NORTH NASHVILLE'S TRANSPORTATION FUTURE

AN EMPLOYMENT, ENVIRONMENTAL, AND EQUITY ANALYSIS

A SEAS CAPSTONE REPORT

SINDHU BHARADWAJ, KIRSTIE HOSTETTER, AND BEN STACEY

ACKNOWLEDGEMENTS

We would like to thank a number of individuals and organizations for their contributions to this report. First, thank you to the Nashville MTA for partnering with us on this endeavor. We would like to especially acknowledge Felix Castrodad, their Director of Planning and Grants, who has been our main point of contact at MTA throughout this process and a valuable source of expertise and perspective for our team. Hary Prawiranata, Senior Modeler at Nashville Area MPO, helped our team as we navigated the MPO's activity-based model and its capabilities, and supported us as we moved into our analyses by providing us with data and trouble-shooting support. Gary Dolce, an environmental scientist at the EPA's Office of Transportation and Air Quality, provided technical guidance on using the MOVES emissions model.

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ABOUT US

SINDHU BHARADWAJ is a transportation equity researcher and advocate. She planned and conducted stakeholder interviews and created metrics based on employment accessibility and greenhouse gases results for this report. As a graduate student at University of Michigan, Sindhu's coursework has focused primarily on climate adaptation and transportation planning. In addition to working with MTA, Sindhu completed a fellowship with the Barr Foundation and MassINC, a Boston-based think tank, to study the potential for transit-oriented development in mid-size cities across Massachusetts. Prior to entering graduate school, Sindhu worked in communications and earned a BA in Politics and Cultural Studies from New York University.

KIRSTIE HOSTETTER has a BS in Environmental Economics from the University of Georgia and is completing her MS at the University of Michigan. While in graduate school, she has focused her coursework and experiences on equitable and sustainable transportation planning. Kirstie was primarily responsible for manipulating the MPO's activity-based model to reflect the Let's Move Nashville plan and for conducting the employment accessibility analyses contained within this report. Upon graduation, Kirstie will be working full-time with Four Nines Technologies, a public transit consulting company. In this role, she will continue working at the intersection of transit, equity, and sustainability by assisting transit agencies with fare policy, ridership and revenue predictions, fare collection technology, asset management, and Title VI analyses.

BEN STACEY served as a Peace Corps Volunteer in the Philippines before coming to the University of Michigan. As a dual-graduate degree student at the School for Environment & Sustainability and Taubman College of Urban & Regional Planning, his research focuses on urban sustainability issues in energy and transportation. At the UM Urban Energy Justice Lab, his research focused on energy policy and its impacts on low-income residents. Ben also developed the framework for a Climate Action Plan as an EDF Climate Corps Fellow at the Orlando Office of Sustainability and Energy. In this project, Ben developed inventories for Nashville's greenhouse gases and criteria pollutants under various policy scenarios after training at the EPA Office of Transportation and Air Quality.

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INTRODUCTION

NORTH NASHVILLE'S TRANSIT FUTURE

What's next for North Nashville?

This report assesses the potential economic, environmental, and social impacts of the Let's Move Nashville transit plan on the North Nashville neighborhood by modeling and comparing implementation scenarios for 2020 and 2030 versus predicted business as usual trends for the same years. The Nashville Metropolitan Transit Authority currently provides North Nashville with a higher level of service relative to the rest of the city. However, system features such as long headways, hub-and-spoke routes, and a lack of regional connectivity impose limitations on residents' mobility. Let's Move Nashville seeks to address each of these issues with the goal of connecting more people to educational, employment, and recreational opportunities. There is much at stake for North Nashville, a historically neglected African-American community beginning to experience redevelopment and an influx of new residents. Our analysis examines the extent to which these goals are achievable for the neighborhood while laying out a methodology that can be replicated for areas throughout Nashville.

Goals

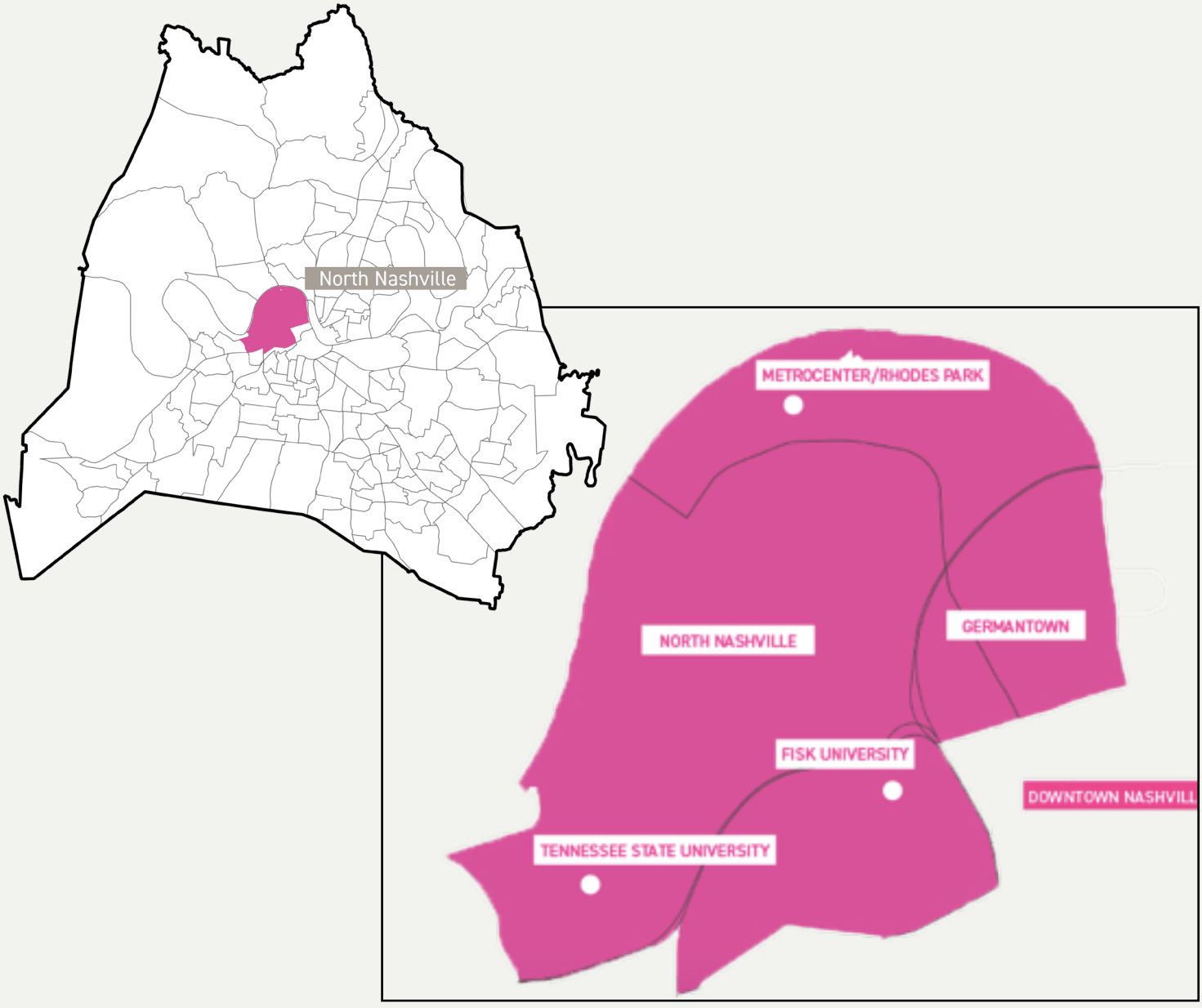
- Understand how Let's Move stakeholders conceptualize equity in relation to transit.
- Determine job accessibility within specific commute times under all scenarios.
- Estimate citywide greenhouse gas emissions reductions achieved through Let's Move Nashville.
- Create a series of transportation sustainability indicators applicable across neighborhoods including North Nashville.

Partners

This report is the result of a collaborative effort between the University of Michigan's School for Environment and Sustainability, the Nashville Metropolitan Transit Authority (MTA), and the Nashville Area Metropolitan Planning Organization (MPO).

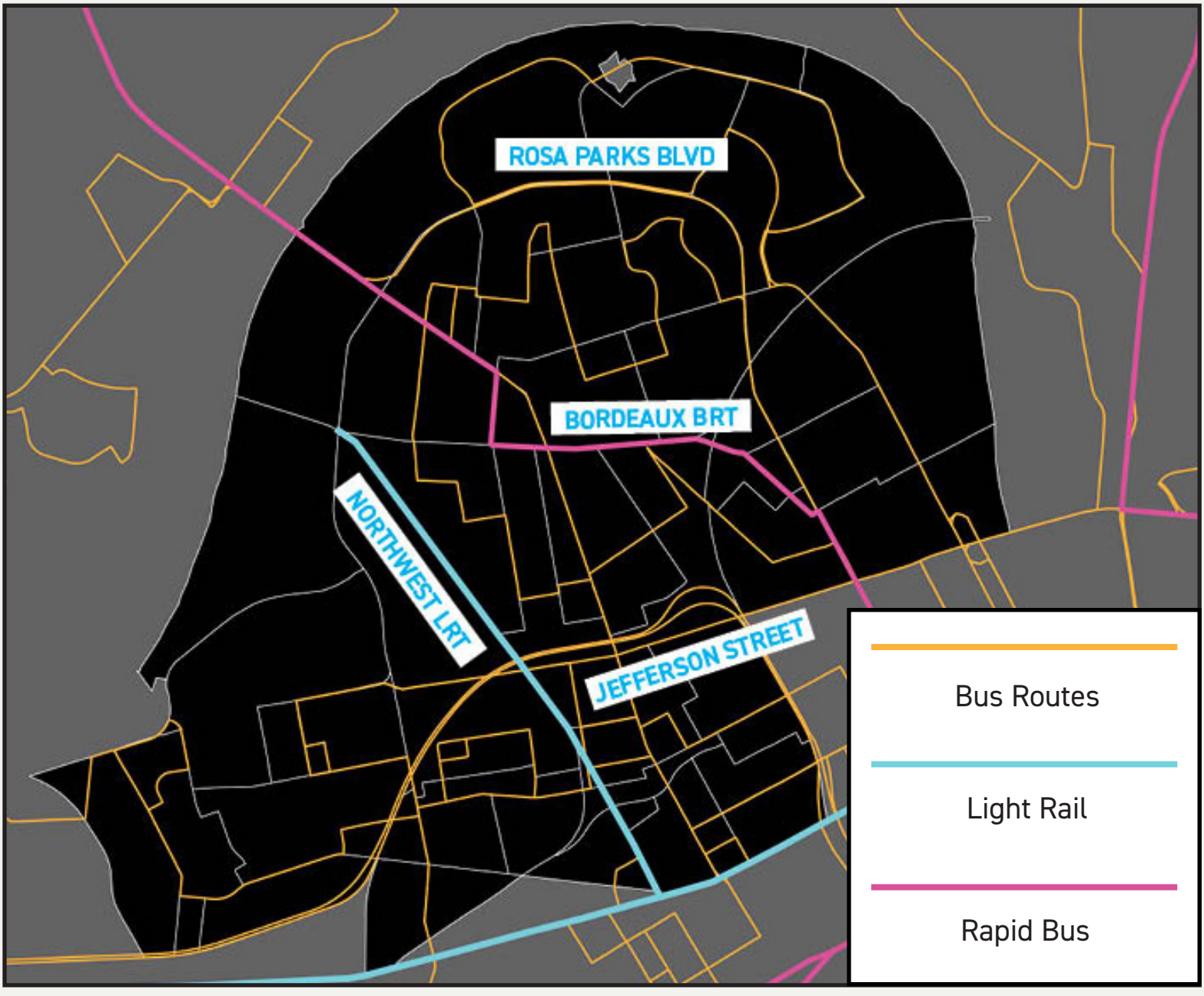
North Nashville

The North Nashville neighborhood is bordered by Downtown Nashville and Jefferson Street to the south, the Cumberland River and Bordeaux-Whites Creek to the north and west, and Germantown to the east. Historically an African-American area, North Nashville has long been a hub for culture, civil rights organizing, and education with three historically Black colleges and universities within its limits.



Let's Move Nashville

Let's Move is a multimodal transportation plan aimed at providing the growing population of Nashville with increased bus, rail, and nonmotorized options for mobility throughout the city. If implemented, the plan would run light rail, rapid bus, and improved local bus lines through North Nashville in addition to placing up to three new transit centers in the neighborhood.



Report Outline

Section One: North Nashville: Past, Present, Future
Identifies historical and current conditions in North Nashville as context for Let's Move's potential impacts.

Section Two: Equity Framework
Presents a set of indicators for assessing Let's Move's performance in providing equitable service and access to important amenities for North Nashville residents.

Section Three: Employment and Accessibility
Reports Let's Move's performance on increasing economic mobility using a cumulative employment accessibility indicator for North Nashville, as modeled using TransCAD.

Section Four: Environmental Projections
Inventories greenhouse gas emissions for the four scenarios and reports potential reductions under implementation of Let's Move.

Section Five: A Transit Sustainability Index
Provides a series of strategies for replicating economic, environmental, and equity analyses across Nashville and implementing recommendations based on findings.

EXECUTIVE SUMMARY

OVERVIEW OF FINDINGS

KEY FINDINGS AND RECOMMENDATIONS

Section One: North Nashville: Past, Present, Future

- The North Nashville neighborhood, with borders defined by the Nashville Planning Department, has a population of about 22,485, up by about 100 between 2009 and 2016.
- North Nashville is still a predominantly Black neighborhood (79.5 percent as of 2016). This share has been declining as Black residents made up 92 percent of the population in 2009.
- There are sizable disparities in household income, home values, and construction permit values within the North Nashville.
- North Nashville still has a large share of transit-dependent residents (29.5 percent versus 13 percent for Davidson County).
- 20.8 percent of North Nashville's roads have bike paths compared to just 7.9 percent for Davidson County. North Nashville also has more miles of sidewalks than roadways while only 27.9 percent of Davidson County's roads have sidewalks.

Section Two: Equity Framework

- Interviews conducted with key Metro government staff, North Nashville community members, and civil society representatives revealed a multifaceted approach to equity in the nMotion and Let's Move planning processes.
- Interviews were transcribed and then coded to reveal themes around how stakeholders conceptualize transit equity.
- The first theme pulled from the interviews was **community engagement**, which included the subthemes of incorporating local knowledge, communication and messaging, and support-building.
- The second theme, **systems and infrastructure**, addressed issues around modal equity, regional service, target ridership, and accessibility.
- The final theme identified, **development and affordability**, involved discussions of health, gentrification, and correcting historical injustice.

Section Three: Employment Accessibility

- Findings from interviews with North Nashville stakeholders led to the completion of an employment accessibility analysis as an indicator of the potential for Let's Move Nashville to bring economic opportunities to North Nashvillians.
- The employment accessibility analysis was completed using a cumulative opportunity measure, a methodology that counts the number of jobs available within various commute time bands and is easy for both policy makers and the general public to understand and interpret.
- AM commute times and Off-Peak commute times for North Nashvillians traveling to locations within Davidson County were calculated based on the Nashville Area Metropolitan Planning Organization's activity-based model using traffic analysis zones (TAZs) as the unit of analysis.
- Analyses show significant improvements to the number of jobs accessible by North Nashvillians within 15 minutes, 30 minutes, 45 minutes, and 60 minutes in the year 2033 if Let's Move Nashville is implemented as opposed to continuing with business-as-usual transit practices.

Jobs Accessible by Transit

AM Commute Times

	15 Min	30 Min	45 Min	60 Min
2017	70,438	193,481	275,413	381,945
2033- BAU	71,625	181,705	338,391	455,124
2033- Let's Move	109,575	291,838	462,713	557,798

Off-Peak Commute Times

	15 Min	30 Min	45 Min	60 Min
2017	70,152	132,896	215,561	313,517
2033- BAU	68,981	131,954	256,148	380,220
2033- Let's Move	100,810	227,831	414,218	523,549

Section Four: Air and Atmosphere

- The Environmental Sustainability section of this study combines state-of-the-art transportation and vehicle emissions models to examine the effect of Let's Move Nashville on transportation related emissions.
- This assessment tracks the progress in reaching goals outlined in the Livable Nashville Report.
- As an indicator for the potential impact on air quality and public health, particularly respiratory impacts from emissions, inventories for criteria pollutants (SO2, CO, PM 2.5, PM 10, and NOx) were generated for North Nashville.
- As a signatory of the Compact of Mayors, Nashville is also committed to reducing its greenhouse gas emissions. This analysis creates an inventory for Nashville-Davidson county in 2017, 2033 and 2033 with Let's Move Nashville.
- The emissions inventories for both GHG and criteria pollutants, captures all road-related travel, not only from transit, but all vehicle types.
- While other GHG contributors in Nashville, such as commercial and residential buildings, have begun to slow and even reverse emission trends, the transportation continued to grow in 2017, reaching 5.3 million metric tons and remained the largest source.
- However, by 2033 the Let's Move Nashville plan not only improves accessibility and mobility through increased transit, but results in GHG reductions beyond those achieved through Corporate Average Fuel Economy or CAFE standards.
- Similarly, the study found that criteria pollutants in North Nashville decreased from 12 percent to 85 percent from 2017 to 2033 Let's Move Nashville plan.

Section Five: A Transportation Sustainability Index

Based on our analysis in sections two, three, and four, our team recommends creating a transportation sustainability index made up of the following key indicators:

- **Equity:** projects implemented and dollars invested in traditionally disadvantaged population, percentage of MTA jobs held by community members, pre-existing social vulnerability indicators as defined by MPO.
- **Employment Accessibility:** access to low-income jobs, access to non-work amenities (shopping, school, recreation), comparison of commute times and job access for areas where minority and low-income population is twice the county mean.
- **Air and Atmosphere**: concentrations of greenhouse gas emissions and criteria pollutants (SO2, NOx, PM 2.5, PM 10, CO) in areas designated as "vulnerable" per MPO criteria.

Jefferson Street, Google Maps

SECTION 1

NEIGHBORHOOD PROFILE

NORTH NASHVILLE: PAST, PRESENT, AND FUTURE

NEIGHBORHOOD CONTEXT

This section provides an overview of conditions in North Nashville since 2005 as well as contextual information about the neighborhood. Population, housing, transportation, employment, and health characteristics provide a basis for assessing potential impacts Let's Move can have on the neighborhood. This section also provides comparisons between North Nashville and Davidson County at large. Data is drawn from ACS Five-Year Estimates, first from 2005-2009 and then 2012-2016.

Image Source: Flickr Images

North Nashville: A Brief History

North Nashville has historically been a Black community since the 19th century when free African Americans settled along the Jefferson Street corridor, opening businesses and creating what became a thriving community. The area continued to grow throughout the 1900s as Fisk and Tennessee State Universities opened and Meharry Medical College moved into the neighborhood. Nashville's formerly extensive streetcar network had a presence in North Nashville, with service along Jefferson Street. For much of the 20th century, North Nashville was economically diverse, a cultural center, and a hub for civil rights organizing. Notably, community residents were instrumental in the push to make Nashville the first desegregated city in the US South.

The area experienced a downturn beginning in the 1960s when urban renewal destroyed much of the existing housing stock and replaced it with more low-income housing. The US Department of Transportation's decision in 1968 to build an interstate running directly through the middle of the community effectively isolated neighborhoods and displaced many businesses and residents. Desegregation further enabled households and businesses to leave the area, as more housing and economic opportunities opened up to them elsewhere. In the wake of these events, North Nashville lost half of its population and experienced a dramatic demographic shift. By 1978, the population dropped from 65,000 to 38,000 and continued to fall until it stagnated at around 20,000 people in the 1990s.

The tumultuous history of North Nashville has left a legacy of mistrust between residents and government and institutional actors, particularly in relation to transportation and displacement. However, the neighborhood's historic institutions, proximity to downtown, and potential transportation assets suggest a trajectory for a vibrant future. North Nashville is currently home to many nonprofits including Jefferson Street United Merchants Partnership (JUMP) and Nashville Organized for Action and Hope (NOAH), among others. Since 2010, the area has seen resurgence, due largely to renewed interest in the Germantown area and a boom in the local real estate market. The transportation infrastructure proposals contained in Let's Move Nashville have the potential to transform the area for the benefit of current residents as well as new ones. A close, collaborative examination of these issues follows.

RESIDENTS

Population

According to ACS Five-Year Estimates for 2012-2016, North Nashville's population was estimated to be 22,485. This is very close to the 2005-2009 estimate of 22,380, indicating that the neighborhood's population has remained stable over the past ten years. This is not the case for Davidson County as a whole which grew from 621,465 to 667,885 residents in the same time frame for a 7.5 percent population growth rate.

Age

North Nashville has a younger population than Davidson County overall, with median ages of 29 and 34 respectively. However, North Nashville's median age rose from 27 in 2009 to 29 in 2016, due primarily to an increase in the share of the population made up of working-age adults.

Employment

Labor force participation in North Nashville has seen an uptick between 2009 and 2016, increasing from 55.3 to 59.7 percent. The unemployment rate has decreased commensurately in the same time period from 10.4 to 8.8 percent. This is still well over the rate for Davidson County as a whole which has remained relatively stable and sits at 4.4 percent as of 2016.

Income

Median household income has risen by almost 23 percent from $21,241 to $26,122 in this timeframe. Even with the increase, North Nashville's overall median is about half of that for Davidson County overall where they median household income is $50,484 up 10 percent from 2009. It is also important to note that there are significant spatial variations in income within North Nashville. As the following map shows, most of North Nashville's households are making less than $25,000 per year with the notable exception of residents in the area directly adjacent to downtown Nashville.

RESIDENT CHARACTERISTICS

Figure 1.1

22,380
2005-2009 est.

22,485
2012-2016 est.

Total Population: North Nashville

Population Growth Rate (2009-2016)

0.47%
North Nashville

7.5%
Davidson County

29
North Nashville

34
Davidson County

Median Age (2016)

Employment Rate: North Nashville

55.3%
2005-2009 est.

59.7%
2012-2016 est.

