over time without tracking mobility. However, for tracking and predicting the risk of displacement in a specific area, this was a commonly-used approach by researchers (Chapple & Zuk, 2016).

Based on this literature review, the US Decennial Census and ACS data after 2000 for the four metro regions were selected to measure displacement in the following report.

## 2.2 Transit accessibility

In this section, literature regarding transit access and transit accessibility to jobs was reviewed.

### 2.2.1 Measures

Accessibility to transit is defined as the ease with which residents and workers can reach transit facilities when considering distance and time (Manout et al., 2018). In the previous literature, the study of transit accessibility involved different aspects of human life and the transportation system, including topics such as public health, employment rates, social exclusion, urban mobility, and sustainable accessibility (Saif et al., 2019). The transit accessibility measures used in previous literature can be grouped into two categories: *opportunity-denominated* measures, which count the number of opportunities people can reach in a given threshold of time or cost; and *time-denominated* measures, which calculate the time or cost needed to reach a given set of opportunities. Opportunity-denominated measures are further subdivided into *cumulative opportunities measures, weighted cumulative opportunities measures,* and *competitive access measures*. Literature about transit accessibility measures is listed in Table X in Appendix 1.

| **Accessibility measures** | |
|---|---|
| ➢ *Opportunity-denominated* measures | ➢ *Time-denominated* measures |
| Opportunity-denominated measures count the number of opportunities people can reach in a given threshold of time or cost. | Time-denominated measures calculate the time or cost needed to reach a given set of opportunities. |

Opportunity-denominated measures are most commonly applied in the transportation planning literature (Levinson & King, 2020). The *cumulative opportunities measure*, which is also called an isochoric measure, is one of the early and widely used accessibility measures in previous studies. It works by calculating the number of potential opportunities reachable within a given threshold (time or distance) (El-Geneidy & Levinson, 2006). Isochrone-based cumulative opportunities measures are a popular accessibility method with no need for defining a destination (Xi et al., 2018). An *isochrone* is a line joining a set of cumulative opportunities located at an equal travel time from a specified location. An isochrone area refers to the set of all cumulative opportunities contained within an isochrone that are reachable in the specified time or less. O'Sullivan et al. mapped isochrones based on the estimation of transit travel time to a central business district (O'Sullivan et al., 2000a). Compared to the cumulative opportunities measure, the *weighted cumulative opportunities measure* weights all the opportunities by impedances (distance, time, and cost) between a given origin and an opportunity point. With known origins and destinations, one prior study proposed a new measure of accessibility that considers the weight of each zone and the number of people commuting to the zone to access an opportunity (El-Geneidy & Levinson, 2006). Last, *competitive access measures* consider the relationship between the supply and demand of opportunities. This method suggests that there is only one candidate for each job opportunity (Levinson & King, 2020). As an example, one study applied competitive measures to calculate the accessibility for transit and automobiles in Los Angeles by considering potential job competitors between the ages of 25 to 64 as the potential labor force (Merlin & Hu, 2017).

Another category of measures includes *time-denominated measures*, which calculate travel time from a given origin to an opportunity. For example, one relevant study identified areas with limited transit access to food stores by calculating the transit travel time from each census tract to the nearest supermarket (Farber et al., 2014).

In this study, opportunity-denominated measures were used to estimate transit accessibility by calculating the number of opportunities low-income populations can reach using a given transit travel mode within a specific time threshold. Transit accessibility was visualized in the form of isochrones.

### 2.2.2 Data

According to the previous section, the data required for measuring transit accessibility should include information about transit service and opportunities. The opportunity indicator used in this study was jobs, which is commonly used in previous literature. Both are discussed below.

*1) Transit information*

The data used to obtain transit information can be divided into two categories: with General Transit Feed Specification (GTFS) data and without GTFS data. The dataset used in the literature is shown in the "Data" column of Table X in Appendix 1.

The General Transit Feed Specification (GTFS), first created by Google and TriMet in 2005, is a standard format for transit agencies to record information about stops, routes, trips, and schedules (Fayyaz et al., 2017). GTFS is widely used in previous literature on transit accessibility measures to provide estimations of travel time from one point to another at different times of the day (Fransen et al., 2015). Furthermore, the standardization of GTFS data makes it possible to analyze transit accessibility across different cities (Bok & Kwon, 2016).

Without GTFS data, researchers obtained information on the transit network, trips, and travel times from numerous sources and measured transit accessibility based on various components. For instance, transit networks containing spatial components of bus or rail routes and stops can be used to calculate the walking travel time by assuming a particular walking speed. One prior study measured transit accessibility by identifying areas accessible from transit stops using the bus route network data (Foda & Osman, 2010). Transportation planning models from regional planning agencies are another source of data on travel time; as an example, this was used in a relevant longitudinal study of travel times for auto and transit (El-Geneidy & Levinson, 2006). Survey datasets are yet another source of trip information; one relevant example is a recent study that utilized an onboard survey conducted in Sacramento County, California to measure transit access to jobs (Alam et al., 2010).

For this project, GTFS datasets were obtained from the transit agencies of Nashville, Memphis, Chattanooga, and Knoxville.

*2) Job information*

Job opportunities are one of the most explored and debated topics in prior studies (Du et al., 2020). Unfair distribution of transit can limit access to jobs (Aman & Smith-Colin, 2020). In this study, job opportunities were selected as the indicator of opportunities to explore transit equity to affordable housing.

There are various datasets that provide job information nationally or regionally. Longitudinal Employer-Household Dynamics (LEHD) data provide the home and work locations of employed people living in the US at the Census Block level. It is a popular dataset that was commonly used to obtain information about workers and jobs in previous studies (Bertolaccini & Use, 2018; Blanchard & Waddell, 2017; El-Geneidy & Levinson, 2006; Zuo et al., 2020). Additionally, the Census Transportation Planning Package (CTPP) is a GIS-based dataset that includes residence, workplace, and worker flows

between home and work; for example, one study accessed the numbers of workers and jobs from the 1990 CTPP to calculate job accessibility in Boston and Los Angeles (Kawabata et al., 2006).

There exist other datasets outside the United States that are used to obtained job information, such as the national household survey in Canada (Boisjoly & El-Geneidy, 2016; El-Geneidy et al., 2016), census flow data in Canada (Cui et al., 2019b), and the transportation tomorrow survey in Toronto (Xi et al., 2018), among others.

In this study, LEHD data were used to measure job access by transit. LEHD data can easily be set up in Conveyal's Analysis software, which was the tool used to calculate and visualize transit access in this study. As mentioned in previous sections, an opportunity-denominated measure was applied to measure job access by transit, which calculated the number of potential jobs that could be reached within a given time.

### 2.2.3 Tools

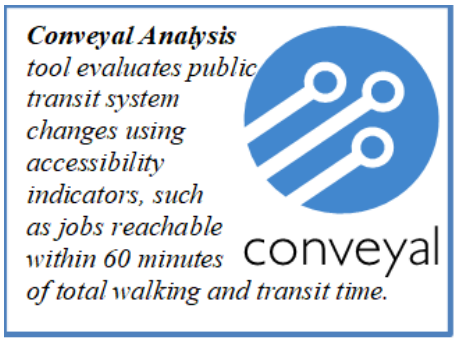
There are various software tools that have been applied in previous studies to measure accessibility. The "Tools" column of  Table X shows the tool used in previous research, which can be found in Appendix 1. A notable prior report summarized seven tools which were applied widely in previous studies: R/Python packages; ArcGIS Network Analyst; Emme 4; OpenTripPlanner and Open Street Maps; Conveyal; TransCAD; and Google Maps (Higgins et al., 2020a). The report analyzed and evaluated four approaches in detail, which were ArcGIS Pro 2.4.2, Conveyal's Analysis tool, Emme 4.4, and OpenTripPlanner (OTP) for R and Python. They classified these four approaches into multi-stream tools, which includes ArcGIS, Emme, and OTP, and a single-stream tool, which is Conveyal's software. Each of these four approaches is briefly discussed below.

ArcGIS desktop is a spatial analysis and mapping tool that can used to calculate transit accessibility by using the built-in Accessibility Calculator custom toolbox (Higgins et al., 2020b). However, it is not clear how the transit routing algorithm is being implemented since it is not open source.

Emme is a Multimodal Transport Planning Software that can generate transit OD matrices based on the existing GTAModel Emme network. This network contains both road and transit information without importing the GTFS data. However, the Emme network only consists of major streets, and it is difficult to build the transit network from GTFS files (Higgins et al., 2020b).

OpenTripPlanner (OTP) is an open-source multimodal trip planner utilizing OpenStreetMap (OSM) for their underlying street networks (Higgins et al., 2020b). It is implemented by using R or Python; therefore, this method may require substantial coding efforts.

Last, Conveyal is a transportation software company that develops open-source tools to map transit accessibility using isochrones and analyzes accessibility impacts of transit system changes (e.g., new bus stop locations). The Analysis tool is a web-based geographic information system built on Conveyal's open-source R5 routing engine that can be used to calculate the accessibility of different travel modes such as transit, walking, driving, and cycling. Conveyal's Analysis tool uses the cumulative opportunities measure (Higgins et al., 2020a).



In this project, Conveyal software was utilized to analyze the transit accessibility in specific areas and to modify transit services. The GTFS data, OpenStreetMap, and the job information data were set up in the software.

## *2.3 Coordination between affordable housing locations and transit services*

This section reviews the most relevant literature on the connection between transit services and affordable housing. A notable recent Transit Cooperative Research Program (TCRP) report conducted a national survey of 51 American transit agencies on the coordination of public transit and affordable housing (National Academies of Sciences Engineering and Medicine, 2022b). It is notable that only half of the investigated transit agencies indicated that they prioritize serving neighborhoods with affordable housing when planning transit services and transit networks. Most of the transit agencies also indicated that they did not feel affordable housing stakeholders usually consider transit in their decision-making. The survey results suggested that more research is needed to examine the transit accessibility of affordable housing programs and improve coordination between housing affordability and transit accessibility.

This report begins to fill this gap by measuring the transit accessibility from affordable housing, identifying affordable housing units with limited transit access to jobs, and proposing and evaluating possible transit modifications that could increase transit accessibility for affordable housing units in Tennessee.

# Chapter 3 Methodology and Data

This section discusses the method and data used to measure transit accessibility from affordable housing units and to measure displacement.

## *3.1 Transit accessibility method*

This section explains how affordable housing locations data, transit information data, and job information data were collected and how accessibility via transit from affordable housing locations was calculated.

### 3.1.1 Data on affordable housing locations

The US Department of Housing and Urban Development (HUD) provides geospatial datasets of rental assistance programs (https://hudgis-hud.opendata.arcgis.com/). Three large rental assistance programs include Low-income Housing Tax Credit (LIHTC); Multifamily Assistance and Section 8 Database (Multifamily); and Public Housing (PH). These datasets were selected for the affordable housing data for this project. The geospatial data for affordable housing units, including the coordinate pairs (longitude and latitude), were downloaded for each program in the four cities (Nashville, Memphis, Knoxville, and Chattanooga). Then, the data cleaning process included checking for duplicate records, confirming data authenticity, and checking accuracy. This was processed in Google Maps and Excel. A summary of cleaned affordable housing data in each rental assistance program is shown in Table I below. It is noted that Nashville had no PH data records in the HUD datasets. Affordable housing locations were used as the origins layer in measuring transit accessibility, which is discussed in the subsequent sections.

**Table I Summary of affordable housing data after data cleaning**

| *City* | *Number of housing units in LIHTC* | *Number of housing units in Multifamily* | *Number of housing units in PH* | *Total number of affordable housing units* |
|---|---|---|---|---|
| *Nashville* | 6,482 | 9,027 | 0 | 15,509 |
| *Memphis* | 15,602 | 6,905 | 4,150 | 26,657 |
| *Knoxville* | 4,588 | 5,901 | 773 | 11,262 |
| *Chattanooga* | 2,267 | 1,685 | 2,147 | 6,099 |

*Note: Affordable housing data were downloaded in early 2022.*

### 3.1.2 Data on job locations

Job locations in the study areas were collected from the latest version (2018) of the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) dataset. The LEHD dataset provides the home and work locations of employed people living in the United States. The geospatial locations of total jobs were uploaded into the Conveyal Analysis software as the destinations layer, as discussed in the subsequent sections.

### 3.1.3 Data on transit information

Transit network and transit service information were obtained from the newest version (February 2022) of the General Transit Feed Specification (GTFS) from four transit agencies (WeGo Public Transit in Nashville, Memphis Area Transit Authority (MATA), Knoxville Area Transit (KAT), and Chattanooga Area

Regional Transportation Authority (CARTA)). The GTFS datasets were then combined with the existing OpenStreetMap to create a new network bundle in Conveyal's Analysis software.

### 3.1.4 Method of measuring transit accessibility

After setting the origins layer (affordable housing locations), destinations layer (jobs), and transit network bundle in Conveyal's Analysis software, transit accessibility could be calculated using cumulative opportunities measure that estimates the number of jobs accessible by transit from each affordable housing location within a given time threshold. The cumulative opportunities measure is an opportunity-denominated access measure that considers the step impedance function. The equation below shows how transit accessibility was measured.

$$A_i = \sum_j O_j f(C_{ij})$$

$$f(C_{ij}) = 1,\ when\ \ C_{ij} \leq t$$

$$f(C_{ij}) = 0,\ when\ \ C_{ij} > t$$

Where:

$A_i$ is the transit accessibility from affordable housing location $i$,

$O_j$ is the number of jobs available at destination $j$,

$C_{ij}$ is the travel time from $i$ to $j$,

$f(C_{ij})$ is an impedance function. $f(C_{ij})$ equals to 1 when travel time is less than the given time threshold $t$, and equals to 0 otherwise.

### 3.1.5 Regional analysis

To visualize transit accessibility at a regional level and compare transit accessibility from affordable housing to regional transit access, the number of jobs accessible via transit from each point in the region was measured and mapped as regional transit accessibility. The formula for measuring regional accessibility was the same as the formula for measuring accessibility to affordable housing locations, except that the origin was every point in the region, not just affordable housing locations.

### 3.1.6 Simulation scenario

The transit accessibility analyses were conducted in Conveyal's Analysis software, with publicly available transit schedule data in GTFS format, jobs distribution from the Census' LEHD Origin-Destination Employment Statistics (LODES), and street network data extracted from OpenStreetMap (OSM). Transit accessibility was determined by the median number of jobs accessible for every possible minute during the morning departure peak period (7–10 am) on a weekday within a 60-minute transit trip. The 60-minute transit trip included up to 20 minutes of walk-access and walk-egress time, assuming a walking speed of 5 km/h (3.1 mph), and up to 3 transit transfers.

## *3.2 Identify affordable housing units with limited transit accessibility and propose transit modifications*

To identify specific locations with low transit access and high numbers of affordable housing units, an inequity index was proposed. It was calculated as the ratio of the percentage of housing units to percentage of jobs accessibility within a 60-minutes transit trip as shown in the equation below. For affordable housing locations, a higher inequity index indicated a higher demand (a higher number of affordable housing units) and a lower transit supply (a lower number of transit accessible jobs). Then, a list including all the affordable housing sorted in descending order by the value of the inequity index was generated. For each city, specific locations were selected from the top of that list to propose transit modifications.

$$\textbf{Inequity index} = \frac{\%\ \boldsymbol{of\ housing\ units}}{\%\ \boldsymbol{of\ jobs\ accessible\ by\ transit\ within\ a\ given\ threshold}}$$

Then, transit modifications were evaluated in Conveyal's Analysis software, which has the following transit modification types:

1) Add trip pattern: Add new trip patterns.
2) Adjust dwell time: Adjust the dwell time along a route or at a particular stop.
3) Adjust speed: Adjust the vehicle speed on an entire route or a route segment.
4) Convert to frequency: Replace the scheduled trips for one or more existing trip patterns with frequency based timetables.
5) Remove stops: Remove some of the stops from a route, while leaving the rest of the route untouched.
6) Remove trips: Remove entire routes or remove specific trip patterns on a particular route.
7) Reroute: Detours, extensions, and curtailments to routes in existing travel patterns.

After each proposed transit modification, an evaluation of transit accessibility changes before and after transit modifications was made. The evaluation outputs included an isochrone map showing the accessible area changes within a given time threshold and a line chart showing the number of accessible jobs changes within different time thresholds.

## *3.3 Displacement method*

This section discusses how socioeconomic information was collected and used to measure displaced populations. The results include a series of maps that identify locations with higher numbers of displaced populations in each county, which are shown in section 3 of Chapter 4. It should be noted that the study area was extended from city to county because some populations were displaced to suburban areas that have more affordable housing (McKenzie, 2013).

### 3.3.1 Data on socioeconomic information

Socioeconomic information is available from the U.S. Census Bureau at the tract level. The number of households in different income categories was calculated with the variable "Household Income in the Past 12 Months". The median household income for each census tract in the past 12 months was downloaded to identify low-income households in each of the four counties. Those variables in 2010 and 2019 were downloaded from the 2010 American Community Survey 5-year summary file and the 2019 American Community Survey 5-year summary file, respectively.

### 3.3.2 Method of measuring displacement

Figure 3-1 shows the process of measuring displaced households in each census tract. As discussed in the literature review section, the change of low-income households over time could be a metric of estimating displacement (Chapple et al., 2017). According to the income level definition used by the Urban Displacement Project (UDP) (Tim et al.), households with an income less than 80% of the regional area median income (AMI) can be defined as low-income households. Thus, low-income households could be identified and counted in each census tract in 2010 and 2019. The displaced households were calculated as the loss of low-income households from 2010 to 2019, and those census tracts with a loss of low-income of households were identified. A series of maps that show census tracts with certain numbers of displaced households in each county are shown in section 3 of Chapter 4.

