Equity Analysis for Long Range Transportation Planning

NCDOT Project 2023-12
FHWA/NC/2023-12
April 2025

Srinivas S. Pulugurtha, Ph.D., P.E., F.ASCE. et al.
The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223-0001

RESEARCH & DEVELOPMENT

EQUITY ANALYSIS FOR LONG RANGE TRANSPORTATION PLANNING

FINAL REPORT

Submitted to:
North Carolina Department of Transportation
Office of Research
(Research Project No. RP2023-12)

Submitted by

Srinivas S. Pulugurtha, Ph.D., P.E., F.ASCE
Suzanne Leland, Ph.D.
Christina Danis, Ph.D.
Ninad Gore, Ph.D.
Muthumari Anbumani, M.S.
Rose Thomalen, M.A.
Abhinav Grandhi, M.S.

The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223-0001

April 30, 2025

Technical Report Documentation Page

1. Report No. FHWA/NC/2023-12	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Equity Analysis for Long Range Transportation Planning		5. Report Date April 30, 2025	
		6. Performing Organization Code	
7. Author(s) Srinivas S. Pulugurtha, Suzanne Leland, Christina Danis, Ninad Gore, Muthumari Anbumani, Rose Thomalen and Abhinav Grandhi		8. Performing Organization Report No.:	
9. Performing Organization Name and Address Department of Civil & Environmental Engineering The University of North Carolina at Charlotte 9201 University City Boulevard Charlotte, NC 28223 - 0001 Email: sspulugurtha@charlotte.edu		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. NCDOT RP2023-12	
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Development Unit 1549 Mail Service Center Raleigh, North Carolina 27699-1549		13. Type of Report and Period Covered Final Report Aug. 1, 2023 – April 30, 2025	
		14. Sponsoring Agency Code RP2023-12	
Supplementary Notes:			
16. Abstract: Equitable transportation is a fundamental civil right of every individual. Incorporating equity in long range transportation planning process and during project prioritization helps to understand and accommodate the needs of underserved communities in future transportation infrastructure developments. This document summarizes (a) definitions of transportation equity adopted by different agencies and researchers, (b) best practices adopted by various agencies, (c) equity indicators used in analysis, and (d) existing research gaps. Moreover, findings from the survey of regional agencies, state departments of transportation (DOTs) and focus groups are summarized to understand the needs and incorporate equity in long range transportation planning. The framework for incorporating equity in long range transportation planning is also presented.			
17. Keywords: Equity, transportation, planning		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 73	22. Price

DISCLAIMER

The contents of this report reflect the views of the authors and not necessarily the views of the University of North Carolina at Charlotte (UNC Charlotte) or the North Carolina Department of Transportation (NCDOT). The authors are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either UNC Charlotte, NCDOT, or the Federal Highway Administration (FHWA) at the time of publication. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

The authors acknowledge the NCDOT for providing financial support for this project. Special thanks are extended to Alena Cook (Chair), Jamal Alavi, Andy Bailey, Hemal Shah, Natasha Earle-Young, Tunya Smith, Emily Richards, Gerald Carter, Jason Schonce, Sarah Lee, Mark Eastman, Bryan Lopez, Jamille Robbins, Harrison Marshall, Brandon Oliver, Arthur Cashwell, Abby Lorenzo, Vicki Eastland, Stephanie Harmon, Jaehoon Kim and Curtis Bradley for serving on the NCDOT Steering and Implementation Committee and providing their valuable suggestions and guidance on the project.

EXECUTIVE SUMMARY

Equitable transportation involves ensuring that transportation services are accessible and affordable to all communities. Addressing equity in long range transportation planning allows agencies like the North Carolina Department of Transportation (NCDOT) to always respond to the needs of all transportation system users and accomplish the goal of equitable transportation. However, there is limited guidance available for conducting systematic and integrated transportation equity analysis for long-range transportation planning. Moreover, there are both data and performance evaluation challenges that exist which require solutions before adopting equity measures in long range transportation planning across the state.

Project objectives:

1) Review the recent developments in transportation equity related research and identify the best practices, existing gaps, limitations, and challenges.
2) Survey the staff of metropolitan planning organizations (MPOs), rural planning organizations (RPOs), and other state departments of transportation (DOTs) as well as conduct focus grouping meetings and gather information on how best equity can be addressed in the early stages of long-range transportation planning.
3) Identify data, data sources, specific performance measures, and evaluation tools for equity analysis in long range transportation planning.
4) Develop guidelines and propose a complementary methodology to that includes equity during future project proposal development/alternatives analysis for long-range transportation planning in North Carolina.

This report recaps the literature on transportation equity and seeks clarification of how equity is incorporated into the long-range transportation policy process while meeting the necessary data requirements. It also includes the following:

(a) results of surveys of MPOs, RPOs, other State DOTs and agencies on how they address transportation equity.
(b) findings and recommendations from focus group meetings involving NCDOT and other state partners to address the transportation equity in the initial stages of long-range transportation planning.
(c) a complementary methodology/tool that NCDOT may consider for analyzing, measuring, coordinating on, and reporting equity in their projects.
(d) an analysis of data gaps that need to be addressed for incorporating equity in long range transportation planning. Below are also important highlights from the surveys and the analyses.

Survey findings from North Carolina public officials who are involved in long-range transportation planning:

- Equity looks different and means something different in various places; NCDOT address misconceptions about transportation equity and produce a widely accepted definition.
- Funding priorities, plans, and goals of long-range transportation planning have been oriented towards road construction and maintenance but not public transportation--this makes creating an equitable, healthy, affordable regional transportation network challenging.
- Many communities are increasing their reliance on public transportation and bike/pedestrian environments, therefore there is an opportunity to incorporate more active and sustainable active transportation in future long-range transportation plans..
- Coordination between regional/local agencies and the DOT field offices makes it difficult for public officials to fully understand how tools are being utilized and whether the data needs to be updated based on community preferences.

Selected highlights from the survey of other State DOTs:

- Equity is defined as fairness in accessibility and mobility across the U.S.
- Equity isa part of the general goals and objectives, mode choice, and project prioritization.
- Automobile-oriented investment is the largest barrier to having equal access to transportation; Improving access to non-motorized modes, considering low-income, elderly, and disabled people, may achieve a better balance.
- Multimodal planning and public engagement are important considerations for incorporating equity.
- Inter-institutional collaboration can improve fairness by reaching out to populations with limited or no access to automobiles therefore improving equitable transportation.

General input from the focus group meetings and interviews with state, regional and local stakeholders and public officials:

- There is a need for a more equitable process in long-range transportation planning.
- There is concern that the current evaluation criteria for funding limits the ability for smaller towns and rural/suburban area projects to compete against urban or larger projects.
- NCDOT should consider the lack of balance between in state funding for public transportation versus state funding for additional highway capacity.
- State allocation of funds should take into consideration local governments available financial capacity to match grant funding.
- If funds are allocated to more multimodal options and active transportation, the result would be more equitable for those who lack access to cars or do not drive
- Participants called for more support complete streets, public safety and the environment as prioritization over highways and roads; they expressed concern that non-automobile users are not being treated fairly in the current prioritization formula.
- There is a notable lag time in project implementation: participants preferred nearby/short-term active transportation and microtransit options to get people to work, school, play, and healthcare instead of or while waiting 10 to 20 years for implementing large-scale transportation projects.
- Respondents identified the limitation of existing tools and outreach and capacity practices in the planning process. This includes:
    - Improved equity tools to account for rural area and urban core low income pockets; these populations needs are not always apparent when looking at only census block group data
    - Rural planning organizations need more staff/capacity to allow for more grass roots outreach in the planning process. This could improve public participation among low-income urban areas.
- Respondents asked about improving messaging/education on how equity increases economic growth:
    - In particular, they asked for ways to improve consensus among both rural and urban legislators about the ways different communities can benefit from investing in transportation across the state of North Carolina.
    - They acknowledged that this would require more compromises among jurisdictions. Therefore, it is important to find ways to build trust among one another to provide more equitable transportation.

Selected highlights related to the equity framework and data gaps are:

- Consideration of equity when defining goals/objectives, scenario planning, and when prioritizing implementation of projects and in the modeling process.
- Geographic information systems (GIS)-based tools may be a useful way improve the assessment of community needs though analyzing the potential impact of selected projects.
- Detailed data (household/individual surveys) should be collected for analysis and modeling. The sample should meet minimum sample size requirements and should be geographically distributed. Data pertaining to and from transportation-disadvantaged populations is vital for incorporating their needs in the process. Tour-based models are an opportunity to account for trip and destination choices of individuals.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1. Introduction

Common travel destinations like employment centers, public services, healthcare centers, education, places of worship, grocery stores, etc. are designed in favor of personally owned vehicles. This often fails to meet the needs of those who do not have access to a driver's license or have a car in their household. About 10 percent of US adults are non-drivers. Urban residents, younger Americans, and those with lower incomes are the most likely to fall into the category of nondrivers (Shaeffer, 2024). Transportation planners and decision-makers alone cannot address equity-related issues to account for or ensure equitable distribution of benefits and costs for all members of society. The problem can be better approached through a collective effort of expertise from a wide range of transportation-relevant occupations and organizations, including community members representing or serving different communities across the state.

For this reason, many agencies undertake equity analysis in their long-range planning processes. However, there is no formal or widely adopted method/tool for evaluating transportation equity in this process. Therefore, conducting extensive review of existing literature and surveying related stakeholders, including the Federal Highway Administration (FHWA), various departments of transportation (DOTs), North Carolina Department of Transportation (NCDOT) Transportation Planning Division, NCDOT Modal Divisions, other NCDOT units, metropolitan planning organizations (MPOs), rural planning organizations (RPOs), transit agencies, and community representatives can lay a solid foundation for proposing an appropriate equity assessment methodology for long range transportation planning in North Carolina. However, applying the methodology would primarily depend on the granularity of the datasets and their quality in defining equity. Therefore, this research aims to identify current research and practices on the collection/ usage of data and a complementary methodology for considering/integrating, analyzing, measuring, coordinating, and reporting equity in long range transportation planning. The findings from this study help NCDOT and other partner agencies in North Carolina to address transportation equity in the initial stages of state-required or federal-required plans like Comprehensive Transportation Plan (CTP), State Implementation Plan (SIP), Metropolitan Transportation Plan (MTP), corridor plan, statewide plan, and subarea plan. This report serves as an informative guide to the best practices and procedures applicable to North Carolina.

1.1. Need for This Research

While most planning agencies consider equity issues in transportation plans/projects, adopting systematic and integrated assessment seldom occurs. Questions about equity issues, such as travel costs, facility planning, and accessibility, arise during and after policy implementation. Considering equity in the initial stages of a planning process, when projects are in the ideation stage, is a proactive, more effective, and efficient way to minimize potential disparities among different populations.

In North Carolina, equity is considered in most transportation plans and projects. The current practice followed by agencies like NCDOT seeks to use available guidance, data, and methods to consider equity appropriately in long range transportation planning. However, at this time, there is no standard way to account for all the transportation equity objectives in long range transportation planning. There is a need to conduct an extensive review of existing literature and survey perceptions of MPOs, RPOs, equity stakeholders, communities, etc. to help better understand how NCDOT is doing at present and fits into the process. It is also essential to research the challenges and limitations of currently available data and tools to adopt an appropriate and complementary equity assessment methodology and performance measures for NCDOT. This will benefit NCDOT and the communities of North Carolina and result in an enhanced project delivery process by allowing the earlier identification of issues and engagement of interested/ affected parties.

The COVID-19 pandemic has grabbed the attention of policymakers and practitioners on equity from a short-term delivery perspective. Unarguably, the pandemic had an impact on e-commerce and the economy. The differences in service opportunities seemed evident for certain population groups and people living in certain areas with access limitations for quicker delivery. Researching and addressing this gap,

particularly considering the delivery of necessary and perishable commodities like food, groceries, medicines, etc. overnight, is imperative. There is a need to research, identify, highlight, and minimize areas that do not have access to short-term deliveries when developing LRTPs. This will help NCDOT and other partner agencies in North Carolina avoid such inequitable situations and better serve all population groups in the future.

1.2. Research Objectives

The objectives of the project are:

1) review the recent developments in transportation equity-related research and identify research gaps and data requirements.
2) to identify best practices, any limitations, and challenges in meeting equity needs.
3) to survey/interview practitioners (MPOs, RPOs, and other State DOTs) and conduct focus group meetings, and to gather information on how stakeholders perceive equity and how it can be best addressed in the early stages of long-range transportation planning.
4) to identify data, data sources, specific performance measures, and evaluation tools for equity analysis in long range transportation planning; and,
5) to develop guidelines and propose a complementary methodology that can be applied to ensure equity is appropriately addressed during project proposal development/ alternatives analysis for long range transportation planning in North Carolina.