$21k
North Nashville (2009)

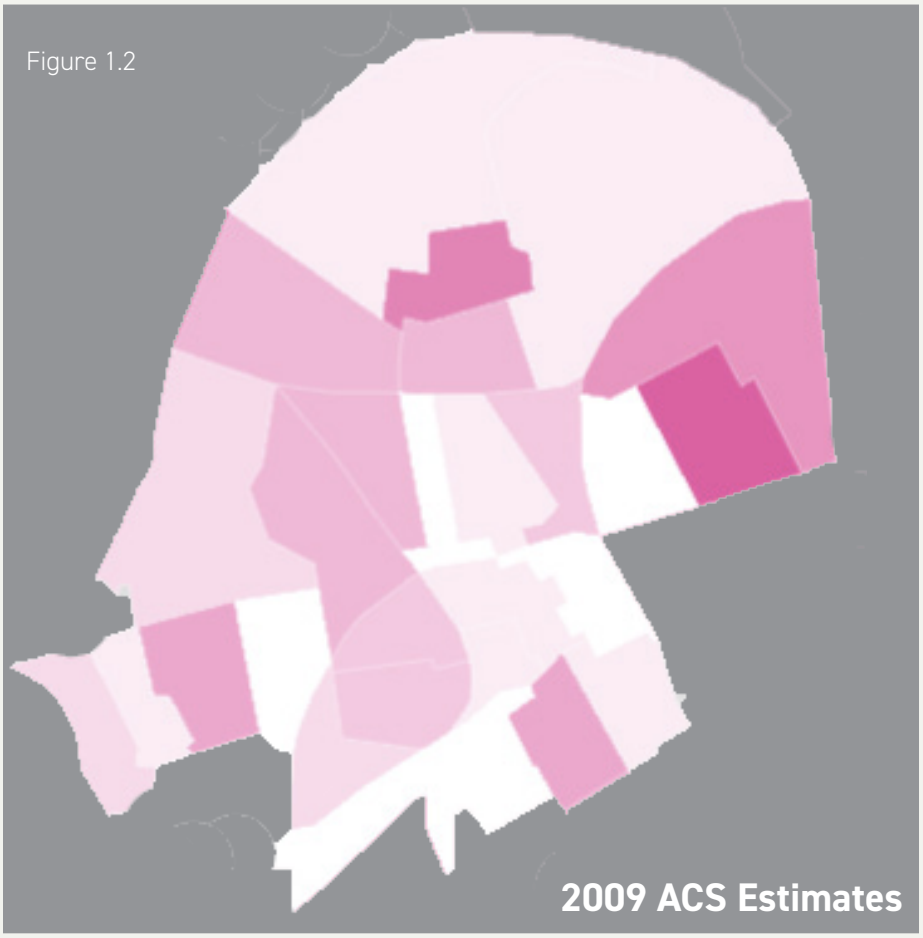
$26k
North Nashville (2016)

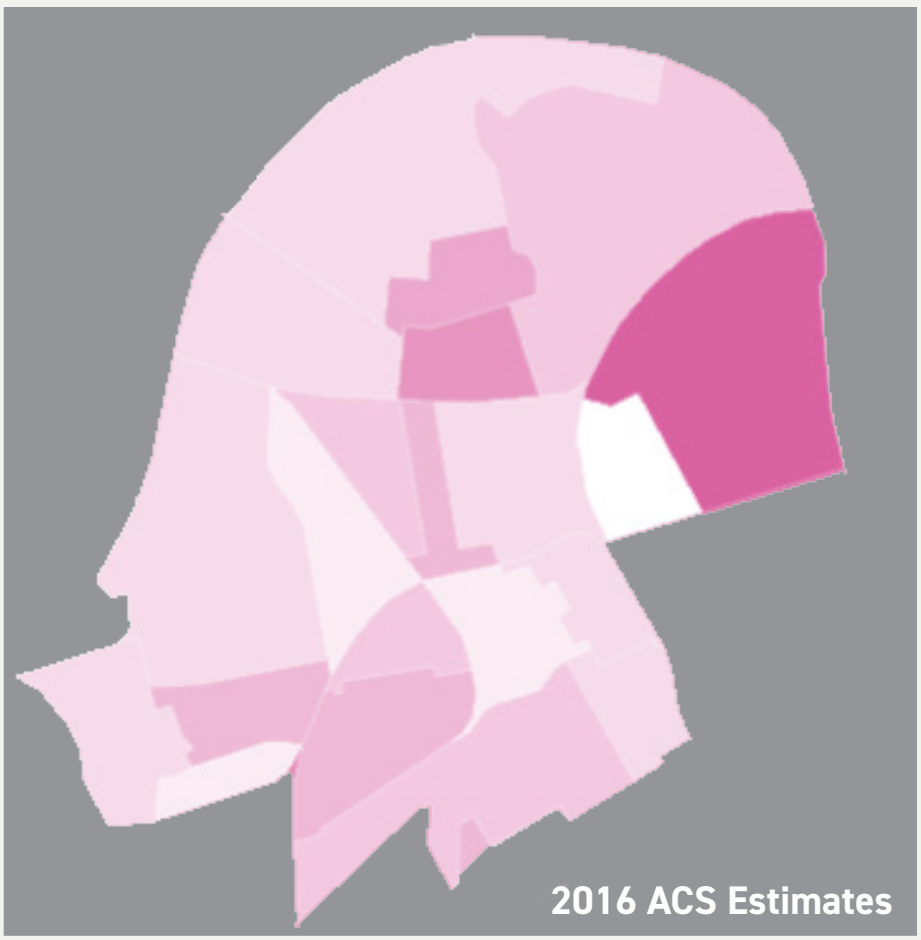
$50k
Davidson County (2016)

Median Income

Data Source: 2005-2009 ACS Estimates and 2012-2016 ACS Estimates

Figure 1.2





MEDIAN INCOME

by Census Block Group

While median income has increased in North Nashville between 2005-2009 and 2012-2016 ACS Estimates overall, the distribution of income across the neighborhood has also shifted. Higher incomes are concentrated in Germantown while block groups with incomes of $15,000 or less are fewer in 2016 than 2009.

< $15,000

$45,000

> $100,000

Race

Historically, North Nashville has been the city's African-American hub and has a higher concentration of Black residents relative to Davidson County overall. However, this share has been dropping over time. 2005-2009 ACS estimates that 92.7 percent of North Nashville's residents were Black as opposed to just 79.5 percent in the 2012-2016 estimates. On the other hand, the share of residents identifying as non-Hispanic White went up from 5.7 percent to 17 percent.

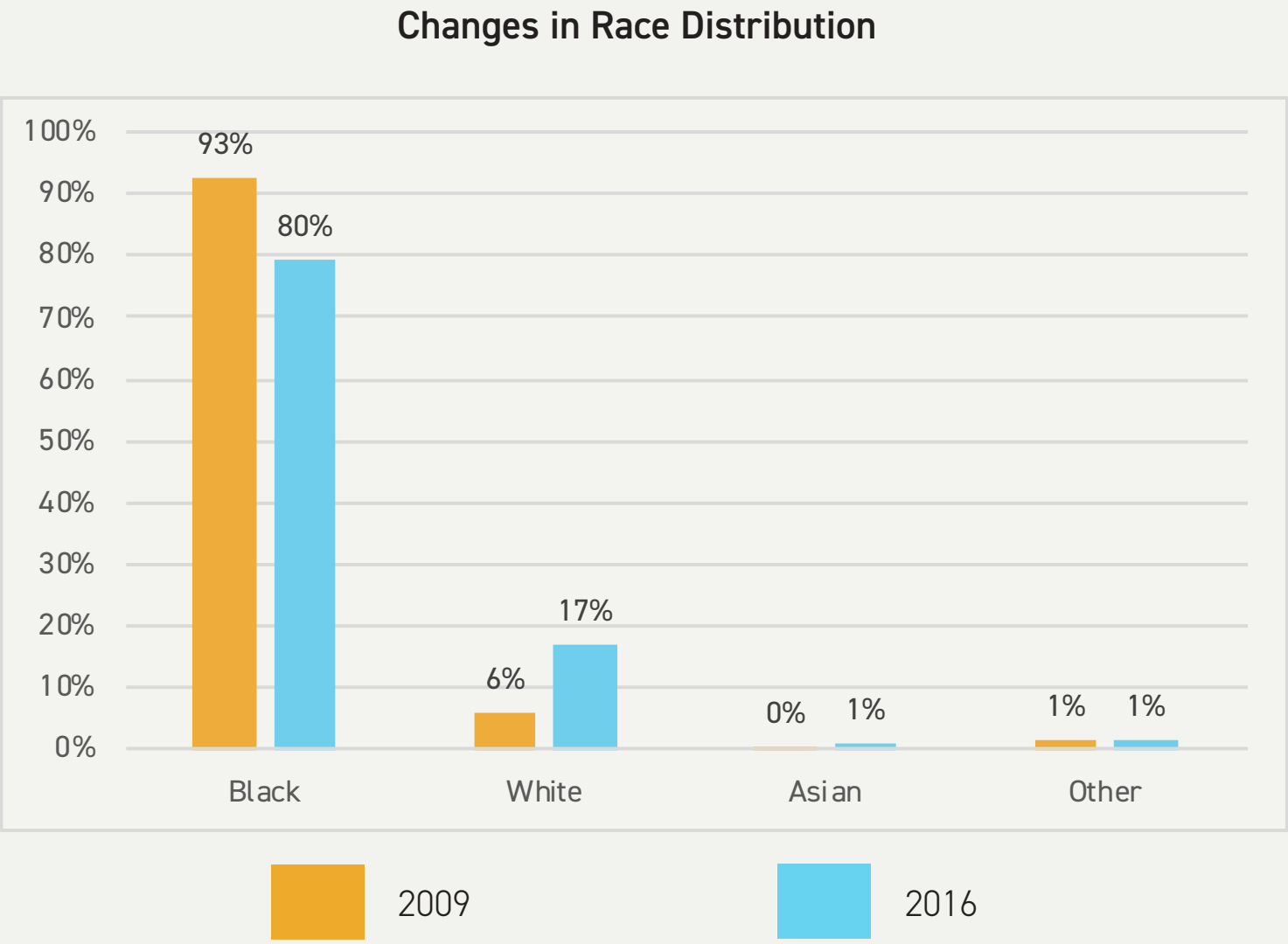


Figure 1.3

Data Source: 2005-2009 ACS Estimates and 2012-2016 ACS Estimates

Racial Distribution in Davidson County and North Nashville

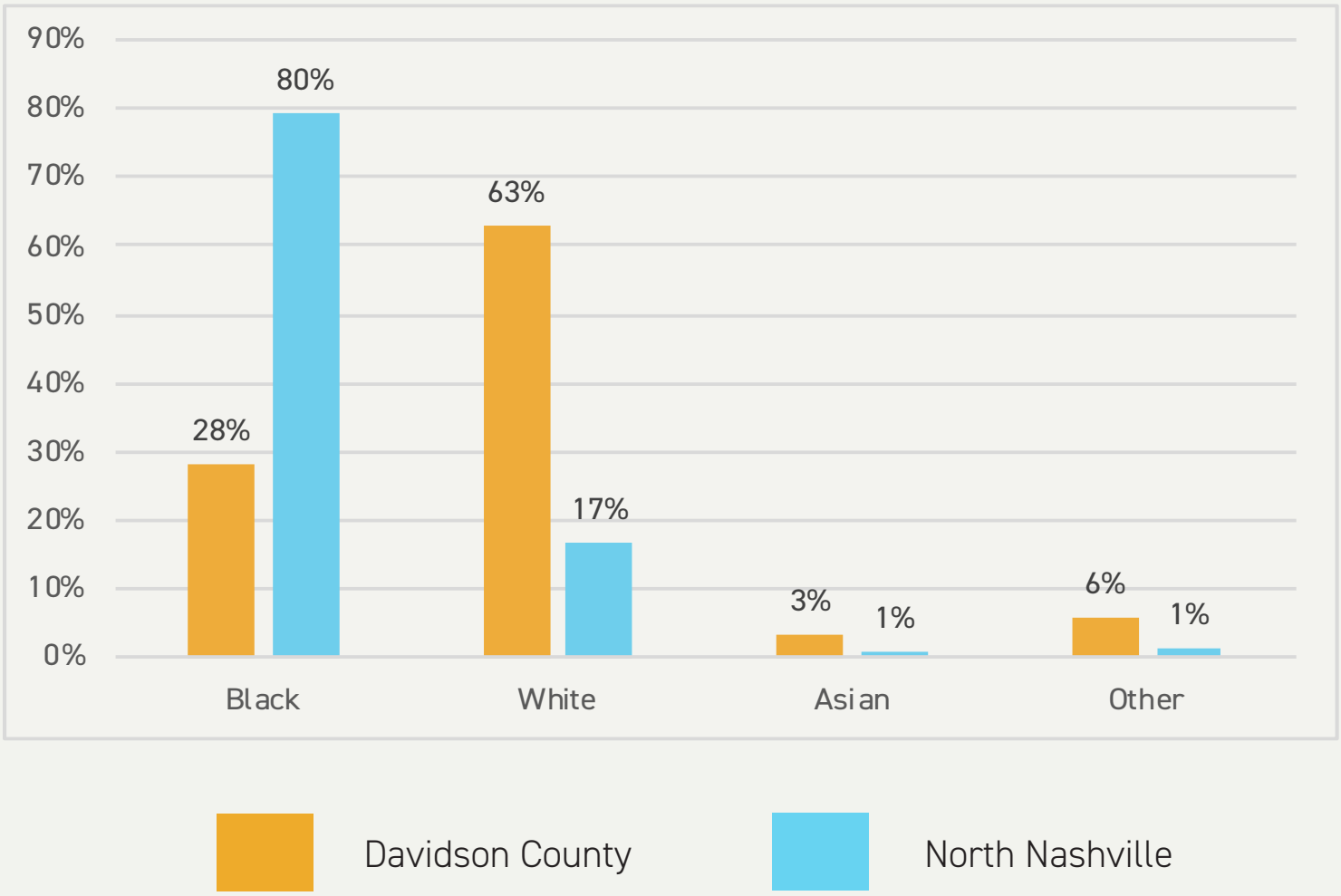


Figure 1.4

Data Source: 2005-2009 ACS Estimates and 2012-2016 ACS Estimates

HOUSING AND DEVELOPMENT

Just under 400 new housing units were built between 2009 and 2016 according to ACS estimates, for a total of 9,829 units in the neighborhood. Nearly three-quarters of these are occupied by renters, up from 68.8 percent seven years ago. The proportion of homeowners in the neighborhood declined equivalently, from 31.2 percent to 26.7 percent. In the same time period, rents and home values saw 27.5 and 30.4 percent increases, respectively. The map below (figure 1.7) illustrates the dramatic increases in median gross rents across North Nashville from 2009 to 2016. This is a significant shift considering the large share of renters in the neighborhood. Also notable, 829 of 1,258 total vacant properties in the neighborhood are neither for sale nor for rent, suggesting there may be blight in the area.

Permits and New Construction

The following table (figure 1.5) shows the aggregated value of all construction permits issued in North Nashville between 2015 through present day. The value of permits issued in the area of the neighborhood directly north of downtown is greater than those for all other areas combined. The value of permits issued in North Nashville accounted for just 4 percent of the total for Davidson County.

It is also worth noting that the total value of permits issued in North Nashville has steadily increased over the past three years. In 2015, 506 permits totalling $203.6 million in value were issued with an average value of $402,390. In 2016, these numbers grew to 797 permits valued at $326 million averaging $409,238. Data from 2017 indicates that permit values are on an upward trajectory, with a total of 828 issues with a combined value of $446.5 million and an average value of $539,250.

Permit Values (2015 to present)

	Total Value
North Nashville	$40,343,585
Metrocenter	$143,655,348
Fisk/Meharry	$29,029,056
Germantown	$263,302,019

Figure 1.5

Data Source: 2005-2009 ACS Estimates and 2012-2016 ACS Estimates, Nashville Open Data

HOUSING CHARACTERISTICS

Figure 1.6

Total Housing Units

North Nashville	Davidson County
9,829	294,794

Proportion of Homeowners

North Nashville	Davidson County
26.7%	53.4%

Median Home Value

North Nashville	Davidson County
$116k	$177k

Median Gross Rent

North Nashville	Davidson County
$719	$904

North Nashville Vacancies

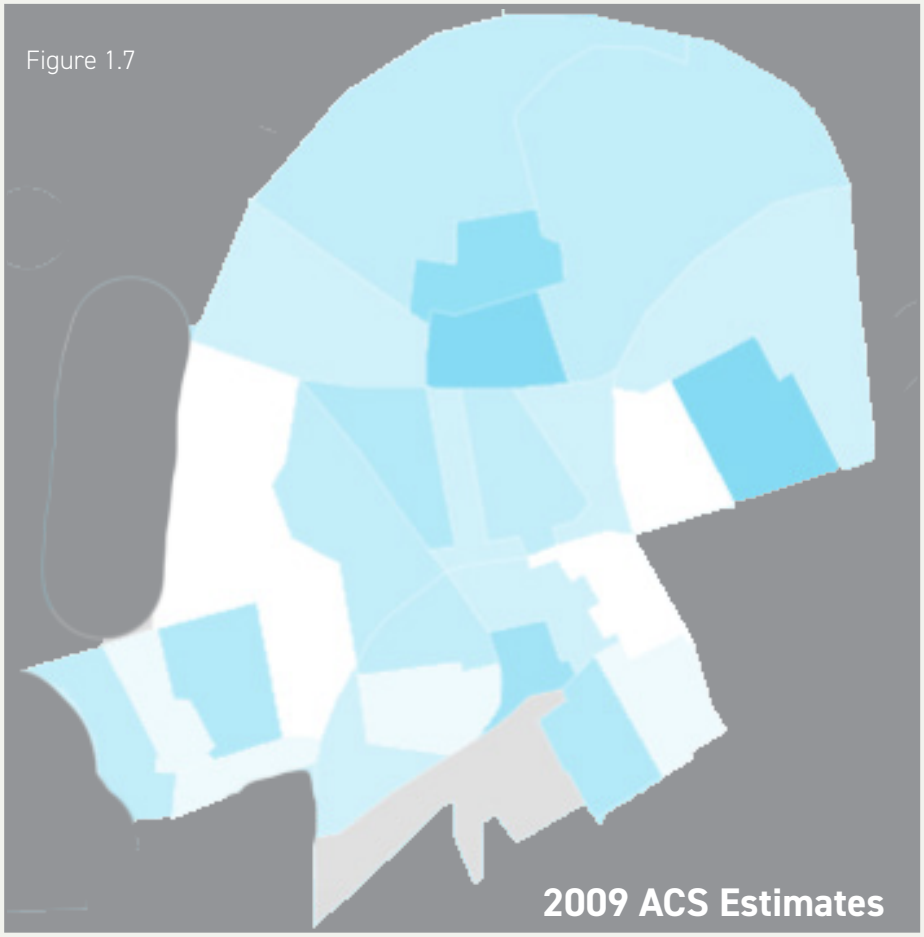
For Rent	For Sale	Other
21%	14%	65%

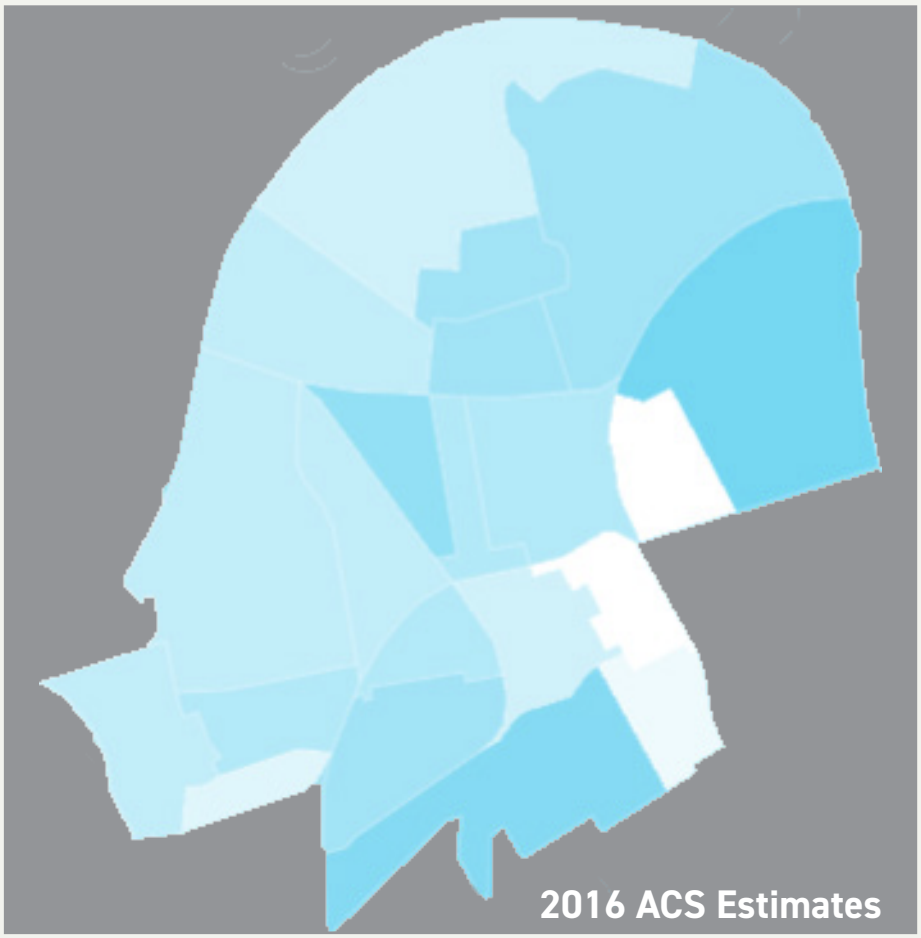
MEDIAN GROSS RENTS

by Census Block Group

Median gross rent in North Nashville was estimated at $536 per month as of 2005-2009 ACS Estimates. This number grew 34.14 percent to $719 according to 2012-2016 ACS Estimates. According to the two enclosed maps, the largest increases are visible in Germantown and the areas around the Cumberland River and central North Nashville.

Figure 1.7





< $350

$750

> $1,500

TRANSPORTATION

Transportation to Work

Mode choice has remained consistent between 2009 and 2016 in North Nashville with about 68 percent of residents choosing to drive to work alone. There was a 1 percent uptick in transit ridership between years, from 8 to 9 percent but this is not a statistically significant difference. The share of residents walking to work has in fact changed the most out of all the modes, dropping from 7.2 percent in 2009 to 4.4 percent in 2016.

Still, the percentage of people in North Nashville making use of alternative transportation modes to commute remains higher than in Davidson County overall, where just 2 percent of residents walk or take transit. This is possibly attributable to the fact that transit dependency is higher in the neighborhood, where nearly 30 percent of residents do not have access to a vehicle. While down from 35 percent in 2009, this figure remains much higher than the transit dependency rate for Davidson County which stands at 13 percent as of 2016. North Nashville residents also have a shorter average commute time than Davidson County overall, at 15 minutes compared to 24 minutes.