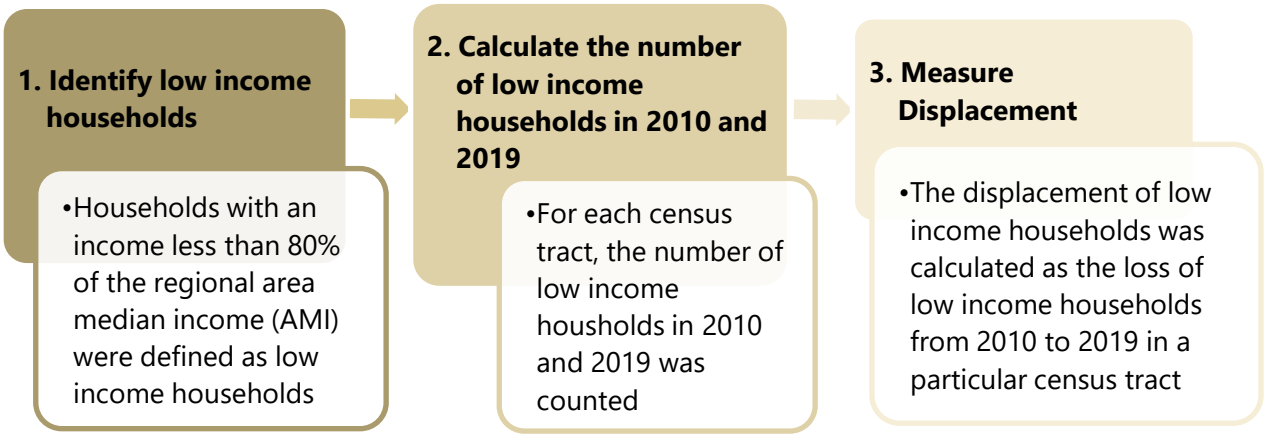



**Figure 3-1 Flow chart of measuring displacement**

# Chapter 4 Results and Discussion

This chapter is organized as follows: first, maps of transit accessibility in the four regions are shown. They include the spatial distribution of affordable housing locations and the results of transit accessibility from affordable housing locations. Then, affordable housing locations that have limited transit access to jobs were identified. Modifications to transit service that could increase access at these locations were proposed and evaluated. Next, a series of maps that show displaced low-income households were created and discussed. Finally, maps were made that show both the affordable housing locations with limited transit accessibility and the location of blocks with displacement. These maps allowed for comparison between affordable housing locations, displaced populations, and accessibility via transit.

## *4.1 Results of the transit accessibility analysis*

### 4.1.1 Regional transit accessibility and affordable housing locations

This section mapped transit accessibility from each point in the region and from the locations of each affordable housing unit for four cities. These maps (Figure 4-1 to Figure 4-4) show the transit accessibility level of each city and compare the transit accessibility from affordable housing to the regional transit accessibility. The darker the purple area, the lower the transit accessibility of affordable housing in that area. Transit accessibility was grouped by quantile (equal count) classification. Each color level represents a transit accessibility interval with the same number of origins. Compared to other cities, Nashville had the highest percentage of areas with low transit accessibility, which was indicated by the purple-colored transit accessibility interval (an interval of zero jobs to 368 jobs). However, Nashville also had the highest accessibility interval of 182,627 to 393,986, shown in dark green. These values also indicate that Nashville had the greatest range of variation in transit accessibility throughout the city, which may be related to the fact that Nashville is a consolidated city-county that also contains large areas of rural and undeveloped land.

The housing locations of Low-Income Housing Tax Credit (LIHTC) units, Multifamily Subsidized Housing (Multifamily) units, and Public Housing (PH) units are shown as yellow circles, red circles and blue circles, respectively. The number of housing units for each location is indicated by the size of the circles. A larger circle indicates a greater number of units for a specific affordable housing location. It is worth noting that there was a large difference between the number of housing units among the public housing locations. For instance, some public housing locations only had from one to five units, while others had more than 100 units. Figure 4-1 to Figure 4-4 suggested that even though the majority of affordable housing was located in green areas with good access to transit, there were still some affordable housing units distributed in purple areas with relatively low access to transit.

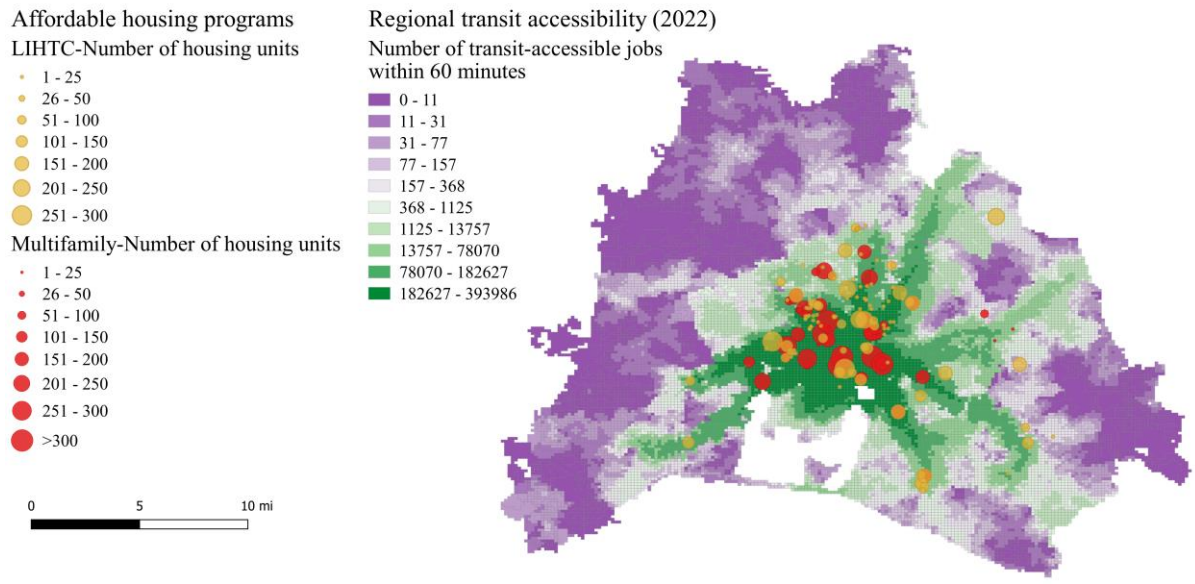



**Figure 4-1 Regional transit accessibility and affordable housing locations in Nashville**

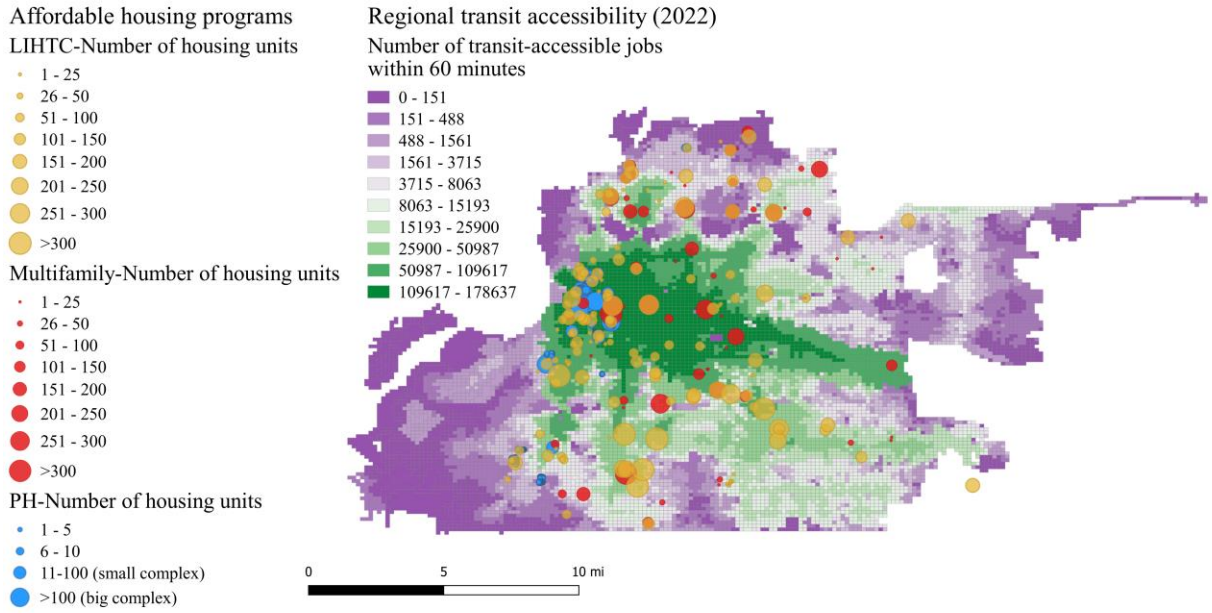



**Figure 4-2 Regional transit accessibility and affordable housing locations in Memphis**

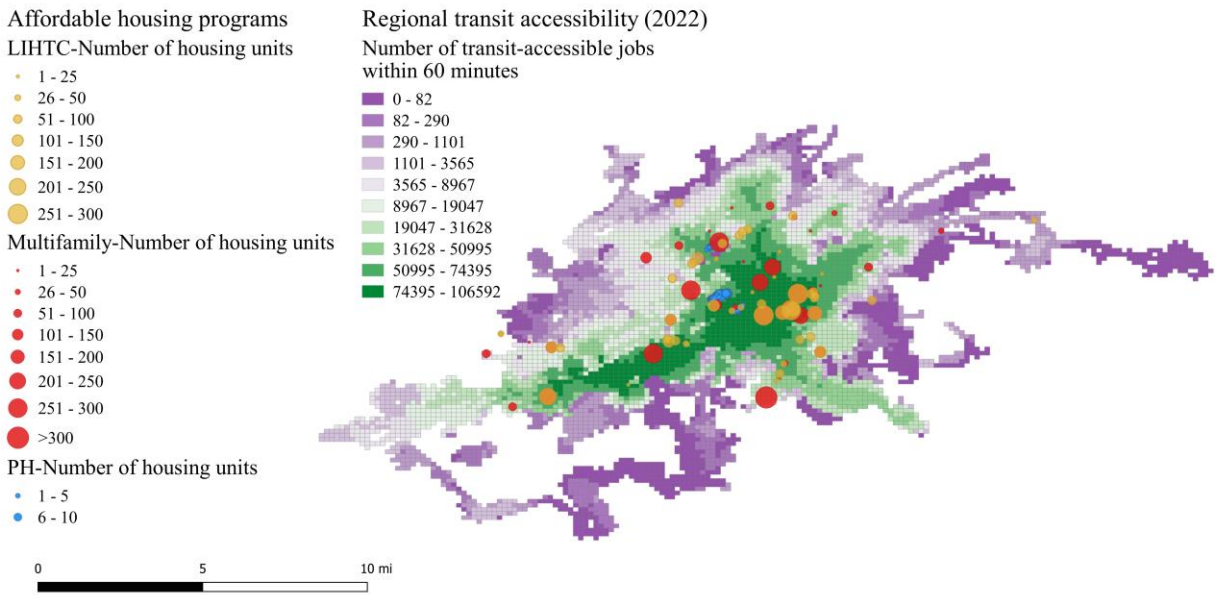



**Figure 4-3 Regional transit accessibility and affordable housing locations in Knoxville**

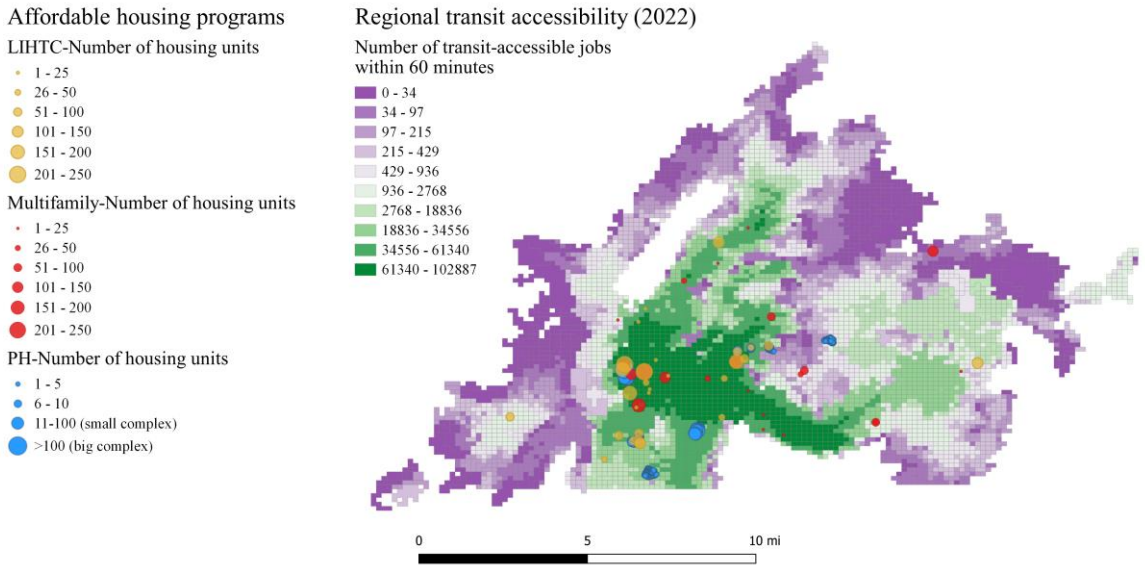



**Figure 4-4 Regional transit accessibility and affordable housing locations in Chattanooga**

### 4.1.2 Transit accessibility from affordable housing locations

This section summarizes the analysis of transit accessibility from affordable housing locations for each affordable housing program in each city, and the results are shown in Table II. From Nashville's affordable housing, one could reach an average of about 169,000 jobs via transit in 60 minutes, which was more than twice the average transit accessibility of affordable housing in the other three cities. Reasons may include the fact that affordable housing in Nashville was mostly located in areas with frequent transit service, and as a large capital city, Nashville has more job opportunities. Another

finding observed from Table II was that there was a large gap between the minimum and maximum transit accessibility of affordable housing. For instance, in Nashville, from one affordable housing unit in a LIHTC, one could only access a minimum of 121 jobs via transit while from another affordable housing unit, one could access a maximum of 368,110 jobs via transit under the same transit scenario.

**Table II Summary statistics of transit accessibility from affordable housing locations**

| City | Affordable housing program | Number of Units | Minimum transit accessibility | Maximum transit accessibility | Average transit accessibility |
|---|---|---|---|---|---|
| Nashville | Total | 15,509 | 121 | 369,926 | **169,792** |
| | LIHTC | 6,482 | **121** | 368,110 | 153,695 |
| | Multifamily | 9,027 | 323 | **369,926** | 212,620 |
| Memphis | Total | 26,657 | 94 | 169,901 | **67,397** |
| | LIHTC | 15,602 | **94** | 145,425 | 65,774 |
| | Multifamily | 6,905 | 99 | **169,901** | 52,098 |
| | PH | 4,150 | 1,257 | 136,969 | 98,424 |
| Knoxville | Total | 11,262 | 52 | 94,404 | **49,638** |
| | LIHTC | 4,588 | **52** | **94,404** | 48,087 |
| | Multifamily | 5,901 | 233 | 94,367 | 50,085 |
| | PH | 773 | 54,475 | 86,514 | 63,754 |
| Chattanooga | Total | 6,099 | 30 | 101,809 | **53,879** |
| | LIHTC | 2,267 | 1,046 | **101,809** | 59,623 |
| | Multifamily | 1,685 | **30** | **101,809** | 50,159 |
| | PH | 2,147 | 533 | 84,097 | 46,338 |

*Note: Data of affordable housing locations was from early 2022; transit data were from February 2022. Bold shows minimum and maximum values.*

## *4.2 Transit accessibility analysis for affordable housing*

### 4.2.1 Identify affordable housing locations with limited transit accessibility

To identify affordable housing locations with lower transit access and higher numbers of units, an inequity index was proposed. This was calculated as the ratio of the percentage of housing units to the percentage of jobs accessible within a 60-minutes transit trip. A higher value of the inequity index indicated a higher demand (a higher number of affordable housing units) and a lower supply (a lower number of transit accessible jobs). Then, a list of all the affordable housing locations sorted by the value of inequity index was generated for each city. Those affordable housing locations with a higher value of inequity index were considered in the following analysis. For each city, locations that could potentially benefit from transit modifications were selected from the top of that list, and these are shown in the following tables (Table III, Table IV, Table V, Table VI). Other affordable housing not shown in these lists either had a high transit access or a small number of units. The complete list of affordable housing locations sorted by the value of the inequity index for each of the four regions is available from the authors upon request.