1.3. Organization of the Report

The remainder of this report comprises seven chapters. Following this introduction chapter are a review of the literature, a survey of regional agencies, a survey of other State DOTs, focus group meetings and interviews, framework and illustrations, and data gaps/challenges.

Chapter 2. Literature Review

In general, equity can be defined as the "distribution of benefits and costs over members of any society" (Boucher and Kelly, 1998). Di Ciommo and Shiftan (2017) defined the three components of equity in transportation: the benefits and costs that are being distributed, the target population over which benefits and costs are distributed, and the distributive principle that determines whether a particular distribution is "morally proper" and "socially acceptable." According to the U.S. Bureau of Labor Statistics (2022) report for the year 2021, the significant expenditure of a U.S. household is for housing and transportation. Especially, households in the bottom quartile of income spend about 32% of their income on transportation. This varies widely within demographic/socioeconomic indicators such as income, race, gender, educational attainment, age, limited English proficiency (LEP), and accessibility (Ezike et al., 2020). Disparities such as high transportation costs are especially burdensome for low-income households because they prevent the low-income households from spending appropriately on other needs such as housing, food, health care, and education.

Equity in transportation is fairly distributing transportation benefits and burdens in society (Pereira and Karner, 2021). Per the Executive Order 12898 of February 11, 1994 - Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Presidential Documents 1994) and Executive Order 13985 of January 20, 2021 - Advancing Racial Equity and Support for Underserved Communities (Presidential Documents 2021), equity is to meet the needs of all groups in terms of mobility and accessibility. Since accessibility to destinations and associated travel costs directly affect people's lives, the availability and quality of transportation significantly impact social fairness or the distribution of benefits and costs among all the members of society (Cantilina et al. 2021). In other words, a transportation plan should benefit different population groups equally and reasonably.

2.1. Definition of Equity

Defining "equity" is vital for effectively assessing how transportation projects and policies can affect the distribution of costs and benefits among communities. Table 1 summarizes the definitions of "transportation equity" used by MPOs, RPOs, and State DOTs in their long-range transportation planning or Transportation Improvement Programs (TIPs).

Table 1. Transportation Equity - Definition

Agency / Plan	Definition of Transportation Equity
FHWA (2012) - Environmental Justice	"Environmental justice means identifying and addressing disproportionately high and adverse effects of the agency's programs, policies, and activities on minority populations and low-income populations to achieve an equitable distribution of benefits and burdens."
District Department of Transportation (DDOT) (2012), Equity statement	"Transportation equity is the shared and just distribution of benefits and burdens when planning for and investing in transportation infrastructure and services. Transportation decisions are made in collaboration and in participation with the community DDOT serves, to establish a system that is safe, accessible, affordable, reliable, and sustainable. Focused attention is given to historically under-resourced communities in order to overcome existing disparities and achieve transportation equity that include, but are not limited to: people of color, people with low income, people living with disabilities, LGBTQ+ people, individuals who identify as female, youth, older adults, residents at risk of displacement, people experiencing homelessness or housing insecurity immigrant and refugee communities, and people with limited English proficiency and literacy"
Vanessa et al. (2013)	"Equitable access to safe, reliable, and affordable transportation options, employment, services, amenities, education and health centers, and cultural destinations. Shared distribution of the benefits and burdens of transportation systems and investments, especially for communities historically impacted by racial injustice, disinvestment, pollution, and unsafe streets. Partnership in the planning, investment, and implementation processes that results in: shared decision-making; more equitable health and quality of life outcomes for high priority areas while strengthening the entire region and serving existing residents; and equitable policies to achieve development without displacement."
Oregon Metro Council (2018), Transportation equity evaluation - regional transportation plan	"The removal of barriers to eliminate transportation-related disparities faced by and improve equitable outcomes for historically marginalized communities, especially communities of color."
U.S. DOT FHWA's Transportation Planning, and	"Equity in transportation seeks fairness in mobility and accessibility to meet the needs of all community members. A central goal of transportation is to facilitate social and economic opportunities

Capacity Building Program (2019) Website	by providing equitable levels of access to affordable and reliable transportation options based on the needs of the populations being served, particularly populations that are traditionally underserved. This population group includes low-income individuals, minority individuals, elderly persons, children, people with LEP, and/or persons with disabilities."
Presidential Documents (2021) - Executive Order 13985 of January 20, 2021, Advancing Racial Equity and Support for Underserved Communities	"Equity means the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality."
Pereira and Karner (2021)	"Transportation equity is a way to frame distributive justice concerns in relation to how social, economic, and government institutions shape the distribution of transportation benefits and burdens in society. It focuses on the evaluative standards used to judge the outcomes of policies and plans, asking who benefits from and is burdened by them and to what extent."
Minnesota DOT (2022), Advancing transportation equity project	"Transportation equity ensures the benefits and burdens of transportation spending, services, and systems are fair and just, which historically has not been the case. Transportation equity also requires sharing power in decision-making with people, especially Black, Indigenous and People of Color."
Seattle DOT (2022), Transportation equity framework	"Equity is a measure of fair treatment, opportunities, and outcomes across race, gender, class, and other dynamics."
Caldwell (2022)	"Equity is achieved when a Houstonian's race, ethnicity, disability, gender identity, and/or sexual orientation do not predict their outcomes or limit their choices. Our city embraces and nurtures its multiculturalism and diversity by offering opportunities for all and deploys policies that support fair and just access to opportunity".
Executive Order No. 292 – Advancing environmental justice for North Carolina (State of North Carolina, 2023)	""Environmental Justice" means the just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, or Tribal affiliation, in agency policies and programming that affect human health, well-being, quality of life, and the environment so that people: (i.) are protected from disproportionate and adverse human health effects and environmental hazards, including: those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and (ii.) have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices."
Litman (2023), Evaluating transportation equity: guidance for incorporating distributional impacts in transport planning	"Horizontal equity (also called fairness and equality) is concerned with the distribution of impacts between people with similar needs and abilities. A fair share of resources. It concerns public resource allocation and implies that people should generally "get what they pay for and pay for what they get." External costs. Costs that travel activities impose on other people, such as delay, risk and pollution, are unfair. Fairness requires minimizing or compensating for such impacts. Vertical equity is concerned with the distribution of impacts between people who differ in needs and abilities. There are five main categories of transportation equity. Inclusivity - vertical equity considering the need and ability i.e., how transportation systems serve people with disabilities, youths and seniors, and other special mobility needs. It justifies multimodal planning and universal design requirements. Affordability - vertical equity considering the income i.e., how transportation systems affect lower-income people. Policies that favor lower-income people are called progressive, and those that favor higher-income people are called regressive. It justifies policies that improve affordable modes and subsidize low-income travelers. Social justice - This considers how transportation systems serve disadvantaged and underserved groups and address structural injustices such as racism and sexism. Procedural equity is defined as inclusive, accessible, authentic engagement and representation in processes to develop or implement programs or policies. Structural equity, or when decision-makers institutionalize accountability - decisions are made with a recognition of the historical, cultural, and institutional dynamics and structures that have routinely advantaged privileged groups in society and resulted in chronic, cumulative disadvantage for subordinated groups.

Although equity is mentioned in LTRPs and other transportation planning documents, there is no consensus on defining the term. Therefore, defining equity and its dimension is necessary as it will assist in defining the problem, identifying a set of indicators, and developing a framework applicable to North Carolina.

2.2. Equity Indicators

Addressing equity early in planning improves planning efficiency (Shiftan and Suhrbier, 2002). Therefore, it is important to consider transportation equity with long-term goals rather than a simple cost-benefit analysis related to any transportation project. While discussing transportation equity, literature has highly relied on societal structures producing less fair distribution of benefits and costs. Racialized spatial segregation often causes problems of transportation inequity (Bullard et al., 2004). Factors such as automobile dependency and governance structure also contribute to transportation equity-related challenges (Kane et al., 2005; Altshuler, 2010). Geurs and Van Wee (2004) reported that automobile-oriented development practices are one of the primary reasons for transportation inequity in North America.

Identifying indicators that could be used to measure equity/inequity is essential for integrating equity in long range transportation planning and design. The degree to which transportation disadvantaged groups are affected needs to be quantified. Demographic/socioeconomic indicators, accessibility, travel time, affordability, safety, public health, and environment-related indicators are the most commonly used equity metrics. A brief explanation of these indicators is presented next.

Demographic/Socioeconomic Indicators: Many users encounter transportation issues/barriers throughout the day. The impact of these barriers may be related to spatial, temporal, economic, physiological, and social factors. Many researchers consider people experiencing challenges in attaining basic access to services, goods, employment, etc. as transportation-disadvantaged or communities of concern (COC). Duvarci and Yigitcanlar (2007) state that the transportation-disadvantaged population includes disabled people, young and elderly, low-income earners, people with LEP, and those without access or limited access to private motor vehicles, urban activities, and transit services. U.S. Environmental Protection Agency (EPA) (2022) mentions these transportation-disadvantaged groups as demographic/socioeconomic indicators. The metrics are communities of color, older adults, people experiencing poverty, people with disabilities, and LEP. Many researchers studied the social vulnerability of transportation-disadvantaged people exposed to natural and human-caused environmental hazards (Brody et al., 2008; Van Zandt et al., 2012).

The transportation-disadvantaged population suffered disproportionately during the pandemic (Delavega et al., 2022). Race and ethnicity (Karner and Niemeier, 2013), income (Ricciardi et al., 2015; El-Geneidy et al., 2016), and employment status (Jones and Wixey, 2005; Pyrialakou et al., 2016) are some of the demographic/socioeconomic indicators used for addressing transportation equity. Some least-used factors include gender (Dobbs, 2005; Rogalsky, 2010) and local language fluency (Litman et al., 2016). Overall, the transportation inequity due to racism, gender disparities, income disparities, age disparities, people with disabilities, rural transportation, and tribal transportation was considered and documented in the past.

Accessibility: Many researchers consider accessibility as a basic measure of equity, as it simultaneously accounts for both land use patterns and a transportation system (Grengs et al., 2013). The degree to which the transportation system provides access to essential services such as work, school, food, healthcare, recreation, and other destinations is referred to as connectivity or accessibility (Geurs et al., 2009; Cao et al., 2010; Hu, 2015; Owen and Levinson, 2015; Xu et al., 2016). This accounts for how well the transportation network connects people to where they need to go. Mobility (physical travel), land use patterns (the geographic distribution of services and activities), and mobility substitutes such as telecommunications and delivery services all impact accessibility.

Overall, the most commonly used performance metrics for assessing accessibility are:

- number of jobs, schools, healthy food, healthcare, and recreation centers within 30 minutes, 45 minutes, and 60 minutes.
- percentage of the population that lives within 0.25 miles of a transit stop or an active transportation facility.

- percentage of state-owned sidewalk miles compliant with the Americans with Disabilities Act (ADA) standards (Minnesota DOT).
- percentage of state highway curb ramps that are compliant with ADA requirements.
- percentage of eligible state highway intersections with accessible pedestrian signals; and,
- percentage of the state's communities whose span of transit service meets the minimum guidelines each year.

Transportation equity projects focus on economic, ecological, and social sustainability. However, the social impacts of transportation have been under-explored, and social impacts are a long way from being included in transportation equity projects. Hence, it is crucial to include social and spatial factors accounting for accessibility to key activities (Geurs and Van Wee, 2004). The accessibility measures should capture the total utility from all travel factors, such as duration, cost, and individual attributes. This will allow individuals to have varying levels of accessibility for varying scenarios of choice depending on their characteristics (Biran et al., 2014).

Travel Time: COCs are often being forced further and further outside of urban areas and away from their workplaces as urban housing costs soar. They have longer commute times since most U.S. cities have inadequate public transit systems. Therefore, travel time could also be considered as an equity metric. Overall, the most commonly used performance metrics associated with travel time are:

- annual per capita delay; and,
- reliability measures such as buffer time (BT) and planning time index (PTI).

Van Wee and Geurs (2011) assessed the current evaluation techniques used to estimate the distribution of transportation projects. They concluded that the current techniques used to assess equity in transportation problems are complex.

A new transportation project is usually proposed and implemented based on a cost-benefit analysis of the transportation project. The cost-benefit analysis related to the implementation of a transportation project is quantified based on travel time savings. Such savings and associated benefits can be maximized if projects are built to serve the majority of the population. On the other hand, accessibility-gains-based decision-making helps implement projects in regions that have less access. Martens and Di Ciommo (2017) concluded from their research that using accessibility gains rather than travel time savings will achieve social equity.