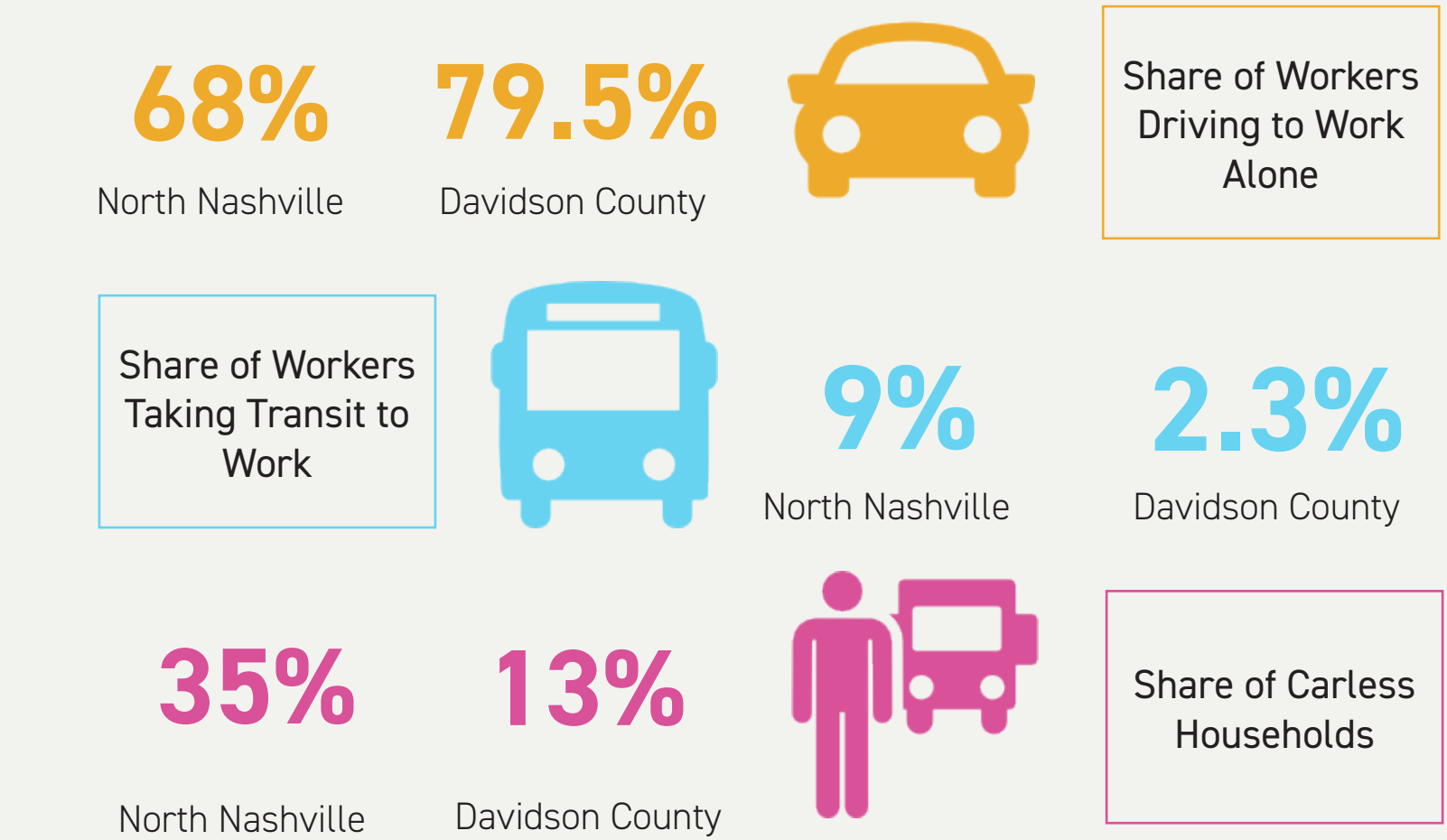


Figure 1.8

Current State of Transit

There are a number of MTA bus lines that currently service North Nashville. Route 9 runs only during the week at headways of 10 to 25 minutes, originating in Downtown then going straight through Germantown to loop around MetroCenter. Route 21 connects North Nashville to six universities in Davidson County, with stops at North Nashville's own Tennessee State University and Meharry Medical College. This route runs every 40 to 60 minutes on weekdays, and hourly on weekends. Route 22, a frequent transit network route operating every 15 minutes on weekdays and every 20 minutes on weekends, connects Bordeaux to Downtown by running along Buchanan and Clarksville Pike in North Nashville. Operating at headways of 30 to 60 minutes on weekdays and hourly on weekends, Route 42 loops around North Nashville before ending at the Farmer's Market. Route 42 thus serves as the neighborhood's most comprehensive connection to Downtown. Finally, Route 60, a free service that operates between Tennessee State University and Downtown, has headways of 15 minutes on weekdays and 20 minutes on weekends.

Route	Weekday Peak Headway	Origin	Destination	Additional Information
9 MetroCenter	10 to 25 minutes	Downtown through Germantown	MetroCenter loop	No service on weekends or holidays
21 University Connector	40-60 minutes	Kroger near The Mall at Green Hills	25th and Clarksville Pike	Stops at Belmont, Fisk, Lipscomb, Meharry Medical, TSU, and Vanderbilt
22 Bordeaux	15 minutes	Downtown then Buchanan and Clarksville Pike	Loops around Bordeaux	Goes to Temple Baptist Church Park & Ride
42 St. Cecelia/ Cumberland	30-60 minutes	Farmer's Market	Loops through all North Nashville before returning to downtown	Main connector of the neighborhood to Downtown
60 Music City Blue Circuit	15 minutes	Bicentennial Mall	TSU	Free service

INFRASTRUCTURE

Relative to Davidson County as a whole, North Nashville has more greenways, bike lanes, and sidewalks on a per-mile basis when compared to road length. For every one mile of road in North Nashville, the neighborhood has 0.07 miles of greenways, 1.23 miles of sidewalks, and 0.2 miles of bike lanes. For comparison, Davidson County has 0.06, 0.28, and 0.1 miles of greenways, sidewalks, and bike lanes respectively.

0.07mi North Nashville

0.06mi Davidson County

Miles of Greenway: Miles of Road

Miles of Sidewalk: Miles of Road

1.23mi North Nashville

0.28mi Davidson County

0.2mi North Nashville

0.1mi Davidson County

Miles of Bike Lanes: Miles of Road

EXISTING REPORTS

The Metro Government of Nashville and Davidson County has created several plans focusing on North Nashville, transportation, and equity. This report seeks to build on them.

Every Place Counts
Every Place Counts is a report that emerged from a USDOT challenge to empower residents and local leaders to draft strategies for revitalizing the Jefferson Street Corridor. The two-day envisioning process resulted in stakeholders agreeing on Jefferson Street's function as a connector of North Nashville's minority neighborhoods, a cultural and mixed-income center, and a site for improved pedestrian and bicycle infrastructure. The report also urges TDOT to explore the feasibility of capping I-40 to reconnect the historic street grid and create green space in the area.

Health Equity in Nashville
The Health Equity report compiles articles and research in order to understand Nashville's public health challenges and advance work towards eliminating health inequity throughout the city. The report highlights North Nashville's history of decline following the construction of I-40 as well as the higher rates of asthma, diabetes, and heart disease among other illnesses. The report's multiple health vulnerability indexes identify an North Nashville as an area of concern.

Partnering for an Equitable and Inclusive Nashville
This report from 2013 was written to inform the recommendations in Nashville Next. The report describes North Nashville's history as a cultural and economic hub for Black Nashvillians and subsequent decline from highway construction. Improvements to public transportation are also highlighted as a priority for the city, as residents identified as socially vulnerable repeatedly mentioned lack of access to reliable transportation as a barrier to employment.

Nashville Next/North Nashville Community Plan
The most recent community plan for North Nashville identifies environmental protection, infill development, and building out a complete transit network as priorities for the neighborhood while preserving the area's historic character. The plan also identifies High Capacity Corridors as candidates for bus rapid transit and improved pedestrian and bicycle facilities over time.

SECTION 2

EQUITY FRAMEWORK

HOW DO LET'S MOVE STAKEHOLDERS CONCEPTUALIZE EQUITY?

INTRODUCTION

Nashville Next names supporting neglected communities and improving opportunities for low-income households as goals for an improved transit network for the city. This section draws from interviews with key Metro government staff, North Nashville community members, civil society, existing reports, and academic literature to create a set of transportation equity goals for the city, all stemming from a single research question of how do transportation professionals and local leaders in Nashville conceptualize transit equity?

Transit equity seeks to define and evaluate public transportation's effectiveness at serving all populations, particularly older adults, low-income people, individuals with disabilities, and others who likely depend on public transit. MTA and other Metro agencies formally incorporate equity considerations into their work. The MTA's Title VI program and the Nashville Area MPO's application of vulnerability indexes to areas throughout Middle Tennessee are strong examples of the inclusion of equity principles in existing plans. The topics and themes highlighted in this section seek to inform efforts to expand this work.

In interviews conducted with officials from the MTA, Metro Health, Planning, Public Works, and the Mayor's Office, many themes about the conception and operationalization of transportation equity emerged. They are categorized and reported in this section.

METHODS

This section is intended to act as a single-case study narrowed in scope to Metro government employees, public officials, and civil society representatives involved in transportation work in North Nashville. This sample provides a snapshot of transportation and equity priorities as well as ongoing work specific to the area.

Nonprobability sampling methods developed the sample reflected in this study. Nashville MTA contacts served as the initial sample and we then relied on the "snowball effect" to connect with additional individuals who could provide insight on the issues of interest. The majority of individuals interviewed are employees of local or state-level government agencies such as MTA, Metro Planning, Public Works, Metro Health, and the Mayor's Office. We also interviewed representatives of business, environmental, and social justice-focused nonprofits operating both in

North Nashville and the Middle Tennessee region at large, including the regional Chamber of Commerce, Jefferson United Merchants Partnership (JUMP), the Harpeth River Watershed Council, and Nashville Organized for Action and Hope (NOAH). Many respondents referred us to other organizations and information sources, reports, and other individuals to contact for this study. Our research team conducted all interviews during the summer of 2017, primarily in May 2017, in Nashville, Brentwood, or remotely over the phone. Each interview lasted approximately 30 to 45 minutes.

To ensure rigor in this study, we triangulated the data by conducting multiple interviews using similar protocols. After each interview, we identified areas for which we may want to find further or discrepant information and incorporated those topics into future protocols. For example, displacement and affordability were topics brought up organically in the first few interviews and therefore, we asked specifically about it in remaining ones.

We recognize that the respondents in this study are, for many reasons, not representative of the North Nashville community. Each respondent held a leadership position in a nonprofit or was responsible for tasks specific to public transportation in the city. For precisely these reasons, it is not this study's intention to generalize results from the interviews to create a prescriptive policy for the neighborhood. Instead, we hope to learn how a certain cross section of Nashville's public officials and civil society actors conceptualize equity for the benefit of their own work as well as to apply towards the success of Let's Move Nashville and other relevant transportation initiatives.

To analyze the data, we first transcribed each interview and removed personal identifiers from the text. We then hand-coded all interview transcripts and analyzed the coding by grouping "families" of similar codes and then identifying themes from these groupings.

FINDINGS

The concept of transportation equity in this research was defined by an emphasis on community engagement, limitations on the existing system and infrastructure, and the role of development in limiting affordable living options in Nashville.

THEME ONE: COMMUNITY ENGAGEMENT

Most respondents mentioned the importance of collaborative planning and gathering input from North Nashville residents to the planning process. Respondents mentioned listening to the needs and requests of community members, building support and resolving conflicts through public outreach, and crafting communication strategies that reflected specific issues and experiences as ways of centering equity in transit planning.

Community Engagement: Incorporating Local Knowledge

Many respondents, particularly those working for Metro government agencies, discussed the value of local knowledge and letting neighborhood groups and residents define priorities for their own areas. Individuals interviewed articulated the idea that local people and community organizations are experts in their own right in many ways. When it came to allocating funding for projects such as greenways and bike paths, local groups are empowered to use the funding in any way they see fit. Interviewees viewed this as a key component of their jobs stating, "We try to let them decide – they know what they need in their community so we provide funding for that."

Respondents also named local organizations' unique knowledge of the communities in which they operate as an important aspect of achieving city-wide goals. Collaborations between neighborhood-based organizations and government entities had the potential to "tap into the right group[s] that can help carry the [right messages." Additionally, the inclusion of local knowledge had the potential to legitimize proposals and initiatives undertaken by Metro officials. Community engagement had generated ideas and data on what Nashville residents wanted out of an ambitious transportation plan which helped, "make a really compelling case for especially stakeholders and elected officials to be able to say...70 percent of people support a visionary, big-picture transit system.."

Community Engagement: Communication and Messaging

The need to craft compelling messages, find the right representatives to present them, and correct misperceptions were all challenges relevant to community outreach. Respondents' recollections of common misperceptions were categorized into three areas: dissatisfaction with existing service, anti-driving fears, and concern about displacement. Using the public outreach process as both a platform for communicating the right messages as well as addressing opposing ones became a prominent priority.

Community Engagement: A Means of Building Support

In discussing building support for nMotion, the predecessor of the Let's Move plan, many respondents emphasized the importance of hearing from local people and stakeholders. When asked about the success of nMotion and the relatively broad level of support it enjoyed relative to past transit proposals, "communicating with people about why you need a plan and going out to talk to neighborhood groups and engage with councilmembers" repeatedly emerged as a factor. The Every Place Counts Design Challenge, which came to Nashville in July 2016, served as an example of how community engagement could help assuage fears about displacement while also disseminating creative proposals to cap interstates and create public space. Universities, business owners, activists, and artists residing in North Nashville were involved in the process ultimately resulting in more "buy-in" from the community on the issues at hand.

However, public engagement also acted as a strategy for resolving conflicts and understanding people's doubts about the ideas being proposed. Respondents recognized that communities are hardly a monolith and public outreach events often resulted in the expression of multiple, often contradictory opinions. As one respondent remarked:

"So when you engage in that community- it's not just one community, it's a series of neighborhoods and like any community there's not consensus on anything so sometimes you'll find people who appreciative that you're there or are jaded and don't want to engage with you or sometimes you'll find people who feel that any type of improvement to the community is not for them but an attempt to gentrify and so when you approach a community you'll probably find those multiple viewpoints."

Public engagement provided a venue for understanding and potentially addressing such conflicting points of view. At the same time, some respondents expressed that inclusion alone was not sufficient if it still meant the underlying issues expressed in the process went unaddressed. Acting upon and operationalizing the information collected through public engagement is as essential of a step as initiating the process in the first place.

THEME TWO: SYSTEMS AND INFRASTRUCTURE

The systems in place allowing current and potential riders to effectively use transit were an overarching topic of conversation in these interviews. Respondents delved into the significance of mode choice and the symbolic meaning of different modes, balancing the interests of existing and future riders, and ensuring access in terms of both infrastructure and affordability as important dimensions of equity in transit planning.

Systems and Infrastructure: Modal Equity

Creating space for bicyclists and pedestrians on roads designed for cars came up as an issue of safety and mode choice in several interviews. In terms of safety, the city's Vision Zero initiative fits into a future where more people are biking. However, there is a need for "a low-stress bikeway network in the city...that's protected and separated from traffic" in order to create a sense of safety for bikers. The addition of sidewalks and pedestrian facilities similarly requires addressing safety issues while also ensuring walkability exists where there are destinations worth reaching. Respondents repeated that considering and prioritizing these non motorized modes was a priority in creating a successful transit system for Nashville.

Prioritization of certain modes of transit over others was another theme repeated across interviews. There is an enduring " idea that the bus is one form of public transportation but rail is this...elevated form of public transit." The appropriateness of bus versus rail for Nashville has been an ongoing debate, with many public officials and civil society representatives expressing the view that light rail, while modern and exciting, may not be as appropriate for Nashville as improved bus service. For instance, a proposed rail network between Clarksville and the Farmer's Market in Nashville running through North Nashville would not be an attractive route for riders looking to get to downtown.

Despite these debates about what Nashville's transit future could look like, respondents were very much aware and critical of the limitations of the city's existing transit system. The hub-and-spoke model of the current system means that most places are not connected through direct routes making trips that would take fifteen minutes by car close to an hour on transit. Limited hours of operation and long headways further inhibit the system's effectiveness:

"A lot of people want to be able to use the system later at night or earlier in the morning and across the board, especially some of these higher ridership lines, people want them to run more frequently. You know, we have the 4 BRT-lites that are running right now but we have some pretty major roads that don't have great frequency. So people are having to wait thirty, forty minutes to an hour in between buses."

Systems and Infrastructure: Ridership and Regional Equity

Attracting new riders while retaining and meeting the needs of current ones is another tension respondents reported having to navigate. Respondents most frequently used the term "equity" in relation to the question of how to strike this balance, stating in one case that, " if we're trying to cater towards tourists for example, but people who live here who need and rely on public transportation don't have a high-quality service, that's a massive failure on our part." Another respondent expressed the same concern stating, "sometimes in this atmosphere of congestion we think "oh let's convert one more car-driver into a bus-rider" but then make sure it's not at the expense of another part of the neighborhood or another community."

In addition to addressing the needs of different groups of riders, respondents frequently mentioned the need to create a system that was truly regional in its reach. Nashville serves as the major job center for the entire region, meaning that individuals who live outside the city cannot contribute to a transit system specific to Davidson County alone. Additionally, problems such as congestion and long commute times also affect those coming into Nashville from throughout the Middle Tennessee area, spurring interest in creating a solution tailored to a broader geography. As one respondent plainly stated:

"...the ideal transit system is one that is pretty comprehensive and is regional. If you don't address the regional component of transit and you just address the Davidson County corridors, you're going to have a big problem."

Systems and Infrastructure: Accessibility

Questions of multimodal transportation and regional connectivity fall under a larger theme of accessibility. This issue is especially relevant when considering that a new transit system's ability to provide low-income and marginalized communities with the means to get to otherwise inaccessible employment and educational opportunities is a key determinant of its success.

Respondents identified transportation as a key factor in "moving people out of poverty," especially in an area like North Nashville where the community still struggles with issues of chronic unemployment and a lack of economic mobility.

Accessibility is especially a challenge in light of the economic boom currently occurring in Davidson County. Due to rising property values in areas close to downtown, proposed sites for affordable housing are located in lower-density areas further away from the urban core where MTA cannot efficiently provide service. nMotion and Let's Move Nashville both propose shortened headways and longer hours of service as ways to make transit better for riders. These two improvements would be difficult, if not impossible, to implement in areas far off from important destinations. This poses a problem for transit-dependent individuals who would be isolated from amenities accessible only by automobile as a result of either displacement or a search for affordable housing.

THEME THREE: DEVELOPMENT AND AFFORDABILITY

Davidson County's enormous economic and population growth in the last decade was among the most discussed topics during these interviews. Nearly all respondents linked equity to the question of what these changes could mean for low-income and minority communities that had lived in Nashville for generations. Addressing past injustice, preventing and accounting for displacement and gentrification, and bringing in a health and environmental equity framework all figured into the conversations we had with respondents around this theme.

Development and Affordability: Historical Injustice

Many respondents commented on the splintering of North Nashville by the construction of I-40 and the distrust it brought about between community members and government. nMotion and later Let's Move became opportunities to correct these past harms and use transit as a tool to make the community whole once again. The necessity of public outreach and sound messaging as discussed in Theme One also figured into this issue. Although community engagement remains a critical component when it came to transit issues and working in North Nashville, respondents revealed the nuance in the situation given North Nashville's historical context. Ensuring equity went beyond the mere process of collecting data and local knowledge but actually translating these findings into concrete quality of life improvements:

"North Nashville is a community where it's historically been studied and studied and studied but there's been very little change."

Development and Affordability: Gentrification

Gentrification, a term often used interchangeably with development and displacement in these interviews, was among the first topics brought up in relation to equity. Respondents discussed the struggle to manage economic growth and higher property values while keeping communities intact. This effort was described as a matter of "striking a balance," where growth could continue but in a more inclusive manner. North Nashville, especially the Germantown community and the Jefferson Street corridor, has already begun to experience many of the economic and demographic changes associated with gentrification (see Section One: Neighborhood Profile for further details).

Respondents drew from anecdotal information and their professional expertise to confirm that the community was on the cusp of dramatic changes, especially in the context of transit improvements:

"Growth has been happening slowly and I think it's going to be a lot like in East Nashville where a lot of it is going to happen all at once...[the] community is preparing for it."

"You see some development but if you pull into one of the neighborhood streets... home after home is being torn down and rebuilt and...so I think that change is occurring as we speak."

"There's a desire within the city to make sure we're not overlooking these areas [and] trying to improve the streetscaping, making it more comfortable for people to walk and bike and take the bus. But we also know that then highlights the area as like "hey, this is a place where you can, you know, come in and redevelopment can occur pretty quickly."

"It's already happening on Buchanan Street... there's a number of common "hipster" things over there that are there that are different from what was there. Like, traditionally it's been an African-American community, you had churches, funeral homes...diners, music halls and that declined over the years. Buchanan particularly was pretty vacant until it became an affordable place for these folks to build their business. And from there we've seen, I think, other residential development occur behind it."

"...[When] you go in as the city you're doing something to improve the area, it immediately gets different folks who are attracted to the area."

However, many respondents expressed optimism that growth in Nashville could still be inclusive, without the displacement that often accompanies such trends:

"Gentrification formally is a matter of displacement but Nashville is uniquely situated that displacement doesn't necessarily need to happen. Redevelopment and revitalization can be experienced along with growth and financial strength of the city at large but it has to be intentional and deliberate."

The importance of being "intentional and deliberate" was another common goal touched upon by respondents. Many tied the transit plan's success and overall sustainability to its ability to be inclusive and limit the likelihood of displacement:

"If you displace people, you are not going to achieve sustainability because you're still going to have lots of carbon being emitted for those people trying to travel and trying to serve them and maybe they're displaced into poorly built housing stock..."

"[If] we do make a greenway investment or a rail link line investment, making sure that the housing stock and policy is coordinated for that so there are opportunities for people of limited means to live along and have access to those investments because otherwise what is the point? You're still going to create sprawl ...because then you're just displacing people out into the suburbs and they don't have access to transportation and social services and that sort of thing."

Despite these objectives, many respondents expressed the opposing viewpoint, suggesting that gentrification in North Nashville was already a cause for concern, and perhaps even inevitable, because of its recent acceleration:

"[The] whole area has been overlooked for a number of years. But it's so close to Nashville, like downtown, I have a feeling that the ship has sailed on that and it's probably going to be gentrified . Just for mostly its proximity."

"Over the years, [Nashville has] been pretty affordable and probably hasn't been completely out-of-whack compared to what we've seen the last ten to twenty years. And so Nashville was once really affordable and it is no longer anywhere close to that anymore. Particularly not in the last five years."

These discrepant viewpoints point to the importance of continuing policies and efforts to manage displacement while also planning ahead for scenarios where transit-dependant and vulnerable populations are more dispersed.

Development and Affordability: Health Equity

The transit and multimodal infrastructure improvements proposed under both Let's Move and Nashville Next have health and environmental dimensions in addition to accessibility and safety ones. While air quality and environmental improvements were peripheral benefits associated with a comprehensive transit system, many respondents identified the public health benefits to be gained from the implementation of nMotion or Let's Move. These benefits spanned from the alleviation of long-term health concerns such as obesity all the way to the use of transit for purposes such as moving people out of extreme weather conditions.

"The Cold Weather Program... works with the homeless population and [brings] them out of the cold and [brings] them where they need to be any time they have an extreme weather day."

"Obesity, physical activity, would be the two most related to built environment. Substance use is another one... those are the ones where built environment [matters most] because they're interrelated."

"If you build these systems, if you complete your streets, if you have these policies in effect, people's lives are better in a lot of ways. They're better economically, they're better from a health perspective...that triple bottom line perspective plays into this always...[and] the city as a whole is starting to look at every endeavor and every effort from the perspective of the triple bottom line."

WHERE DO WE GO FROM HERE?