**Table III List of affordable housing locations with limited transit access in Nashville**

| Inequity Index Rank | Affordable Housing Project | Affordable Housing Program | Measures | Nashville |
|---|---|---|---|---|
| 1 | Terrace Park Townhomes Phase II | *LIHTC* | Inequity Index | 1,496 |
| | | | Transit Access | 258 |
| | | | N Units | 172 |
| 2 | Townhomes of Nashboro Village | *LIHTC* | Inequity Index | 819 |
| | | | Transit Access | 200 |
| | | | N Units | 73 |
| 3 | Cobblestone Corners | *LIHTC* | Inequity Index | 680 |
| | | | Transit Access | 317 |
| | | | N Units | 96 |
| 4 | Old Hickory Towers | *LIHTC* | Inequity Index | 577 |
| | | | Transit Access | 840 |
| | | | N Units | 216 |
| 5 | Heartland Christian Tower | *Multifamily* | Inequity Index | 396 |
| | | | Transit Access | 323 |
| | | | N Units | 57 |
| 6 | Ellington View Apts | *LIHTC* | Inequity Index | 345 |
| | | | Transit Access | 208 |
| | | | N Units | 32 |

**Table IV List of affordable housing locations with limited transit access in Memphis**

| Inequity Index Rank | Affordable Housing Project | Affordable Housing Program | Measures | Memphis |
|---|---|---|---|---|
| 1 | Greenview Townhomes | *LIHTC* | Inequity Index | 1,092 |
| | | | Transit Access | 94 |
| | | | N Units | 158 |
| 2 | Southwind Lakes Apts Phase I | *LIHTC* | Inequity Index | 1,057 |
| | | | Transit Access | 123 |
| | | | N Units | 200 |
| 3 | Wesley Highland Meadows | *LIHTC* | Inequity Index | 963 |
| | | | Transit Access | 135 |
| | | | N Units | 200 |
| | | *Multifamily* | Inequity Index | 958 |
| | | | Transit Access | 135 |
| | | | N Units | 199 |
| 4 | Surrey Apartments I | *Multifamily* | Inequity Index | 709 |
| | | | Transit Access | 99 |
| | | | N Units | 108 |
| 5 | Chapel Place Homes | *LIHTC* | Inequity Index | 331 |
| | | | Transit Access | 171 |
| | | | N Units | 87 |
| 6 | Tanglewood Apts (Memphis) | *LIHTC* | Inequity Index | 135 |
| | | | Transit Access | 953 |
| | | | N Units | 198 |

**Table V List of affordable housing locations with limited transit access in Knoxville**

| Inequity Index Rank | Affordable Housing Project | Affordable Housing Program | Measures | Knoxville |
|---|---|---|---|---|
| 1 | Carlton Concepts Apts II | *LIHTC* | Inequity Index | 364 |
| | | | Transit Access | 52 |
| | | | N Units | 39 |
| 2 | River View Park Apts | *LIHTC* | Inequity Index | 364 |
| | | | Transit Access | 128 |
| | | | N Units | 96 |
| 3 | Cassell Ridge Apts | *LIHTC* | Inequity Index | 357 |
| | | | Transit Access | 190 |
| | | | N Units | 140 |
| 4 | Holston Ridge Apts | *LIHTC* | Inequity Index | 273 |
| | | | Transit Access | 128 |
| | | | N Units | 72 |
| 5 | Cassell View Apts | *LIHTC* | Inequity Index | 184 |
| | | | Transit Access | 190 |
| | | | N Units | 72 |
| 6 | Carlton Concepts Apts | *LIHTC* | Inequity Index | 103 |
| | | | Transit Access | 52 |
| | | | N Units | 11 |
| 7 | St Mary's Riverview I & II | *Multifamily* | Inequity Index | 77 |
| | | | Transit Access | 233 |
| | | | N Units | 37 |

**Table VI List of affordable housing locations with limited transit access in Chattanooga**

| Inequity Index Rank | Affordable Housing Project | Affordable Housing Program | Measures | Chattanooga |
|---|---|---|---|---|
| 1 | Silvertree Seniors Chattanooga Apartments | *Multifamily* | Inequity Index | 2,264 |
| | | | Transit Access | 30 |
| | | | N Units | 124 |
| 2 | Cromwell Hills Apts | *PH* | Inequity Index | 205 |
| | | | Transit Access | 533 |
| | | | N Units | 200 |
| 3 | Eastwood Manor | *Multifamily* | Inequity Index | 123 |
| | | | Transit Access | 438 |
| | | | N Units | 98 |
| 4 | Rainbow Creek Apts | *LIHTC* | Inequity Index | 54 |
| | | | Transit Access | 150 |
| | | | N Units | 1,521 |
| 5 | Cummings Place Apt | *LIHTC* | Inequity Index | 48 |
| | | | Transit Access | 92 |
| | | | N Units | 1,046 |
| 6 | Orange Grove II | *Multifamily* | Inequity Index | 38 |
| | | | Transit Access | 457 |
| | | | N Units | 32 |
| 7 | Walden Group Home | *Multifamily* | Inequity Index | 6 |
| | | | Transit Access | 850 |
| | | | N Units | 10 |

### 4.2.2 Propose and evaluate transit modifications for specific locations

This section proposes and evaluates possible transit modifications for specific affordable housing locations identified in Section 4.2.1. Due to length constraints, only one location was selected for each city to be discussed in detail in this section. Other locations in Nashville, Memphis, Knoxville, and Chattanooga are not shown in this report, but they are available from the authors upon request. It is worth mentioning that all the proposed transit modifications in this report have been discussed with the local transit agencies and their feedback has been considered in the following results.

To propose transit modifications, investigation of the surrounding transit services and network distribution was required. After selecting a possible type of transit modification provided in the Conveyal software, a detailed modification process was conducted. Then, evaluation of transit accessibility before and after modification was analyzed. Finally, conclusions that incorporated feedback from transit agencies were presented. Thus, the following sections were organized as: nearby transit service, surrounding network distribution, possible transit modifications, evaluation, and conclusions.

*1) Terrace Park Townhomes Phase II in Nashville*

In Nashville, Terrace Park Townhomes Phase II had the highest inequity index. Terrace Park Townhomes Phase II is an affordable housing project in the LIHTC program, which includes 172 assisted units. The address is 3110 Elm Hill Pike, Nashville TN 37214. There were only 258 jobs that were accessible via transit within 60 minutes from Terrace Park Townhomes Phase II during 7 a.m. to 10 a.m. on a weekday in February 2022.

#### Nearby transit service

Transit information in Nashville was obtained from February 2022 GTFS provided by WeGo Public Transit. Route 18 was the closest transit route to Terrace Park Townhomes Phase II. Route 18 provided transit services between downtown and the airport from 5 am to 12 am, and the headway was about 45 minutes during the AM peak on weekdays. Six trip patterns were included in Route 18. Figure 4-5 shows the information for each trip pattern of route 18. This includes the departure time of each trip and the count of trips, the service day, and trip direction of each trip pattern. In Figure 4-5, the bottom X-axis represents the unique ID for each trip pattern, and the top X-axis includes the service day and trip direction.

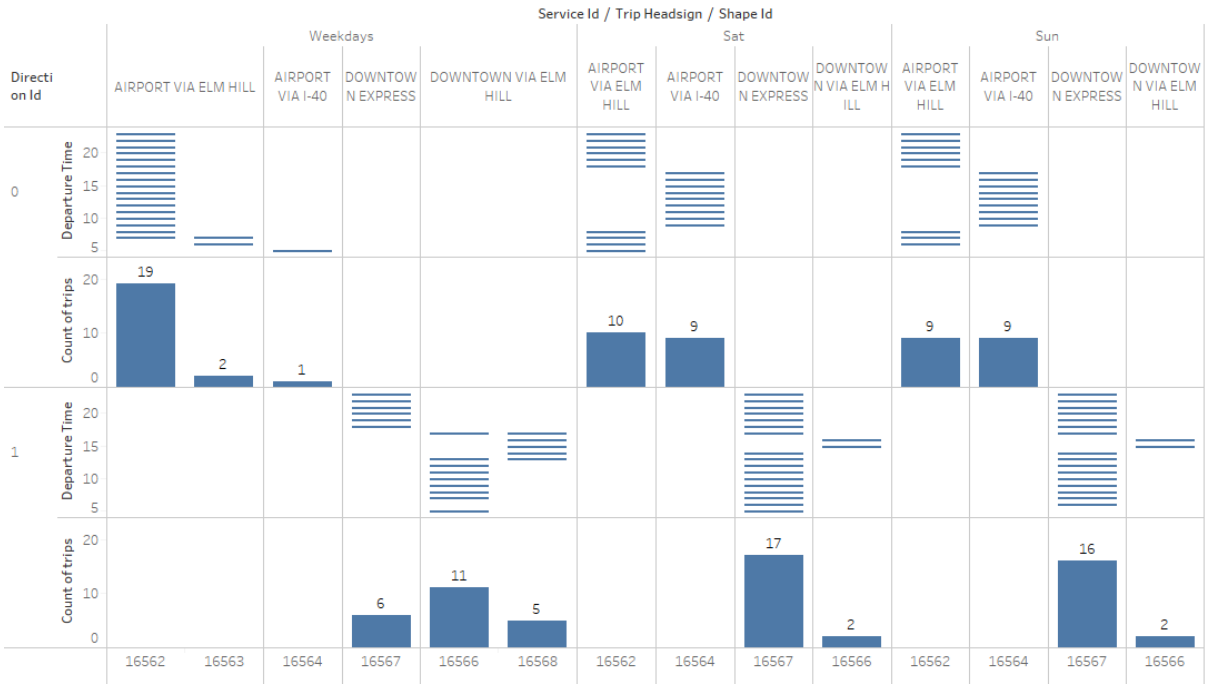



**Figure 4-5 Departure time, count of trips for trip patterns of WeGo transit route 18**

## Surrounding network distribution

The road network distribution around Terrace Park Townhomes Phase II was observed using the street view tool in Google Maps. Figure 4-6 is a satellite view map including the location of Terrace Park Townhomes Phase II, the nearby transit route (shown as a pink line), the nearby transit stops (shown as black squares), and the road between the closest transit stop and the affordable housing location (shown as the black dashed line). The nearest bus stop was called Elm Hill Pike & Nelson Pl WB, which was 1.7 miles away from the housing units. The roadway to the nearest bus stop was Elm Hill Pike, which was a two-lane road with two solid yellow lines and a speed limit of 40 mph.

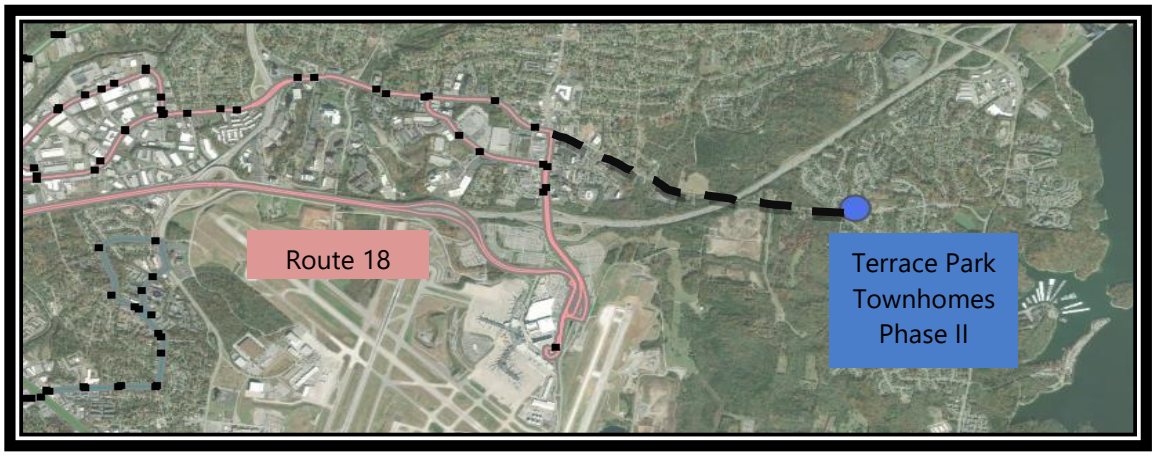


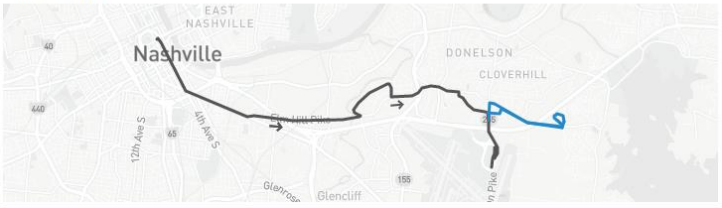

**Figure 4-6 Satellite view of Terrace Park Townhomes Phase II and surrounding road and transit network**

## Possible transit modifications

Reroute was selected as the possible transit modification type to improve transit access to Terrace Park Townhomes Phase II. The first step in rerouting Route 18 was to select the trip patterns to be modified. Considering that the number of transit accessible jobs was calculated during the typical commute time (assumed to be the 7–10 a.m. peak hours), trip patterns should cover weekday operations during the 7 a.m. to 10 a.m. peak period. The selected travel patterns should cover trips from both directions and should be geographically close to the affordable housing units. Trip pattern 16563 (from downtown to the airport with 2 trips per day) and trip pattern 16566 (from the airport to downtown with 11 trips per day) were selected to reroute. Figure 4-7 shows modification details for trip pattern 16563 and trip pattern 16566 including rerouting geometry, added segments, added stops, and added dwell time. The total added travel time for the added segment was about 10 minutes per trip.

Reroute #18 to airport (2 / 2) Reroute

Route: 18 AIRPORT




| | |
|---|---|
| **Pattern** | 36 stops from CENTRAL 4TH AVE - BAY 13 to NASHVILLE INTERNATIONAL AIRPORT via ACORN DR & ELM HILL PK SB (2 trips) |
| **Original length** | 15.7 km (9.7 mi) |
| **New length** | 22.1 km (13.7 mi) |
| **New segment length** | 6.7 km (4.2 mi) |
| **Change in length** | 6.4 km (4 mi) |
| **Average speed (along added segments)** | 50 km/h (31.1 mph) |
| **Dwell time (added segments)** | 60 |
| **Stops removed** | 0 |
| **Stops added** | 2 |

Reroute #18 to downtown (1 / 2) Reroute

Route: 18 AIRPORT


| | |
|---|---|
| **Pattern** | 36 stops from NASHVILLE INTERNATIONAL AIRPORT to CENTRAL 4TH AVE - BAY 13 via ELM HILL PIKE & AIR LANE DR WB (15 trips) |
| **Original length** | 16.1 km (10 mi) |
| **New length** | 21.9 km (13.6 mi) |
| **New segment length** | 6.3 km (3.9 mi) |
| **Change in length** | 5.8 km (3.6 mi) |
| **Average speed (along added segments)** | 50 km/h (31.1 mph) |
| **Dwell time (added segments)** | 60 |
| **Stops removed** | 0 |
| **Stops added** | 2 |

**Figure 4-7 Modification summary for WeGo trip pattern 16563 (left) and WeGo trip pattern 16566 (right)**

## Evaluation

Isochrone maps and transit accessibility charts before and after modifications were compared to evaluate the proposed transit modification. Figure 4-8 shows overlapping isochrones where blue indicates the isochrones under the pre-modified scenario and red indicates the isochrones under the modified scenario. The location of Terrace Park Townhomes Phase II is indicated as a blue icon in Figure 4-8. Figure 4-8 shows that the red isochrone covers a larger area than the blue isochrone, which means that people from Terrace Park Townhomes Phase II could travel farther within an hour under the improved transit network. Figure 4-9 shows that people from Terrace Park Townhomes Phase II could get to 54,715 jobs within 1-hour after rerouting.

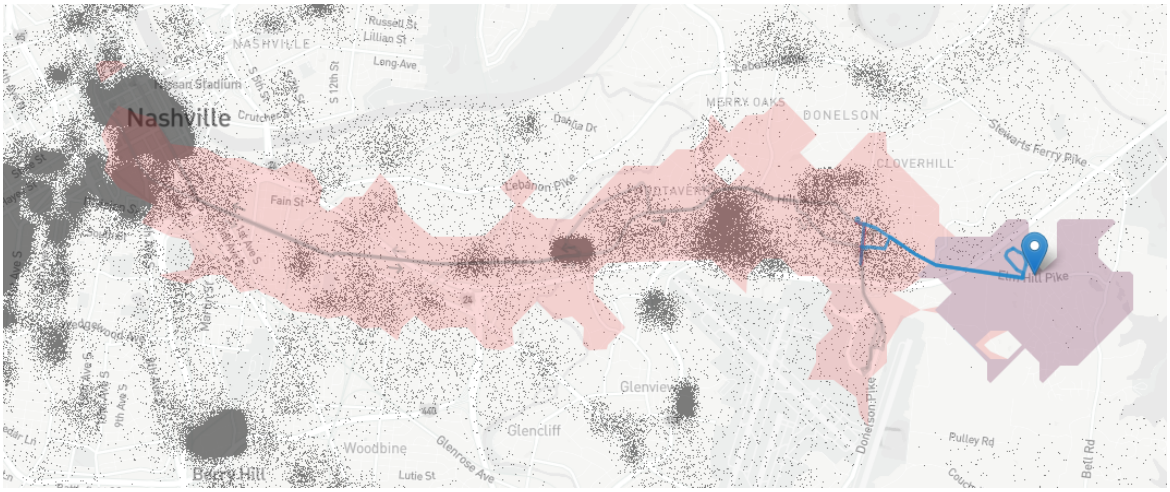



**Figure 4-8 Overlapping isochrones before and after modifying WeGo transit Route 18 for Terrace Park Townhomes Phase II**

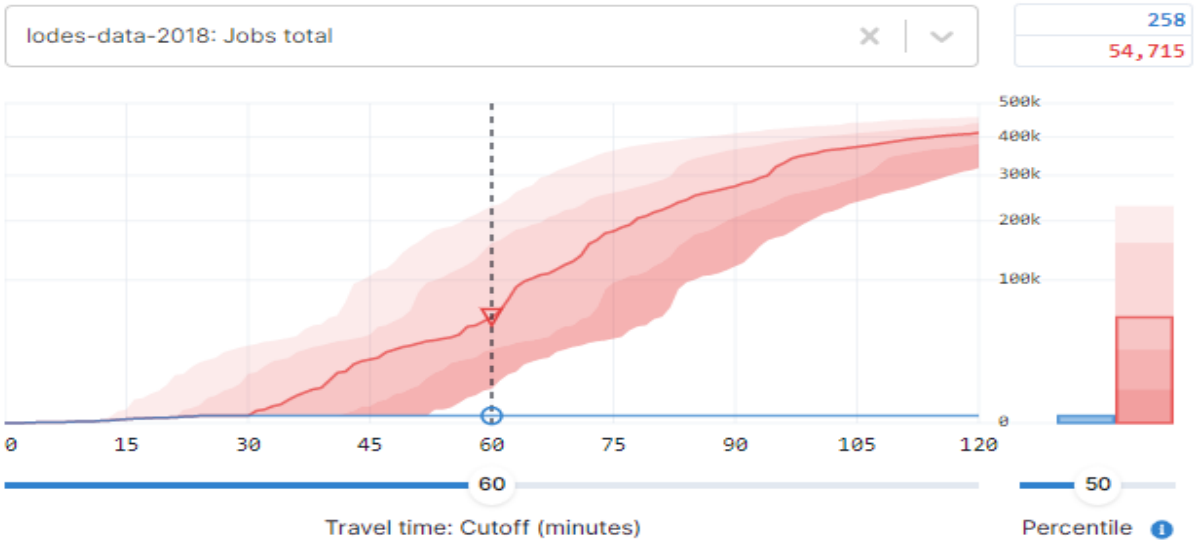



**Figure 4-9 Charts of transit accessibility results before and after modifying WeGo transit Route 18 for Terrace Park Townhomes Phase II**

## Conclusions

Rerouting Route 18 to make it pass through the affordable housing neighborhood was a possible transit modification proposed for Terrace Park Townhomes Phase II in Nashville. According to the evaluation results, this modification increased the transit accessibility from 258 accessible jobs to 54,715 accessible jobs, which was substantial. However, the modification also increased the total travel time by 10 minutes on the route. Therefore, this is a transit service change worth considering; however, the costs of providing the additional service and the implications on total travel time need to be taken into consideration. Future research could also consider offering demand-response transportation services. WeGo Public Transit has recently implemented a demand-response transportation service called "WeGo Link" that could help connect fixed transit routes to people who must walk a long distance from the nearest bus stop. Therefore, new WeGo Link service could be evaluated in future

studies of transit accessibility. In addition, future research should also analyze the impact of transit service changes on all nearby affordable housing locations, not just Terrace Park Townhomes.