Kaplan et al. (2014) developed connectivity-based measures for equity. Travel time, reliability of the given service, and route transfers along a given path were considered to develop the connectivity-based measure. Less equitable areas were identified based on this measure.

The spatial unit of assessment is especially important in transportation equity analysis. Many researchers considered census tracts as their area unit of assessment (Cutler et al., 2008; Spielman and Thill, 2008). The issue with census data is that it is not updated frequently.

Affordability/Economic Vitality: This indicator delves into the racial/ethnic disparities individuals and households face in three areas: housing cost burden, internet access, and utility expenses. People who are "housing cost-burdened" spend more than 30% of their household income on rent or mortgage payments. Housing and utility costs disproportionately affect people of color, who are more likely to pay well above this threshold. High housing and utility costs limit low-income residents' ability to pay for other essential services such as transportation, childcare, health care, or food (City of Dallas, 2021).

Overall, the most commonly used performance metrics for assessing affordability are:

- percentage of household income spent on transportation.
- housing and transportation affordability index.
- displacement by population group.
- travel cost savings.
- freeway congestion.
- interstate reliability.

- number of jobs within a 30-minute bike commute (in development).
- number of jobs within a 30-minute car commute; and,
- number of jobs within a 30-minute transit commute.

Safety: Lower-income neighborhoods suffer from vehicle occupant fatality rates higher than those in wealthier neighborhoods. Also, residents of most rural areas endure fatality rates approximately six times higher than most urban areas (Marshall and Ferenchak, 2017). Overall, the most commonly used performance metrics for assessing safety are:

- number of fatalities by road-user category (bicycles, pedestrians, and vehicles).
- crashes by severity (property damage only, injury, and fatality); and,
- crash hot spots.

Health and Environment: Public health is another aspect related to transportation equity and has been studied by many researchers recently. Road expansion/widening projects improve mobility and accessibility. Even though these investments reduce travel times/congestion, pollutant emissions will significantly increase over time (Shamsher and Abdullah, 2013). The low-income population is often disproportionately exposed to traffic-related air pollution and noise pollution (Shih et al., 2020; Gibb et al., 2020; Kocak et al., 2021). The "RP 2022-17: Including Equity in Benefit-Cost Analysis" documents literature and best practices adopted by State DOTs, MPOs, and RPOs in addressing equity. The study focuses on the health equity perspective. The benefit-cost analysis focuses on calculating the change in deaths, years of life lost, and disability, as well as the costs associated with changes in air pollution, physical activity, and traffic injuries.

Overall, the most commonly used performance metrics for assessing health and environment are:

- healthcare availability.
- vehicle emissions.
- noise pollution.
- emergency evacuation; and,
- walking score.

2.3. Summary of Current Practices Adopted by State DOTs and MPOs

The idea of including equity in transportation planning models typically focuses on different impacts for different groups and modes in terms of accessibility, mobility, travel time, safety, transportation expenditure and affordability, and transportation investments (Manaugh et al., 2015). Significant strides were made in the direction of addressing equity in long range transportation planning by many State DOTs. The Minnesota DOT launched the 'Advancing Transportation Equity' initiative to understand how equity can be best addressed in their planning process. They extensively reviewed current practices and provided recommendations to advance transportation equity in Minnesota. The 'transportation equity program' developed by Seattle DOT provides discounted transit passes and vehicle access to low-income Seattle residents. The "RP 2022-17: Including Equity in Benefit-Cost Analysis" project aimed to establish the methodology, data sources, and implementation approaches to include specific equity concerns in benefit-cost evaluations undertaken within the NCDOT strategic prioritization processes. The research aimed (a) to identify critical resources that could be used to create two cross-modal measures (air quality and physical health) that are intrinsically linked to equity and (b) incorporate these measures into NCDOT's prioritization process.

The project entitled 'Defining North Carolina's Transportation disadvantaged populations,' funded by NCDOT, proposed a practice-ready methodology to identify the location and needs of transportation-disadvantaged populations across the state (Lane et al., 2014). The city of Raleigh in North Carolina established a pedestrian plan to identify priority areas based on demand. The pedestrian and bicycle plan of the city of Raleigh also focused on prioritizing facilities for the older, younger, and low-income groups.

Table 2 summarizes the best practices adopted by the DOTs and MPOs in their equity analysis process.

While the section summarizes an overview of current equity practices, readers are encouraged to check recent changes in related policies and priorities as some executive orders (for example, Executive Order 12898) were rescinded earlier this year.

Table 2. Equity Practices Adopted by State DOTs and MPOs

Agency / Plan / Program	Demographic Factors	Data / Tool	Comments
Atlanta Regional Commission (ARC), Equitable Target Areas (ETA) (2018)	• Ethnic minority • Female • Foreign-born • LEP • Low-income • Older adults • People with disabilities • Racial minority • Youth	• Census • Geographic Information Systems (GIS) • ACS	• Criteria Bin Scoring (0 to 4) • Census tracts are classified into five bins based on standard deviations relative to the regional mean • Cumulative bin scoring (0 to 36) • Overlay of all nine demographic factors to get a cumulative numeric score
Atlanta Regional Commission (ARC) (2016) - TIP; Environmental Justice (EJ) model	• Ethnic minority • Low-income • Racial minority	• Census • GIS	• Cumulative Bin scoring (0 to 12) • Overlay of all nine demographic factors to get a cumulative numeric score
Baltimore Regional Transportation Board (2016) - Maximize 2040		• GIS • Census • ACS • Tour-based travel-demand model	• Assessment indicators: safety, accessibility, & mobility; crash severity; complete streets; access to job/activity centers / transit station; level of service; transit options; ridership, emissions and greenhouse gas • Comparison of results for COCs and non-COCs under two future scenarios: baseline and preferred alternative
Delaware Valley Regional Planning Commission (2021) - Connections 2050 LRTP	• Racial minority • Ethnic minority • Foreign-born • LEP • Disabled • Low-income • Youth • Older adults • Female	• Census • GIS • Disadvantage EJ Analysis Tool	• Indicators of Potential Disadvantage (IPD) score is determined by standard deviations relative to an indicator's regional average
Madison Area Transportation Planning Board (MATPB) (2012a,b) - 2035 RTP	• Minority households in poverty • Carless households	• ACS	• Transit travel times • Map of projects overlaid with COCs • Qualitative transportation project analysis, including maps of projects likely to have negative and positive impacts • Travel time analysis of COCs to selected destinations
Madison Area Transportation Planning Board (MATPB) (2022) - TIP	• Minority, low-income, carless households	• ACS • GIS	• Transit service • Map of projects overlaid on COCs • Narrative discussion of expected positive/negative impacts
Massachusetts DOT, Baseline Equity Indicators Project (Williams, 2021)		• The Accessibility Observatory • Streetlight (Big Data for Mobility)	• Assessment indicators: access to essential places, healthcare, higher education, jobs, & open space; average travel time; carbon monoxide emissions; congested vehicle miles traveled (VMT); 5% of short trips commuting to transit stations • Map of projects overlaid with COCs
Memphis MPO (2016) - 2040 RTP	• Minority • Low-income • LEP	• ACS • GIS • Travel-demand model	• Scenario analysis • Mode to work by EJ communities. • EJ communities in relation to transit and non-motorized networks • Highway capacity, transit, and bike/pedestrian projects are compared with planned investments in EJ communities and the total regional investment in the transportation sector

Metropolitan Area Planning Agency (MAPA) (2018) - MTP	• Minority households in poverty • Carless households	• GIS • ACS	• Jobs within 30 minutes by transit/auto • % of funding in EJ areas compared to total funding, normalized by the % of the population living in EJ areas
Metropolitan Council (2014) - Thrive 2040	• Minority • Low-income • LEP • Disabled	• ACS • GIS • Regional travel demand model	• Map of projects overlaid on the map of COCs • Highway and transit accessibility of plan compared to existing conditions
Metropolitan Transportation Commission (MTC) (2021a,b) - covering San Francisco Bay Area, Plan Bay Area 2050	• Low-income, minority elderly • LEP • Carless households • Disabled • Single-parent households • Rent-burdened households • Percent income spent on housing and transportation. • % of rent-burdened households in high growth areas	• Census • California Dept. of Finance population projections • Association of Bay Area Governments (ABAG) population, household, employment, housing, and land use forecasts • MTC travel demand model • Urban Sim Bay Area travel survey • Bay Area transit passenger demographic survey	• Assessment indicators: average VMT per populated square mile within 1,000 feet of heavily used roads; average travel time for commute trips and non-work-based trips • Three distinct scenarios were used to compare COCs' performance indicators to those of the general population (current, baseline, plan) • Projects map superimposed on COCs map
Metropolitan Transportation Commission (MTC) (2014, 2016) - covering San Francisco Bay Area, 2017 TIP Investment Analysis	• Low-income • Minority • Elderly	• ACS • Public User Micro Sample (PUMS) • California household travel survey • Bay Area transit passenger demographic survey	• Share of investments by mode and COC $ of transit investments per capita • For each population category, comparison of the proportion of investments to the share of travel by mode • Project map was superimposed on COCs map
Mid-America Regional Council (MARC) (2020) - Transportation outlook 2040	• Minority • Low-income	• Local transit agency service data GIS	• Assessment indicators: transit access: % of jobs within 0.5 miles of transit; total jobs in employment core; % jobs within 90-minutes by transit; Average headways; hours of service • Map overlay • Compared headway and service hours between COCs and non-COCs
Mid-America Regional Council (MARC) (2015)-2020-2024 TIP	• Minority • Low-income • Disability • Older adults • Veterans • Carless households	• GIS • Travel-demand model	• Prioritization of funds for projects that are in COCs to non-COCs. • Count the number of initiatives supporting specific policy objectives, such as safety • Comparison of safety performance in COCs to non-COCs
Mid-Ohio Regional Planning Commission (MORPC) (2016) - MTP	• Minority L • ow-income • Disability • Elderly • Carless households	• ACS • Tour-based travel demand model	• Assessment indicators: number of jobs; average travel time; transit access to CBD; congested VMT during peak hours • Comparison of COC and non-COC requirements for performance under the current, no-build, and plan scenarios • Map of projects overlaid on COCs
Nashville Area MPO (2016) - Middle Tennessee Connected 2016–2040 RTP	• Minority • Carless households • Poverty • Disabled • Female heads of household	• Census	• List of projects that overlap with areas having high concentrations of at least 3 COCs

	• Elderly • LEP		
North Central Texas Council of Governments (NCTCOG) (2016) - Mobility 2040	• Minority • LEP • Disabled • Female heads of household • Low-income • Carless households	• ACS • GIS	• Assessment indicators: number of jobs accessible within 60–90 minutes; average level of service and average travel time • Scenario analysis comparing results of COCs and non-COCs • Narrative discussing expected negative/positive impacts of projects in COCs
Ohio DOT (2021) - Access Ohio 2045	• Low-income • Minority	• Transportation cost index • Composite equity score • Transit network explorer tool	• Cost benefits by block group • Activity based travel demand model • Disaggregate model
Oregon Metro Council (2018) covering Portland, OR region, RTP	• Young persons • Older adults • Minority • LEP • Low-income	• U.S. Census Regional spatial analysis boundary	• Map of projects (by category) overlaid on map of COCs • Transportation investments per person per acre in COCs compared to the regional average
Southern California Association of Governments (SCAG) (2016) - RTP/SCS	• Low-income • Minority • Disabled • Foreign-born • LEP • Elderly • Children, individuals without a high school diploma • Carless households	• ACS • GIS (SCAG land use dataset, CPAD California statewide integrated traffic records system) • Google Earth • Traffic model • Emissions data (ARB, SCAG transportation model)	• Assessment indicators: travel time reduction; access to jobs, shopping, parks, natural lands, and schools w/in 1-mile; 30-minute auto or 45-minute transit; noise and traffic exposure • Compared performance outcomes of baseline and planned scenarios for COCs to regional outcomes

Note: MTP: Metropolitan Transportation Planning; RTP: Regional Transportation Planning; TIP: Transportation Improvement Program; LEP: Limited English Proficiency; COC's: Communities of Concern; ACS: American Community Survey; GIS: Geographic Information System; EJ: Environmental Justice.