The themes and findings highlighted in this section informed much of the technical research carried out in the next three sections. Hearing directly from Metro government staff and local leaders in North Nashville enabled our research team to identify areas and issues of interest to stakeholders in the community. Our economic analysis draws upon many of the themes touched upon in the accessibility section of these interviews specifically to assess the ways in which Let's Move Nashville, higher ridership, and shorter headways will change employment prospects for North Nashville residents.

Additionally, much of the interview content on health equity allowed us to determine meaningful applications of our findings around pollutants and greenhouse gas emissions, discussed more extensively in Section Four. Perhaps most significantly, the themes and issue areas as laid out in this section provided much of the basis for constructing the Transit Sustainability Index presented in Section Five synthesizing may aspects of transit performance designated valuable by the MTA.

SECTION 3

EMPLOYMENT & ACCESSIBILITY

MEASURING TRANSIT'S EFFECTS ON RESIDENTS' EMPLOYMENT OPPORTUNITIES

INTRODUCTION

An Overview of Employment Accessibility Analyses

Before discussing employment accessibility analyses, "accessibility" must be defined. Though many definitions of accessibility exist within the literature, a commonly accepted and easily understood definition states that, "Accessibility is a product of mobility and proximity, enhanced by either increasing the speed of getting between point A and point B (mobility), or by bringing points A and B closer together (proximity), or some combination thereof" (Cervero, 2005). Thus, an employment accessibility analysis should evaluate both of these aspects of mobility.

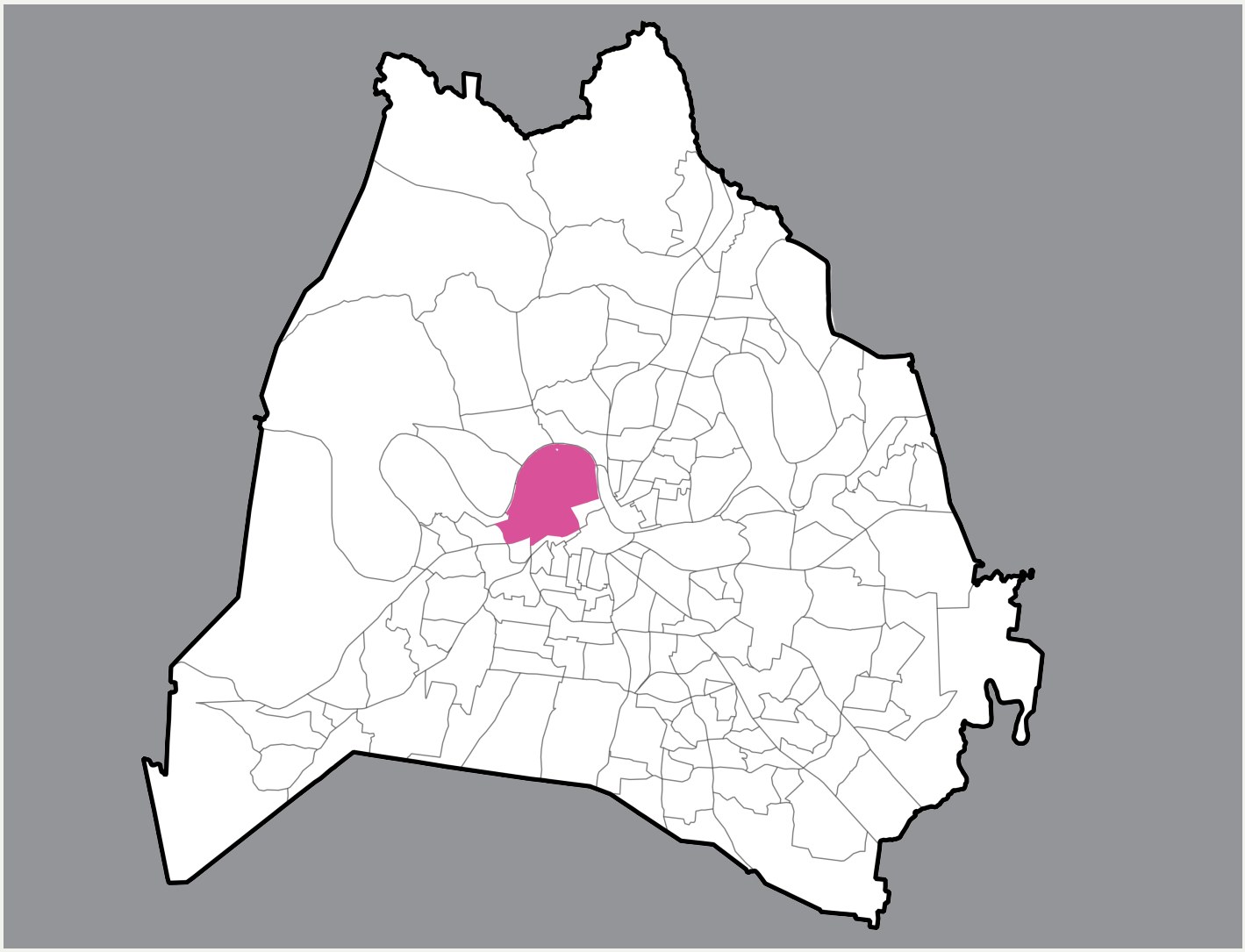
Researchers have created many ways to evaluate employment accessibility. Some measures attempt to quantify the benefit of proximity versus mobility in what are known as gravity-based measures by using complex mathematical equations and estimations of coefficients to represent demand and influence. However, the literature finds that people are less sensitive to questions of mobility versus proximity when considering commuting trips (Cervero, 2005). Instead people care about overall accessibility; in other words, they will ask, "Can I simply reach the potential work location?"

Knowing that people care less about the details of their accessibility when considering employment opportunities and with the expectation that the results in this report will be communicated primarily to policymakers and the general public, this study instead chooses to use an isochronic measure of employment accessibility. Isochronic measures, also known as cumulative opportunity measures, count the number of opportunities accessible within various travel time or distance thresholds (Cervero, 2005). Results of isochronic measures of employment accessibility are easy to communicate, to interpret, and to display visually. These measures are also the easiest for Nashville stakeholders to replicate if they so choose.

Since people commonly think of their commute in terms of the time the travel takes as opposed to the distance they travel, this report evaluates employment accessibility using an isochronic measure that determines the number of employment opportunities accessible within different commute time thresholds.

METHODS

The methodology for this analysis builds upon the data outputs of the Nashville Area Metropolitan Planning Organization's activity-based model. Since Let's Move Nashville is exclusive to Davidson County, model outputs were trimmed down to only those traffic analysis zones (TAZs) within Davidson County. These TAZs serve as the base unit for data model outputs, and are tied to specific geographic locations within the county.



North Nashville TAZs within Davidson County TAZs

Figure 3.1

Model outputs include what are called "transit skims." These skim files contain estimates of the travel time by transit between each set of TAZs, broken into a number of travel time components. These components are:

- Access walk time
- Initial wait time
- In-vehicle time
- Transfer walk time
- Transfer wait time
- Transfer penalty time
- Egress walk time

Travel time components can then be aggregated to obtain a total transit travel time between two TAZs.

Since this report focuses on North Nashville residents' access to employment, the 55 North Nashville TAZs were used as the origins for commute time estimates. Potential destinations for each North Nashville TAZ included all 1,265 Davidson County TAZs, resulting in 69,575 origin-destination pairs. Once the total transit travel time for each pair was extrapolated from the data, the Davidson County TAZs were divided by total transit travel time among the thresholds established for this employment accessibility analysis: 15 minutes or less, 30 minutes or less, 45 minutes or less, 60 minutes or less, and more than 60 minutes.

The MPO model's data output includes a predicted number of employment opportunities by TAZ. Thus, the connection can be made between travel time thresholds and number of employment opportunities accessible. Since the complete list of origin-destination pairs includes each Davidson County TAZ multiple times, and thus the employment numbers associated with that TAZ multiple times, a new dataset was created with only one copy of each Davidson County TAZ. This ensured that no employment opportunities were counted more than once in the final results. In this final dataset, each Davidson County TAZ was assigned the shortest total transit travel time possible from a North Nashville TAZ origin, then sorted into the appropriate time threshold. The employment opportunities associated with each Davidson County TAZ were thereby sorted into the various time thresholds as well, producing this report's final measure of employment accessibility. (A more in-depth illustration of the steps taken to perform the employment accessibility analysis can be found in Appendix A.)

Since transit travel times vary by time of day due to traffic, route frequencies, and transit hours of operation, the "transit skims" mentioned above are created for four different times of day: AM, midday, PM, and off-peak. Due to time constraints, the analyses within this report focus on AM commute times, since this is the most common time for commutes from home to work, and off-peak commute times, since interviews for this study revealed that many residents of North Nashville work third shifts or other non-traditional hours.

FINDINGS

Jobs Accessible by Transit

AM Commute Times

	15 Min	30 Min	45 Min	60 Min
2017	70,438	193,481	275,413	381,945
2033- BAU	71,625	181,705	338,391	455,124
2033- Let's Move	109,575	291,838	462,713	557,798

Figure 3.2

Off-Peak Commute Times

	15 Min	30 Min	45 Min	60 Min
2017	70,152	132,896	215,561	313,517
2033- BAU	68,981	131,954	256,148	380,220
2033- Let's Move	100,810	227,831	414,218	523,549

Figure 3.3

From the above results, it can be concluded that implementation of Let's Move Nashville would increase employment accessibility for North Nashvillians compared to the both the status quo and 2033 assuming business-as-usual practices continue. In fact, gains are made in every time threshold of AM commutes and in every time threshold of off-peak commutes.

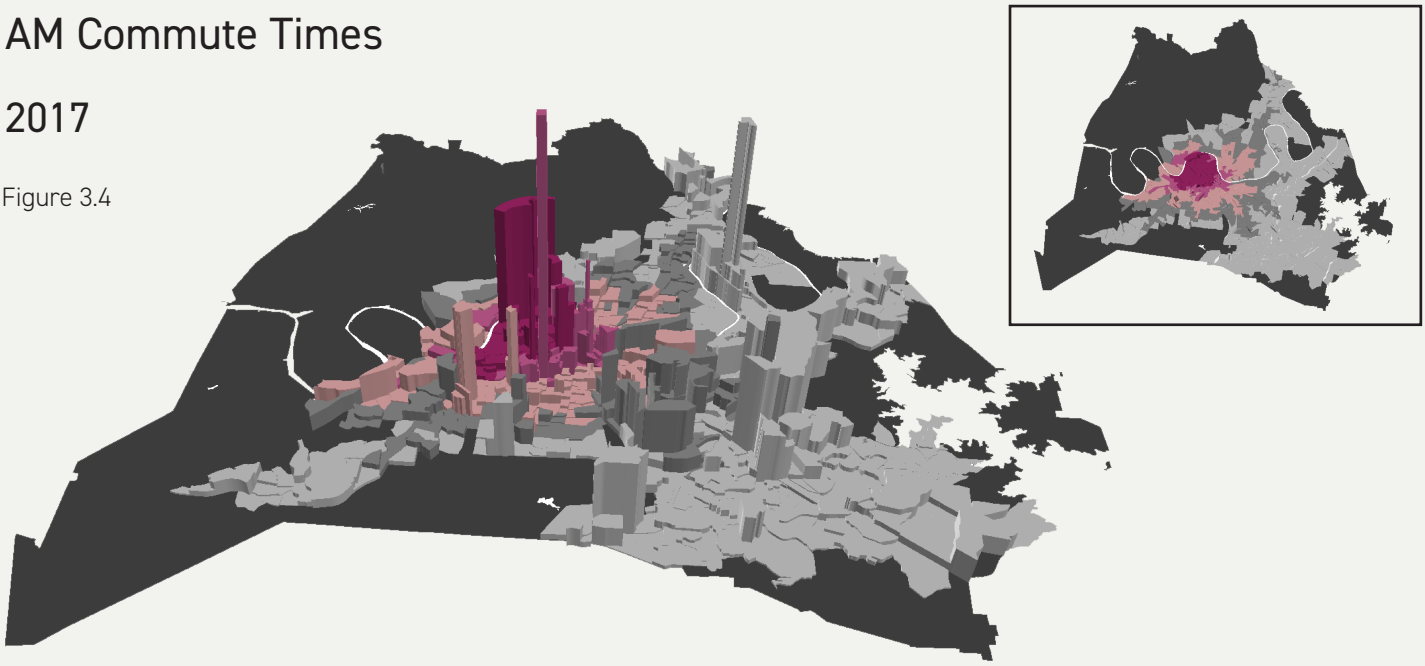
FINDINGS VISUALIZED

The maps (figures 3.4 to 3.9) display a more detailed view of these employment accessibility results by mapping the travel time threshold extents and the magnitude of employment opportunities accessible in each scenario. For context, the highest TAZ employment bar in each scenario (it is the same across the scenarios) represents 15,898 employment opportunities.