*2) Wesley Highland Meadows in Memphis*

Next, a possible transit modification for Wesley Highland Meadows in Memphis was discussed and evaluated below. Wesley Highland Meadows is an affordable housing project in the LIHTC and Multifamily programs, which includes 200 assisted units. The address is 3517 Andy Way Ln, Memphis, TN 38128. Residents in Wesley Highland Meadows could access 135 jobs via transit within 60 minutes during the hours of 7 a.m. to 10 a.m. on a weekday in February 2022.

It should be noted that MATA also developed a similar transit vison for the closest transit route to Wesley Highland Meadows in the Memphis Transit Vision (see: https://transitvision.memphistn.gov/). The Memphis Transit Vision was developed with extensive input from the public, stakeholders, and elected officials for shaping the future transit system in Memphis. In the Draft Recommended Network designed and released in the Memphis Transit Vision, the Memphis transit network was redesigned to make substantial modifications for people to use transit to get to work, school, and everyday life destinations.

### Nearby transit service

Transit information in Memphis was obtained from February 2022 GTFS provided by Memphis Area Transit Authority (MATA). Route 40 was the closest transit route to Wesley Highland Meadows. Route 40 provided transit service between Downtown and Stage Rd during 6 a.m. to 10 p.m., and the headway was 90 minutes during the AM peak on weekdays. Two trip patterns were observed for Route 40. There were five buses departing during the AM peak hour (7:00 a.m. to 10:00 a.m.), three of which departed from the downtown direction and the other two towards the downtown direction.

### Surrounding network distribution

The road network distribution around Wesley Highland Meadows was observed using the street view and satellite view tools in Google Maps. Figure 4-10 is a satellite view map including the location of Wesley Highland Meadows, the nearby transit route (shown as the light brown line), the nearby transit stops (shown as black squares), and the road between the closest transit stop and the affordable housing location (shown as the black dashed line). The nearest bus stop was called James@Highland, which was 0.4 mile away from the housing units. The roadways to the nearest bus stop were Andy Way Ln and N Highland Rd. These roads were one-lane and four-lanes, respectively, and had a speed limit of 10 mph and 40 mph, respectively.

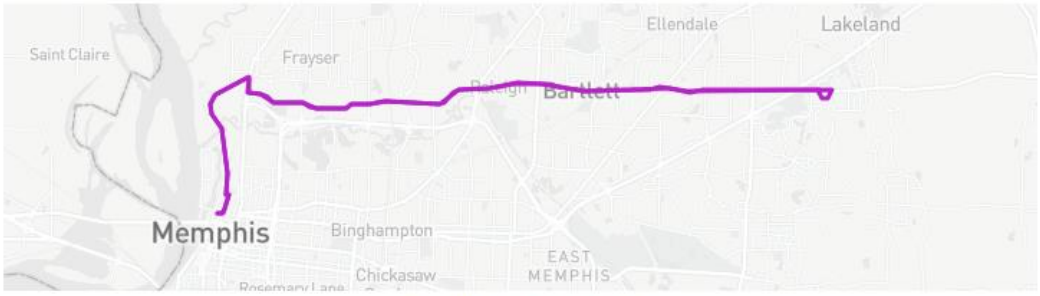

**Figure 4-10 Satellite view of Wesley Highland Meadows, the surrounding road, and the transit network**

### Possible transit modifications

The closest route to Wesley Highland Meadows (Route 40) was low frequency (90 minutes). The walking distance from the affordable housing units to the nearest bus stop was about 0.4 miles (8 minutes walking). In the Draft Recommended Network in the Memphis Transit Vision, Route 40 was renamed as Route 14, and the frequency of Route 14 is 60 minutes. To improve transit accessibility at Wesley Highland Meadows and evaluate the modification of Route 40 in the Memphis Transit Vision, the service frequency of Route 40 during the AM peak was increased from every 90 minutes to every 60 minutes. Figure 4-11 summarizes the adjusted frequency during the AM peak for the two trip patterns of Route 40. The number of trips increased from five to seven, with one increase in either direction.

**Increase frequency for #40** (1 / 1) Adjust frequency

**Route: 40 STAGE**




*All existing trips are removed.*

**New frequencies**

| Name | Direction | Start time | End time | Frequency | Days of service | Number of trips | Length |
|---|---|---|---|---|---|---|---|
| Frequency Entry - from downtown | 0 | 06:15 | 10:45 | 60 | ~~Mo~~ ~~Tu~~ ~~We~~ ~~Th~~ ~~Fr~~ ~~Sa~~ ~~Su~~ | 4 | 33.6 km (20.9 mi) |
| Frequency Entry - to downtown | 1 | 07:44 | 10:44 | 60 | ~~Mo~~ ~~Tu~~ ~~We~~ ~~Th~~ ~~Fr~~ ~~Sa~~ ~~Su~~ | 3 | 35.3 km (21.9 mi) |

**Figure 4-11 Adjusted AM-peak frequency for MATA transit Route 40**

## Evaluation

Isochrone maps and transit accessibility charts before and after the modifications were compared in order to evaluate the proposed transit modification. Figure 4-12 shows overlapping isochrones where blue indicates the isochrones under the pre-modified scenario and red indicates the isochrones under the modified scenario. The location of Wesley Highland Meadows is indicated as a blue icon in Figure 4-12. Figure 4-12 shows that the red isochrone covers a larger area than the blue isochrone, which means that people from Wesley Highland Meadows could travel farther within an hour under the modified transit network. Figure 4-13 shows that people from Wesley Highland Meadows can get to 6,400 jobs within 1-hour after increasing the frequency of Route 40 from 90 minutes to 60 minutes in the AM peak.

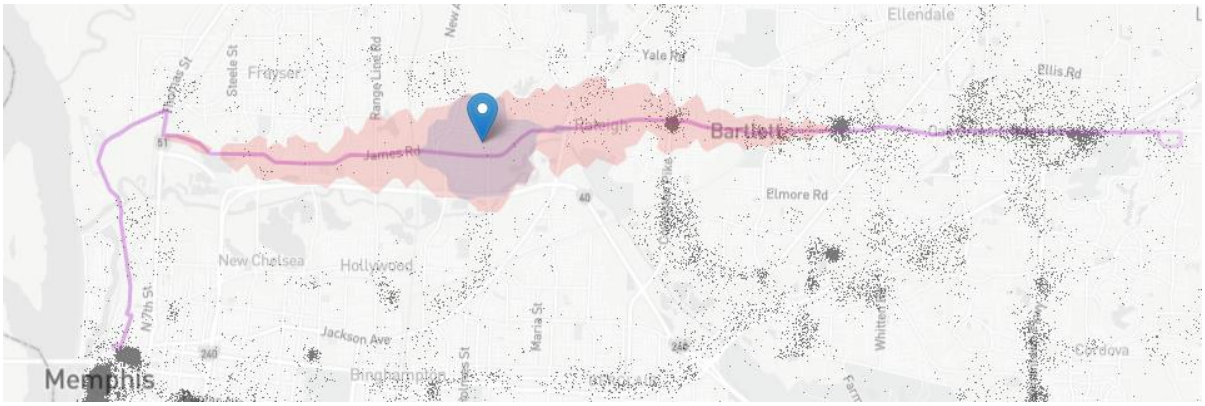



**Figure 4-12 Overlapping isochrones before and after modifying MATA transit Route 40 for Wesley Highland Meadows**

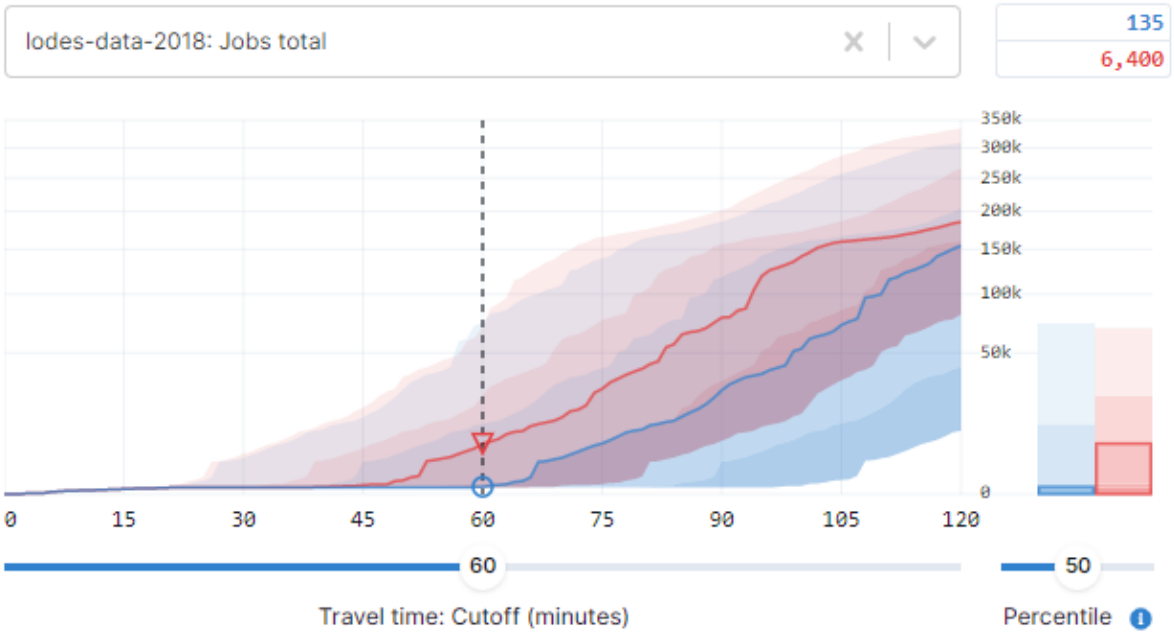



**Figure 4-13 Charts of transit accessibility results before and after modifying MATA transit Route 40 Wesley Highland Meadows**

### Conclusions

To improve transit accessibility of Wesley Highland Meadows, the headway of Route 40 may be changed from every 90 minutes to every 60 minutes during the AM peak. According to the evaluation results, this modification increased the number of accessible jobs from 135 to 6,400. Increasing the frequency of Route 40 was also proposed in the Memphis Transit Vision. In conclusion, this is a transit modification proposal worth considering to increase transit accessibility for the residents of Wesley Highland Meadows which also aligns with local priorities. However, the evaluation of the proposed transit modifications should also consider the impact of transit service changes on all nearby affordable housing locations in the future research.

#### *3) Cassell Ridge Apts, Holston Ridge Apts, and Cassell View Apts in Knoxville*

Next, a possible transit modification for Cassell Ridge Apts, Holston Ridge Apts, and Cassell View Apts in Knoxville was evaluated. The reason for analyzing these three locations together was that the properties are close to each other, so the proposed transit modifications could be applied to all three locations simultaneously.

Cassell Ridge Apts had the third highest inequity index in Knoxville. Cassell Ridge Apts is an affordable housing project in the LIHTC program and includes 140 assisted units. The address is 1209 Cassell Valley Way, Knoxville, TN 37912. During 7 a.m. to 10 a.m. on a weekday in February 2022, residents in Cassell Ridge Apartments could access 190 jobs via transit within 60 minutes. Holston Ridge Apts in Knoxville is an affordable housing project in the LIHTC program and includes 72 assisted units. The address is 1230 Mystic River Way, Knoxville, TN 37912. Residents in Holston Ridge Apartments could access 128 jobs via transit within 60 minutes. Cassell View Apts in Knoxville is an affordable housing project in the LIHTC program and includes 72 assisted units. The address is 1111 Elk Hill Way, Knoxville, TN 37912. Residents in Cassell View Apartments could access 190 jobs via transit within 60 minutes.

### Nearby transit service

Transit information in Knoxville was obtained from the February 2022 GTFS provided by Knoxville Area Transit (KAT). Route 20 was the closest transit route to Cassell Ridge Apartments, Holston Ridge Apartments, and Cassell View Apartments. Route 20 provided transit service on Central Street and Clinton Highway from 6 a.m. to 12 a.m., and the service frequency was about 30 minutes during the AM peak on weekdays. Four trip patterns were observed for Route 20. Figure 4-14 shows the information for each trip pattern of Route 20, including the departure time of each trip and the count of trips, the service day, and trip direction of each trip pattern. In Figure 4-14, the bottom X-axis represents the unique ID for each trip pattern, and the top X-axis shows the service day and trip direction.

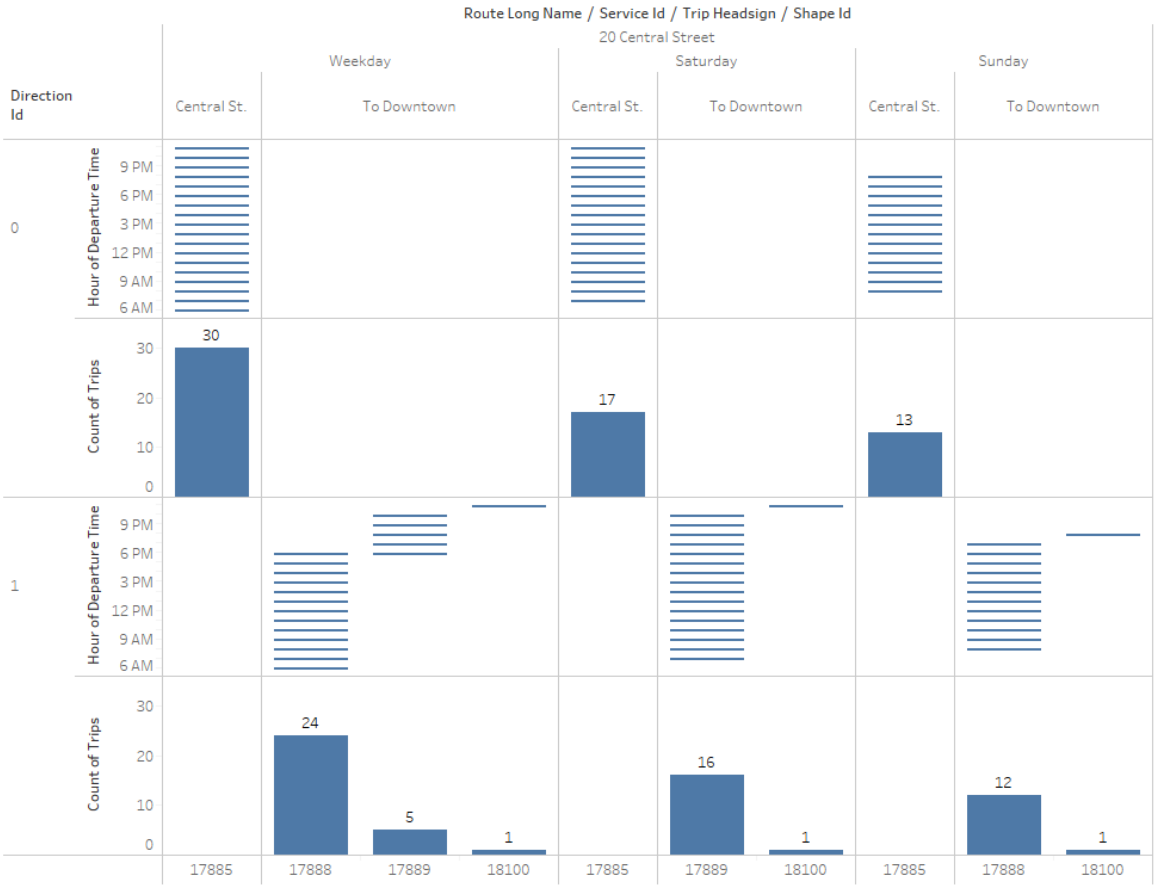



**Figure 4-14 Departure time and count of trips for trip patterns of KAT transit Route 20**

## Surrounding network distribution

The road network distribution around the three apartment complexes was observed using the street view and satellite view tools by Google Maps. Figure 4-15 is a satellite view map including the location of Cassell Ridge Apartments, Holston Ridge Apartments, and Cassell View Apartments. The nearby transit route is shown as yellow line, the nearby transit stops are shown as black squares, and the road between the closest transit stop and the affordable housing location is shown as a black dashed line. The nearest bus stop was called Clinton HWY NB @ Tillery Road and was located 1 mile away from the housing units. The roadways to the nearest bus stop included Cassell Dr, Gap Rd, Wilson Rd, and Tillery Dr. These roadways were two-lane roads with two solid yellow lines and a speed limit of 35 mph.