2.4. Integrating Equity in Transportation Planning, Design, and Modeling

Johnston et al. (2001) integrated land use and travel demand models for the Sacramento region. The model's inputs are origin-destination matrices for various kinds of travel purposes created using the economic interactions between activities in various zones that result from these patterns. These matrices are fed into a multi-modal network representation that uses stochastic user equilibrium for the traffic assignment model (with capacity restraint) and nested logit forms for the mode choice models (Williams, 1977). Beiler and Mohammad (2016) used GIS to develop a rigorous methodology for identifying transportation justice (TJ) areas. They created a framework that included a comprehensive list of EJ and TJ factors and incorporated regional averages, relative threshold scales, and index values to identify TJ areas. An index is given to each TJ area to identify areas of concern. The index can help agencies to have a well-defined, step-by-step method that can be integrated into the long-range transportation planning process.

Maurici et al. (2017) proposed a methodology for analyzing equity in public transit using bus frequency modeling. The level of service for existing social equity in the districts of the City of Palma was computed. Simulations are done for various headway scenarios to optimize the level of service. A multi-criteria analysis based on socioeconomic variables such as demographic structure, unemployment, and income, etc. was used to compute an index of social demand for public transportation by the district. Carleton and Porter (2018) developed a transit demand model by including equity parameters in a supply-demand model. Census Transportation Planning Products Program (CTPP) data were used to estimate the total population, poverty status, minority status, age (for both youth and elders), linguistic isolation (i.e., LEP), and zero-vehicle households (ZVH) in each traffic analysis zone (TAZ) (2006–2010, 5-year estimate

data for 86 TAZs). They compared the proportional distribution of the existing service to the proportion of the various disadvantaged populations.

Discrete choice modeling was used in several studies on travel behavior. Recently, artificial intelligence (AI) / machine learning (ML) techniques like deep neural network (DNN) have become more common and widely employed to improve prediction accuracy (Allahviranloo and Recker, 2013; Cui and Gong, 2018; Wang et al., 2020). Researchers have used DNN to predict the mode of transportation (Cantarella and de Luca, 2005; Wang et al., 2020).

When assessing the equity impacts of LRTPs, the challenge is measuring the distributional impacts of each transportation policy over different COCs. The standard approach to equity analysis is first to identify COCs, then compute equity indicators, and finally compare the changes in equity indicators between COCs for different policies.

Different tools and methods are used to facilitate transportation equity analysis. In recent years, systematic efforts have been made to propose meaningful methods for transportation equity analysis that are appropriate for regional-level assessment. Many studies and regional planning efforts have applied large-scale travel demand models for transportation equity analysis (Rodier et al., 2002; Castiglione et al., 2006; Oregon Metro Council, 2018). A transportation equity analysis aims to evaluate how the benefits and costs of planned transportation projects and land use changes will be allocated among COCs. Due to their capacity to produce disaggregate transportation metrics, activity-based travel demand models have been implemented for equity analysis (Castiglione et al., 2015, Bills and Walker, 2017, Bills, 2022).

2.5. Research Gaps

Lack of Attention on Intersectionality with Other Equity Factors

Several demographic/socioeconomic factors influence issues with transportation equity. There is a need for research considering the combined effects of numerous factors on transportation equity, as many studies have focused on the effects of individual characteristics, such as income or race (Guo et al., 2020). For instance, research might examine how access to public transit is affected by income and race. This would entail examining how people from various demographic/socioeconomic and historically disadvantaged backgrounds experience varying degrees of access to public transportation and how these factors interact with each other.

Limited Research on the Effects of Transportation Policies and Projects on Marginalized Communities: Marginalized groups that can be adversely affected by transportation policies and efforts include low-income communities, communities of color, and those with disabilities. However, estimating the consequences for historically disadvantaged population groups presents another difficulty. For instance, estimating the amount of displacement caused by new developments, restricted transit options, or increased pollution exposure might be unclear due to the lack of adequate stakeholder input.

Insufficient Data on the Travel Behavior of Marginalized Communities: It can be difficult to build transportation networks that suit the needs of marginalized communities since there is sometimes insufficient data on their travel habits. This lack of information can be attributed to various factors, such as historical neglect of the transportation requirements of marginalized communities, a lack of funding for data collection and analysis, and difficulties in reaching populations that can collect information.

Transportation planners may find it difficult to pinpoint the precise mobility requirements of minority populations without good data on travel behavior (Karner et al., 2020). For instance, planners might not be aware of the population's reliance on public transit, or the distance residents must travel to receive basic services in each community. Hence, many communities may not have appropriate access to transportation networks that would allow them to access jobs, healthcare, education, and other critical services.

Lack of Research on the Effectiveness of Equity Interventions: Several factors contribute to the lack of research on the effectiveness of equity interventions, including limited research funding, a lack of standard

metrics for evaluating equity interventions, and difficulties in measuring the impact of these interventions over time. Without rigorous research, it can be difficult to determine which equity interventions are most effective and how to allocate resources efficiently to promote equitable transportation access.

Need for More Participatory Research: Participatory research can help transportation planners and policymakers better understand the transportation needs and priorities of different communities, allowing them to develop more responsive policies and interventions. Involving marginalized communities in the research process can help ensure that research questions are appropriate and tailored to their requirements and priorities, data collection methods are appropriate and supportive, and research findings are interpreted and communicated in a straightforward and implementable manner. During the planning stage, additional efforts are required, such as co-designing research questions, engaging community members, analyzing collected data, and visualizing results (Sanchez and Wolf, 2005).

Lack of Defined Framework: No clear implementation methodology exists for understanding or developing strategies for represented communities. Most agencies fall somewhere in the middle. The typical method is to create maps of the necessary populations using pre-established threshold criteria to differentiate COC zones from non-COC zones, create overlay maps to show the proximity of projects to underserved population locations, and then decide based on a visual or tabular computation of the number of investments in relation to the locations or proportions of underserved populations within the region. Some organizations talk about the current needs of underserved populations, but few link the findings to potential future disparities and/or mitigation strategies.

Chapter 3. Survey of Regional Agencies in North Carolina to Identify Their Needs and Practices on Addressing Equity

This chapter presents findings from the survey of MPOs, RPOs, and other related stakeholders engaged in long range transportation planning.

3.1. Survey Data Collection and Methodology for North Carolina MPOs and RPOs

The survey questionnaire was developed in consultation with the staff of NCDOT. Its primary aim is to gather information about how regional transportation officials view and distribute equity in their long-range transportation planning processes. The survey incorporates both quantitative and qualitative methods, including open-ended questions, and is exploratory in nature.

The survey questionnaire was administered online through Qualtrics from May 16th to July 6th, 2023. Out of the 652 individuals contacted, 141 responded, resulting in a response rate of 22%. Of these, 58 respondents met the criteria for full participation (i.e., working in long range transportation planning) within one of the target regional organizations engaged in long range transportation planning.

The email addresses for respondents were provided to the research team by NCDOT and contained public email addresses for North Carolina Officials. Most contacts were from MPOs, RPOs, counties, regional councils, and school districts, with only a few from city organizations. Respondents received two reminders to complete the survey following the initial invitation.

3.2. Findings from the Survey Questionnaire

Demographics: The demographic information of the survey respondents is summarized in Table 3.

Table 3. Demographic Information of Survey Respondents

Demographic Characteristic	Proportion of Sample
Gender	
Male	64.00%
Female	36.00%
Education	
High school or less	20.00%
Associate degree	13.00%
Bachelor's degree	30.00%
Post-graduate degree	55.00%
Certifications	
Professional Engineer (PE)	11.00%
Institute of Transportation Engineers (ITE)	22.00%
American Institute of Certified Planners (AICP)	67.00%
Race/Ethnicity	
Caucasian/White	87.00%
African American/Black	11.00%
Asian/Pacific Islander	2.00%
Age	
Under 24	5.00%
25-34	2.00%
35-44	18.00%
45-54	45.00%
65 or over	30.00%

Most respondents are male, comprising 64%, while females comprise 36%. Regarding education, a sizable portion of respondents hold advanced degrees: 55% possess a postgraduate degree, and 30% have a bachelor's degree. A smaller segment has completed an associate degree (13%) or has a high school education or less (20%).

In terms of professional certifications, 67% of respondents hold certification from the American Institute of Certified Planners (AICP), 22% are members of the Institute of Transportation Engineers (ITE), and 11% are certified as Professional Engineers (PE). The racial and ethnic composition is Caucasian/White, accounting for 87% of respondents. African American/Black respondents represent 11%, and Asian/Pacific Islander respondents account for 2%.

The age distribution shows that 45% of respondents are between 45 and 54 years old, making it the largest age group. Those 65 years old or over constitute 30% of respondents. Younger age groups are less represented, with 18% between 35 and 44 years old, 2% between 25 and 34 years old, and 5% under 24 years old.

This demographic breakdown highlights a respondent base that is male, highly educated, and Caucasian/White, with a significant portion being middle-aged or older. This context is essential for interpreting the survey results and understanding the perspectives represented.

Regional Government Respondent Characteristics: Figure 1 illustrates the distribution of organizational types among the survey respondents involved in long range transportation planning in North Carolina. The largest group of respondents, accounting for 27.87%, comes from RPOs. County representatives make up the second largest group at 26.23%. MPOs account for 16.39% of respondents, while regional councils and those categorized under "Other" each represent 11.48% of the respondents. Smaller proportions of the survey participants come from City organizations (4.92%) and transportation committees (1.64%). This diverse distribution of respondents ensures a comprehensive representation of perspectives across different geographic and administrative contexts in the survey.

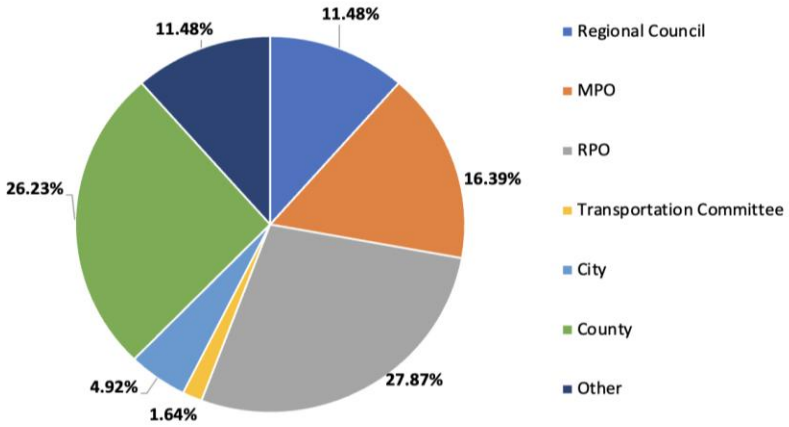


Figure 1. Organizational Representation of Survey Respondents

Profession: Table 4 displays the distribution of survey respondents by their occupation. Out of the 58 respondents who selected their occupation, the largest category is transportation planners, comprising 22.41% of the total. This is followed by executive directors at 17.24% and department directors at 8.62%. Program managers represent 5.17% of respondents, making this the least common profession among those surveyed.

A significant proportion of respondents, 43.10%, selected "Other" for their occupation, indicating that their official titles were not listed among the provided options. The open-ended responses for this category revealed that many identified as specialized staff and/or elected officials serving in regional organizations. This group includes board members, elected officials, and one assistant superintendent, all of whom noted their involvement in transportation planning. This distribution highlights the diverse range of professional roles involved in long range transportation planning.

Population Size of Area: Figure 2 illustrates the distribution of population sizes served by the organizations of survey respondents. The largest group, accounting for 34%, serves areas with populations between

200,000 and 499,999. This is followed by 29% of respondents serving areas with populations between 50,000 and 199,999 and 22% serving areas with populations between 10,000 and 49,999. Smaller segments include 7% of respondents serving areas with populations less than 10,000, 5% serving areas with populations between 500,000 and 2 million, and 2% serving areas with populations over 2 million. This distribution reflects the diverse range of population sizes across which transportation planning and services are provided in North Carolina.

Table 4. Distribution of Responses by Profession

Occupation	Frequency	Percent
Planner-Transportation	13	22.41
Executive Director	10	17.24
Department Director	5	8.62
Program Manager	3	8.62
Other	25	43.10

Note: Other: Board member 9; Other: Assistant Superintendent 1

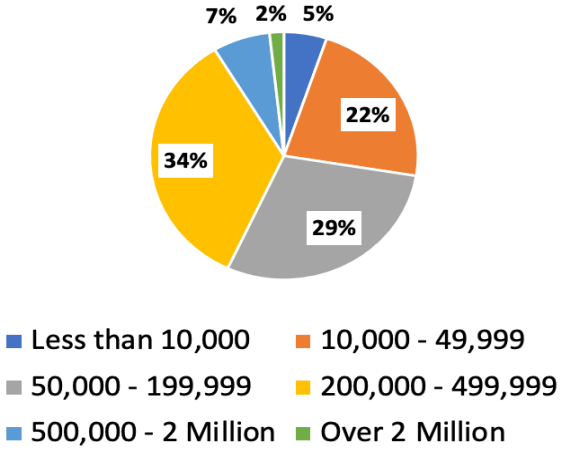


Figure 2. Population of the Geographic Area Served by Respondent Organizations

Budget of Agency: Figure 3 presents the distribution of operating budgets for the organizations for the fiscal year 2022-2023. The largest segment, representing 52% of respondents, indicates an operating budget of less than $5 million. The next largest segment, 29%, shows organizations with operating budgets between $5 million and $25 million. A smaller portion, 11%, represents organizations with budgets ranging from $26 million to $75 million. The smallest group, comprising 9% of respondents, indicates operating budgets between $76 million and $200 million. This distribution highlights the varying financial scales of the organizations involved in long range transportation planning across North Carolina.