AM Commute Times

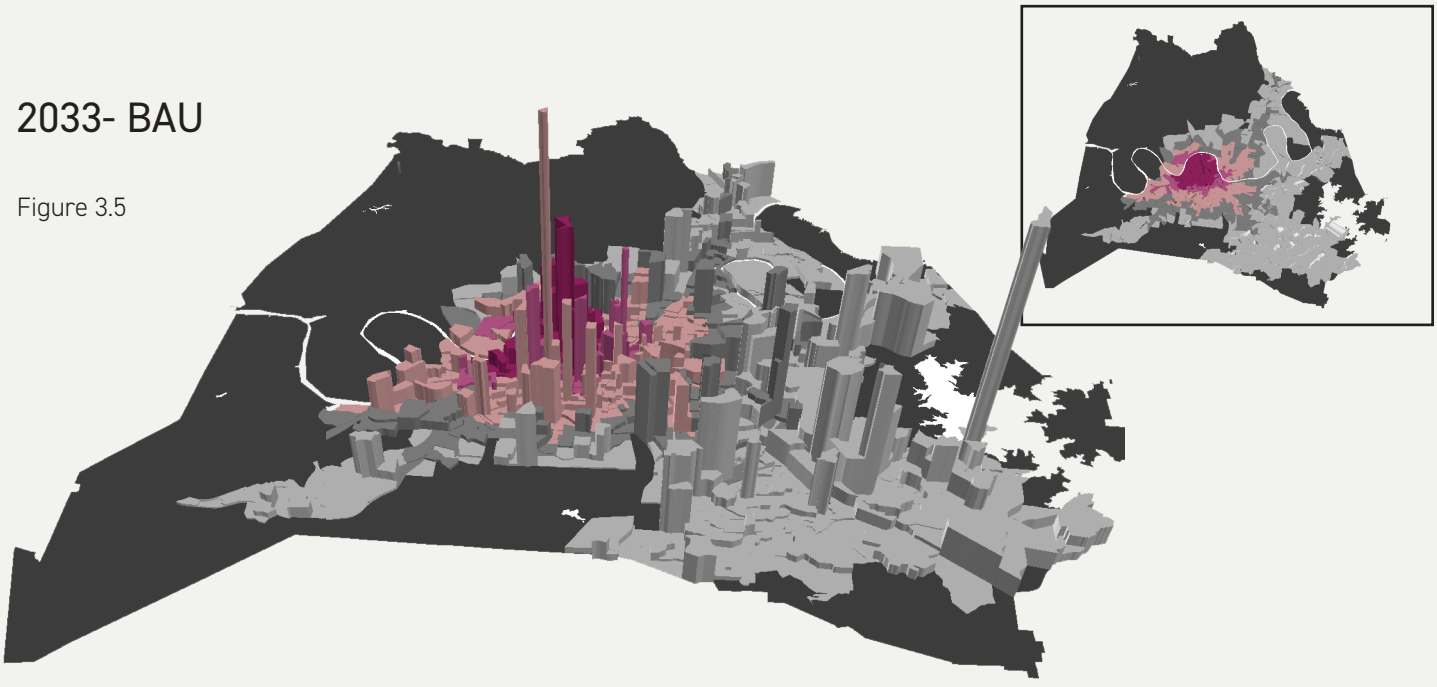
2017

Figure 3.4



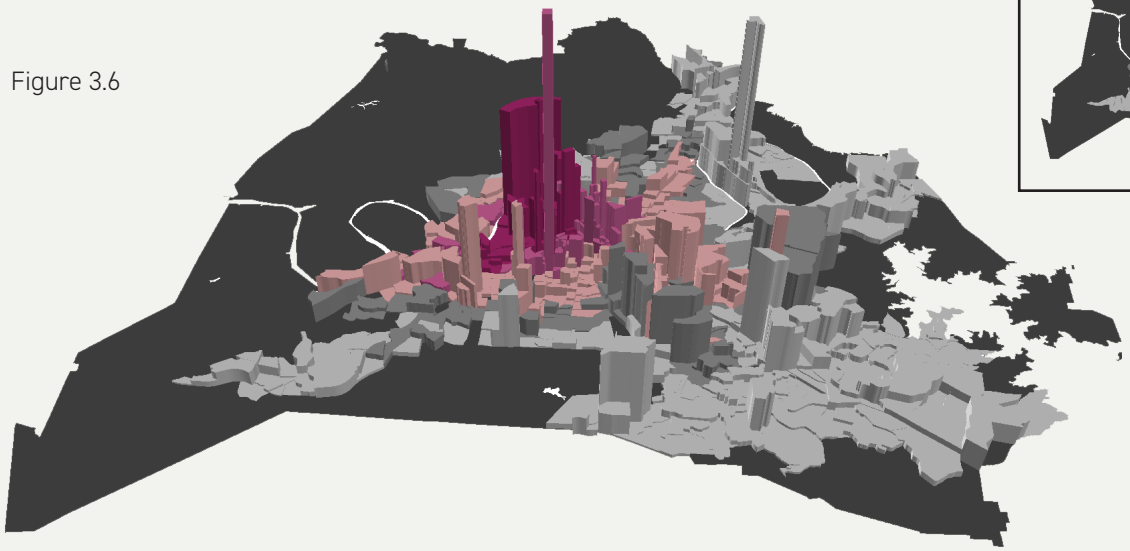
2033- BAU

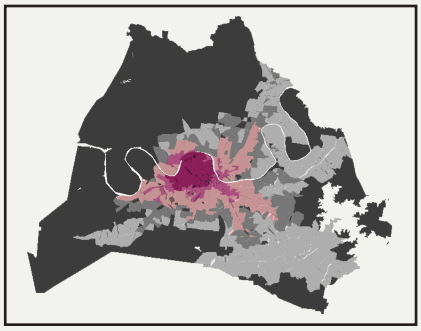
Figure 3.5



2033- LMN

Figure 3.6

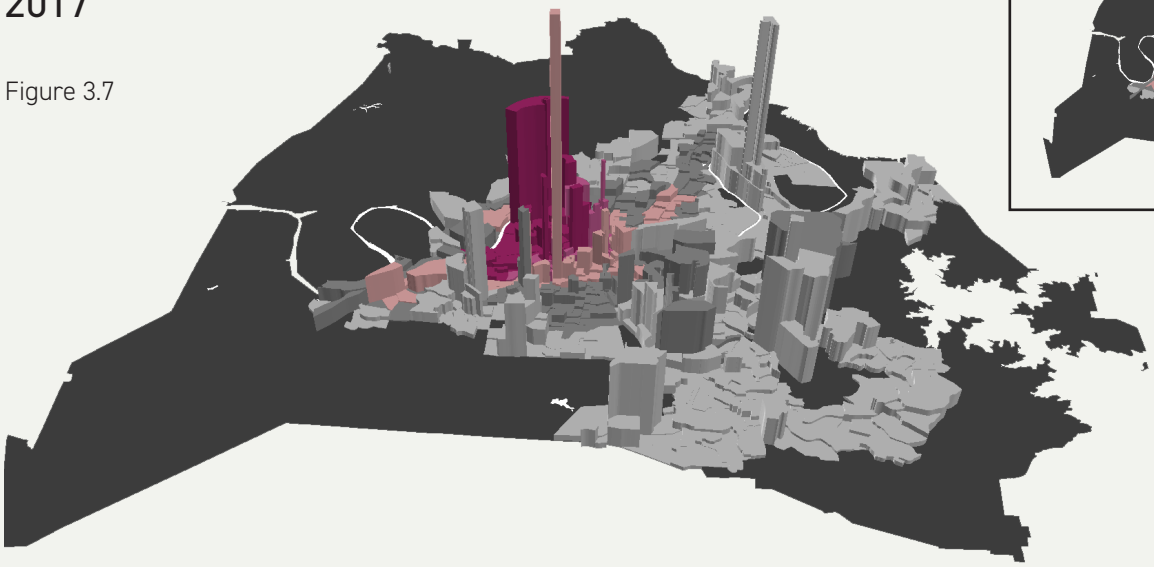


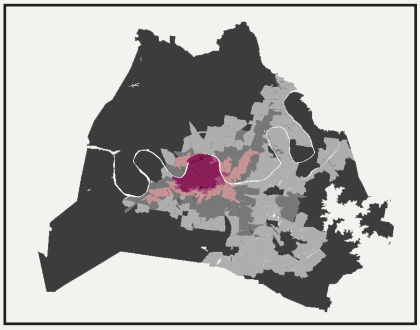


Off-Peak Commute Times

2017

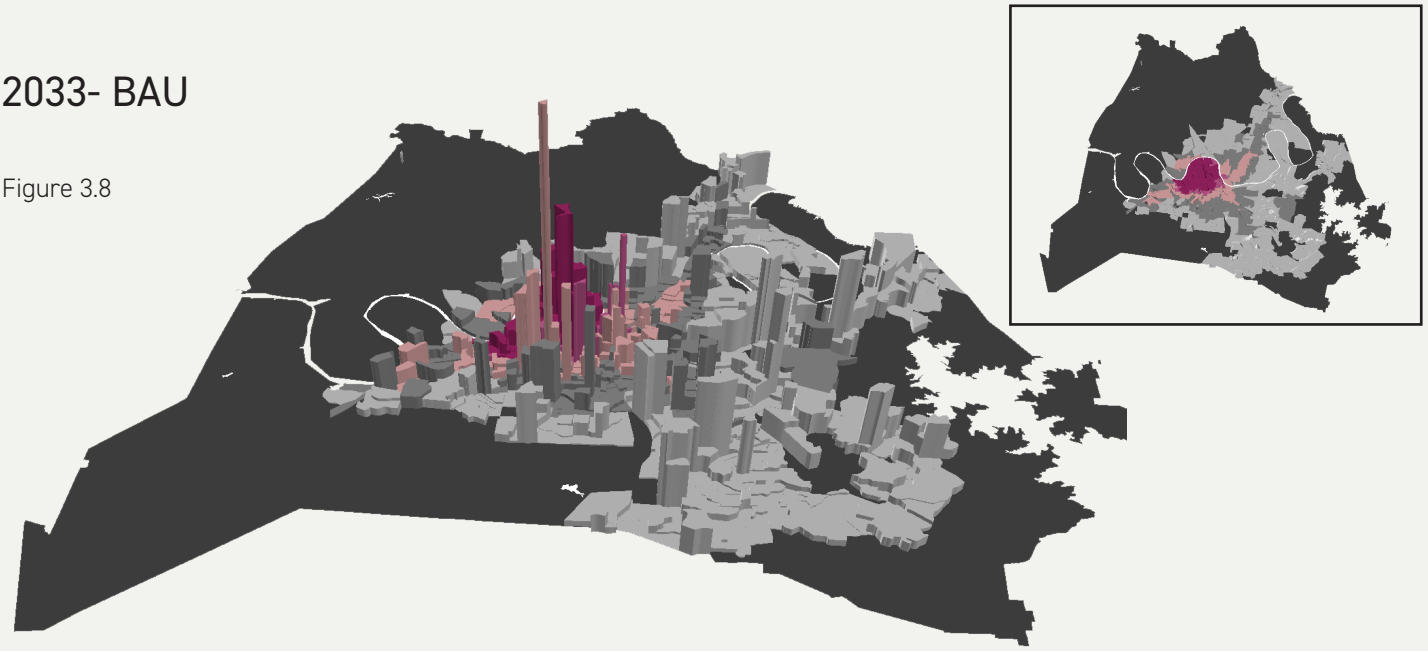
Figure 3.7





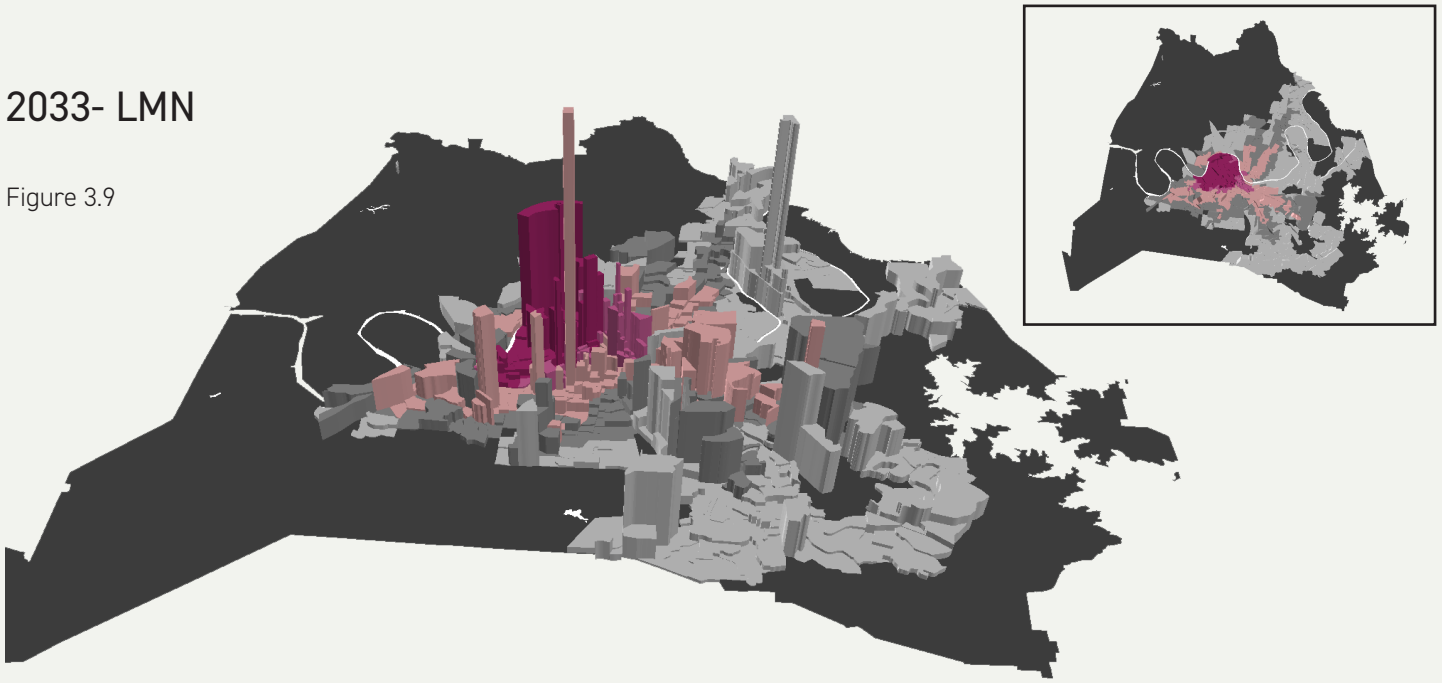
2033- BAU

Figure 3.8



2033- LMN

Figure 3.9



LIMITATIONS

While these results are encouraging, there are limitations to the above analyses. First, the employment categories generated by the MPO's model are not disaggregated enough to match level of educational attainment with likelihood of being qualified for a certain employment opportunity. As such, not all North Nashville residents will be qualified for all of the employment opportunities listed here. Second, the employment opportunities represented in this analysis are not necessarily open opportunities; that is, only a small percentage of these employment opportunities will actively be seeking applications, while the majority will already be filled.

Even with these limitations, the analysis above provides a strong illustration of the potential for Let's Move Nashville to increase employment accessibility for North Nashvillians.

SECTION 4

ENVIRONMENTAL PROJECTIONS

FOR A LIVABLE AIR AND ATMOSPHERE

INTRODUCTION

In hopes of developing a more sustainable city, the Livable Nashville Committee was formed in 2016. The draft *Livable Nashville* report, released in February 2017, provided recommended actions across 5 focus sectors: Mobility, Climate and Energy, Green Buildings, Waste Reduction and Recycling, and Natural Resources. The report recommended fundamental shifts in Nashville's mobility systems,including access to low carbon trip choices (walking, biking, transit), increasing alternative fuel vehicles, and integrating smart technology. Livable Nashville, alongside nMotion and Let's Move Nashville, further emphasized the need to reduce negative impacts of the transportation sector, particularly reducing criteria pollutants and greenhouse gas (GHG) emissions.

As in most U.S. cities, transportation is the number one source of GHGs in Nashville, higher than either commercial or residential building energy consumption. As a participant in the Covenant of Mayors, a global coalition including over 1,000 municipal leaders in 86 countries, Nashville is committed to a mission of "accelerat[ing] ambitious, measurable climate and energy initiatives that lead to an inclusive, just, low-emission and climate resilient future."

Nashville's first comprehensive greenhouse gas (GHG) inventory captured the county's total emissions in 2005. Since then, transportation has ranked as the single largest contributor (33 percent. In 2014, the transportation sector constituted 37 percent (4,986,501 metric tons) of Nashville's GHG emissions. With a growing population and a "commute into work" culture, Nashville's transportation GHGs had grown by 6.7 percent from 2005 to 2014, while the next largest contributors, commercial and residential energy use, decreased by 9.4 percent and 12.7 percent respectively.

The Let's Move Nashville plan will fundamentally change mobility in Nashville. New infrastructure, including a frequent transit network, bus rapid transit (BRT) and a highly-efficient light rail system, will have significant impact on the mobility and transportation choices of Nashville residents and visitors alike. This study captures the impacts of Let's Move Nashville on transportation sector emission and strides taken towards creating a more livable city.

KEY FINDINGS

- Increased population and travel demand results in total vehicle miles travel (VMT) growth by 1.5 billion (18 percent) from 2017 to 2033 Business-As-Usual.
- GHGs decline by 2033 under Business-As-Usual to a level ten percent lower than 2017. This reduction is due mainly to Corporate Average Fuel Economy (CAFE) standards that improve CO2e efficacy in passenger cars and trucks manufactured between 2017 and 2025 and afterward.
- Let's Move Nashville reduces GHG emissions by an additional 104,195 metric tons, or an additional two percent below 2017 levels.
- Under Let's Move Nashville, GHG emission levels drop below the 2005 baseline levels for the first time.

Peak-hour criteria pollutant emissions are also substantially reduced by 2033 Business-As-Usual (with increased CAFE standards) and further through the Let's Move Nashville. Let's Move Nashville plan criteria pollutant emissions compared to 2017 levels decrease by:

- Carbon monoxide (CO): 24 percent
- Particulate matter (PM 2.5 and PM 10): 69 percent
- Nitrogen oxides (NOx): 58 percent

Peak emissions of sulfur dioxide (SO2) continue to increase under Business-As-Usual and the Let's Move Nashville plan. However:

- Sulfur dioxide (SO2): 17 percent lower increase than Business-As-Usual

METHODS

To project greenhouse gas (GHG) and criteria air pollutant emissions, this study uses today's best practices in transportation and vehicle emissions modeling. For each scenario, changes in human population, transportation demand, congestion, mode opportunities, and changing characteristics in vehicle populations were integrated. To capture the resulting changes in GHG and criteria pollutant emissions, these changes were integrated in the Nashville MPO Activity-Based-Model and then the EPA's Mobile Vehicle Emissions Simulator (MOVES 2014a). Combining these two models, this study captures the changes in mobile road source emissions over time and between two policy approaches: Business-As-Usual and the Let's Move Nashville plan (figure 4.1).

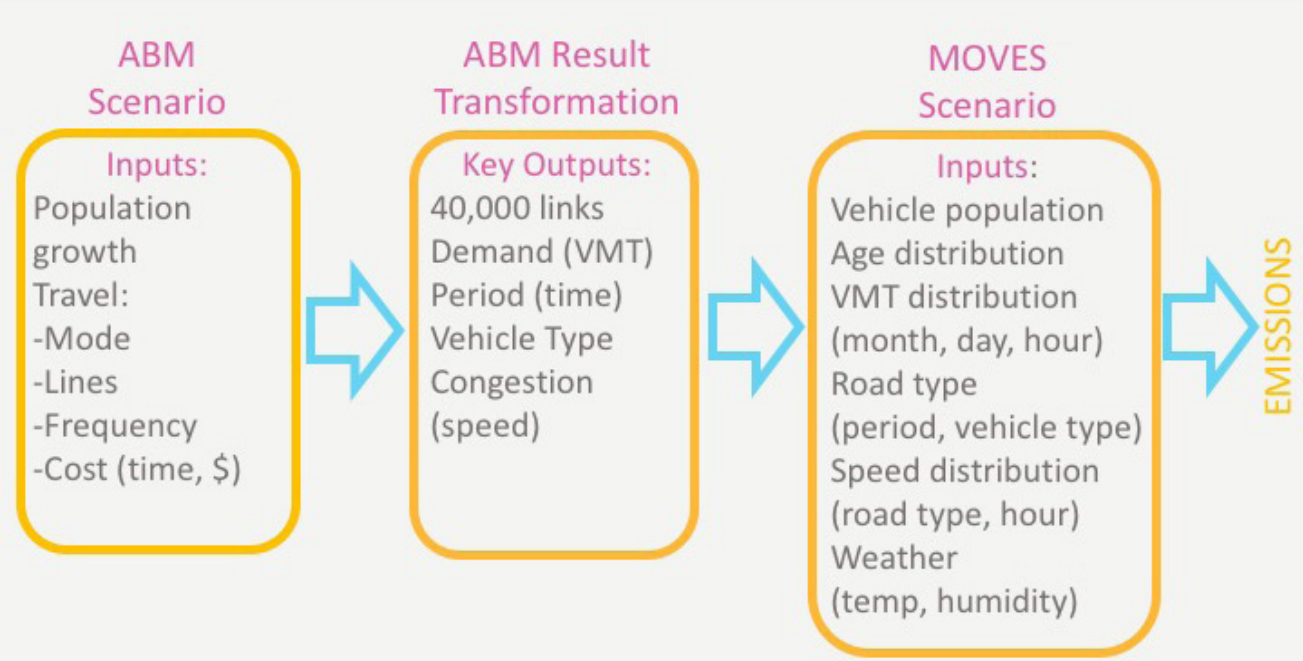


Figure 4.1: General process for modeling emissions using the Nashville MPO Activity-Based model and EPA MOVES2014a model.

MOVES

The Motor Vehicle Emissions Simulator (MOVES) is the state-of-the-art tool developed by the EPA for estimating air pollution emission generated by on-road mobile sources. MOVES analysis is required for regulatory purposes such as State Implementation Plans (SIP), and conformity analysis to reach criteria pollutant attainment levels. It is also the EPA's best tool for creating greenhouse gas (GHG) inventories and was used to inventory 2005, 2011 and 2014 GHG emissions in the Livable Nashville report.

MOVES is used for scenario planning and policy analysis on a variety of geographic scales: state, county, or subcounty. MOVES calculates emissions based on factors such as vehicle type, age, distance traveled, speed, road type, fuel type and meteorological conditions. It incorporates emissions from running and evaporative processes, as well as brake and tire wear and other key processes. This study uses MOVES 2014a, the most up-to-date version, which includes national fuel economy standards as of October 2015, including regulations for heavy-duty vehicles from 2014-2018 and light-duty vehicles from 2017-2025. EPA regulatory guidelines for State Implementation Plans (SIP) were applied in conducting the criteria pollutant inventory. EPA guidelines for conducting greenhouse gas inventory were also applied while no regulatory procedure currently exists.

The MOVES input data, was locally defined and tailored to each scenario as described in Appendix B. Locally defined inputs included: vehicle population, vehicle miles traveled, average speed distribution, road type distribution, meteorology, fuel type distribution, and age distribution. Default MOVES data was rarely used and followed EPA guidelines. MOVES allows emissions analyses to be conducted with users define parameters, called RunSpecs. These RunSpecs are contained in Appendix C. In total, six MOVES scenarios have been included in the analysis, as shown in the table below and with file names included in Appendix D.

To project GHG emissions, a full year inventory was conducted for 2017 and 2033 under Business-As-Usual. A third inventory was generated for 2033 under Let's Move Nashville. For these inventories, travel in Davidson County was captured on all road and for all source vehicle types throughout the entire analysis year. Emissions were measured as CO2e, or carbon dioxide equivalent, including methane (CH2) and nitrogen dioxide (NO2). Figure 4.2 illustrates these scenarios.

Figure 4.2: A total of 6 emission inventories for scenarios modeled in this study.

To highlight the GHG reductions achieved through Let's Move Nashville's transit bus fleet transition to fully electric busses, bus counts (MOVES Population) and CO2e emissions were removed for these busses. This was performed manually, since the MOVES 2014a does not yet integrate options for transit bus fuel type, electric.

To quantify the impact of Let's Move Nashville on criteria pollutants that typically impact respiratory health, emission inventories were generated for North Nashville. The inventory effectively captures one hour of peak emissions (5:00pm-6:00pm), during the hottest month of the year, August. Health impacts of various pollutants can be seen in Appedix F.

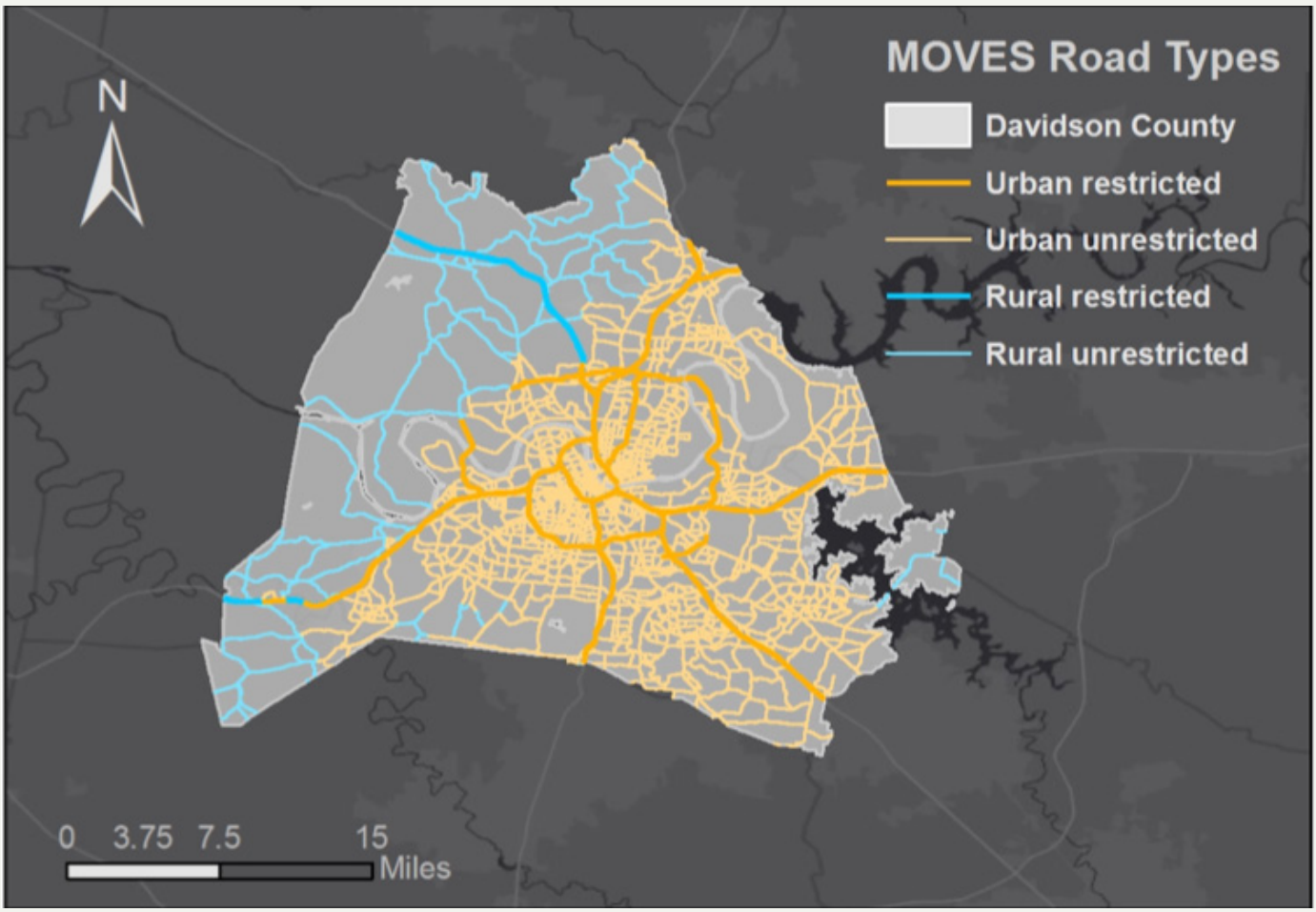


Figure 4.3: Map (left) of the road types in Davidson County Nashville as defined by MOVES including Rural Restricted, Rural Unrestricted, Urban Restricted, Urban Unrestricted. MOVES calculated emissions for 13 vehicle source types.

RESULTS: GREENHOUSE GAS EMISSIONS

Annual greenhouse gas (GHG) inventories were captured for Davidson County for three scenarios: 2017, 2033 Business-As-Usual, 2033 Let's Move Nashville (figure 4.4). These scenarios captured variation in human population, vehicle population, vehicle miles traveled, time of travel, and congestion (speed), as shown in Appendix H. Of particularly importance, the Let's Move Nashville plan decreased road travel, in 2033, by **77.9 million miles per year,** with 57.5 million from light duty vehicles (ie. passenger cars and trucks).

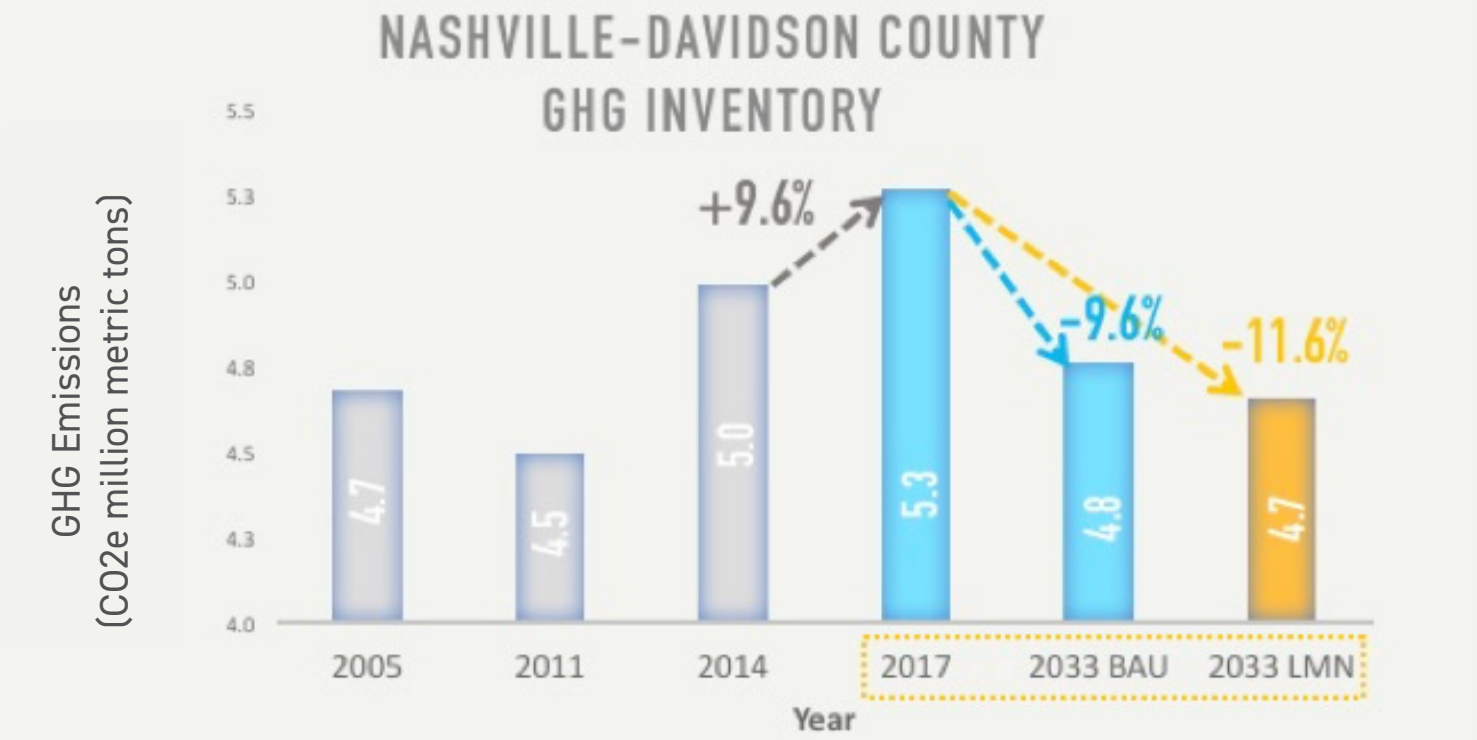


Figure 4.4: Greenhouse gas emission inventories established for 2005, 2011, 2014 (Source: Livable Nashville report) calculated for 2017, and projected through 2033 under two scenarios: Business-As-Usual (BAU) and Let's Move Nashville (LMN).

2017 to 2033: Business As Usual

When compared to the Livable Nashville 2005 baseline, the transportation sectors GHG emissions continued to grow, rising 13% above the 2005 baseline. By 2033 however, this trend reverses. In the 2033 Business-As-Usual scenario, annual CO2e emissions decrease to 9.6 percent below 2017 levels, resting just above the 2005 baseline. Let's Move Nashville achieves a further two percent reduction (104,195 MT), and for the first time, Nashville's transportation sector falls below 2005 baseline. Full results can be found in Appendix I.

This reversal of CO2e emission trends, is projected to decrease 2017 annual emissions by 506,708 MT by the year 2033. This substantial decrease was analyzed by vehicle source type and road type to identify where reductions were achieved, and where any GHG emission growth persisted (figure 4.5 & figure 4.8).