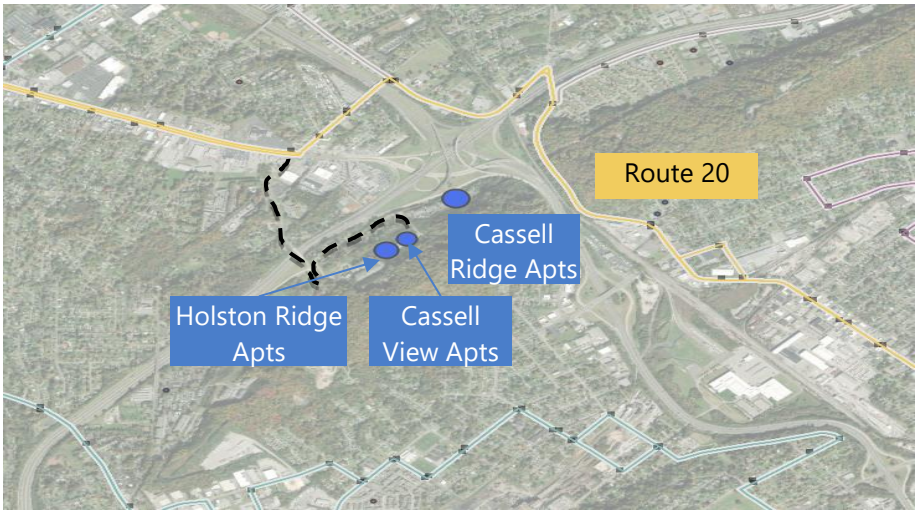



**Figure 4-15 Satellite view of Cassell Ridge Apartments, Holston Ridge Apartments, and Cassell View Apartments and the surrounding road and transit network**

### Possible transit modifications

Reroute was selected as the possible transit modification type to improve transit access to Cassell Ridge Apartments, Holston Ridge Apartments, and Cassell View Apartments. The first step in rerouting Route 20 was to select the trip patterns to be modified. Trip pattern 17885 (outbound from downtown with 30 trips per day) and trip pattern 17888 (inbound to downtown with 24 trips per day) were selected to reroute. Based on suggestions from staff at KAT, five bus stops were added to serve these three apartments due to the lack of sidewalks and pedestrian access along the added route segment. The locations of added bus stops are shown as red stars in Figure 4-16. Figure 4-17**Error! Reference source not found.** shows modification details for trip pattern 17885 and trip pattern 17888. This included rerouting geometry, added segments, added stops, and added dwell time. The total added travel time for the added segment was about 23 minutes per trip.

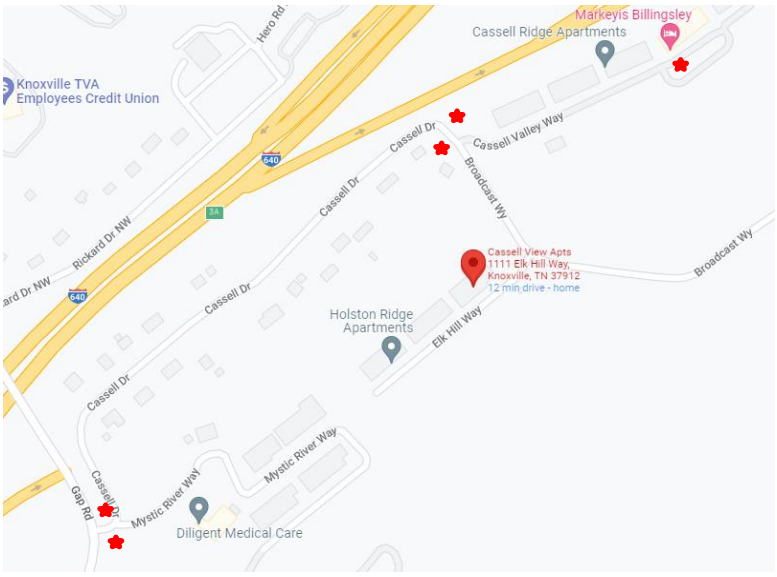
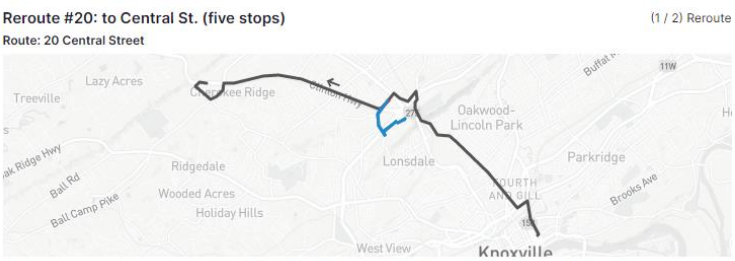
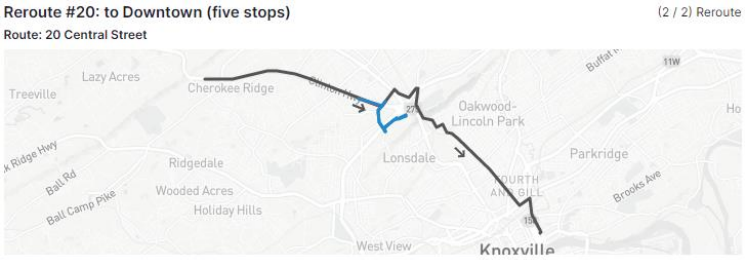



**Figure 4-16 Locations of the five added bus stops near Cassell Ridge Apts, Holston Ridge Apts, and Cassell View Apts**




| | |
|---|---|
| **Pattern** | 40 stops from Knoxville Station to Northwest Crossing (48 trips) |
| **Original length** | 14.8 km (9.2 mi) |
| **New length** | 18.6 km (11.5 mi) |
| **New segment length** | 4.1 km (2.6 mi) |
| **Change in length** | 3.8 km (2.3 mi) |
| **Average speed (along added segments)** | 30 km/h (18.6 mph) |
| **Dwell time (added segments)** | 180 |
| **Stops removed** | 0 |
| **Stops added** | 5 |




| | |
|---|---|
| **Pattern** | 37 stops from Northwest Crossing to Knoxville Station local (24 trips) |
| **Original length** | 13.7 km (8.5 mi) |
| **New length** | 17.5 km (10.9 mi) |
| **New segment length** | 4.6 km (2.9 mi) |
| **Change in length** | 3.7 km (2.3 mi) |
| **Average speed (along added segments)** | 30 km/h (18.6 mph) |
| **Dwell time (added segments)** | 180 |
| **Stops removed** | 0 |
| **Stops added** | 5 |

**Figure 4-17 Modification summary for KAT transit trip patterns 17885 (left) and 17888 (right)**

## Evaluation

Isochrone maps and transit accessibility charts before and after the modifications were compared to evaluate the proposed transit modifications. Figure 4-18 shows overlapping isochrones where blue indicates the isochrone under the pre-modified scenario and red indicates the isochrone under the modified scenario. The blue icon shown in Figure 4-18 indicates the location of Cassell Ridge Apts. It shows that the red isochrone covered a larger area than the blue isochrone, which means that people from Cassell Ridge Apartments could travel farther within an hour under the modified transit network. Figure 4-19 shows that people at Cassell Ridge Apts could get to 16,806 jobs within one hour after implementing the transit modifications. Transit accessibility before and after modifications in Holston Ridge Apts and Cassell View Apts were also evaluated and are shown in Figure 4-20 and Figure 4-21. The proposed modification could increase the number of accessible jobs from 128 to 16,287 for people at Holston Ridge Apartments and from 190 to 17,685 for people at Cassell View Apartments.

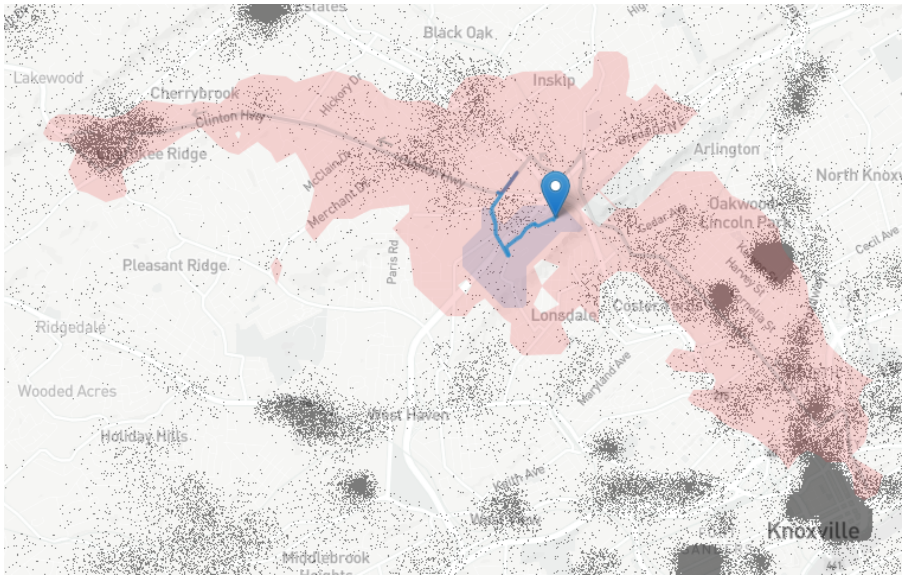



**Figure 4-18 Overlapping isochrones before and after modifying KAT transit Route 20 for Cassell Ridge Apartments**

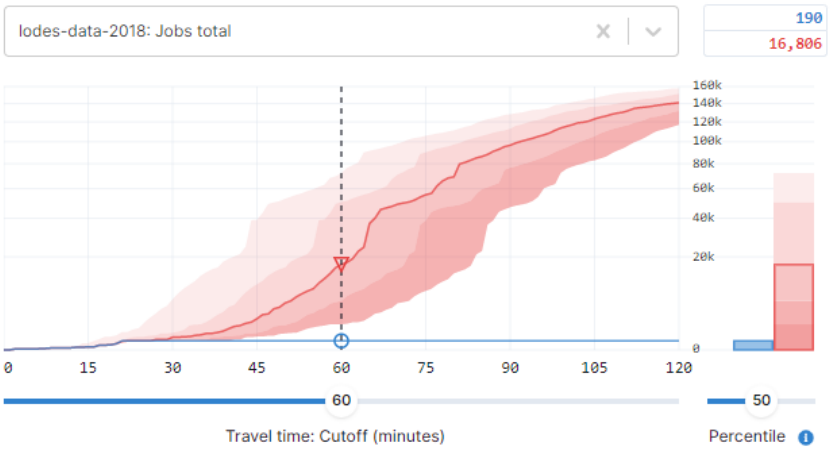



**Figure 4-19 Charts of transit accessibility results before and after modifying KAT transit Route 20 for Cassell Ridge Apartments**

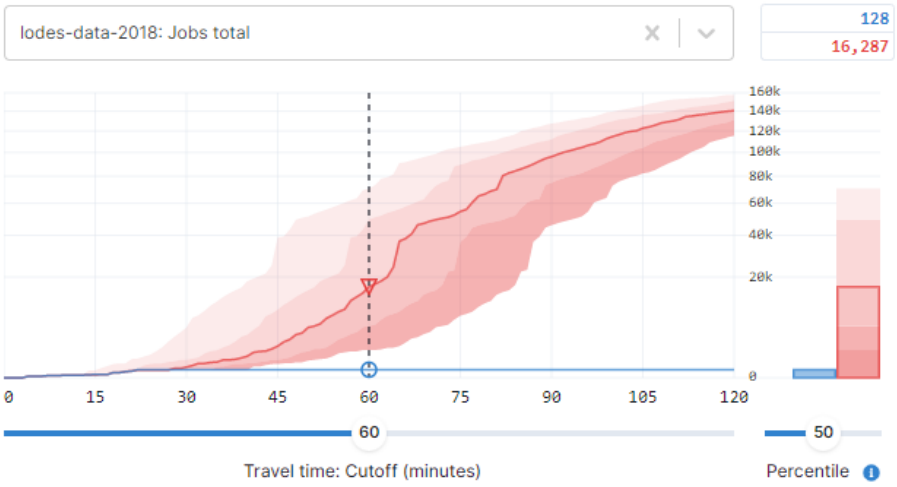



**Figure 4-20 Charts of transit accessibility results before and after modifying KAT transit Route 20 for Holston Ridge Apartments**

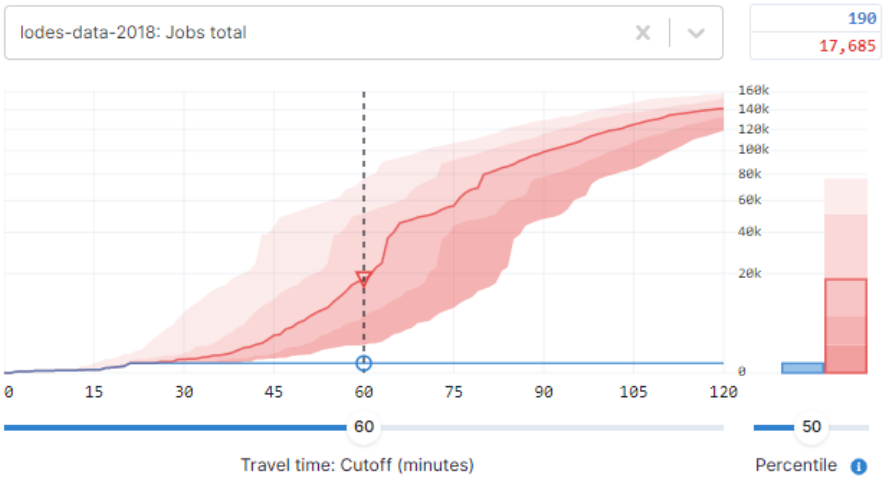



**Figure 4-21 Charts of transit accessibility results before and after modifying KAT transit Route 20 for Cassell View Apartments**

### Conclusions

Rerouting Route 20 to make it pass closer to the affordable housing units is a possible transit modification for Cassell Ridge Apartments, Holston Ridge Apartments, and Cassell View Apartments. This modification increased transit accessibility, but it also increased the total travel time for other passengers by 23 minutes. Therefore, the costs of providing the additional service and the implications on total travel time need to be taken into consideration. Future research could also consider offering demand-response transportation services, which was not evaluated in this report. In addition, the impact of this transit service change on all nearby affordable housing locations should be evaluated in future research.

#### *4) Rainbow Creek Apartments in Chattanooga*

Rainbow Creek Apartments is an affordable housing project in the LIHTC program with 150 assisted units. The address is 7604 Standifer Gap Rd, Chattanooga, TN 37421. Approximately 1,521 jobs were accessible via transit within 60 minutes from Rainbow Creek Apartments during 7 a.m. to 10 a.m. on weekdays in February 2022.

### Nearby transit service

Transit information in Chattanooga was obtained from the February 2022 GTFS provided by Chattanooga Area Regional Transportation Authority (CARTA). Route 4 was the closest transit route to Rainbow Creek Apartments. Route 4 provided transit service along the route between Eastgate and Hamilton Place from 4:20 a.m. to 12:40 a.m. The service frequency was about 30 minutes during the AM peak on weekdays. Five trip patterns were observed on weekdays for Route 4. Figure 4-22 shows the information for each trip pattern of Route 4 and includes the departure time of each trip and the count of trips, the service day, and trip direction of each trip pattern. In Figure 4-22, the bottom X-axis represents the unique ID of each trip pattern, and the top X-axis shows the service day and trip direction.

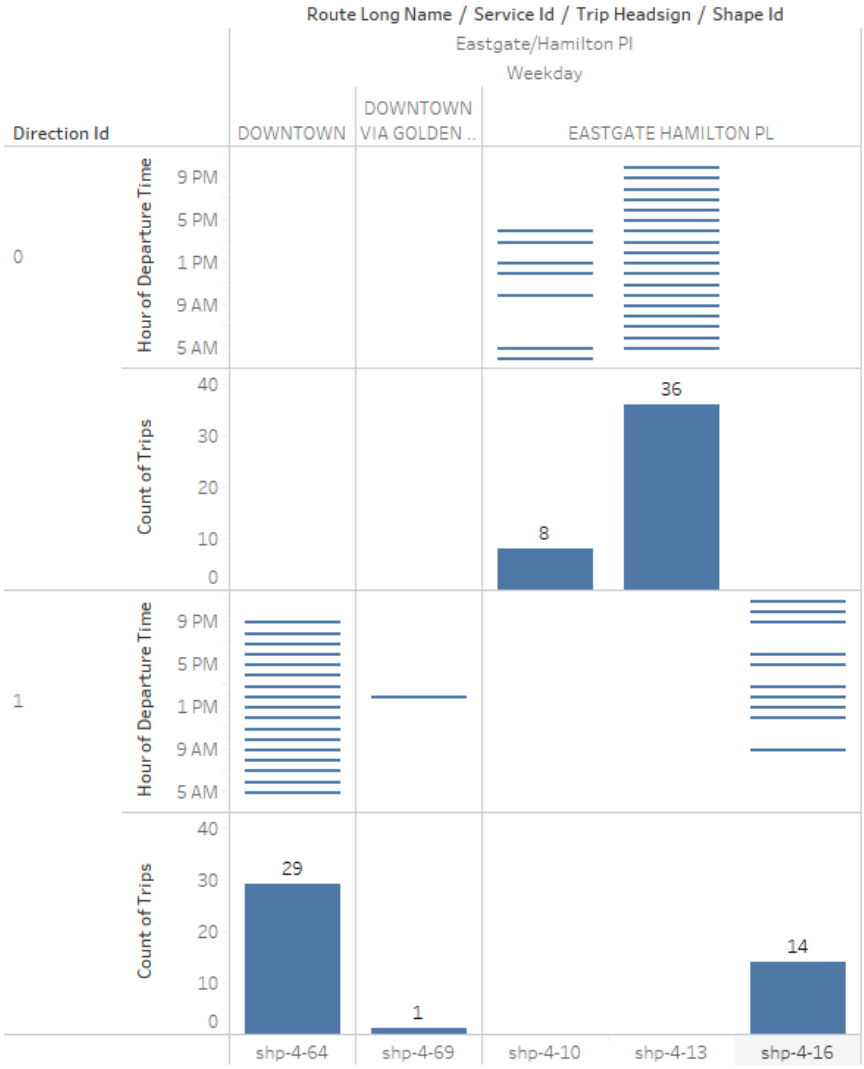



**Figure 4-22 Departure time and count of trips for the trip patterns of CARTA transit Route 4 in weekdays**

## Surrounding network distribution

The road network distribution around Rainbow Creek Apartments was observed using the street view and satellite view tools in Google Maps. Figure 4-23 is a satellite view map including the location of Rainbow Creek Apartments, the nearby transit route (shown as a teal line), the nearby transit stops (shown as black squares), and the road between the closest transit stop and the affordable housing location (shown as a black dashed line). The nearest bus stop was called Gunbarrel + Commons and was 1.8 miles away from the housing units. The roadways to the nearest bus stop are Standifer Gap Rd and Gunbarrel Rd, which were a two-lane two-way roadway and a four-lane two-way roadway, respectively.