Economic Conditions: Figure 4 illustrates the economic conditions in the respondents' regions over the past five years. The largest segment, representing 43% of respondents, indicates that their regions have experienced economic growth. Meanwhile, 34% of respondents report that economic conditions have remained stable. Conversely, 22% of respondents perceive the economic conditions in their regions as declining. This data highlights the diverse economic landscapes that regional transportation planners must consider in their long-range transportation planning efforts.

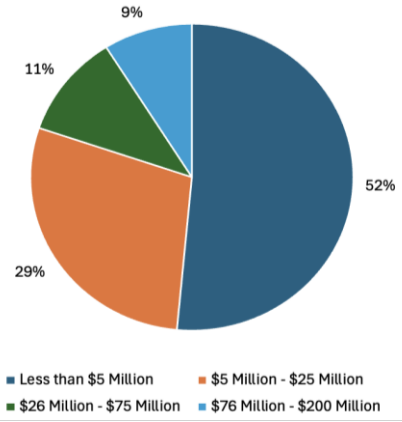


Figure 3. Organization Operating Budget (FY 22-23)

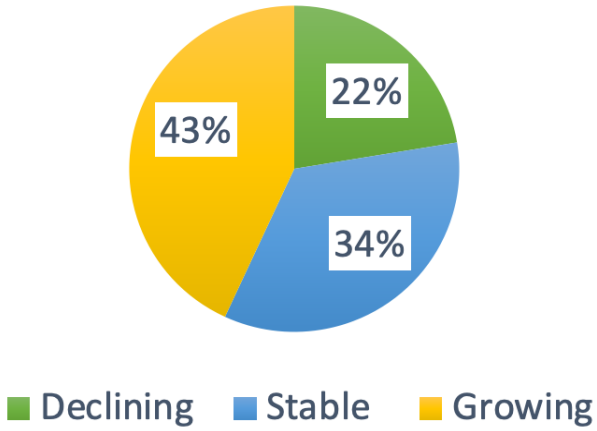


Figure 4. Economic Conditions in the Respondent's Region During the Last Five Years

Values: Figure 5 illustrates the values organizations prioritize in their most recent LRTPs. Efficiency is the most emphasized value, prioritized by 46% of respondents. This is followed by effectiveness (37%). Equity is a priority for 14% of organizations, reflecting a significant but lesser focus than efficiency and effectiveness. Accountability is the least prioritized value, with only 4% of respondents indicating it as a primary focus. This distribution highlights a predominant emphasis on operational and performance metrics in transportation planning, with a relatively lower emphasis on equity and accountability.

Community Priorities: Figure 6 illustrates the respondents' levels of agreement with the statement that long range transportation planning is a priority for the communities they serve. Most respondents, comprising 45%, agree that it is a priority, while 33% strongly agree. A smaller portion, 10%, remains neutral on the matter. On the other hand, 5% of respondents disagree, and 7% strongly disagree with the statement. This data indicates that most respondents perceive long range transportation planning as an important priority for their communities.

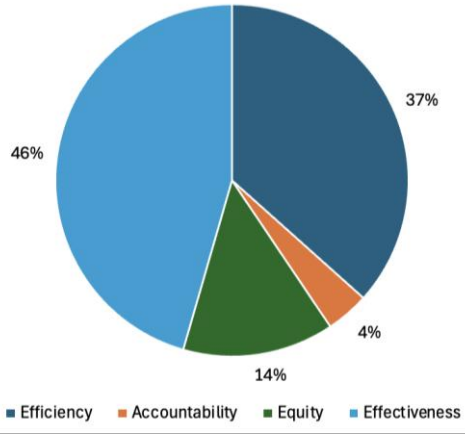


Figure 5. Value Prioritized by Organizations in Most Recent LRTP

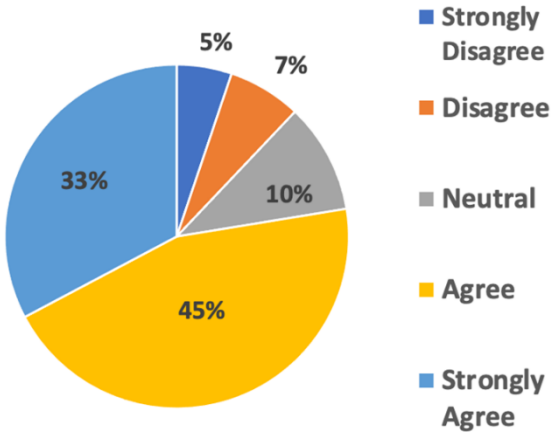


Figure 6. Long Range Transportation Planning as a Priority for the Community They Serve

NCDOT Priorities: Figure 7 shows the distribution of respondents' opinions on whether long-range transportation planning is a priority for NCDOT. Most respondents, 51%, agree that long range transportation planning is a priority for NCDOT, while 30% strongly agree. A smaller segment, 12%, is neutral on the matter. Meanwhile, 4% of respondents disagree, and another 4% strongly disagree with the statement. This data indicates a strong consensus among respondents that long range transportation planning is indeed a significant priority for NCDOT, with over 80% agreeing or strongly agreeing with this viewpoint.

Equity in Public Transportation : Figure 8 illustrates the respondents' perceptions regarding the equity of public transportation services in their communities. According to the chart, 76% of respondents believe that public transportation is not the same for everyone in their communities, while only 24% feel that it is equitable. This significant disparity suggests that most respondents perceive substantial inequities in public transportation services, indicating that many communities may face challenges in providing equal access and quality of transportation for all residents. The data underscores the need for targeted efforts to address and improve equity in public transportation systems to ensure fair and equal service for all community members.

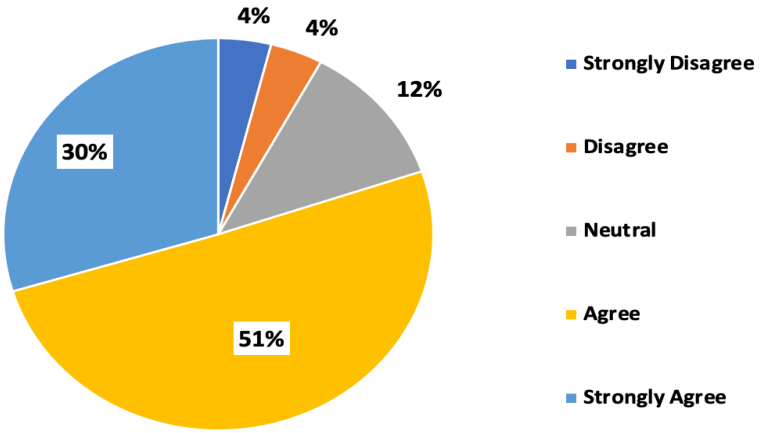


Figure 7. Long Range Transportation Planning is a Priority for NCDOT

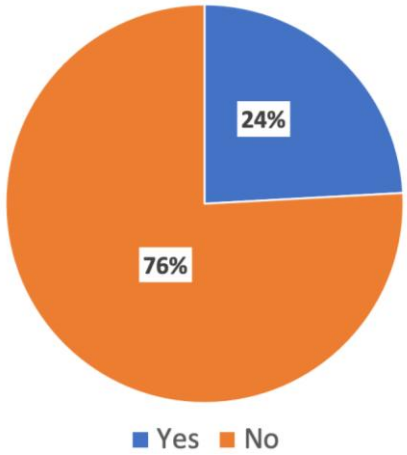


Figure 8. Equity in Public Transportation

Barriers to Equal Access: Figure 9 depicts the largest barriers to equal access to transportation in the communities served by the respondents. The data indicates that most respondents, 54%, view automobile investments as the largest barrier to equal access to transportation. This is followed by 26% of respondents identifying poor quality transit as a significant barrier. A smaller proportion, 10%, cite a lack of involvement, while 8% point to safety concerns. The least cited barrier, at 3%, is poorly maintained transit. This distribution highlights the predominant challenge of automobile-centric investments in hindering equitable access to transportation, suggesting a need for increased focus on improving public transit quality and accessibility.

Increasing Equity: In the survey, respondents were asked to indicate the extent to which they agreed that specific statements would increase equity in long-range transportation planning in their region. With 34 respondents answering this question, the differences in mean scores for each statement were very slight, indicating a consensus. Most respondents "somewhat agree" that all the statements would enhance equity in transportation, with minimal disagreement. The results are summarized in Table 5.

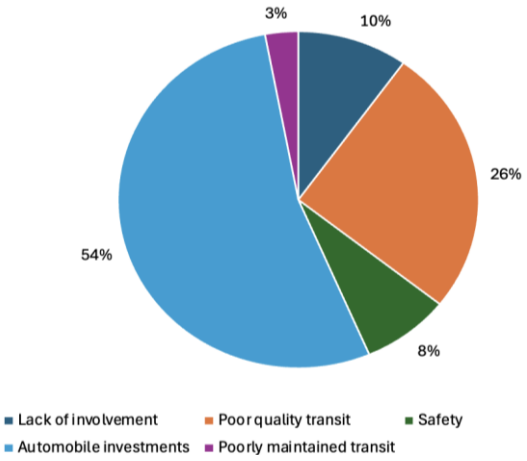


Figure 9. Barriers to Equal Access

The statement that received the highest level of agreement was "Provide more access to non-vehicle transportation to low-income neighborhoods," with a mean score of 4.17. This was closely followed by "Focus on individuals who do not have reliable access to personal vehicles (elderly, disabled, low-income)," which had a mean score of 4.15. Respondents also strongly supported "Improved coordination between nearby communities" (mean = 4.12) and "Improve existing safety infrastructure (lighting, curb cuts, complete streets, improved connectivity)" (mean = 4.09).

Additionally, providing more on-demand transportation modes received a mean score of 4.06, indicating solid support. The statement with the lowest, yet still relatively high, agreement was "Improved connectivity of bike lanes, sidewalks, etc.," with a mean score of 3.97.

These results suggest a broad consensus among respondents that all these measures would contribute to increasing equity in transportation planning. There was little disagreement, underscoring a shared belief in the effectiveness of these proposed actions. This feedback highlights key areas for potential focus to enhance equity in long range transportation planning.

Table 5. Mean Score of Different Strategies to Increase Equity

Please indicate the extent to which you agree or disagree that the following statement would increase equity.	Mean (1-5)	N (Max. 34)
Provide more access to non-vehicle transportation to low-income neighborhoods.	4.17	34
Improve existing safety infrastructure (lighting, curb cuts, complete streets, improved connectivity)	4.09	34
Provide more on-demand transportation modes	4.06	34
Focus on individuals who do not have reliable access to personal vehicles (elderly, disabled, low-income)	4.15	34
Improved coordination between nearby communities	4.12	33
Improved connectivity of bike lanes, sidewalks, etc.	3.97	34

Table 6 summarizes the distribution of the responses (from strongly disagree to strongly agree) for each strategy. The survey results indicate a high agreement among respondents on several strategies to increase equity in long range transportation planning. The strategy with the highest consensus was "Providing more access to non-vehicle transportation to low-income neighborhoods," with 20 respondents

agreeing and 15 strongly agreeing. Close behind was the strategy to "Focus on individuals who do not have reliable access to personal vehicles (elderly, disabled, low-income)," which garnered agreement from 27 respondents and strong agreement from 13 respondents.

Further strong support was observed for "Improving existing safety infrastructure" and "Improving coordination between nearby communities." For these strategies, 18 respondents agreed and 16 strongly agreed on the need for enhanced safety infrastructure, while 20 agreed and 16 strongly agreed on the importance of better community coordination.

The strategy of providing more on-demand transportation modes also received solid backing, with 22 respondents agreeing and 12 strongly agreeing. Although the strategy to "Improve connectivity of bike lanes, sidewalks, etc." had the lowest level of agreement, it still saw significant support, with 18 respondents agreeing and 14 strongly agreeing.