GHG Reductions: Vehicle Source Type

In 2033 Business As Usual, 794,346 MT decrease in annual GHG that occurred from 2017 levels. These reductions were concentrated in passenger cars (59 percent), trucks (33 percent) and commercial light duty trucks (8 percent) (figure 4.5). These decreases are the result of increasingly stringent Corporate Average Fuel Economy (CAFE) standards which were phased in from 2017-2025 (figure 4.6). These standards apply to automotive manufacturers, impacting the fuel efficiency (ie. miles per gallon) across entire fleets sold in a period of time. MOVES2014a captures CAFE standard impacts on emissions, and integrates changing emission rates with the vehicle source type population and age distribution inputs. Growth in CO2e emissions of 287,638 MT was seen in single unit trucks (25 percent) and combination trucks (73 percent).

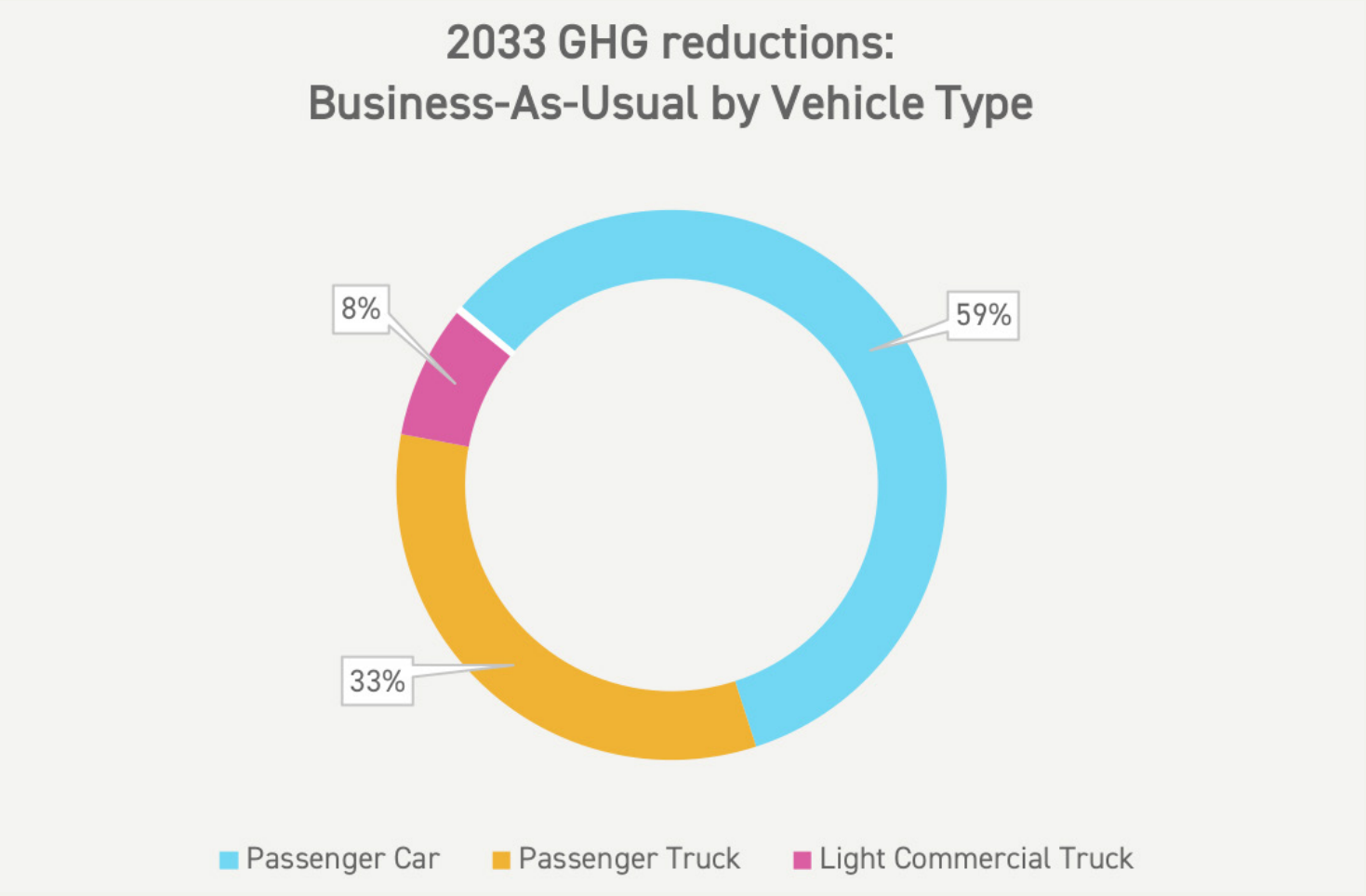


Figure 4.5: 2033 GHG Reductions in a Business-As-Usual scenario.

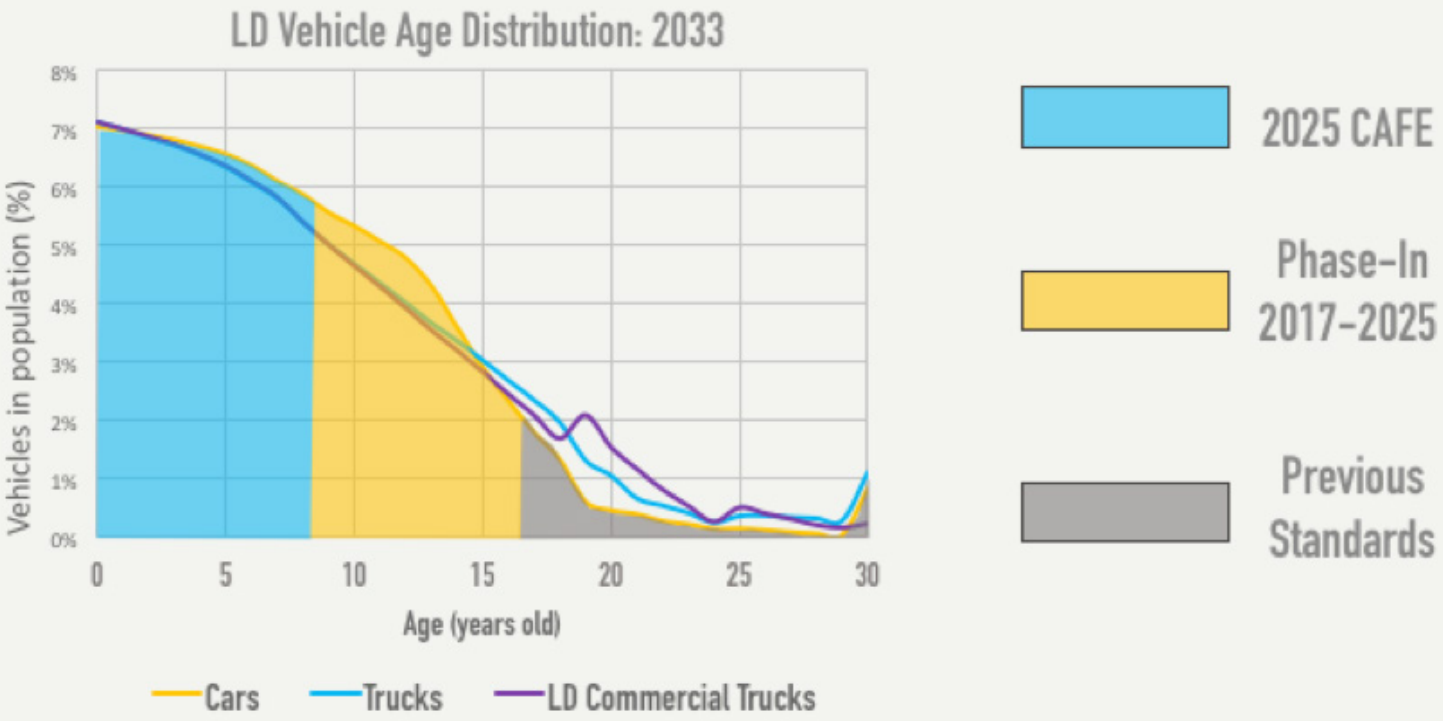


Figure 4.6: Vehicle age distribution (2033) for the three largest sources of CO2e reductions (passenger cars, trucks and light duty commercial trucks). Shaded areas show vehicles which meet currently adopted emission standards.

GHG Reductions: Road Type

When analyzed by road type, the majority of the CO2e reductions from 2017 to 2033 Business As Usual occur on urban restricted (32 percent) and urban unrestricted (55 percent) roads (figure 4.7). No road type showed increased CO2e emissions when including all vehicle source type use.

Let's Move Nashville Versus Business-As-Usual

When analyzed by road type, the majority of the CO2e reductions from 2017 to 2033 Business-As-Usual occur on urban restricted (32 percent) and urban unrestricted (55 percent) roads (figure 4.9). No road type showed increased CO2e emissions when including all vehicle source type use.

When compared to the 2033 Business-As-Usual baseline, the Let's Move Nashville plan, while increasing opportunities for travel and job accessibility, further decreases GHG emissions. For the first time, annual GHG emissions for the transportation sector drop below the 2005 baseline (figure 4.4). The reduction from BAU to LMN, achieves an additional 104,195 metric tons of CO2e.

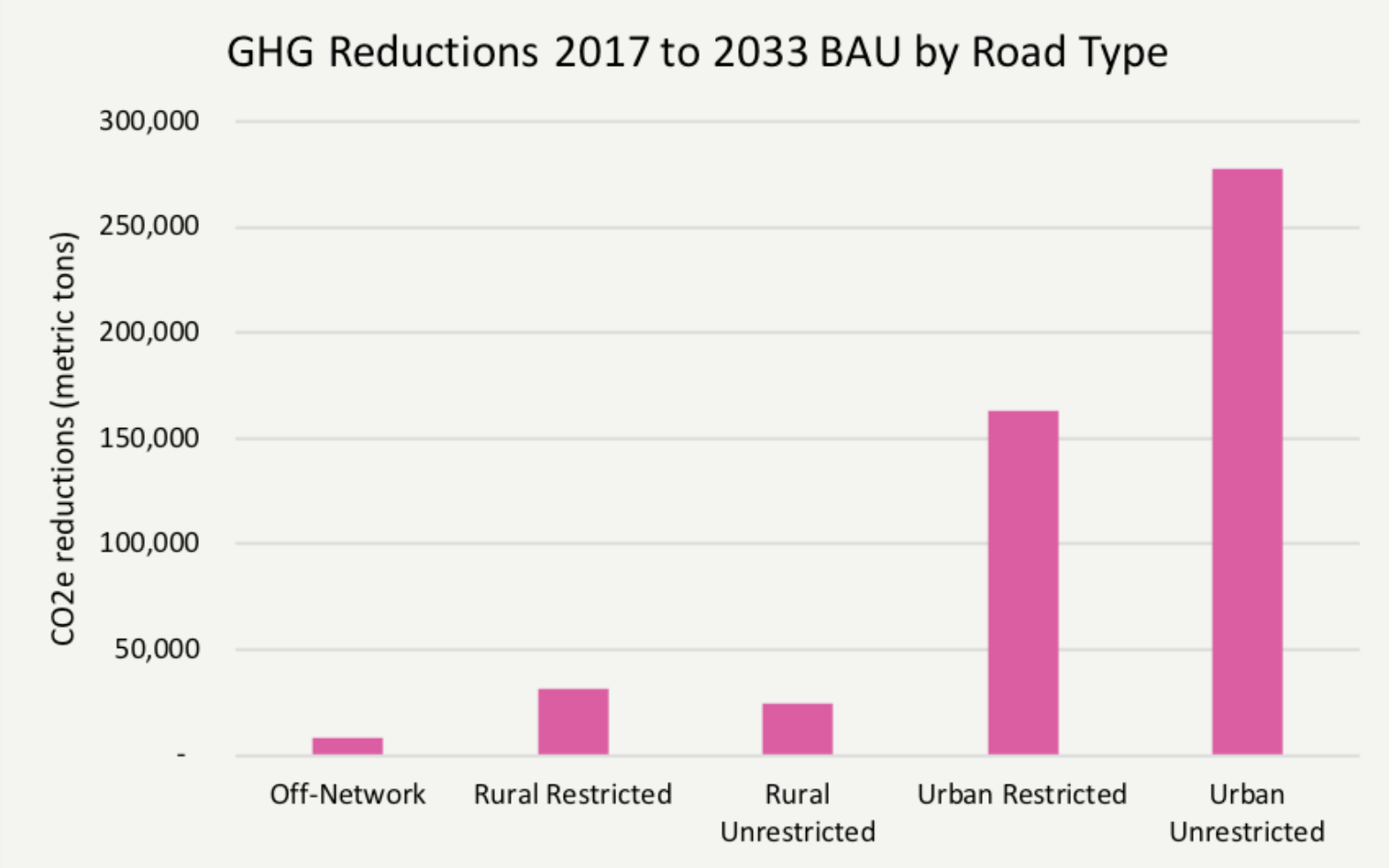


Figure 4.7: GHG Reductions 2017 to 2033 BAU by Road Type as defined in MOVES 2014a in Nashville-Davidson County.

GHG Reductions: Vehicle Source Types

When analyzed for vehicle source types contributing to this reduction, single unit trucks (46 percent) and combination trucks (33 percent) accounted for most of the GHG savings, followed by passenger cars (9 percent) and trucks (6 percent) (figure 4.8). As the transit bus fleet transitions under Let's Move Nashville to electric fuel, the resulting reductions equate to 4,816 MT of CO2e, representing 4.6 percent of the plans additional achieved GHG.

GHG Reductions: Road Type

When additional GHG emission reductions achieved through Let's Move Nashville plan were analyzed by road type, the largest decrease occurred on urban restricted roads (75 percent), followed by rural unrestricted roads (15 percent) and urban restricted (7 percent). The additional GHG reductions achieved through the Let's Move Plan GHG are likely a result of the cumulative effects of reduced passenger vehicle miles traveled, particularly on unrestricted urban roads, and the resulting congestion relief leading to improved performance of single and combination truck emissions related to average speed traveled.

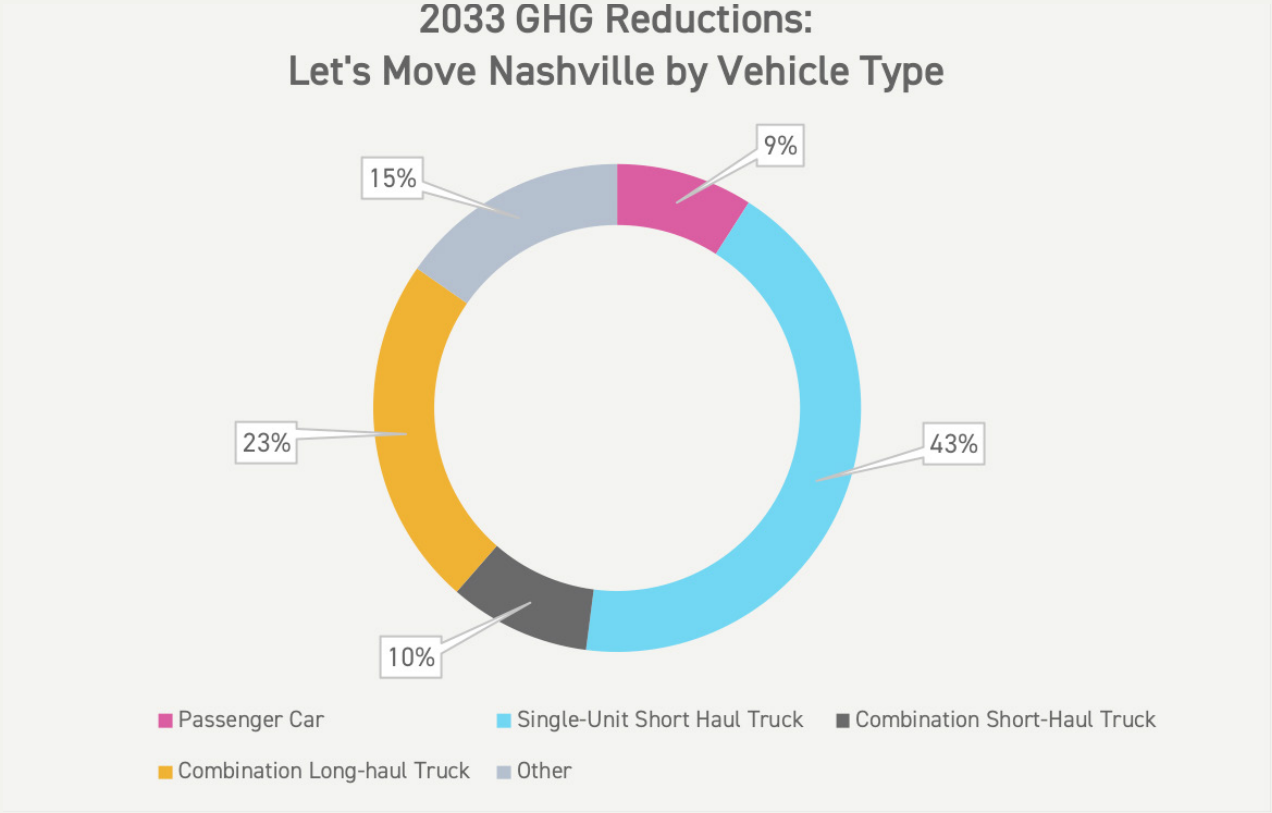


Figure 4.8: 2033 GHG Reductions Let's Move Nashville by Vehicle Type, resulting from the implementation of the Let's Move Nashville plan by vehicle source type when compared to the 2033 Business As Usual baseline.

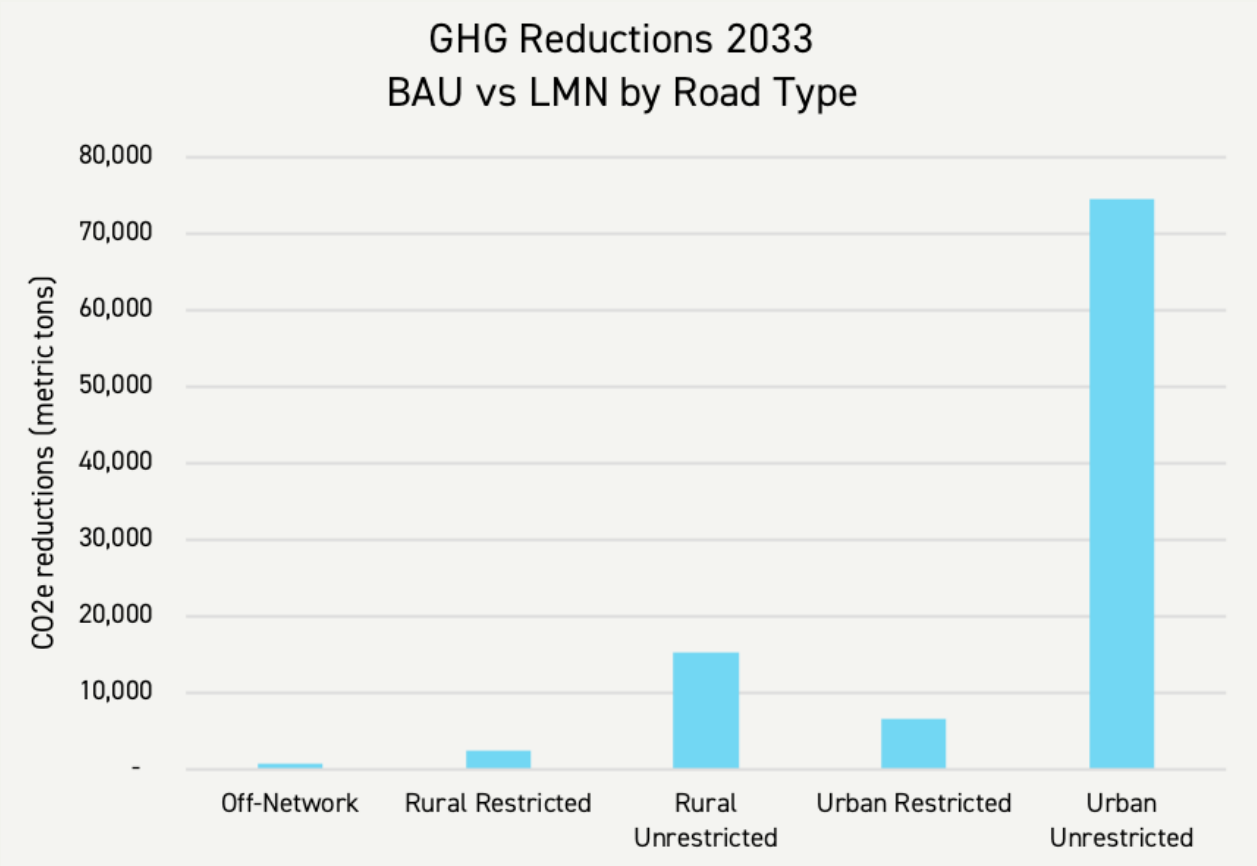


Figure 4.9: 2033 GHG Reductions: Let's Move Nashville by Road Type, resulting from the implementation of the Let's Move Nashville plan by vehicle source type.

RESULTS: CRITERIA POLLUTANTS

Four criteria pollutants sulfur dioxide (SO2) particulate matter (PM2.5 and PM10) carbon monoxide (CO) and a ground ozone precursor (NOx), were inventoried for peak hour emissions in three scenario models: North Nashville 2017, 2033 Business As Usual and 2033 Let's Move Nashville. In North Nashville, total annual VMT decreased with the implementation of Let's Move Nashville by a cumulative 13 million vehicle miles, as shown in the Appendix G. Particularly important in this analysis, was the model results showing 18.9 million VMT reduction in combination trucks. This analysis first compared peak-hour emissions inventories were compared from 2017 to 2033, and secondly compared policy scenarios: Business-As-Usual and Let's Move Nashville. Full results can be found in Appendix J.

Emission Trends: 2017 to 2033 Business-As-Usual

Emissions from 2017 to 2033 without the Let's Move Nashville plan implementation, decreased as follows: PM 2.5 (64 percent), PM 10 (674 percent), NOx (50 percent), and CO (24 percent). Sulfur dioxide (SO2) increased by 63 percent (figure 4.11).