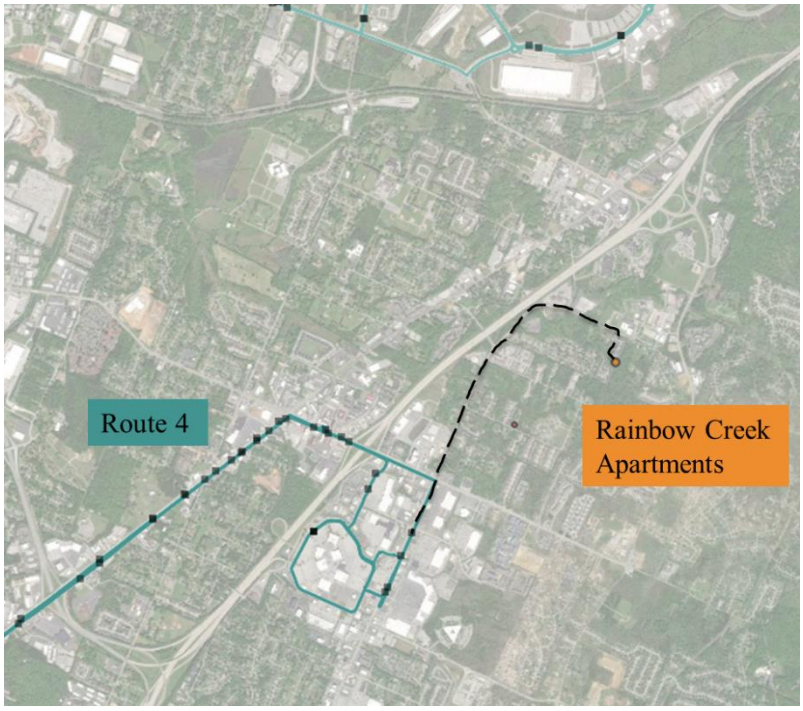


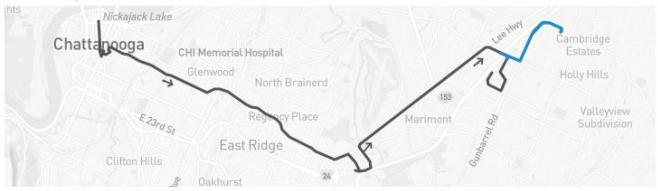

**Figure 4-23 Satellite view of Rainbow Creek Apartments and the surrounding road and transit network**

## Possible transit modifications

Reroute was selected as the possible transit modification type to improve transit access to Rainbow Creek Apartments. The first step in rerouting Route 4 was to select the trip patterns to be modified. Trip patterns shp-4-13 (outbound from downtown with a 1-hour frequency) and trip patterns shp-4-64 (inbound to downtown with a 1-hour frequency) were selected to reroute. Figure 4-24 shows modification details for trip patterns shp-4-13 and shp-4-64. The modifications included rerouting geometry, added segments, added stops, and added dwell time. The total added travel time for the added segment was about 13 minutes per trip.

Rerouting #4: From Downtown (1 / 2) Reroute

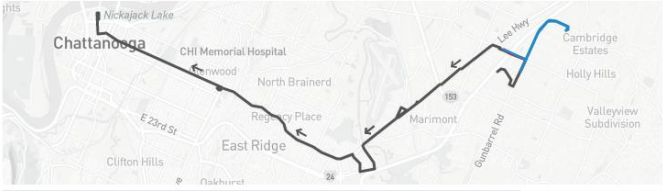
Route: 4 Eastgate/Hamilton Pl




| | |
|---|---|
| Pattern | 99 stops from MARKET + 4TH to HAMMALL (78 trips) |
| Original length | 23.3 km (14.5 mi) |
| New length | 29 km (18 mi) |
| New segment length | 6.2 km (3.8 mi) |
| Change in length | 5.7 km (3.5 mi) |
| Average speed (along added segments) | 30 km/h (18.6 mph) |
| Dwell time (added segments) | 60 |
| Stops removed | 0 |
| Stops added | 1 |

Rerouting #4: To Downtown (2 / 2) Reroute

Route: 4 Eastgate/Hamilton Pl




| | |
|---|---|
| Pattern | 86 stops from HAMMALL to MARKET + 4TH (55 trips) |
| Original length | 24.3 km (15.1 mi) |
| New length | 29.2 km (18.2 mi) |
| New segment length | 6.2 km (3.8 mi) |
| Change in length | 4.9 km (3 mi) |
| Average speed (along added segments) | 30 km/h (18.6 mph) |
| Dwell time (added segments) | 60 |
| Stops removed | 0 |
| Stops added | 1 |

**Figure 4-24 Modification summary for CARTA transit trip patterns shp-4-13 (left) and CARTA trip patterns shp-4-64 (right)**

## Evaluation

Isochrone maps and transit accessibility charts before and after modifications were compared to evaluate the proposed transit modification. Figure 4-25 shows overlapping 60-minute isochrones where blue indicates the isochrones under the pre-modified scenario and red indicates the isochrones under the modified scenario. The location of Rainbow Creek Apartments was indicated as a blue icon in Figure 4-25. Figure 4-25 shows that the red isochrone covered a larger area than the blue isochrone, which means that people at Rainbow Creek Apartments could travel farther within 60 minutes under the modified transit network. Figure 4-26 shows that people at Rainbow Creek Apartments could get to 24,454 jobs within 60 minutes after transit modifications.

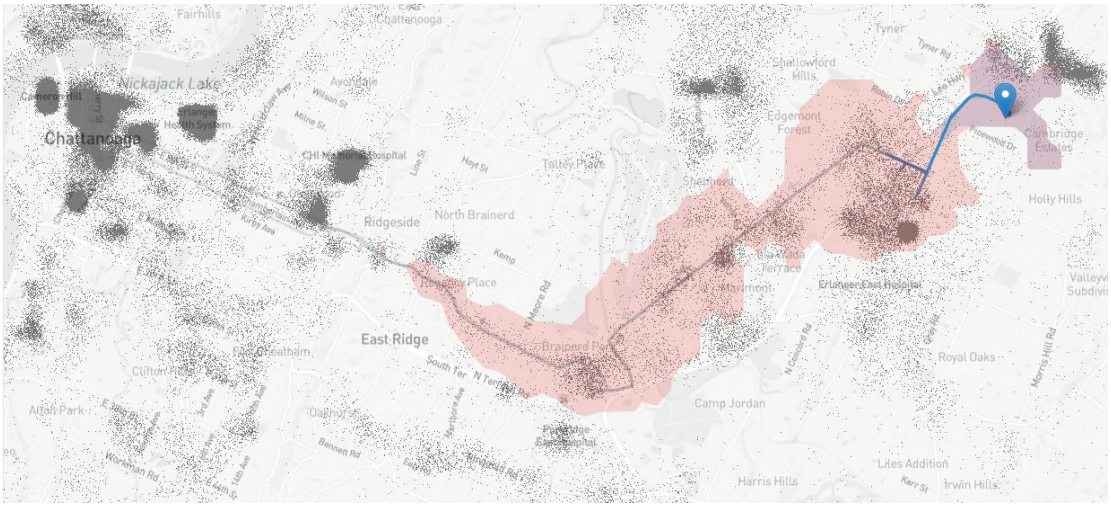



**Figure 4-25 Overlapping isochrones before and after modifying CARTA transit Route 4 for Rainbow Creek Apartments**

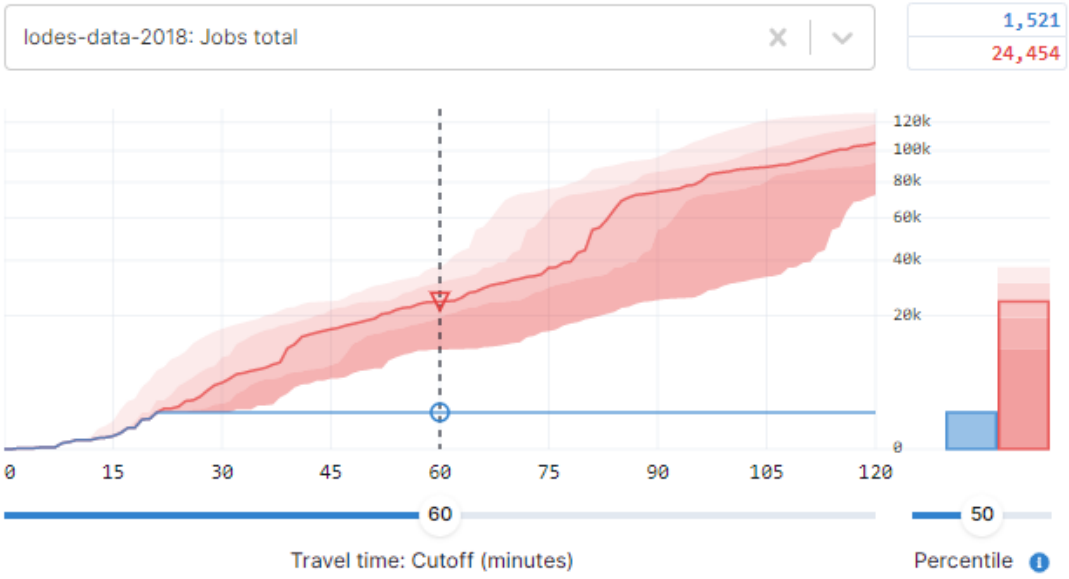



**Figure 4-26 Charts of transit accessibility results before and after modifying CARTA transit Route 4 for Rainbow Creek Apartments**

### Conclusions

Rerouting Route 4 to make it pass near to Rainbow Creek Apartments was a possible transit modification that increased transit accessibility from 1,521 accessible jobs to 24,454 accessible jobs. However, the reroute also added to the total travel time by 13 minutes. In addition, extending Route 4 might cause operational difficulties because Route 4 is already very long, and the Shallowford Rd corridor between I-75 and Gunbarrel Rd near the end of Route 4 is one of the most congested segments in the city. In conclusion, this is a transit service change worth considering; however, the difficulties of extending Route 4 and the implications on total travel time need to be taken into consideration. Future research could consider evaluating demand-response transportation services to meet the needs of these residents. CARTA provides multiple dial-a-ride routes in low density areas, and at the time of writing, CARTA was in the planning stages for a nearby demand-response service. Therefore, measuring transit accessibility provided by demand-response transportation services is an important task for future research. In addition, future research should also consider the impact of fixed route transit service changes on all nearby affordable housing locations.

## *4.3 Results of the displacement analysis*

As discussed in section 3.4.2, the number of displaced households was calculated as the loss of low-income households from 2010 to 2019. The census tracts with a loss of low-income households were marked as having displacement. This section provides summary statistics for the loss of low-income households from 2010 to 2019, as well as a series of maps that identify census tracts with a higher number of displaced households in each county.

Table VII summarizes the number of low-income households in 2019 and the decrease in low-income households from 2010 to 2019 in each block in each county. It can be noted that Davidson County lost about 73 households per census block on average in the period of 2010 to 2019, which was the highest displacement rate among the four counties. Hamilton County had the greatest number of low-income households on average in 2019 and the least loss of low-income households from 2010 to 2019. This indicates that, compared to the other three counties, Hamilton County had a higher percentage of low-income households, and the number of low-income households has not changed much over time.

**Table VII Summary statistics for low-income households in 2019 and the loss of low-income households over time**

| ***Variables*** | **Davidson (N=10,222)** | | | **Shelby (N=16,179)** | | | **Knox (N=8,059)** | | | **Hamilton (N=8,398)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Min* | *Max* | *Mean* | *Min* | *Max* | *Mean* | *Min* | *Max* | *Mean* | *Min* | *Max* | *Mean* |
| Number of low-income households in 2019 in block level | 74 | 1706 | 670 | 98 | 1719 | 722 | 76 | 2280 | 698 | 126 | 1518 | 755 |
| Loss in low-income households from 2010 to 2019 in block level | 0 | 517 | 73 | 0 | 324 | 35 | 0 | 589 | 48 | 0 | 261 | 27 |

Table VII provides the number and percentage of blocks with and without a loss of low-income households from 2010 to 2019 in each county. Over half of the blocks in Davidson County have

experienced displacement, while for the other three counties, less than half of the blocks have lost low-income households.

As shown in Table VIII, Davidson County experienced the most displacement of low-income households, followed by Knox and Shelby counties, and finally Hamilton County, which experienced the least change in the number of low-income households.

**Table VIII Summary statistics of low-income households in block level**

| Variables | Davidson (N=10,222) | | Shelby (N=16,179) | | Knox (N=8,059) | | Hamilton (N=8,398) | |
|---|---|---|---|---|---|---|---|---|
| | # | % | # | % | # | % | # | % |
| Number of blocks without loss of low-income households from 2010 to 2019 | 5068 | 49.6 | 11440 | 70.7 | 4475 | 55.5 | 6017 | 71.6 |
| Number of blocks with loss of low-income households from 2010 to 2019 | 5154 | 50. 4 | 4739 | 29.3 | 3584 | 44.5 | 2381 | 28.4 |
| *#: Frequency; %: Percent* | | | | | | | | |

To observe the spatial distribution of displacement, maps that identify census tracts with higher numbers of displaced households in each county were created. Figure 4-27 to Figure 4-30 show the number of low-income households lost from 2010 to 2019 in different colors, where gray indicates no low-income household loss, blue indicates a small amount of loss, and dark purple indicates a large amount of loss. It can be noted that displaced areas were distributed in both urban areas and suburban areas.

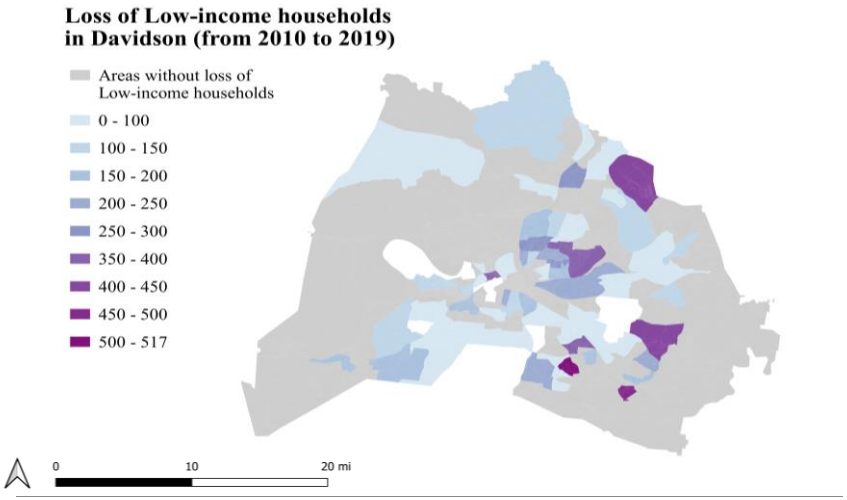



**Figure 4-27 Spatial distribution of loss of low-income households from 2010 to 2019 in Davidson County**

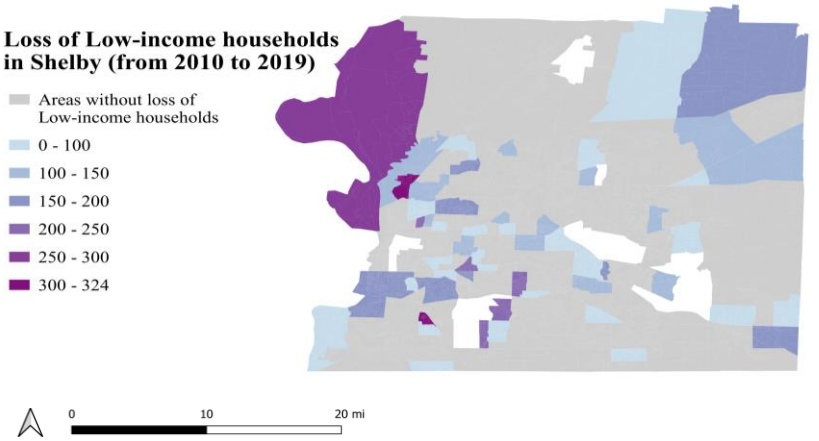



**Figure 4-28 Spatial distribution of loss of low-income households from 2010 to 2019 in Shelby County**

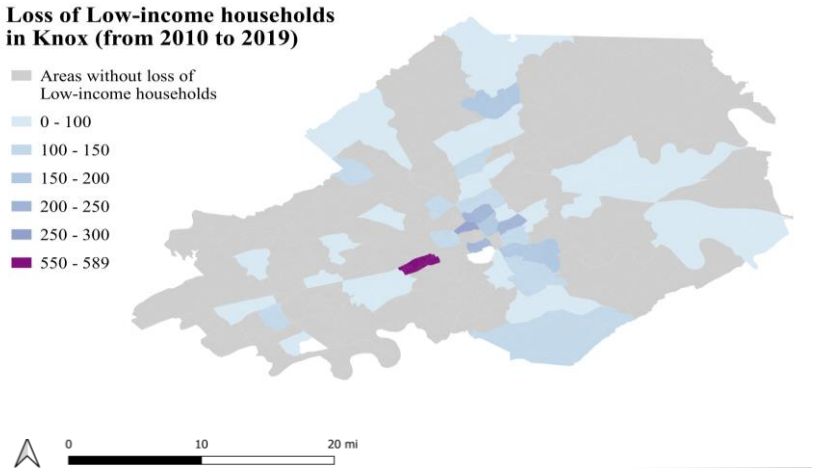



**Figure 4-29 Spatial distribution of loss of low-income households from 2010 to 2019 in Knox County**

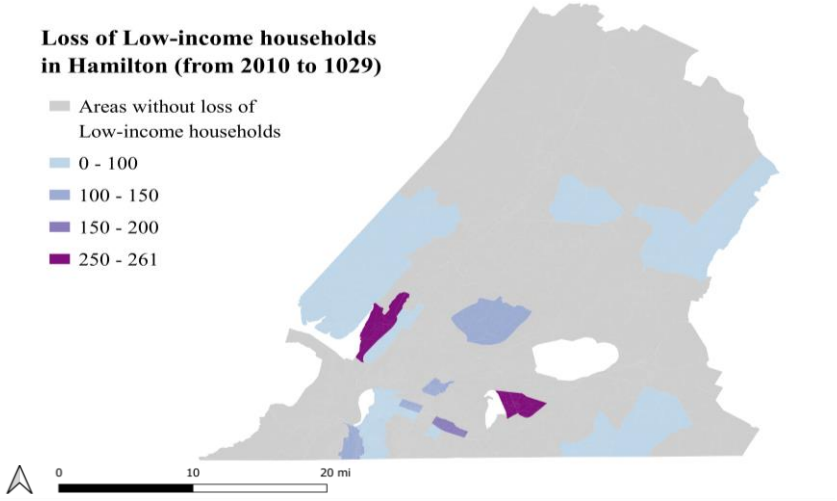



**Figure 4-30 Spatial distribution of loss of low-income households from 2010 to 2019 in Hamilton County**

## *4.4. Comparison between affordable housing, displacement, and transit accessibility*

Next, the results of the transit accessibility analysis of affordable housing and the locations of displaced populations were compared. The results include a series of maps showing specific areas of concern that could benefit from future affordable housing and/or transit modifications. These maps could be used to identify specific areas of concern, such as areas with large numbers of displaced populations with limited transit accessibility.