Overall, the survey results suggest a broad consensus among respondents that these strategies would contribute to increasing equity in transportation planning. There was minimal disagreement, underscoring a collective belief in the efficacy of these proposed actions. These insights highlight critical areas for focus to enhance equity in long range transportation planning (Table 6).

Table 6. Respondents' Agreement on Strategies to Increase Equity in Long Range Transportation Planning

Strategies	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Provide more access to non-vehicle transportation to low-income neighborhoods.	3	1	9	20	15
Improve existing safety infrastructure (lighting, curb cuts, complete streets, improved connectivity)	1	2	9	18	16
Provide more on-demand transportation modes	2	2	10	22	12
Focus on individuals who do not have reliable access to personal vehicles (elderly, disabled, low-income)	1	1	5	27	13
Improved coordination between nearby communities	1	2	7	20	16
Improved connectivity of bike lanes, sidewalks etc.	3	3	10	18	14
Total	**11**	**11**	**50**	**125**	**86**

Equity Strategies Included in Recent LTRP: Figure 10 illustrates the equity strategies included in the respondents' most recent LRTPs. "Public engagement processes" was the most common strategy, selected by 19% of respondents. "Multi-modal planning" was also prominent and included 20% of respondents. Many respondents (11%) reported incorporating "Air quality/environmental justice" and "Prioritizing affordable and efficient modes" strategies in their plans. Other frequently reported strategies included "Smart Growth Policies" (9%), "Vehicle Reduction Targets" (7%), "Equity analysis in early stages" (9%), and "Accessibility-Based Analysis" (8%).

Fewer respondents indicated that their plans included elements of "Universal Design" (3%) or "Compensation for Past Harms" (1%). Notably, "Affirmative Action Programs" were among the least reported strategies, with only 4% of respondents including them in their plans.

This distribution highlights the varying emphasis placed on different equity strategies in long range transportation planning, with some strategies being more commonly adopted than others.

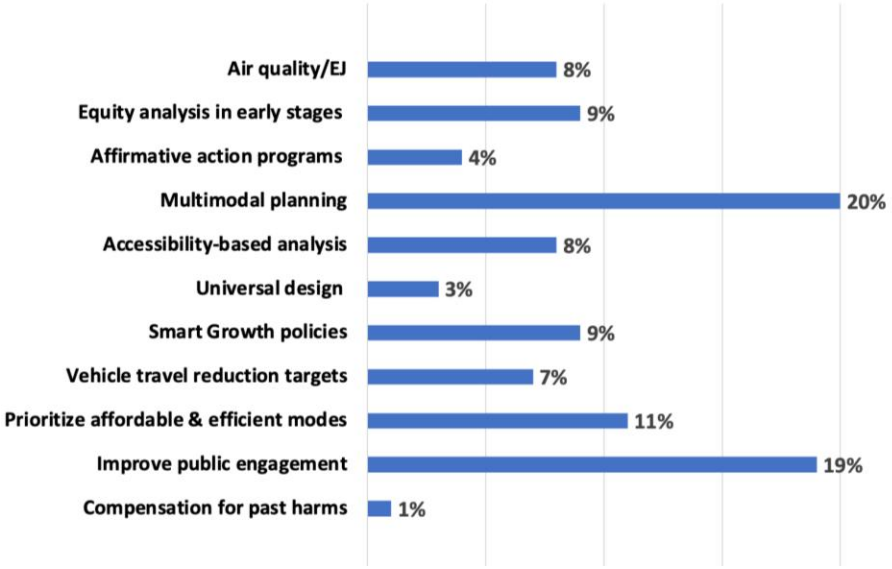


Figure 10. Equity Strategies Included in Recent LRTP

Groups of Citizens: Figure 11 illustrates the groups of citizens included in respondents' previous LRTPs. The data indicates that respondents focus on ensuring rural communities (23%), low-income communities (20%), and disabled citizens (20%) are included in the planning process. However, respondents also include citizens with limited access to vehicles (15%) and historically disadvantaged citizens (12%), though perhaps with less emphasis on these groups. Finally, only a few respondents report including citizens experiencing homelessness or housing insecurity (6%) or immigrants (4%) in their last LRTP. This distribution highlights a strong focus on addressing the needs of rural, low-income, and disabled citizens in long range transportation planning. However, it also underscores the need for greater inclusion of homeless individuals and immigrants to ensure comprehensive equity across all community groups.

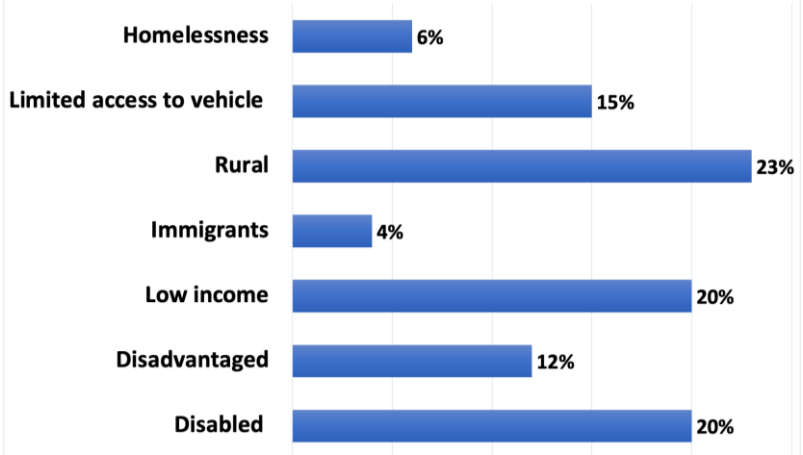


Figure 11. Groups of Citizens Included in Previous LRTP

Equity Concerns: Figure 12 illustrates the primary equity concerns identified by respondents. The data indicates that safety is the most significant equity concern, cited by 28% of respondents. This is followed by accessibility to vital locations, which 22% of respondents identified as a key issue. Travel time and reliability were concerns for 19% of respondents, while both affordability and environmental impacts were cited by 15%. A small percentage, 1%, noted other concerns. This distribution highlights the emphasis placed on safety and accessibility in equity considerations for transportation planning. It suggests that these areas may require focused efforts to address critical issues. Ensuring safe transportation options and

improving access to essential locations are top priorities. Additionally, addressing travel time reliability and affordability is crucial for equitable transportation. Although slightly less prioritized, environmental impacts remain an important concern that must be addressed to ensure comprehensive equity in transportation planning.

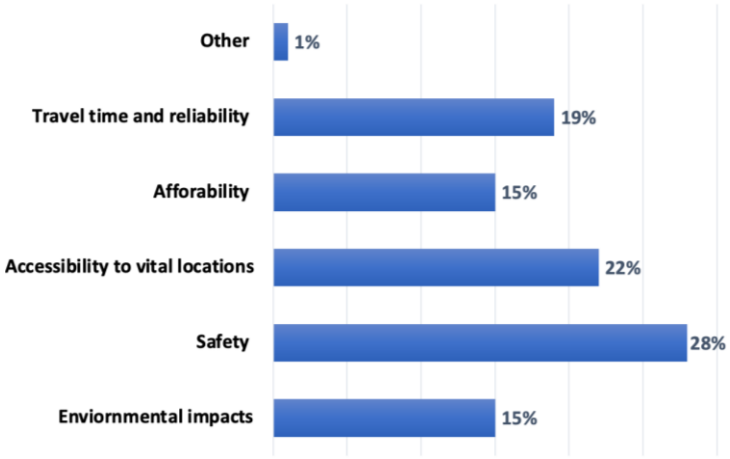


Figure 12. Primary Equity Concerns

Other respondents reported additional equity concerns related to transportation. One significant issue highlighted was the plight of non-drivers in heavily populated areas who may lack adequate financial resources, summarized by the statement, "Transportation is as best as you can afford." Another respondent expressed concern about whether their organization is maximizing existing resources effectively. Additionally, one respondent mentioned the importance of resiliency and evacuation routes, emphasizing these aspects in their last LRTP. These varied concerns underscore the complexity of achieving transportation equity and the need to address financial accessibility, resource optimization, and emergency preparedness in transportation planning.

Activities to Ensure Diversity in Planning Process: Figure 13 illustrates the diversity strategies used to improve the respondents' last LRTPs. Collaborating with community-based organizations was the most common strategy, utilized by 31% of respondents. Both direct outreach to hard-to-reach populations and conducting focus groups within the community were employed by 25% of respondents. Translating surveys into languages other than Spanish was used by 15% of respondents, while 4% reported using other strategies. This distribution highlights the importance placed on community engagement and targeted outreach in enhancing the inclusivity and effectiveness of LRTPs. The emphasis on collaboration and direct outreach efforts suggests a proactive approach to ensuring diverse voices are included in the planning process.

Equity Considerations During Project Prioritization: Figure 14 illustrates the equity considerations organizations suggested during the project prioritization phase of planning. The most common consideration, identified by 29% of respondents, was examining the potential for displacement. This was followed by target investments to improve accessibility, which 24% of respondents prioritized. Looking at past projects with an equity lens was considered by 23% of respondents, while identifying where historical underinvestment has contributed to safety issues was considered by 20% of respondents. The least common consideration, reported by 4% of respondents, was categorized as "Other". This distribution highlights a strong focus on mitigating displacement and improving accessibility, reflecting the commitment to addressing equity in the project prioritization process.

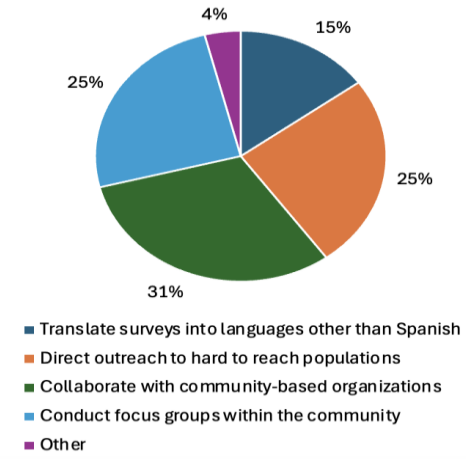


Figure 13. Diversity Strategies to Improve Last LRTP

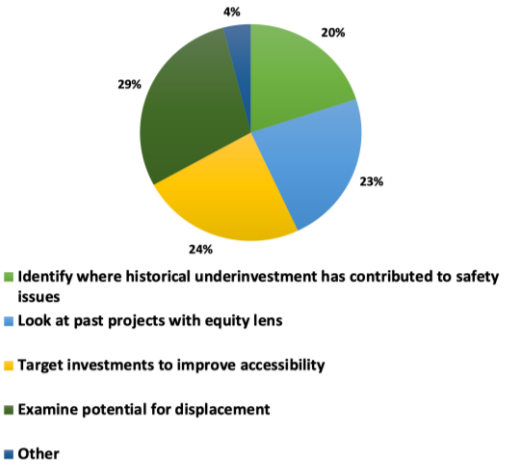


Figure 14. Diversity Strategies to Improve Last LRTP

Health and Environmental Equity Considerations: Figure 15 illustrates the health and environmental strategies organizations use in their transportation planning efforts. The most frequently adopted strategy, reported by 16% of respondents, is reducing roadway congestion. This is followed by improving access to the economy, which is a priority for 14% of respondents. Increasing the number of bike and pedestrian commutes is prioritized by 13% of respondents, while 12% focus on improving mobility and independence for senior residents.

Other strategies include creating tourism destinations (10%), improving opportunities for children to commute safely (9%), and enhancing community health (8%). 7% of respondents consider improving environmental health. Less commonly adopted strategies include considering that projects could reduce miles traveled (5%) and acknowledging that increased air traffic creates noise and air pollution (4%).

This distribution highlights a broad range of health and environmental strategies, with a notable emphasis on reducing roadway congestion and improving economic access. The varied strategies reflect a comprehensive approach to addressing both health and environmental concerns in transportation planning.