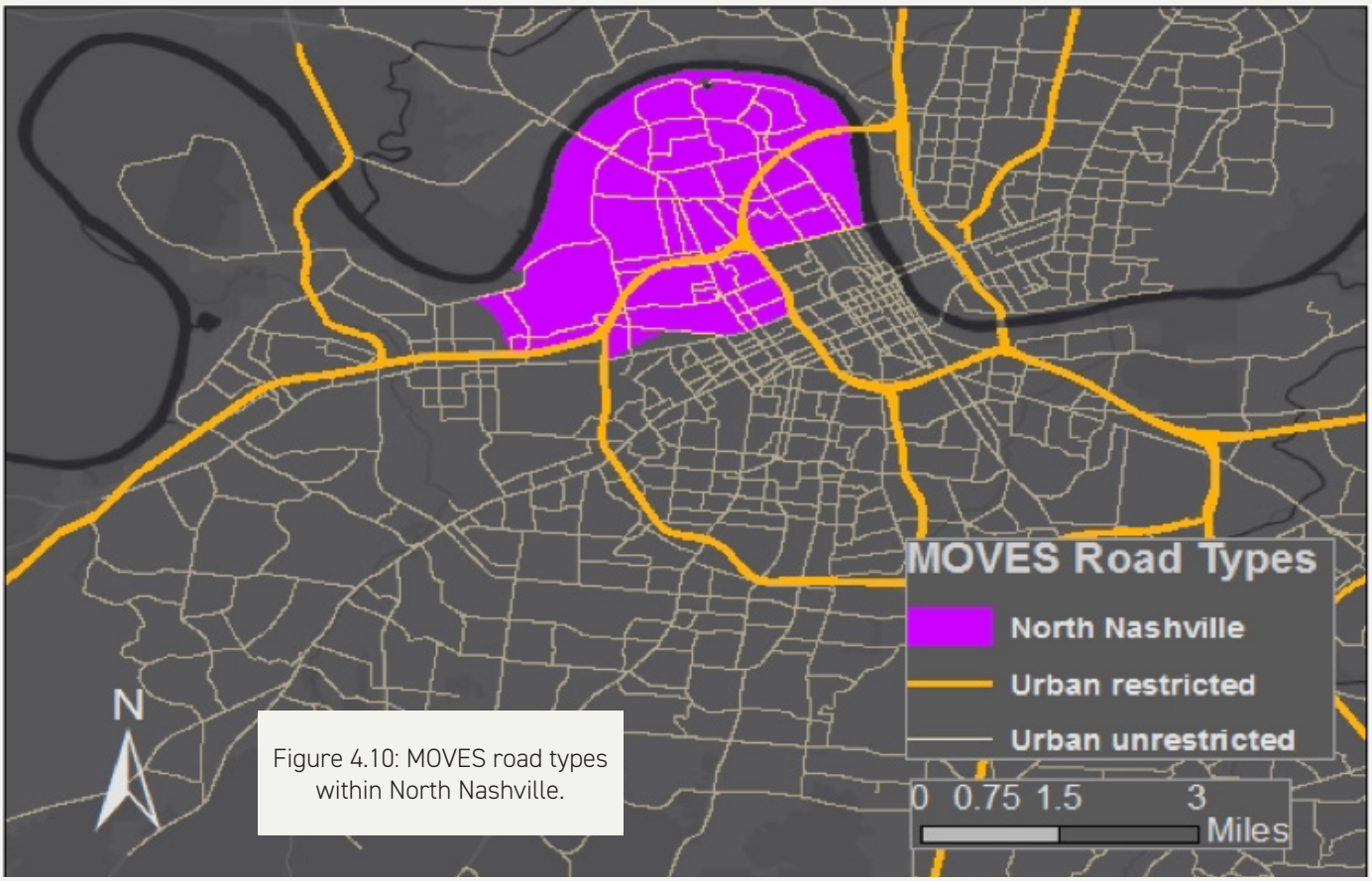


Figure 4.10: MOVES road types within North Nashville.

Emission Trends: 2033 Let's Move Nashville

Emissions with the Let's Move Nashville plan implementation, are projected to reduce emissions from the 2033 Business As Usual baseline, for all pollutants in this analysis. SO2 increases 17 percent less from 2017, compared to the 2033 Business As Usual. Other pollutants are reduced even further below the 2017 baseline: CO (1 percent), NOx (8 percent), PM 2.5 and PM 10 (5 percent) as shown in the figure below.

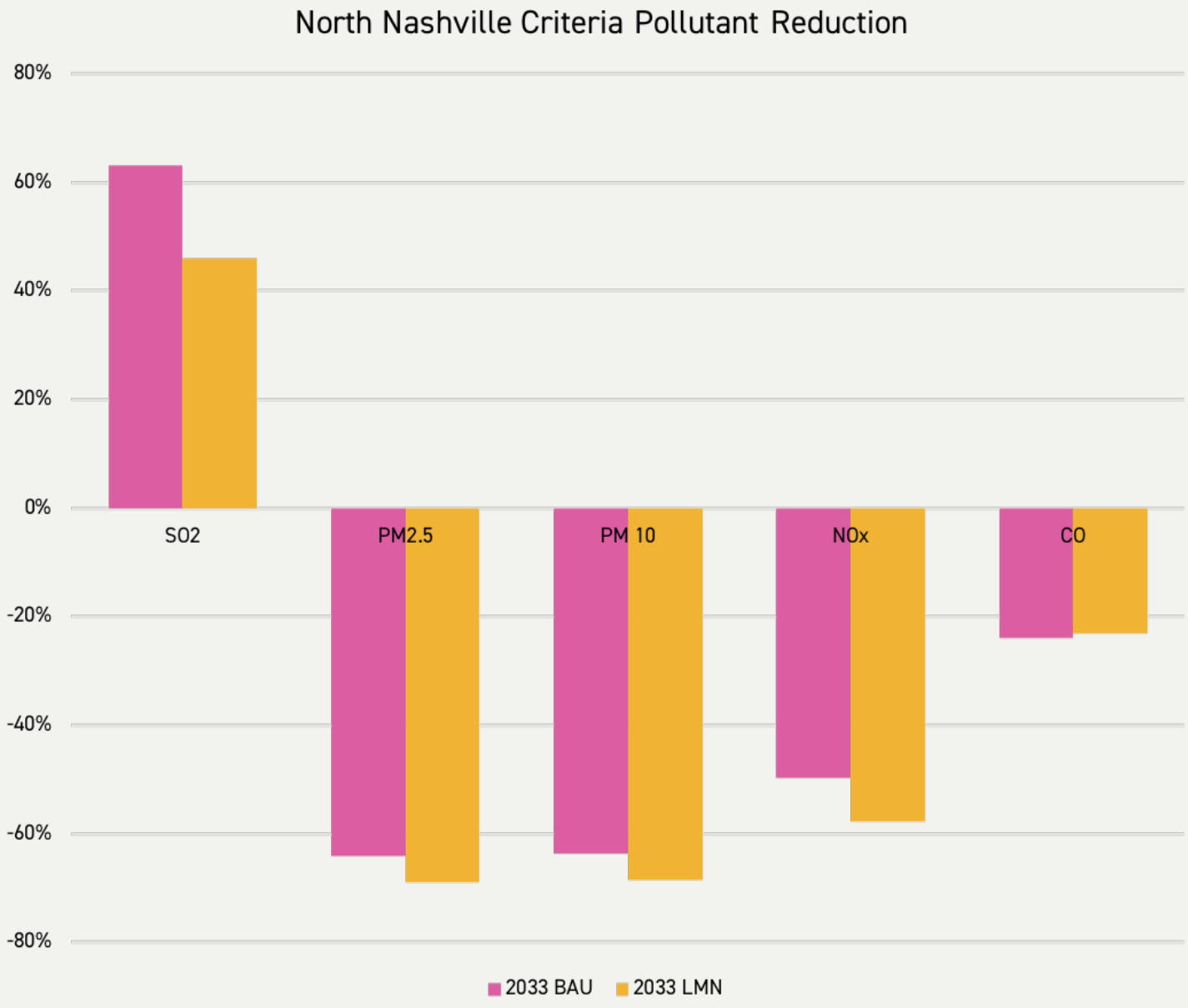


Figure 4.11: Reductions in criteria pollutants in North Nashville. The reductions shown in 2033 Business-As-Usual (BAU) and Let's Move Nashville (LMN) are measured against the 2017 baseline.

Vehicle Source Type

For pollutants that are projected to experience reductions in peak pollution levels, the following vehicle types were the main source of pollutant reductions from 2017 to 2033:

- Nitrogen oxides (NOx): Passenger cars (16 percent) and trucks (20 percent) and combination long haul trucks (26 percent).
- Particulate Matter 2.5 (PM 2.5): Refuse trucks (18 percent), single unit short-haul trucks (11 percent), combination short-haul trucks (11 percent) and long-haul combination trucks (50 percent).
- Particulate Matter 10 (PM 10): Refuse trucks (16 percent), combination short-haul truck (10 percent) and combination long haul trucks (44 percent).
- Carbon monoxide (CO): passenger cars (29 percent) and passenger trucks (43 percent).

Additional reductions as a result from Let's Move Nashville came from the following vehicle source types:

- Nitrogen oxides (NOx): combination short-haul trucks (29 percent) and combination long haul trucks (71 percent).
- Particulate Matter 2.5 (PM 2.5): combination short-haul trucks (26 percent) and combination long haul trucks (74 percent).
- Particulate Matter 10 (PM 10): combination short-haul trucks (26 percent) and combination long haul trucks (74 percent).
- Carbon monoxide (CO): motorcycles (3 percent), combination short-haul trucks (29 percent) and combination long haul trucks (68 percent).

Sulfur Dioxide (SO2)

This is the only criteria pollutant projected to increase from 2017 to 2033 Business As Usual. When analyzed by vehicle source type, the sulfur dioxide increases occur mainly from combination long and short-haul trucks, with 133.5kg of the 181kg increase coming from this source. However, in 2033 Let's Move Nashville, 99 percent of the decrease in sulfur dioxide (SO2) emission compared to BAU is from combination short and long haul trucks. This is likely due to a combination of increased VMT and speed/congestion changes experienced by 2033 Business As Usual, and changes in those factors that result from the Let's Move Nashville Plan.

Road Type

When analyzed by road type, the reductions from 2017 to 2033 occurred as follows:

- Nitrogen oxides (NOx): off-network (10 percent), rural restricted (54 percent) and rural unrestricted (36 percent).
- Particulate Matter 2.5 (PM 2.5): off-network (1 percent), rural restricted (64 percent) and rural unrestricted (35 percent).
- Particulate Matter 10 (PM 10): off-network (1 percent), rural restricted (64 percent) and rural unrestricted (35 percent).
- Carbon monoxide (CO): off-network (29 percent), rural restricted (39 percent) and rural unrestricted (32 percent).

When analyzed by road type, the reductions from 2033 Business as Usual to Let's Move Nashville occurred as follows:

- Nitrogen oxides (NOx): rural restricted (89 percent) and rural unrestricted (11 percent).
- Particulate Matter 2.5 (PM 2.5): rural restricted (83 percent) and rural unrestricted (17 percent).
- Particulate Matter 10 (PM 10): rural restricted (85 percent) and rural unrestricted (15 percent).
- Carbon monoxide (CO): rural restricted (100 percent).

SECTION 5

TRANSIT SUSTAINABILITY INDEX

SCALING UP A TRIPLE-BOTTOM LINE ANALYSIS

TRANSIT SUSTAINABILITY INDEX

The sustainability analysis contained within this report has three dimensions: equity, environment, and employment. The Let's Move Nashville plan and materials supporting its proposals emphasized transit's ability to make improvements in people's lives and for urban areas more broadly in each of these three areas. North Nashville's current demographics, proximity to downtown, and service changes proposed under Let's Move uniquely positioned the neighborhood for the study laid out in this report. However, North Nashville is far from the only community in Davidson County slated to see changes in the near and distant future, from the proposals in Let's Move or other potential developments. The methods and findings described in this report are intended to provide a basis for creating a flexible, region-wide tool for assessing transit equity.

The question of how to measure transit sustainability is largely unresolved. North American transportation agencies and academic researchers examining this issue have yet to make use of or even create a standardized measure of equity in transit systems. Examining recent (2005 onwards) transportation plans from the 25 largest North American cities revealed wide disparities in how they address the concept of equity (Manaugh, 2015). Nearly all cities include language of varying specificity about social equity in their reports or mission statements but many have struggled to operationalize these concepts, due largely to its abstract nature (Handy, 2008; Dale and Newman, 2009). Incorporating environmental indicators into transit planning has also been a challenging task, although these measures are more standardized in planning due to the fact that federal regulations require compliance on air quality as well as consideration of environmental justice concerns. Regarding employment and accessibility, Boisjoly and El-Geneidy (2016) also note that transit planning has traditionally focused on mobility over the ease with which riders could reach desirable destinations. A shift towards monitoring how well transit allows riders to access employment, educational, and recreational opportunities is a step towards creating an effective sustainability metric.

Communities report experiencing fast rates of displacement to outlying parts of Davidson County including Antioch, Hermitage, and Madison. A metric to transparently monitor how well the system is serving those in need across time and space can further inform MTA's decision-making throughout the implementation and operation of Let's Move.

STRUCTURE OF PROPOSED INDEX

Based on our findings in the previous three sections, we propose structuring a transit sustainability index identifying Census tracts, neighborhoods, or TAZs around three categories of indicators as outlined below. In addition to the research presented in this report, the chosen indicators have a basis in academic literature as well as in other North American transit agencies' planning documents.

Demographics and Social Characteristics

The following indicators are meant to capture where vulnerable populations are located throughout Davidson County as well as measure how MTA and other municipal stakeholders are investing in high-need communities. We drew many from data the Nashville MPO already collects and reported on in the 2016-2040 Regional Transportation Plan. Others come from recommendations set in transportation plans from cities outside Nashville as well as equity considerations mentioned in Section Two (figure 5.1).

Employment and Accessibility

We derived indicators under this category based on findings and the discussion included in Section Three generated through analysis from the Activity-Based Model. Indicators reflecting information beyond the analysis in this report come from other transit agencies or academic articles, as cited under "Rationale." In order to create comprehensive accessibility and employment metrics, we recommend clearly distinguishing between accessibility and mobility (figure 5.2).

Environment and Air Quality

All five indicators in this category come from criteria pollutants and the greenhouse gas inventory outlined in Section Four of this report. To further enrich the "theme" of environment and air quality in relation to transit evaluation, we recommend examining finer-grained data on block-level emissions once made available by the MPO as well as the formal designation of "environmental justice areas," defined as communities vulnerable to negative health effects from environmental factors (figure 5.3).

Indicator	Data Source	Rationale
Households in Poverty	Nashville MPO	Personal or household income at or below the U.S. Department of Health and Human Services (HHS) poverty guidelines
Non-Hispanic Minority Population	Nashville MPO	US Department of Transportation Order 5610.2(a) on Environmental Justice
Hispanic Population	Nashville MPO	Identification as signalled by US Census data
Limited English Language Proficiency	Nashville MPO	Executive Order 13166 (2000) on limited English proficiency (LEP)
Senior Population	Nashville MPO	-
Projects implemented and dollars invested in traditionally disadvantaged or under-served populations [as defined through other indicators]	Nashville MTA or appropriate agency	New Orleans Regional Planning Commission
Carless or Transit-Dependent Households	Nashville MPO	US Census
Single-Parent Households	Nashville MPO	US Census
Physically Disabled Population	Nashville MPO	US Census, Americans with Disabilities Act (ADA)

Figure 5.1

Indicator	Data Source	Rationale
Number of jobs accessible within 15, 30, 45, and 60 minutes by transit	Activity-Based Model	Boisjoly and El-Geneidy (2016)
Share of recreational and shopping destinations within a one- and two-mile travel buffer from each neighborhood; within 45 minutes by bus or all transit modes during the evening peak period	Activity-Based Model	Regional Transportation Plan 2040 (Southern California Association of Governments, 2016)
Share of population within a one- and two-mile travel buffer from a regional park or school	Activity-Based Model	Regional Transportation Plan 2040 (Southern California Association of Governments, 2016)
Number of hospitals, weighted by number of beds, within a 40-minute transit trip	Activity-Based Model	Long Range Transportation Plan 2040 (Boston Regional Metropolitan Planning Organization, 2015)
Share of population within 0.25-miles walkshed of a transit stop	Nashville MTA	Boisjoly and El-Geneidy (2016)

Figure 5.2

Indicator	Data Source	Rationale
Sulfur Dioxide (SO2)	EPA MOVES (Motor Vehicles Emissions Simulator)	US EPA
Carbon Monoxide (CO)	EPA MOVES (Motor Vehicles Emissions Simulator)	US EPA
Nitrogen Dioxide (NOx)	EPA MOVES (Motor Vehicles Emissions Simulator)	US EPA
Particulate Matter (PM 2.5, PM 10)	EPA MOVES (Motor Vehicles Emissions Simulator)	US EPA
Greenhouse Gas Emissions	EPA MOVES (Motor Vehicles Emissions Simulator)	US EPA

Figure 5.3

SOURCES & APPENDICES

DATA AND METHODOLOGIES

SOURCES

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APPENDIX A

This appendix serves to illustrate in further detail the steps taken to perform the employment accessibility analysis contained within this report. These steps should make the employment accessibility analysis replicable by other Nashville stakeholders with access to the MPO's activity-based model outputs.

TransCAD

- Open the TAZ file for the model year of analysis.

- Create a selection of the specific TAZs you will be using for your analyses. For this study, one selection was made to isolate Davidson County TAZs (possible destinations of commuting travel), and another selection was made to isolate North Nashville TAZs (possible origins of commuting travel).

- Open all transit skim matrices that will be used in the analysis. This study only looked at transit skim matrices where individuals walked to a transit stop because of the focus on transit-dependent individuals. The transit matrices analyzed thus included "WalkBRT" (walk to bus rapid transit), "WalkComRail" (walk to commuter rail), "WalkExpBus" (walk to express bus), "WalkLocal" (walk to local bus), and "WalkUrbRail" (walk to light rail). Transit skim matrices are also available, however, to depict the travel times of those who drive to each of these types of transit, if that analysis is so desired.

- For each of the transit skim matrices to be analyzed, create two new "indices" that serve to parse your data down to rows that identify your origins of commuting travel and columns that identify your possible destinations of commuting travel. In the process of creating an index, the user will be asked to select the current identifier being used in the skim matrices from the TAZ file. During this study, that identifier was "NewID". The user must then create a new name for the index, choose which selection (from step 2) the index will include, and select a new identifier to be used for the transit skim matrix. This study created a North Nashville index and a Davidson County index, both using TAZ number as the identifier. Transit skim matrices were then manipulated to show North Nashville TAZs as the rows and Davidson County TAZs as the columns.

- Export each transit skim matrix as a CSV file. When exporting a transit skim matrix, a window will prompt you to select (1) how you want the data exported and (2) which elements of the matrices should be included in the export.

You should select that the information in each cell be exported, and that in-vehicle time, initial wait time, transfer penalty time, transfer wait time, transfer walk time, access walk time, and egress walk time be included in the export.

- **Export the TAZ file as a .xls file, .xlsx file, or another tabular, non-proprietary file.**

Microsoft Access

- **Import all transit matrix CSV files and the TAZ tabular file into Microsoft Access, or another database management software.** You will need to relabel your fields (columns) with your identifiers and the time components selected in step 5, as the CSV files exported from TransCAD do not include column headers. This can be done by opening each of the transit skim tables in Access and viewing them in "Design View." From here, field names can be changed.

- **Create a new column that is a numerical calculated field equal to the sum of all fields representing sub-components of total transit travel time.**

- **Use the "Number Filters" drop down menu on the total transit travel time field to select all records equal to zero, and then delete them.** Deleting all records with total transit time equal to zero will not affect the employment accessibility analysis results and helps Access to process data faster and with less computer capacity necessary.

- **Tell Access that the TAZ field in the TAZ file and the Davidson County TAZ fields in each of the transit skim tables are related, and thus can constitute a single record.**This can be done by going to "Database Tools" and then clicking "Relationships." Once you arrive at this page, you will want to add the TAZ file and all transit skim tables to the screen. To establish a relationship between TAZ in the TAZ file and Davidson County TAZ in the transit skim tables, simply click TAZ in the TAZ file, then drag and drop it onto Davidson County TAZ. Repeat for each transit skim table.

- **Create a query to bring unique records containing the North Nashville TAZ field, Davidson County TAZ field, Total Transit Travel Time, and relevant TAZ employment opportunity figure into a single table.** A new query will have to be run for each transit skim table to prevent the duplication of records.

Microsoft Excel

- Copy the records returned by the query to an Excel spreadsheet. For this study, a new sheet was created for each model and time of day (e.g. 2017 AM and 2017 off-peak).

- Create a second set of the records in each Excel spreadsheet, order this second set of records so records are ascending by Total Transit Travel Time, and use the "Remove Duplicates" function on the records in Excel to remove any duplicate Davidson County TAZs. Completing this step ensures that no employment opportunities are double counted. Manipulating the records to be ascending by Total Transit Travel Time has the employment opportunities associated with each TAZ count for the shortest possible commute time from a North Nashville TAZ.

- Create a new column in the set of records with no duplicates that specifies the time threshold into which each record falls according to its Total Transit Travel Time. In this study, an if statement was constructed to determine if a record's Total Transit Travel Time was in the 15 minutes or less threshold, 30 minutes or less threshold, 45 minutes or less threshold, 60 minutes or less threshold, or the over 60 minutes threshold.

- Create a pivot table for each model year and commute time of day with the time threshold column as the row and sum of employment opportunities as the calculated figure.

APPENDIX B: MOVES METHODS AND INPUTS

MOVES Input	Metric	Description	Importance	Source and Calculations
VMT (vehicle miles traveled)	VMT (annual) by HPMS class: • Motorcycles • Light duty • Buses • Single-unit trucks • Multi-unit trucks	Total annual VMT by HPMS vehicle type. Month Fraction of annual VMT of each source type Day fraction by type of day (weekend day) by source type Hourly	VMT by source and road type are multiplied by emission factors to generate inventory. This is has the greatest impact on inventory. Reflects seasonal variance Reflects variance by weekday/weekend activities (work, school, tourism). Reflects variance within days (AM, mid-day (MD), PM peaks and off-peak (OP).	Activity-Based-Model (ABM) "assignment_results," provides average annual daily VMT (AADVMT) for PASS, COM, SU and MU. These are converted to HPMS classes by applying 2014 fractions as follows: • PASS + COM → moto,light duty, buses • SU → SU • MU → MU MOVES "aadvmt-converter-tool-moves2014" tool used to calculate annual VMTs, monthly and daily distributions. Hourly fractions are calculated using assignment_results. PASS fractions were applied to source types: (11,21,31,32,41,42,43); SU (51,52,53,54), MU (61, 62) Road type distributions were compiled from functional class as described in "Road Type Distribution" below.
Source Type Population	Vehicle source types (13): 11 - Motorcycle 21- Passenger car 31- Passenger truck 32- Light commercial truck 41- Intercity bus 42-Transit bus 43- School bus 51-Refuse truck 52-Single-unit short haul truck 53- Single-unit long haul truck 54- Motor home 61- Multi-unit short haul truck 62- Multi-unit long haul truck	The number of each vehicle source type in area being modeled.	Source type population is important for emission processes such as starts, hoteling and evaporative.	Two ratio calculations were used to predict source type populations. For most source types, the ratio of human population (2014 US Census Bureau ACS 1-year) to vehicle population (2014 registration data) was applied. For source types 51, 51, 61, 62 (SU and MU), populations were calculated as a ratio of source type VMT to source type population in 2014.
Source Type Age Distribution	Fraction of source type population for each model year (0 to 30 years).	Shows distribution of the each source type fleet by age.	Older vehicles experience greater deterioration to emission control systems and may not meet newer, more stringent emission or CAFÉ standards.	MOVES "age-distribution-projection-tool-moves2014" was used for all source type populations to normalize (standard economic conditions), the 2014 population age structure. Transit bus fleet however, was calculated using planned fleet turnover data (MPO). Increased transit fleet size and fuel type shift (to electric/hybrids) were accounted for under LMN scenarios. Because bus fuel options do not allow for BEV or EV buses, these were removed from the population for the GHG analysis.