Figure 4-31 to Figure 4-34 show the loss of low-income households from 2010 to 2019 in each tract of the county, the locations and sizes of each affordable housing project, and the spatial distribution of the fixed route transit network and transit stops. The city boundaries of Nashville, Memphis, Knoxville, and Chattanooga are shown as black dashes.

These four maps suggest that the relationship between transit accessibility, affordable housing, and displacement differs across regions. In the case of Nashville and Knoxville, the census tracts with more displaced low-income households were mostly distributed along transit routes and in areas with fewer affordable housing units. In Memphis, the fixed route transit network and the locations of affordable housing units were more evenly distributed in areas with or without displacement. However, in Chattanooga most of displacement occurred in areas with lower transit coverage and few affordable housing units. These regional differences suggest that planning and policy changes to address displacement should be tailored to the local context.

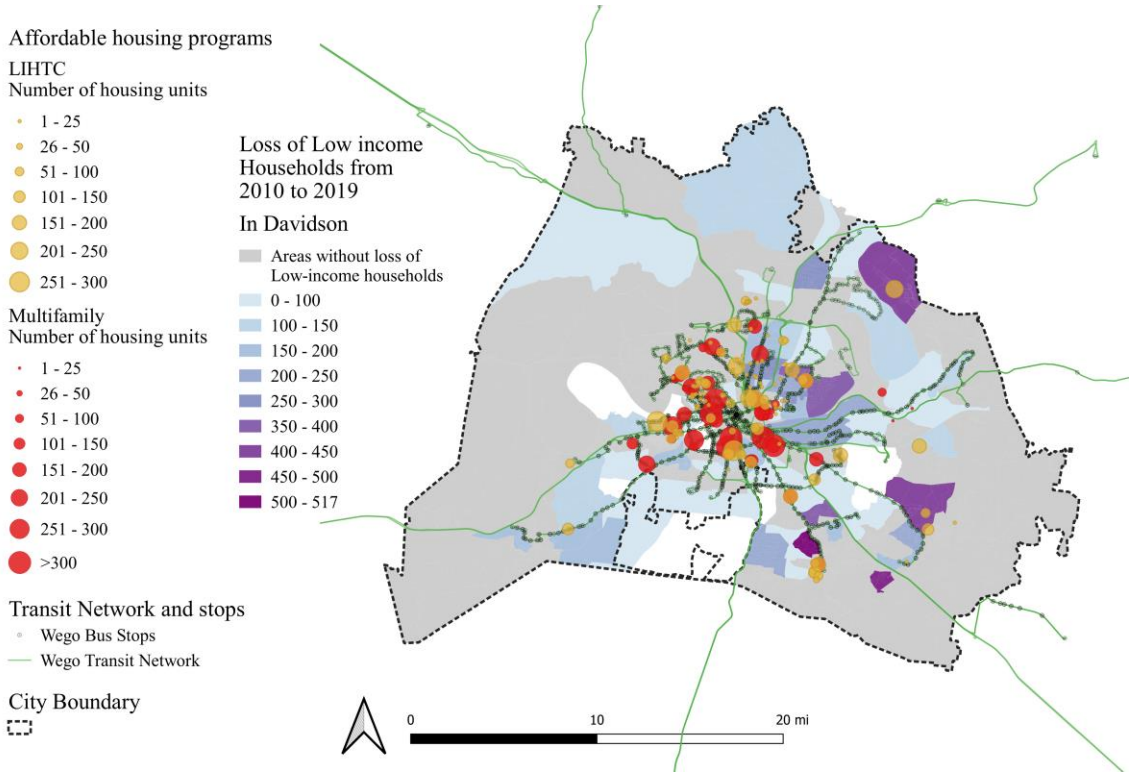



**Figure 4-31 Displacement, affordable housing, and the transit network in Davidson County**

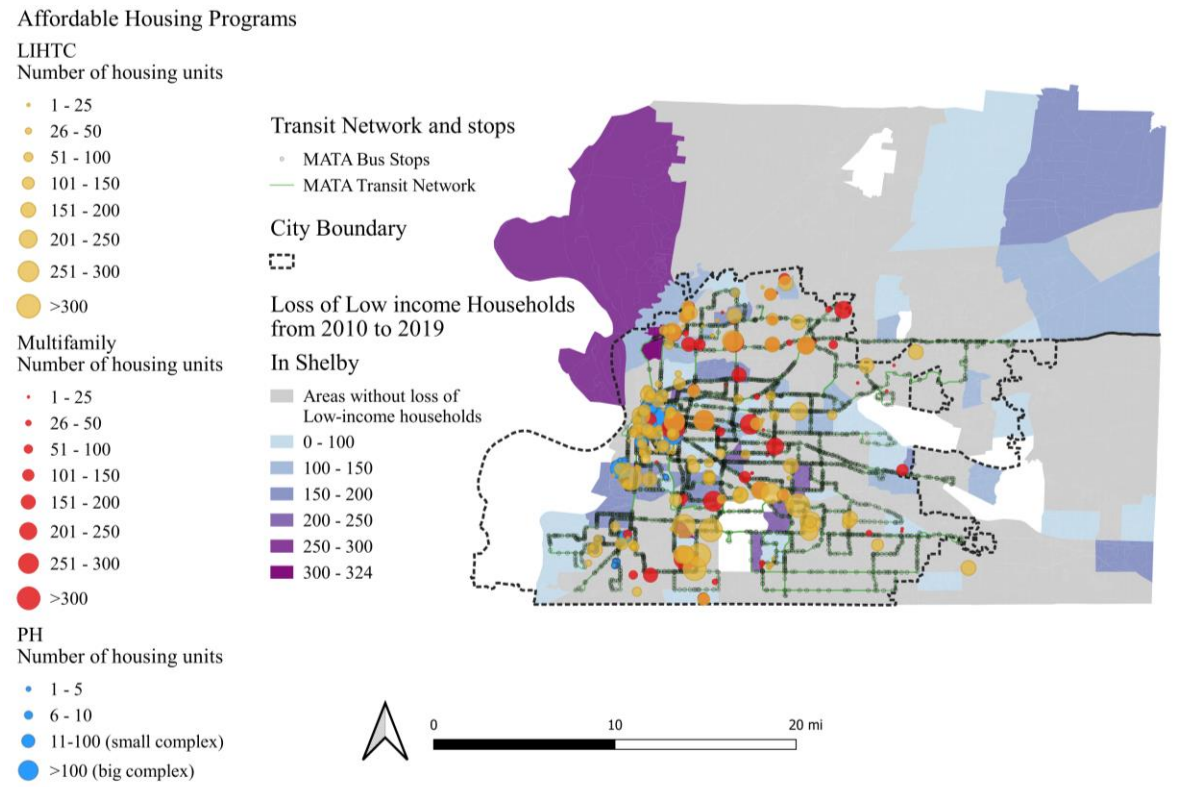



**Figure 4-32 Displacement, affordable housing, and the transit network in Shelby County**

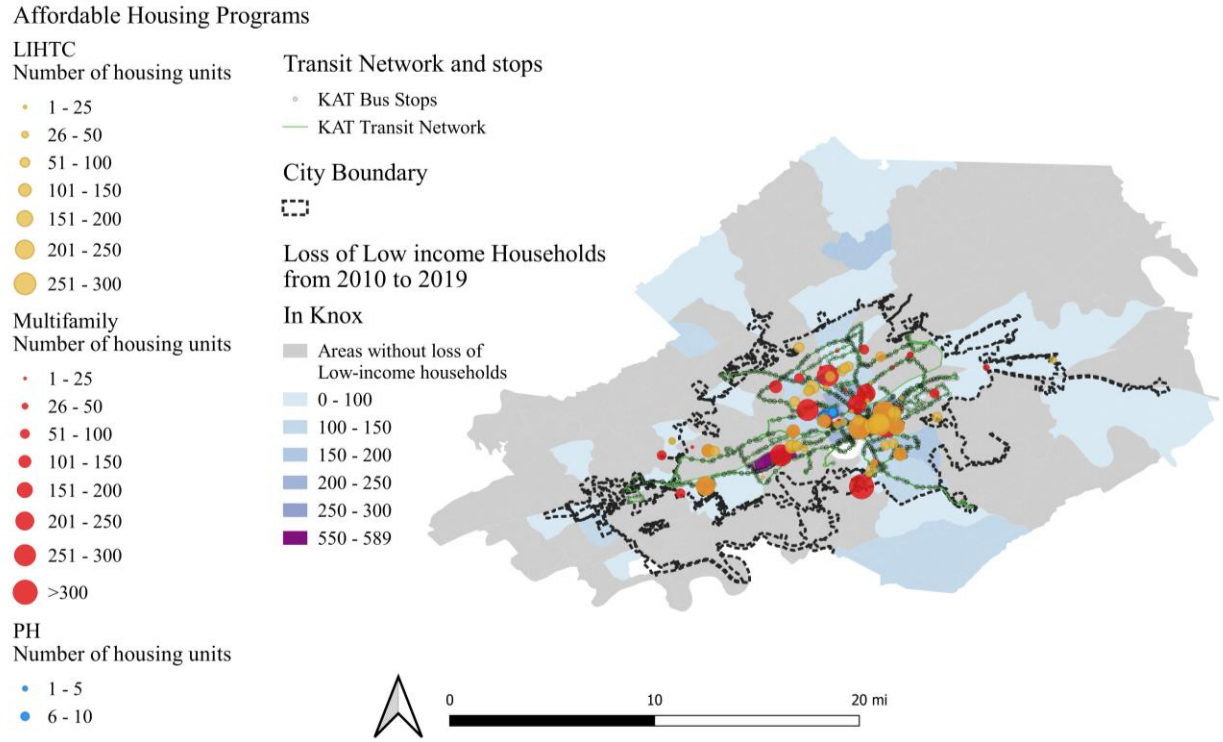



**Figure 4-33 Displacement, affordable housing, and the transit network in Knox County**

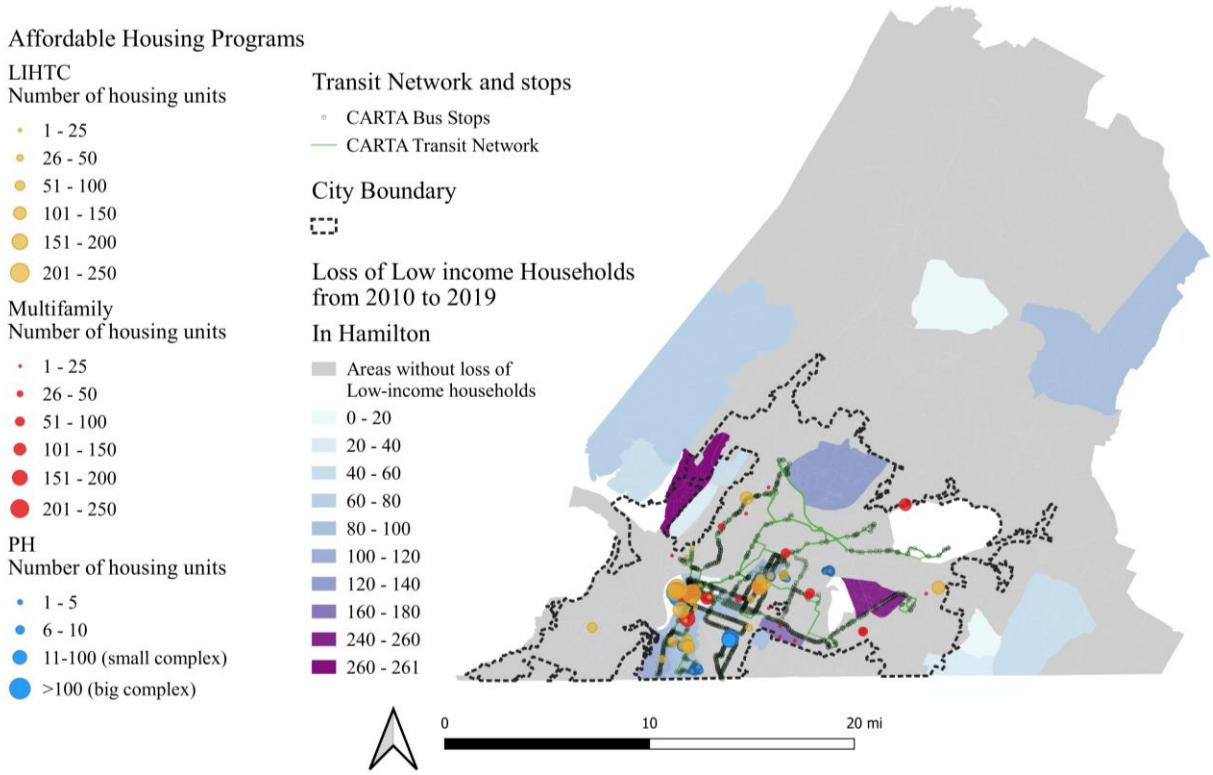



**Figure 4-34 Displacement, affordable housing, and the transit network in Hamilton County**

# Chapter 5 Conclusions and Future Research

This chapter presents conclusions, areas for future research, and recommendations for the Tennessee Department of Transportation and local transit agencies in Nashville, Memphis, Knoxville, and Chattanooga based on the research findings.

## 5.1 Conclusions

This section presents a brief summary of the key findings of this report.

The results of transit accessibility analysis for Nashville, Memphis, Knoxville, and Chattanooga identified affordable housing units with limited transit accessibility. Possible transit modifications for a small number of locations were proposed and evaluated. Overall, many affordable housing units were located in areas with relatively high levels of transit service. However, some locations in each of the cities were hard to serve using fixed transit routes. For Memphis, some of the affordable housing locations considered in this report were near low-frequency transit routes that could be improved by increasing the frequency, such as from 90 minutes to 60 minutes. Many of the locations in Knoxville, Chattanooga and Nashville were not located close to existing fixed route services, and therefore, demand-response transportation services, such as dial-a-ride or micro transit services, could be considered in future research.

The results of the displacement analysis include statistics and a series of maps of displacement. Overall, Davidson County lost the most low-income households on average in the period from 2010 to 2019 and had the highest displacement rate among the four counties. This was followed by Knox and Shelby counties, and finally Hamilton County, which experienced the least change in the number of low-income households.

The transit accessibility of affordable housing results, the displacement analysis results, and the transit network were then combined and visualized in a series of maps (one for each of the four major regions in Tennessee). These four maps suggested that the relationship between transit accessibility, affordable housing, and displacement differed across regions. For Nashville and Knoxville, the census tracts with more displaced low-income households were mostly located close to transit routes and in areas with fewer affordable housing units. On the other hand, in Memphis, the fixed route transit network and the locations of affordable housing units were relatively evenly distributed in areas with or without displacement. Last, in Chattanooga, most of the displacement occurred in areas with lower transit coverage and few affordable housing units.

## 5.2 Recommendations

**Recommendation 1: Consider fixed route transit service modifications near affordable housing units with limited accessibility**

Several recommendations for transit service modifications were identified for affordable housing locations with low transit accessibility and a high number of affordable housing units. Those recommendations for each affordable housing location were made by considering the transit network and the street network surrounding each specific location. One recommendation for each city was presented in section 2 of Chapter 4 and is briefly summarized below.

In Nashville, rerouting Route 18 is a possible transit modification proposed for Terrace Park Townhomes Phase II. According to the evaluation results, this modification increased the transit

accessibility from 258 accessible jobs to 54,715 accessible jobs, which was substantial. However, the modification also increased the total travel time by 10 minutes on the route. Therefore, the costs of providing the additional service and the implications on total travel time need to be taken into consideration. At the time of writing, WeGo was planning a WeGo Link on-demand transportation service to Hermitage, Goodlettsville and South Nashville, which will add a connection to the fixed route transit network for Terrace Park Townhomes apartments (WeGo Public Transit, 2022). Future research could consider measuring the transit accessibility of this new demand-response transportation service provided by WeGo Link.

In Memphis, to improve transit accessibility of Wesley Highland Meadows, the frequency of Route 40 may be increased from every 90 minutes to every 60 minutes during the AM peak. According to the evaluation, this modification increased the number of accessible jobs from 135 to 6,400. Increasing the frequency of Route 40 was also proposed in the Memphis Transit Vision. Therefore, this proposed transit modification increased transit accessibility for the residents of Wesley Highland Meadows and aligned with local priorities.