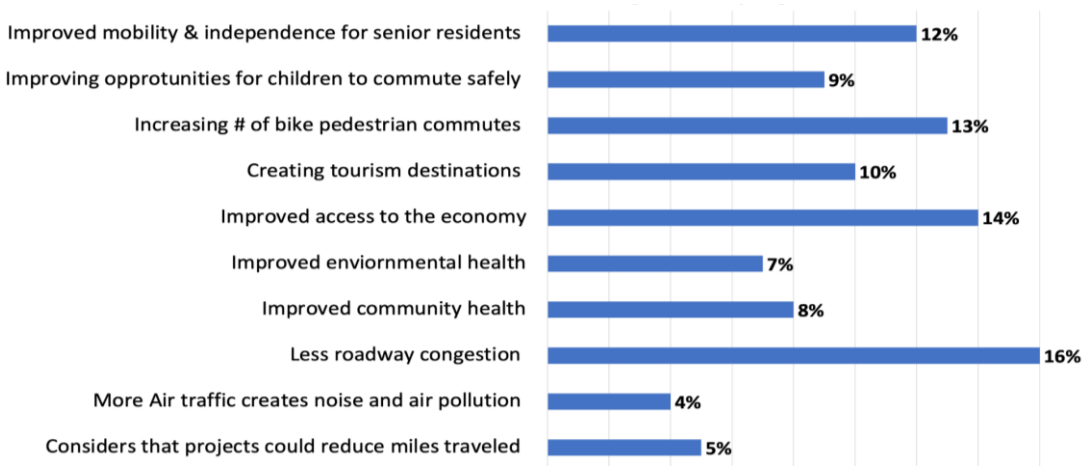


Figure 15. Health and Environmental Considerations

Addressing Access Disparities During the Pandemic: Figure 16 illustrates whether organizations addressed access disparities of necessary perishable items during the pandemic. According to the chart, 45% of respondents reported that their organizations did not address these disparities. In contrast, 32% of respondents indicated that their organizations did address access disparities. Additionally, 23% of respondents were unsure whether their organizations acted on this issue. This distribution highlights that half of the organizations did not take measures to address access disparities for perishable items during the pandemic, pointing to a significant gap in response efforts. The data also suggests that while some organizations did act, a notable portion of respondents lacked awareness of their organizations' efforts, indicating a need for better communication and documentation of actions taken during crisis situations.

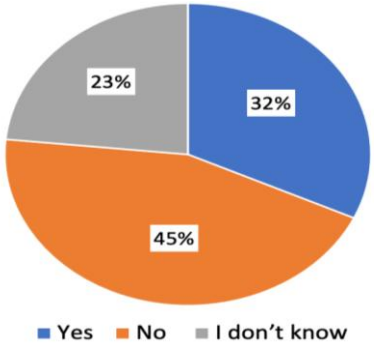


Figure 16. Addressing Access Disparities of Necessary Perishable Items During the Pandemic

The ways of doing so varied among the respondents who reported having actively addressed these disparities. Open-ended responses included strategies such as delivering meals to strategic locations, creating a food route mapping application to display food pantry locations, and creating a free Wi-Fi location map. Respondents reported that farmers' markets and the distribution of fruits and vegetables to low-income and elderly populations were other ways their organization addressed access disparities.

Thoughts About TDI NCDOT: Figure 17 illustrates the awareness of the Transportation Disadvantage Index (TDI) tool developed by NCDOT among respondents' organizations. According to the chart, 56% of respondents indicated that their organizations had not heard of the tool, while 44% of respondents confirmed that their organizations were aware of it. This distribution shows that most organizations are unfamiliar with the TDI tool, suggesting a potential gap in communication and dissemination of this resource. Increasing awareness and understanding of the tool could help more organizations leverage it to address transportation disadvantages effectively.

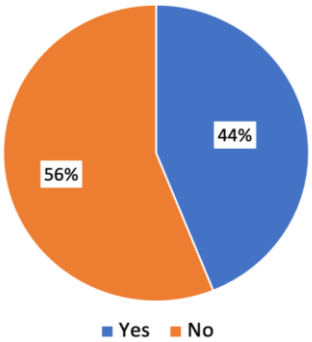


Figure 17. Awareness of the Transportation Disadvantage Index Tool Developed by NCDOT

Qualitative Insights about Equity in Long Range Transportation Planning: At the end of the survey, respondents were invited to share any additional comments regarding long-range transportation planning equity in their region. Eleven respondents provided insights through an open-ended question, shedding light on priorities and concerns not fully captured by the survey's structured questions.

Several respondents expressed concerns about misconceptions surrounding equity. One noted, *"Equity looks different and means something different in different places, but there should also be more work to address falsehoods regarding transportation equity."* Another highlighted a barrier to equity not specified in the survey: *"Change is a slow process. NCDOT partners with the RPOs to conduct LRTPs and has limited staff. We have been told that they can only add four new CTPs a year. At that rate, it will be 10+ years before the state will see this change, and I have not heard that TPD is doing equity analyses in CTPs."*

The importance of improving transportation was emphasized as vital to growth, especially in low-wealth communities. One respondent stated, *"Improving transportation has been identified as one of the top 5 priorities/concerns in this 'low-wealth' community. It is vital to growth in this county."*

Funding concerns, also highlighted in the survey, were reiterated in the open-ended responses. As one respondent noted, *"The funding priorities, plans, and long-range NCDOT goals are so oriented to road construction and maintenance that it makes creating an equitable, healthy, affordable regional transportation network impossible. No amount of studies showing that highway expansion just results in increased congestion seems to nudge one iota toward the logical necessity of increased reliance on public transportation and bike/ped. It is extremely frustrating and dangerous to the health and well-being of our state and communities."*

Three additional comments stressed the need for improved connectivity and multimodal transportation, particularly bikeways. One respondent pointed out, *"The most important thing that needs to be addressed is less reliance on automobiles as the only form of day-to-day transportation for most people. More should be done to promote sustainable, walkable communities with effective transit options."* Another echoed this sentiment: *"We need to incorporate more bikeways that connect communities and enhance public transportation to decrease dependence on highway construction."*

Some respondents also mentioned the need to improve rural roads and major four-lane roads. Finally, one comment focused on the need for better coordination with NCDOT: *"The local official would like more coordination with various NCDOT Division Engineers and field offices to understand how NCDOT tools are being utilized fully and if data needs to be updated based upon community responses to the data."*

These qualitative insights provide a deeper understanding of the complexities and challenges of achieving equity in long range transportation planning. They underscore the importance of addressing misconceptions, improving funding allocations, enhancing multimodal connectivity, and fostering better coordination with key stakeholders.

Chapter 4. Survey of Other State Departments of Transportation to Identify Their Practices in Addressing Equity

4.1. Survey Questionnaire

A well-structured questionnaire was employed to survey representatives from other State DOTs. The objectives of the survey were threefold. Firstly, the survey aimed to identify and examine the best practices implemented by other State DOTs for transportation equity analysis. Secondly, the survey sought to gain valuable insights into stakeholders' perspectives on equity, particularly in the early stages of long-range transportation planning and the timely delivery of perishable goods to diverse communities. Thirdly, it aimed to pinpoint pertinent data, potential data sources, specific performance measures, and evaluation tools crucial for effective equity analyses within the realm of long-range transportation planning.

A web-based questionnaire was developed based on the findings of the literature synthesis. The draft questionnaire underwent internal review and modifications based on the suggestions of the Institutional Review Board (IRB) and collaborative discussions with the NCDOT Technical Advisory Committee, ensuring that each part of the questionnaire effectively contributed to the overarching goals of the research. The committee's insights and feedback played a crucial role in shaping the final questionnaire, ensuring its relevance and effectiveness in eliciting nuanced responses from participants.

The survey in this research encompassed 28 questions strategically divided into five distinct parts. Each part served a specific purpose in aligning with the research objectives and ensuring a comprehensive exploration of practitioners' perspectives on transportation equity.

Part 1 (6 Questions - Demographic Characteristics): This section aimed to capture essential participant details, focusing on demographic characteristics such as location and experience in transportation planning-related projects in the organization. It sought to establish a foundational understanding of the critical information about the financial resources available to the DOT during the specified fiscal year and the respondents' perspective on equity regarding access to public transportation within their state.

Part 2 (16 Questions - Equity in Long Range Transportation Planning): This section delved into identifying best practices, potential limitations, and challenges associated with meeting equity needs in long range transportation planning. Questions were meticulously crafted to extract insights from State DOTs, regarding their challenges, strategies, and perspectives on defining equity, disadvantaged groups, and achieving equitable outcomes in transportation planning. In addition, respondents were asked to select all the relevant stages or aspects of the planning process where inputs related to equity were considered. Furthermore, questions related to the unit of segmentation and related software employed by the DOT for travel demand modeling and long-range transportation planning were also addressed.

Part 3 (1 Question on USDOT's Equitable Transportation Community (ETC) Explorer Familiarity): This section sought to capture respondents' perceptions of the value and relevance of the Equitable Transportation Community Explorer and its potential for widespread adoption.

Part 4 (2 Questions - GIS Tool Usage): This segment explored participants' utilization of Geographic Information System (GIS) tools in their transportation planning process. It aimed to gauge the prevalence and effectiveness of GIS tools in addressing equity considerations.

Part 5 (3 Questions - Disparities in Short-Term Delivery During the Pandemic): In response to the unique challenges posed by the pandemic, this section addressed disparities related to short-term delivery. It aimed to gather insights into how practitioners perceived and navigated issues surrounding the timely delivery of essential goods during the pandemic, shedding light on potential disparities and innovative solutions.

Participants in the survey included representatives from other state DOTs. The participants were identified through a systematic review of the state DOT website. After receiving ethical approval from the IRB (IRB-23-0634), the questionnaire link was forwarded to the identified participants via e-mail. To

augment the response rate, reminders were sent approximately two weeks after the original e-mail date, and the survey was kept open until the final week of August 2023. Eighteen responses were received.

4.2. Findings from the Survey Questionnaire

The results from the analysis of the survey questionnaire are presented in five sections, as explained next.

Demographics: This section aims to build a foundational understanding of the respondents, focusing on their geographical location and experience in transportation planning projects within their organizations. The survey elicited responses from participants across a spectrum of states, yielding a total of 18 completed responses, and the state-wise distribution of these responses is summarized in Table 7. The geographical representation includes Alabama, California, Colorado, Connecticut, Indiana, Iowa, Kentucky, Michigan, New Hampshire, New Jersey, New Mexico, North Carolina, Oklahoma, and Vermont. It is crucial to note that while the overall response count stands at 18, there are limitations related to incomplete responses for specific questions within the survey.

Table 7. Number of Responses by State

S. No	State	Number of Responses Received
1	Alabama	1
2	California	2
3	Colorado	1
4	Connecticut	1
5	Indiana	1
6	Iowa	1
7	Kentucky	1
8	Michigan	1
9	New Hampshire	1
10	New Jersey	1
11	New Mexico	1
12	North Carolina	4
13	Oklahoma	1
14	Vermont	1
	Total	18

The survey included a question seeking information about respondents' roles within their DOT. Participants were presented with a list of roles and asked to identify the one that best described their position. Figure 18 illustrates the state-wise distribution of responses by role. The distribution of responses reflects a diverse range of roles within the surveyed DOTs.

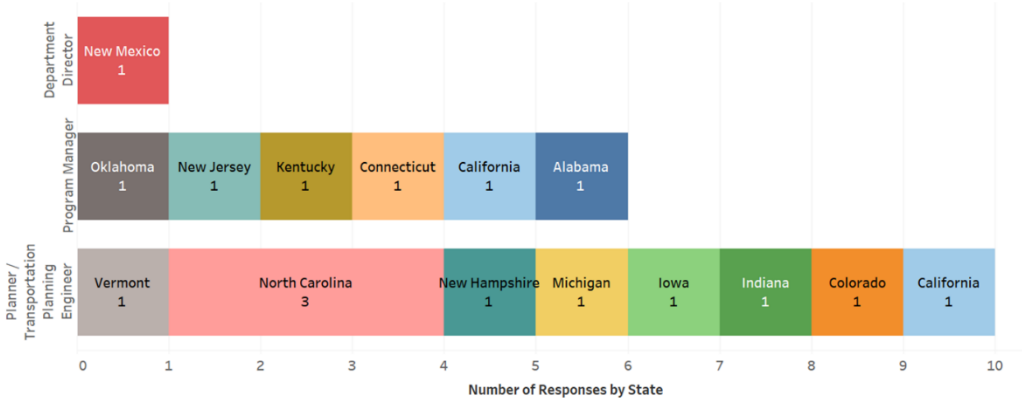


Figure 18. Respondents' Role in Their Organization

Among the responses, 58.8% identified themselves as transportation planners (Figure 18), indicating a significant representation from this professional category. Program managers constituted

35.3% of the responses, representing another substantial segment of participants. A smaller yet notable portion, 5.9%, comprised department directors, displaying a leadership perspective within the surveyed group. The distribution sheds light on the varied expertise and responsibilities among those engaged in transportation-related functions, enriching the understanding of the survey data.