MOVES Input	Metric	Description	Importance	Source and Calculations
Road Type Distribution	5 road types of MOVES: • Off-network • Rural restricted • Rural unrestricted • Urban restricted • Urban unrestricted	Fraction of source type VMT on each road type. Restricted indicates access via ramps.	Vehicles behave differently (running processes) on these road types, resulting in variance of emissions.	ABM "assignment_results," captures road type use (volume) by functional class (FC) and time period (AM, MD, PM, OP). FC is consolidated into MOVES road types as follows: MOVES 1 = Not included* MOVES 2 = FC (1) MOVES 3 = FC (2+6+7+8+9) MOVES 4 = FC (11+12) MOVES 5 = FC (14+16+17+19) VOL is converted to VMT as a ratio of volume by period to total volume, applied to total VMT. *Off-Network includes parking lots and truck rest stops and calculated automatically within MOVES.
Average Speed Distribution	Fraction of travel time spent in each of 16 "speed bins"	Fractions for time (VHT not VMT) for every source type on each road type	Vehicle power, speed and accelerate strongly impact emissions. Captures variance in vehicle emissions due to operating speed and time, reflecting road constraints and congestion.	Speed distributions were extracted from assignment_ results by vehicle class (PASS, COM, SU, MU) and applied to relevant MOVES source types. Average speed was determined for each link (approximately 40,000) by VMT/VHT for each vehicle class, time period. Average speed distributions were captured with periods (AM, MD, PM, OP) and applied to all hours within the period. Weekdays and weekends were not differentiated. This created 48 unique average speed distributions. Buses however, were consolidated in with passenger speeds due to data constraints.

APPENDIX C: MOVES RUNSPECS

Area of analyses:	**Davidson County**	**North Nashville**
RunID	01, 03, 05	11, 13, 15
Scale: Model Domain/Scale Calculation Type	 Onroad County Inventory	 Onroad County Inventory
Time Span: Time aggregation level. Years Months Days Hours	 Hour 2017 or 2033 All All All	 Hour 2017 or 2033 August Weekday 1700-1800
Geographic Bounds: Region States County	 County TN Davidson	 County TN Davidson
Vehicles: Fuels Source Use Types Selections	 All All All	 All All All
Road Type:	All	All
Pollutants and Processes:	CO2 equiv. (prerequisites incl. NO2, CH4)	Primary exhaust PM2.5 – Total Primary exhaust PM10 – Total Sulfur Dioxide (SO2) NO NOx CO
Output: General:	Mass: Kilograms Energy: Joules Distance: Miles Activity: Distance traveled Population	Mass: Grams Energy: Joules Distance: Miles Activity: Distance traveled Population
Output: Emissions Details	Always: Time: Year Location: County Pollutant On Road/Off Road: Road Type Source Use Type	Always: Time: Hour Location: County Pollutant On Road/Off Road: Road Type Source Use Type

APPENDIX D & E: MOVES SCENARIOS/2014 DECODER

Analysis	Geo Scale	Scenario	Year	MOVES RunSpec	MOVES Input Database County Data Manager	MOVES Output Database MySQL
GHG County Inventory Year	Nashville-Davidson County	Business-As-Usual	2017	01_DC_2017_BAU_GHG_mrs	01_DC_2017_BAU_GHG_in	01_DC_2017_BAU_GHG_out
			2033	03_DC_2033_BAU_GHG_ mrs	03_DC_2033_BAU_GHG_in	03_DC_2033_BAU_GHG_ out
		Let's Move Nashville	2033	05_DC_2033_LMN_GHG_ mrs	05_DC_2033_LMN_GHG_in	05_DC_2033_LMN_GHG_ out
Criteria Pollutants County Inventory Peak hr.	North Nashville	Business-As-Usual	2017	11_NN_2017_BAU_POL_ mrs	11_NN_2017_BAU_POL_in	11_NN_2017_BAU_POL_ out
			2033	13_NN_2033_BAU_POL_ mrs	13_NN_2033_BAU_POL_in	13_NN_2033_BAU_POL_ out
		Let's Move Nashville	2033	15_NN_2033_LMN_POL_ mrs	15_NN_2033_LMN_POL_in	15_NN_2033_LMN_POL_ out

File naming system: IDnumber_GeographicScope_Year_ Scenario_EmissionType_fileExtension

MOVES Decoder 20150319

Source Type - sourcetypeid

ID	sourcetypename
11	Motorcycle
21	Passenger Car
31	Passenger Truck
32	Light Commercial Truck
41	Intercity Bus
42	Transit Bus
43	School Bus
51	Refuse Truck
52	Single Unit Short-haul Truck
53	Single Unit Long-haul Truck
54	Motor Home
61	Combination Short-haul Truck
62	Combination Long-haul Truck

Road Type - roadtypeid

ID	roaddesc
1	Off-Network
2	Rural Restricted
3	Rural Unrestricted
4	Urban Restricted
5	Urban Unrestricted
6	Rural Restricted w/o ramps
7	Urban Restricted w/o ramps
8	Rural Restricted Ramps
9	Urban Restricted Ramps

Process - processid

ID	processName
1	Running Exhaust
2	Start Exhaust
9	Brakewear
10	Tirewear
11	Evap Permeation
12	Evap Fuel Vapor Venting
13	Evap Fuel Leaks
15	Crankcase Running Exhaust
16	Crankcase Start Exhaust
17	Crankcase Extended Idle Exhaust
18	Refueling Displacement Vapor Loss
19	Refueling Spillage Loss
90	Extended Idle Exhaust
91	Auxiliary Power Exhaust
99	Well-to-Pump

Activity - activityTypeID

ID	Activity Description
1	Distance traveled
2	Source Hours
3	Extended Idle Hours
4	Source Hours Operating
5	Source Hours Parked
6	Population
7	Starts
9	Average Horsepower
10	Fraction Retrofitted
11	Number Units Retrofitted
12	Load Factor
13	Hotelling Diesel Aux
14	Hotelling Battery or AC
15	Hotelling All Engines Off

Fuel Type - fuelTypeID

ID	regClassName
1	gas
2	diesel
3	CNG
4	LPG
5	E-85
9	electricity

Operating Mode - OpMode ID

101	Soak Time <6 minutes
102	6 minutes <= Soak Time < 30 minutes
103	30 minutes <= Soak Time < 60 minutes
104	60 minutes <= Soak Time < 90 minutes
105	90 minutes <= Soak Time < 120 minutes
106	120 minutes <= Soak Time < 360 minutes
107	360 minutes <= Soak Time < 720 minutes
108	720 minutes <= Soak Time
200	Extended Idling
201	Auxilary Power Units Use
203	Battery Power
204	Engine Off

Day - dayID

ID	dayName
2	Weekend
5	Weekdays

Regulatory Class - regClassID

ID	regClassName	regClassDesc
0	Doesn't Matter	Doesn't Matter
10	MC	Motorcycles
20	LDV	Light Duty Vehicles
30	LDT	Light Duty Trucks
40	LHD <= 10K	Class 2b Trucks w/ 2 Axles & 4 Tires (8,500 lbs < GVWR <= 10,000 lbs)
41	LHD<=14k	Class 2b Trucks w/ 2 Axles & at least 6 Tires or Class 3 Trucks (8,500 lbs < GVWR <= 14,000 l
42	LHD45	Light Heavy Duty (14K lbs < GVWR <= 19.5K lbs)
46	MHD	Medium Heavy Duty (19.5K lbs < GVWR < =33K lbs)
47	HHD	Heavy Heavy Duty (GVWR > 33K lbs)
48	Urban Bus	Urban Bus (see CFR Sec. 86.091_2)

Pollutant - pollutantid

ID	pollutantname	ID	pollutantname
1	Total Gaseous Hydrocarbons	79	Non-Methane Hydrocarbons
2	Carbon Monoxide (CO)	80	Non-Methane Organic Gases
3	Oxides of Nitrogen (NOx)		
5	Methane (CH4)	81	Fluorene particle
6	Nitrous Oxide (N2O)	82	Indeno(1,2,3,c,d)pyrene particle
		83	Phenanthrene particle
20	Benzene	84	Pyrene particle
21	Ethanol		
22	MTBE	86	Total Organic Gases
23	Naphthalene particle	87	Volatile Organic Compounds
24	1,3-Butadiene	88	NonHAPTOG
25	Formaldehyde		
26	Acetaldehyde	90	Atmospheric CO2
27	Acrolein	91	Total Energy Consumption
		92	Petroleum Energy Consumption
30	Ammonia (NH3)	93	Fossil Fuel Energy Consumption
31	Sulfur Dioxide (SO2)	98	CO2 Equivalent
32	Nitrogen Oxide (NO)	99	Brake Specific Fuel Consumption (BSFC)
33	Nitrogen Dioxide (NO2)		
34	Nitrous Acid (HONO)	100	Primary Exhaust PM10 - Total
35	Nitrate (NO3)	106	Primary PM10 - Brakewear Particulate
36	Ammonium (NH4)	107	Primary PM10 - Tirewear Particulate
		110	Primary Exhaust PM2.5 - Total
40	2,2,4-Trimethylpentane	111	Organic Carbon
41	Ethyl Benzene	112	Elemental Carbon
42	Hexane	115	Sulfate Particulate
43	Propionaldehyde	116	Primary PM2.5 - Brakewear Particulate
44	Styrene	117	Primary PM2.5 - Tirewear Particulate
45	Toluene	118	Composite - NonECPM
46	Xylene	119	H2O (aerosol)
		120	Primary PM2.5 - NonECNonSO4PM
51	Chloride	121	CMAQ5.0 Unspeciated (PMOTHR)
52	Sodium	122	Non-carbon Organic Matter (NCOM)
53	Potassium		
54	Magnesium	168	Dibenzo(a,h)anthracene gas
55	Calcium	169	Fluoranthene gas
56	Titanium	170	Acenaphthene gas
57	Silicon	171	Acenaphthylene gas
58	Aluminum	172	Anthracene gas
59	Iron	173	Benz(a)anthracene gas
60	Mercury Elemental Gaseous	174	Benzo(a)pyrene gas
61	Mercury Divalent Gaseous	175	Benzo(b)fluoranthene gas
62	Mercury Particulate	176	Benzo(g,h,i)perylene gas
63	Arsenic Compounds	177	Benzo(k)fluoranthene gas
65	Chromium 6+	178	Chrysene gas
66	Manganese Compounds		
67	Nickel Compounds	181	Fluorene gas
68	Dibenzo(a,h)anthracene particle	182	Indeno(1,2,3,c,d)pyrene gas
69	Fluoranthene particle	183	Phenanthrene gas
70	Acenaphthene particle	184	Pyrene gas
71	Acenaphthylene particle	185	Naphthalene gas
72	Anthracene particle		
73	Benz(a)anthracene particle		
74	Benzo(a)pyrene particle		
75	Benzo(b)fluoranthene particle		
76	Benzo(g,h,i)perylene particle		
77	Benzo(k)fluoranthene particle		
78	Chrysene particle		

APPENDIX F: CRITERIA POLLUTANT DESCRIPTIONS

Particulate Matter (PM2.5 and PM 10):

- Description: These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles. "PM2.5" and"PM10" represent particle size in micrometers. A human hair is typically 70 micrometers in diameter. These cause reduced visibility (haze) in parts of the United States, including some national parks.
- Health effects: Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.

Nitrogen oxide (NO2):

- Description: NO2 primarily gets in the air from the burning of fuel. NO2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment.
- Health effects: Breathing air with a high concentration of NO2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO2.

Sulfur Dioxide (SO2):

- Description: SO2 is the component of greatest concern and is used as the indicator for the larger group of gaseous sulfur oxides (SOx). The largest sources of SO2 emissions are from fossil fuel combustion at power plants andother industrial facilities.
- Health effects: Short-term exposures to SO2 can harm the human respiratory system and make breathing difficult. Children, the elderly, and those who suffer from asthma are particularly sensitive to effects of SO2.

Carbon Monoxide (CO):

- Description: CO is a colorless, odorless gas that can be harmful when inhaled in large amounts. CO is released when something is burned. The greatest sources of CO to outdoor air are cars, trucks and other vehicles or machinery that burn fossil fuels.
- Health effects: Very high levels of CO are not likely to occur outdoors. However, when CO levels are elevated outdoors, they can be of particular concern for people with some types of heart disease. These people already have a reduced ability for getting oxygenated blood to their hearts in situations where the heart needs more oxygen than usual. They are especially vulnerable to the effects of CO when exercising or under increased stress. In these situations, short-term exposure to elevated CO may result in reduced oxygen to the heart accompanied by chest pain also known as angina.

APPENDIX G: KEY MOVES INPUTS

VMT		Davidson County		North Nashville		
	2017	2033 BAU	2033 LMN	2017	2033 BAU	2033 LMN
Total		**9,921,973,890**	**9,921,973,890**	**8,373,695,226**	**669,396,463**	**656,361,597**
Motorcycles		53,379,875	53,379,875	44,418,183	3,539,918	3,575,172
Light duty vehicles		8,830,564,608	8,830,564,608	7,348,043,384	585,604,128	591,436,094
Buses		9,340,969	9,340,969	7,772,758	619,452	625,621
Haul Trucks		328,774,129	328,774,129	301,808,890	13,067,246	18,482,877

Population	Davidson County			North Nashville		
	2017	2033 BAU	2033 LMN	2017	2033 BAU	2033 LMN
Human Population	689,338	813,530	813,530	18,795	22,181	22,181
Motorcycles	9,994	11,795	11,795	272	322	322
Passenger Cars	293,649	346,553	346,553	8,006	9,449	9,449
Passenger Trucks	122,283	144,313	144,313	3,334	3,935	3,935
Light Commercial Trucks	25,792	30,439	30,439	703	830	830
Intercity Buses	11	13	13	0	1	1
Transit Buses	269	276	276	7	8	8
School Buses	711	839	839	19	23	23
Refuse Trucks	306	362	362	8	10	10
Single-Unit Short Haul Trucks	14,289	18,038	18,038	14	20	28
Single-Unit Long Haul Trucks	657	829	829	1	1	1
Motor Homes	2,777	3,278	3,278	76	89	89
Combination Short-Haul Trucks	3,995	5,263	5,263	4	14	9
Combination Long-Haul Trucks	4,356	5,738	5,738	4	15	9

APPENDIX H: GHG EMISSIONS RESULTS

CO2e Emissions by Vehicle Source Type

SOURCE TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Motorcycle	18,358	21,535	21,395
Passenger Car	1,651,671	1,183,693	1,174,231
Passenger Truck	1,018,564	756,928	751,119
Light Commercial Truck	226,871	164,070	162,791
Intercity Bus	547	624	632
Transit Bus	7,000	5,183	367
School Bus	3,682	4,173	4,230
Refuse Truck	26,769	31,350	30,858
Single-Unit Short Haul Truck	823,113	878,574	833,777
Single-Unit Long Haul Truck	46,019	59,351	56,300
Motor Home	20,163	20,050	19,679
Combination Short-Haul Truck	346,202	477,282	467,501
Combination Long-haul Truck	1,077,627	1,157,063	1,132,804
TOTAL	5,266,586	4,759,878	4,655,683

CO2e Emissions by Road Type

ROAD TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Off-Network	119,086	111,114	110,341
Rural Restricted	227,501	195,980	193,643
Rural Unrestricted	316,150	291,825	276,541
Urban Restricted	2,263,403	2,100,352	2,093,877
Urban Unrestricted	2,340,446	2,062,830	1,988,253
TOTAL	5,266,586	4,759,878	4,655,683

Note: Difference in total CO2e emissions between vehicle source type and road type is due to transit bus emission reductions from electric fuel type switch that were manually removed from 2033 BAU and 2033 LMN.

APPENDIX I: CRITERIA POLLUTANTS EMISSIONS RESULTS

SO_2 Emissions by Vehicle Source Type

SOURCE TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Motorcycle	1.4	2.8	2.8
Passenger Car	88.7	108.6	109.2
Passenger Truck	54.7	70.6	70.9
Light Commercial Truck	12.4	15.4	15.5
Intercity Bus	0.0	0.2	0.2
Transit Bus	0.5	0.8	0.8
School Bus	0.3	0.4	0.5
Refuse Truck	18.7	21.6	26.0
Single-Unit Short Haul Truck	19.7	23.9	40.0
Single-Unit Long Haul Truck	1.2	1.9	2.9
Motor Home	12.6	12.6	15.4
Combination Short-Haul Truck	19.2	62.7	40.0
Combination Long-haul Truck	58.9	148.5	96.5
TOTAL SO_2 emissions (kg/peak hr.)	**288.3**	**470.1**	**420.6**

SO_2 Emissions by Road Type

ROAD TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Off-Network	2.3	2.2	2.2
Urban Restricted	172.2	318.7	275.0
Urban Unrestricted	113.8	149.2	143.5
TOTAL SO_2 emissions (kg/peak hr.)	**288.3**	**470.1**	**420.6**

PM 2.5 Emissions by Vehicle Source Type

SOURCE TYPE:	**2017**	**2033 Business As Usual**	**2033 Let's Move Nashville**
Motorcycle	13.74	29.10	29.14
Passenger Car	211.41	210.84	212.26
Passenger Truck	146.66	149.42	150.55
Light Commercial Truck	30.23	32.90	33.16
Intercity Bus	0.97	0.59	0.63
Transit Bus	2.12	1.08	1.71
School Bus	5.70	1.21	1.27
Refuse Truck	430.38	56.48	67.76
Single-Unit Short Haul Truck	259.20	41.29	69.19
Single-Unit Long Haul Truck	19.59	3.92	6.03
Motor Home	220.24	33.62	40.87
Combination Short-Haul Truck	382.23	147.75	94.58
Combination Long-haul Truck	1474.47	437.92	285.36
TOTAL PM 2.5 emissions (kg/peak hr.)	**5,213.9**	**1,146.1**	**992.5**

PM 2.5 Emissions by Road Type

ROAD TYPE:	**2017**	**2033 Business As Usual**	**2033 Let's Move Nashville**
Off-Network	44.4	27.0	27.0
Urban Restricted	2,110.2	787.5	657.5
Urban Unrestricted	1,042.3	331.6	308.0
TOTAL PM 2.5 emissions (kg/peak hr.)	**5,213.9**	**1,146.1**	**992.5**

PM 10 Emissions by Vehicle Source Type

SOURCE TYPE:	**2017**	**2033 Business As Usual**	**2033 Let's Move Nashville**
Motorcycle	15.5	32.9	32.9
Passenger Car	238.9	238.2	239.8
Passenger Truck	165.1	168.6	169.9
Light Commercial Truck	33.8	37.1	37.4
Intercity Bus	1.1	0.6	0.7
Transit Bus	2.3	1.2	1.9
School Bus	6.2	1.3	1.4
Refuse Truck	467.8	61.4	73.7
Single-Unit Short Haul Truck	281.9	45.1	75.5
Single-Unit Long Haul Truck	21.3	4.3	6.6
Motor Home	239.8	36.8	44.7
Combination Short-Haul Truck	415.5	160.6	102.8
Combination Long-haul Truck	1,602.7	476.0	310.2
TOTAL PM 10 emissions (kg/peak hr.)	**3,491.9**	**1,264.0**	**1,097.4**

PM 10 Emissions by Road Type

ROAD TYPE:	**2017**	**2033 Business As Usual**	**2033 Let's Move Nashville**
Off-Network	50.2	30.5	30.5
Urban Restricted	2,303.0	866.9	725.9
Urban Unrestricted	1,138.7	366.6	341.0
TOTAL PM 10 emissions (kg/peak hr.)	**3,491.9**	**1,264.0**	**1,097.4**

CO Emissions by Vehicle Source Type

SOURCE TYPE:	**2017**	**2033 Business As Usual**	**2033 Let's Move Nashville**
Motorcycle	7,147.6	12,372.8	12,292.1
Passenger Car	142,490.3	119,233.3	120,677.8
Passenger Truck	111,547.6	76,704.6	77,444.9
Light Commercial Truck	20,348.5	17,049.6	17,219.0
Intercity Bus	5.7	5.4	5.7
Transit Bus	55.8	69.6	101.5
School Bus	51.9	26.5	27.3
Refuse Truck	2,933.5	778.0	931.1
Single-Unit Short Haul Truck	5,395.1	2,567.7	4,301.5
Single-Unit Long Haul Truck	256.1	75.2	115.7
Motor Home	13,393.6	3,252.3	3,898.3
Combination Short-Haul Truck	2,254.1	1,880.8	1,200.9
Combination Long-haul Truck	7,959.1	4,522.6	2,938.3
TOTAL CO emissions (kg/ peak hr.)	**315,855.9**	**238,538.2**	**241,154.1**

CO Emissions by Road Type

ROAD TYPE:	**2017**	**2033 Business As Usual**	**2033 Let's Move Nashville**
Off-Network	34,351.3	12,409.1	12,412.6
Urban Restricted	176,280.9	146,837.4	149,911.3
Urban Unrestricted	103,206.7	79,291.8	78,830.2
TOTAL CO emissions (kg/ peak hr.)	**313,838.9**	**238,538.2**	**241,154.1**

CO Emissions by Road Type

ROAD TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Off-Network	34,351.3	12,409.1	12,412.6
Urban Restricted	176,280.9	146,837.4	149,911.3
Urban Unrestricted	103,206.7	79,291.8	78,830.2
TOTAL CO emissions (kg/peak hr.)	**313,838.9**	**238,538.2**	**241,154.1**

NOx Emissions by Vehicle Source Type

SOURCE TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Motorcycle	349.6	690.8	682.3
Passenger Car	8,910.4	3,488.6	3,499.2
Passenger Truck	9,535.4	2,852.8	2,858.8
Light Commercial Truck	1,336.0	680.5	682.4
Intercity Bus	22.6	19.0	20.2
Transit Bus	94.4	69.9	95.9
School Bus	107.5	49.5	51.9
Refuse Truck	6,788.6	2,128.2	2,555.6
Single-Unit Short Haul Truck	4,507.1	1,634.5	2,740.0
Single-Unit Long Haul Truck	318.8	157.2	242.1
Motor Home	3,917.6	1,022.4	1,244.0
Combination Short-Haul Truck	6,471.3	5,614.4	3,585.0
Combination Long-haul Truck	23,251.4	14,503.5	9,423.6
TOTAL NOx emissions (kg/peak hr.)	**65,610.8**	**32,911.4**	**27,681.1**

NOx Emissions by Road Type

ROAD TYPE:	2017	2033 Business As Usual	2033 Let's Move Nashville
Off-Network	4,253.5	1,001.6	1,001.9
Urban Restricted	39,979.3	22,465.9	18,112.4
Urban Unrestricted	21,378.0	9,443.8	8,566.8
TOTAL NOx emissions (kg/peak hr.)	**65,610.8**	**32,911.4**	**27,681.1**