In Knoxville, rerouting Route 20 is a possible transit modification proposed for Cassell Ridge Apartments, Holston Ridge Apartments, and Cassell View Apartments. According to the evaluation, this modification increased transit accessibility, but it also increased the total travel time for other passengers by 23 minutes. Therefore, the costs of providing the additional service and the implications on total travel time need to be taken into consideration. Future research could also consider evaluation of demand-response transportation services in this area.

In Chattanooga, rerouting Route 4 to make it pass near to the affordable housing units is a possible transit modification for Rainbow Creek Apartments. This modification increased transit accessibility from 1,521 accessible jobs to 24,454 accessible jobs. However, the reroute also added to the total travel time by 13 minutes. In addition, extending Route 4 might cause operational difficulties because Route 4 is already very long, and the Shallowford Rd corridor between I-75 and Gunbarrel Rd near the end of Route 4 is highly congested. Therefore, the difficulties of extending Route 4 and the implications on total travel time need to be taken into consideration. Future research could consider evaluating demand-response transportation services to meet the needs of these residents. CARTA provides multiple dial-a-ride routes in low density areas, and at the time of writing, CARTA was in the planning stages for a demand-response service that would be nearby. Therefore, measuring transit accessibility provided by demand-response transportation services is an important task for future research.

The analysis of transit service modifications for other affordable housing units in Nashville, Memphis, Knoxville, and Chattanooga are available from the authors upon request.

**Recommendation 2: Implement policies to reduce or mitigate displacement in specific areas**

This report provided a series of maps that showed the spatial distribution of the loss of low-income households from 2010 to 2019. These maps can be used to help identify the trends in the displacement of low-income households in each county. Policy recommendations should focus on reducing or preventing further displacement of low-income households in the areas of concern; for example, local housing authorities may provide rental subsidies to low-income households in these areas, and local transit agencies could offer free or discounted fare programs to encourage low-income households to take transit. However, additional research is also recommended to further assess displacement; this could include conducting a survey that tracks displacement both spatially and temporally and also investigates the causes driving displacement.

**Recommendation 3: Coordinate new affordable housing development and transit service planning**

This report presented a series of maps that showed the relationship between existing affordable housing location, displacement, and transit accessibility. These maps suggest that there is a complex relationship between transit accessibility, affordable housing, and displacement. Despite this complexity and differences across regions, it is generally recommended that local transit agencies and housing authorities coordinate transit planning and affordable housing development. For example, housing authorities should consider placing new affordable housing buildings in areas with higher transit access; additionally, transit agencies could offer free or discounted fare programs to encourage these residents to take transit. Other planning and policy options could also be considered to facilitate housing and transit coordination in the future. The same recommendation can be applied to coordinate transit planning with siting other essential services, such as the location of grocery stores or health centers.

## *5.3 Areas for Future Research*

**Area for Future Research 1: Measure transit access to other essential services**

The transit accessibility metric used in this report was the number of jobs that are accessible via transit during the AM peak hours on weekdays, which did not include shift work trips, overnight trips, or weekend trips. Although providing access to jobs is an important function of public transit, some travelers – especially low-income populations who may be transit dependent – rely on transit to get to grocery stores, healthcare facilities, schools, outdoor recreational areas, or other essential services. These other essential services are increasingly being considered in transportation planning. For example, WeGo is working with the Nashville Metro Public Health Department to develop a list of grocery stores that will allow WeGo planners to assess transit access to grocery stores for equity populations and their riders as a whole (National Academies of Sciences Engineering and Medicine, 2022a). Therefore, additional future research is needed to evaluate the transit accessibility to essential services for low-income populations throughout Tennessee.

**Area for Future Research 2: Adjust the transit travel time threshold for specific areas**

Opportunity-denominated measures require a time threshold to be set in advance to measure transit accessibility. The time threshold was set to 60 minutes in this report to measure the number of jobs accessible via transit from affordable housing units in the four cities. However, the typical acceptable commuting time by transit for residents could be different in different regions. For example, people in smaller cities like Knoxville and Chattanooga typically spend less time in transit than people in larger cities like Nashville and Memphis. In future research, the transit travel time threshold should be adjusted considering typical transit travel time in specific areas.

**Area for Future Research 3: Evaluate the impacts of transit service changes on all affordable housing locations in the vicinity**

In this report, the evaluation of proposed transit service modifications only considered changes in transit accessibility to specific affordable housing locations along a single modified transit route. However, localized changes in transit service may affect accessibility level of other affordable housing locations. Therefore, analyzing the impact of transit service changes on all nearby affordable housing locations is an important area for future research.

**Area for Future Research 4: Measure accessibility of demand-response transportation services**

In this report, only accessibility levels of fixed transit routes were measured because the schedule and spatial distribution information of fixed route transit networks could be easily obtained from GTFS data. However, many local transit agencies provide demand-response transportation services to help increase access to areas that are difficult to serve with existing fixed route transit networks. For example, WeGo Link provides rides for riders who have difficulty getting to and from their bus stop. Similarly, MATA's Ready! buses provide free curbside transit service at any location within a specified service area. However, the transit accessibility of demand-response transportation services was not measured by the opportunity-denominated measures in this report due to a lack of readily available data. Therefore, data should be compiled for demand-response transportation services in future research to evaluate transit accessibility levels. A recent article proposed a method to measure access of demand-response transportation services in Los Angeles by uploading data of demand-response zones into Conveyal's software (Stewart, 2022). This could be done for Tennessee if data showing demand-response zones are made available.

**Area for Future Research 5: Evaluate accessibility for affordable housing units nationwide**

A simple inequity index was proposed in this project to identify specific locations with low transit access and high numbers of affordable housing units in four cities in Tennessee (Nashville, Memphis, Knoxville, and Chattanooga). This could potentially be expanded nationwide using General Transit Feed Specification (GTFS) data from the Bureau of Transportation Statistics (BTS) and geospatial data on affordable housing locations from the U.S. Department of Housing and Urban Development's (HUD) Open Data website. A standardized, nationwide inequity index could be useful to housing authorities as a reference when planning affordable housing locations, and it could also help low-income renters compare and select affordable housing locations based on their needs.

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# Appendix 1: Additional Literature

**Table IX Literature on displacement measures**

| Study | Data sources | Study period | Study area | Displacement Metrics | Results/findings |
|---|---|---|---|---|---|
| **(Freeman, 2005)** | Panel Study of Income Dynamics (PSID) | 1980 to 2000 | United States | All types of residential mobility, and reason for moving is involuntary | The displacement rate is 1.3% in the United States from 1980 to 2000. This measure exaggerates the extent of gentrification-induced displacement because the category of "involuntary moving" includes some responses that may not be considered displacement. |
| **(Martin & Beck, 2016)** | Panel Study of Income Dynamics (PSID) | 1980 to 2010 | United States | All types of residential mobility, and reason for moving is involuntary | Property tax pressure is one reason for involuntary moving. |
| **(Newman & Wyly, 2006)** | New York City Housing and Vacancy Survey | 1991,1993, 1996, 1999 and 2002 | New York City | Reasons for moving include high housing expense, landlord harassment, and displacement by private action | The displacement rate in each period (1989-91, 1991-93, 1993-96,1996-99,1999-2002) is 8.15%, 9.45%, 6.22%, 8.87%, and 9.87% respectively. |
| **(Wyly et al., 2010)** | New York City Housing and Vacancy Survey | 2002,2005, and 2008 | New York City | Reasons for moving include high housing expenses, poor housing services, being evicted, landlord harassment, displaced by public activity, and displaced by private action | The displacement rate in each period (1999-2002, 2002-2005, 2005-2008) is 13.4%, 13.1%, and 12.4% respectively. |
| **(Carlson, 2020)** | American Community Survey, New York City Housing and Vacancy Survey | 2005, 2008, and 2011 | New York City | Three approaches measuring displacement:<br>1.The loss in the number of low-income households.<br>2.The number of households moving out of a housing project.<br>3.The number moving involuntarily | Reasons for moving are important for measuring displacement. |
| **(Vigdor et al., 2002)** | American Housing Survey | 1974 to 1993 | Boston | Exit rates of neighborhoods | Poor households were more likely to exit poverty than to be replaced by a non-poor household. |

**Table IX CONTINUED**

| Study | Data sources | Study period | Study area | Displacement Metrics | Results/findings |
|---|---|---|---|---|---|
| **(Ellen & O'Regan, 2011)** | American Housing Survey | 1991 to 1999 | United Sates | Exit rates of neighborhoods | No evidence of heightened exit rates for renters or poor households was found. |
| **(Desmond & Shollenberger, 2015)** | Urban renters survey conducted in Milwaukee | 2009 to 2011 | Milwaukee | Involuntary moving includes formal and informal evictions, foreclosures, and housing being condemned | Renters who experienced involuntary displacement were more likely to relocate to poorer and higher-crime neighborhoods |
| **(McKinnish et al., 2010)** | Confidential Census Long Form data | 1990 and 2000 | United Sates | Rates of in-migration and out-migration in neighborhoods | The population movements associated with the gentrification of urban communities in the 1990s are not consistent with displacement and harm to minority families |
| **(Chapple et al., 2017)** | Affordable housing data including Condo conversion data; Housing Choice Vouchers (Section 8); Low-income Housing Tax Credit and Ellis Act evictions data | | Los Angeles, San Francisco | The loss of affordable housing (For LA: housing with median gross rent of less than 80% of the county median; for SF: housing with low-income households who pay less than 30% of their income on rent) | There is a significant and positive relationship between gentrification and the loss of affordable housing |
| **(Chapple et al., 2017)** | 2000 Decennial Census, 2009-2013 ACS | | Bay Area | The loss of low-income households (households who make less than 80% of the city's median income) | Neighborhoods with a high renter ratio were more likely to lose low-income households, while minority neighborhoods were more likely to gain. |
| **(Chapple & Zuk, 2021; Zuk & Chapple, 2015)** | US Decennial Census in 1990, 2000, and 2010 and ACS from 2008-2012 and 2013-2018 | | Los Angeles, Atlanta, Memphis, etc. | The loss of low-income households (households who make less than 80% of the city's median income) | The resulting typology map shows displacement of low-income households. |

**Table X Literature on transit accessibility measures**

| Study | Data sources | Study area | Tools | Measurement |
|---|---|---|---|---|
| **(El-Geneidy et al., 2016)** | GTFS data of eight transit agencies,<br>Statistics Canada National Household Survey | Montreal Area, Canada | OpenTripPlanner | Cumulative opportunities measure |
| **(Boisjoly & El-Geneidy, 2016)** | GTFS data,<br>Statistics Canada National Household Survey | Greater Toronto and Hamilton Area, Canada | OpenTripPlanner | Cumulative opportunities measure |
| **(Blanchard & Waddell, 2017)** | GTFS data,<br>LEHD | San Francisco Bay Area, California | UrbanAccess package in Python | Cumulative opportunities measure |
| **(Cui et al., 2019a)** | GTFS data,<br>Statistics Canada 2016 Census Flow (job) | Montreal, Canada | ArcMap,<br>Conveyal | Cumulative opportunities measure |
| **(Xi et al., 2018)** | Transportation Tomorrow Survey (job)<br>National Road Network (NRN) | Greater Toronto and Hamilton Area | EMME, ArcGIS | Cumulative opportunities measure |
| **(Zuo et al., 2020)** | GTFS,<br>LEHD | Hamilton County, Ohio | Mathematical method | Cumulative opportunities measure |
| **(O'Sullivan et al., 2000b)** | GTFS data | UK | ArcGIS Desktop | Cumulative opportunities measure |
| **(El-Geneidy & Levinson, 2006)** | Metropolitan Council transportation planning model<br>LEHD | Twin Cities | GIS Platform | Cumulative opportunities measure,<br>Weighted cumulative opportunities measure |

**Table X CONTINUED**

| Study | Data sources | Study area | Tools | Measurement |
|---|---|---|---|---|
| **(Higgins et al., 2020a)** | GTFS<br>OpenStreetMap | Toronto | ArcGIS Desktop,<br>Emme 4,<br>OpenTripPlanner,<br>Conveyal | Cumulative opportunities measure,<br>Time-denominated measure |
| **(Bertolaccini & Use, 2018)** | GTFS data,<br>LEHD data | Hartford, Connecticut | | Weighted cumulative opportunities measure |
| **(Kawabata et al., 2006)** | 1990 Census Transportation Planning Packages | Boston, Los Angeles, and Tokyo | | Competitive access measure |
| **(Merlin & Hu, 2017)** | ACS (2009-2014)<br>LEHD | Los Angeles | | Competitive access measure |
| **(Tribby & Zandbergen, 2012)** | Bus routes network | Albuquerque, New Mexico | | Time-denominated measure |
| **(Fayyaz S et al., 2017)** | GTFS data<br>Census data | St. George, Utah | | Time-denominated measure |
| **(Bok & Kwon, 2016)** | GTFS data | Asian metropolitan area and five North American areas | | Time-denominated measure |
| **(Farber et al., 2014)** | GTFS data | Ohio and Kentucky | ArcGIS | Time-denominated measure |
| **(Foda & Osman, 2010)** | Bus routes network | Alexandria, Egypt | GIS Platform | Time-denominated measure |

# Appendix 2: Case Studies

The five American cities selected for case studies were: Atlanta, GA; Asheville, NC; Raleigh, NC; Indianapolis, IN; and New Orleans, LA. Preference was given to southern cities that have implemented policy or are engaged in projects to address equity around public transit. An example of such a policy is to establish tax increment financing districts near transit corridors. New development generates excess property tax revenue, which then may be used to fund the creation of transit-oriented affordable housing (National Housing Conference ND). An example of such a project is the development of new routes designed to increase connectivity between low-income communities and areas with greater job opportunities. Table XI–provides an overview of the studies. The following sections go into further detail and include the date implemented, the administrative body, the lifespan, the method of funding, and the budget. The purpose of the policy or project and its relevance to equitable housing and transportation in Tennessee is also discussed.

**Table XI Overview of cities selected for case studies**

| | |
|---|---|
| Atlanta, GA | • An Affordable Housing Trust Fund was developed to protect existing residents around the BeltLine Equitable Development plan from property tax increases and facilitate the development of new affordable housing. |
| Asheville, NC | • Plans were made to develop a downtown transit center that will include affordable housing as well as commercial and public spaces. |
| Raleigh, NC | • The Equitable Development Around Transit (EDAT) Plan was created to focus on the development of mixed-use communities around Raleigh's bus rapid transit (BRT) stations. |
| Indianapolis, IN | • A $15 million equitable transit oriented development loan fund was created to develop at least 1000 affordable units within a half mile of transit. |
| New Orleans, LA | • Zoning changes, development incentives, and improved transit infrastructure were recommended in order to support greater access to transit. |

### Atlanta, Georgia

The BeltLine Equitable Development Plan is a public-private initiative to redevelop 22 miles of historical freight rail lines into a commuter rail line loop, which could lead to the creation of 30,000 new permanent jobs and 5,600 new affordable housing units. The primary source of funding comes from tax increment financing districts called Tax Allocation Districts (TAD), as well as from the city of Atlanta, philanthropic contributions, local, state and federal grants, and public-private partnerships. To ensure that future growth is distributed equitably around the city, the BeltLine will facilitate the creation of mixed-use, mixed-income communities with the BeltLine Affordable Housing Trust Fund (BAHTF). Atlanta's BeltLine and all associated programs are relevant to equitable public transit in Tennessee

because of the demographic and geographic similarities between Atlanta, Memphis, and Nashville. However, none of the rail lines have been built to date.

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**Asheville, North Carolina**

Asheville's city council has agreed to develop a transit center in downtown Asheville that will include affordable housing as well as commercial and public spaces. Additionally, Asheville created the Mapping Racial Equity Project, an ArcGIS story map that studies the relationship between redlining in the 1930s and 1940s and modern-day displacement of black households. The work in Asheville is relevant to affordable housing in Tennessee because of the demographic and geographic similarities between Asheville and the Tennessee cities in this study.

**References:** https://avltoday.6amcity.com/public-transit-affordable-housing-asheville-nc/

**Raleigh, North Carolina**

The Equitable Development Around Transit (EDAT) Plan is the city of Raleigh's vision to create denser, mixed-use development near bus rapid transit (BRT) stations. Included in the plan is an Equitable Policy Toolkit which uses three mechanisms to facilitate mixed-use development around BRT stations, including 1) zoning, 2) affordable housing production and funding, and 3) equity programs. The plan uses transit oriented development zones that include a density bonus for affordable housing to be built 50% higher than the surrounding buildings, with 30% of the units in the bonus reserved as affordable. The EDAT Plan is relevant to equitable public transportation in Tennessee because Raleigh's EDAT Plan provides insight into what kind of policies for equitable development may be most suitable in Tennessee.

**References:** https://cityofraleigh0drupal.blob.core.usgovcloudapi.net/drupal-prod/COR22/EDATGuidebook.pdf

**Indianapolis, Indiana**

Through a partnership between Cinnaire and the Indianapolis Neighborhood Housing Partnership, a $15 million equitable transit-oriented development loan fund was set up for the creation of at least 1000 affordable housing units within a half-mile of transit. The goal of the partnership is to enable equitable access to jobs, education, and healthcare, among others. This plan is relevant to equitable public transportation in Tennessee because Indianapolis is a bus service-only transit system, similar to the transit systems in Tennessee.

**References:** https://www.housingonline.com/2019/05/15/cinnaire-announces-first-property-purchased-for-indianapolis-equitable-transit-oriented-development-fund/

**New Orleans, LA**

In New Orleans, a collaborative effort between city officials and the Regional Transit Agency aims to support greater access to transit by making recommendations for zoning changes, development incentives, and improved transit infrastructure, among others. One of the city's goals is to incentivize affordable housing development near transit. This plan is relevant to equitable public transportation in Tennessee because of the demographic and geographic similarities between New Orleans and the four Tennessee cities in this study, especially Memphis.

**References:** https://www.nola.gov/transportation/transit-oriented-communities/