Participants were asked to indicate the number of years of experience in their current positions. The distribution of responses reveals a diverse range of professional tenures. Approximately 27.8% of respondents reported having 0 to 5 years of experience, indicating a significant portion of early-career professionals. Those with 5 to 10 years of experience constituted 33.33% of the responses, highlighting a substantial mid-career representation. Participants with 10 to 15 years of experience comprised 16.7% of the cohort, while individuals 20 years and above in their current positions accounted for 22.2% of the respondents (Figure 19).

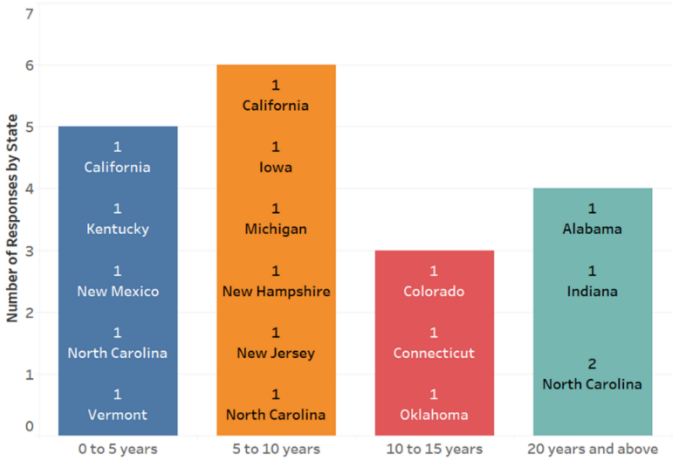


Figure 19. Experience of Participants

The survey results underscore a clear focus among respondents, all of whom hold planning and policy-related roles within their respective DOTs. Figure 20 shows that a substantial majority (72.2%) identified transportation planning as the central focus area for their units, exhibiting shared commitment to strategic and forward-thinking planning initiatives within the surveyed DOTs. Complementing this, 27.8% of participants indicated a focus on policy, emphasizing the significance of regulatory and guideline development within their units. Other focus areas such as road design, traffic signals/ITS, traffic safety, transit, pedestrian/bicycle, and pavement were not included. The exclusive targeting of respondents in planning and policy roles has allowed for a precise examination of how equity is included in planning projects.

The survey inquired into understanding the financial landscape of DOTs by inquiring about the operating budget for the fiscal year 2022-2023 or the most recent financial period. The responses reveal a diverse distribution, with 16.7% (Figure 21) of participants reporting an operating budget of less than $1 billion. A sizable portion, constituting 27.8%, falls within the range of $1 billion to $3 billion, displaying a substantial mid-range financial scope. Furthermore, 33.33% of respondents operate with budgets ranging from $3 billion to $5 billion, indicating a significant representation within this higher financial bracket. The allocation of budgets decreased for larger financial ranges, with 16.7% falling to $10 billion to $20 billion category and 5.6% exceeding $20 billion. These results illuminate the varied fiscal capacities of the surveyed DOTs, providing valuable insights into the financial scale and distribution among transportation planning and policy projects.

Figure 20. Focus Area in DOT

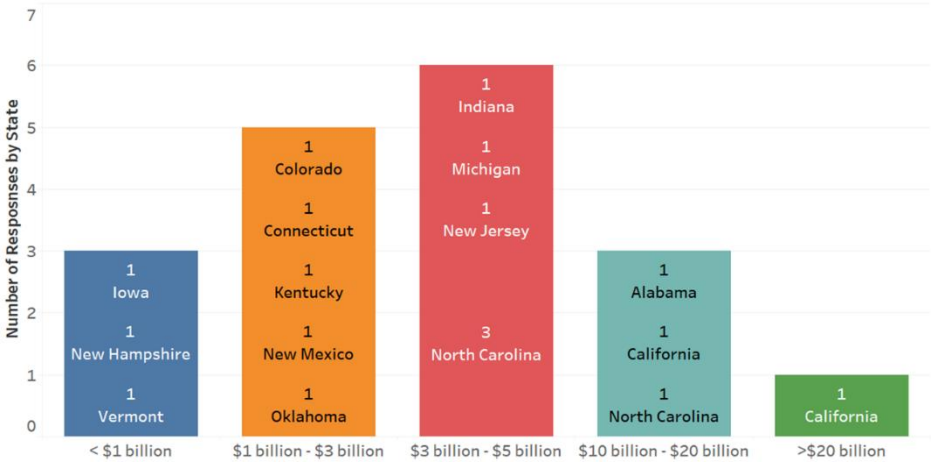


Figure 21. Financial Budget for FY 2022-2023 in DOT

Including Equity in Long Range Transportation Planning: This section of the survey probed into the critical theme of equity in long range transportation planning, serving as the core section aimed at extracting valuable insights from practitioners within State DOTs. This section presents the results of the 16 carefully crafted questions designed to explore best practices, potential limitations, and challenges associated with integrating equity considerations into long range transportation planning.

The questions were strategically formulated to draw on the expertise of respondents, unraveling their perspectives on defining equity, identifying disadvantaged groups, and achieving equitable outcomes in the complex landscape of transportation planning. Respondents were invited to share their experiences, strategies, and challenges, offering a nuanced understanding of the role of equity in shaping LRTPs.

Moreover, participants were asked to specify the stages or aspects of the planning process where equity-related inputs are or should be considered, providing a comprehensive view of how equity considerations should be integrated throughout transportation planning. Additionally, questions concerning the unit of segmentation and the software utilized for travel demand modeling and long-range transportation planning by DOTs further enrich the exploration of equity practices within this critical domain. This section aimed to uncover actionable insights to inform future strategies and initiatives for fostering equity in long range transportation planning.

Fairness in Access to Public Transportation: The survey inquired about professionals' perceptions regarding the fairness of access to public transportation in their respective states based on their professional expertise, and the results are presented in Figure 22.

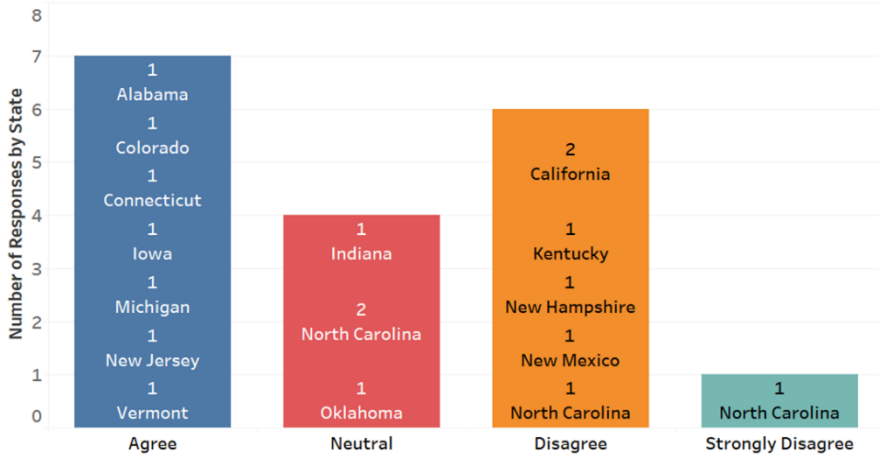


Figure 22. Fairness in Access to Public Transportation

The responses indicate a diversity of opinions within the surveyed group. A noteworthy 38.9% (Figure 22) of participants expressed agreement that access to public transportation in their state has been equal, suggesting a positive assessment of the equity in transportation accessibility. On the other hand, 33.33% disagreed with the notion of equal access, signaling a sizable portion of respondents who perceive disparities in public transportation availability. A smaller yet notable 22.22% maintained a neutral stance on the matter, while 5.6% strongly disagreed with the assertion. The survey results reveal interesting patterns among professionals from specific states regarding their perceptions of access to public transportation. Notably, respondents from California, Kentucky, New Hampshire, New Mexico, and North Carolina collectively disagree, indicating that access to public transportation is not perceived as equal.

Priority in Long Range Transportation Planning: The respondents were asked to identify their top priorities within their respective states' LRTPs, and the results are presented in Figure 23. Safety is predominant, with 44.4% of respondents highlighting it as the top priority. This underscores a collective commitment to ensuring safe mobility. Following safety, effectiveness garnered attention as a key priority, with 27.8% of participants emphasizing the need for efficient and impactful transportation planning. Efficiency (cost-effectiveness) and equity emerged as additional priorities, securing 16.7% and 11.1% of responses, respectively. The diversity in priorities reflects a multifaceted approach to long range transportation planning, with professionals balancing considerations of safety, effectiveness, cost-effectiveness, and equity in shaping the future of transportation infrastructure and policies in their respective states. These insights are instrumental in understanding the nuanced priorities that guide strategic decision-making processes across different regions.

The survey results reveal noteworthy variations in the prioritization of equity among professionals in different states. Specifically, respondents from North Carolina and California (Figure 23) stand out by designating equity as their top priority in their last LRTP. Respondents from New Mexico, New Hampshire, Michigan, Kentucky, Iowa, Indiana, and California indicated safety as the top concern in their last LRTPs. Vermont and Alabama have prioritized efficiency in their long-range transportation planning. On the other hand, New Jersey and Colorado have prioritized effectiveness in their latest LRTPs. The survey results indicate that equity is one of the priorities among other considerations in long range transportation planning.

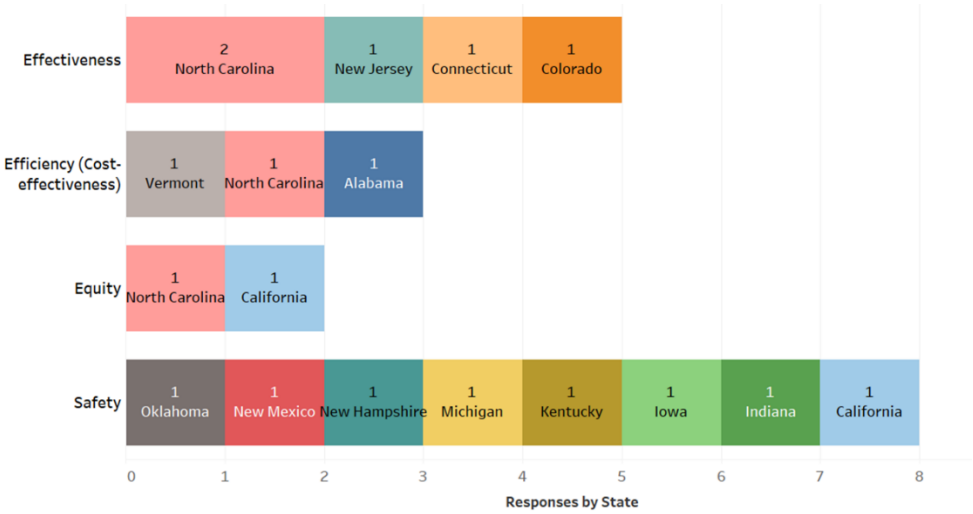


Figure 23. Top Priority in Long Range Transportation Planning by State

Defining Transportation Equity: The question about defining transportation equity is asked to gain insights into how professionals within the surveyed units conceptualize and understand the concept of transportation equity. The responses indicate diverse perspectives on defining transportation equity. A significant portion, 30% (Figure 24), emphasized "Fairness in accessibility," highlighting a focus on ensuring equal access to transportation services for all community members. "Fairness in mobility" was selected by 23.33% of respondents, emphasizing a broad consideration of equitable movement within the transportation system. Additionally, 20% defined equity as "Fairness in the distribution of benefits and burdens," emphasizing the importance of equitable outcomes in the overall impact of transportation initiatives. A smaller proportion, 6.6%, selected "Equal distribution of benefits to all underserved communities," indicating a targeted focus on specific underserved groups. Similarly, 6.6% are "Still working on it," suggesting ongoing efforts to refine and articulate a precise definition of transportation equity within their units. These varied responses reflect the complexity and consensus of defining and implementing equity in the context of transportation planning.

Barrier to Equal Access to Transportation: The survey results in Figure 25 suggest that, according to the professionals surveyed, the largest barrier (64.7% of respondents) to people having equal access to transportation in their State is perceived to be automobile-oriented investments. This underscores a concern that prioritizing investments that cater to private automobiles may contribute to disparities in transportation access. Additionally, 17.6% of respondents identified "Poor transit service quality" as a significant barrier, emphasizing the importance of reliable and frequent public transportation options. Lack of involvement from transportation disadvantaged groups in planning is noted by 11.8% of respondents, indicating a recognition of the importance of inclusive planning processes. The "poorly maintained or lack of transit facilities and safety concerns" options received 0% and 5.9% of responses, respectively. These findings provide valuable insights into the perceived challenges that professionals identify as hindering equitable access to transportation, informing potential areas of focus for policy interventions and improvements in transportation planning.

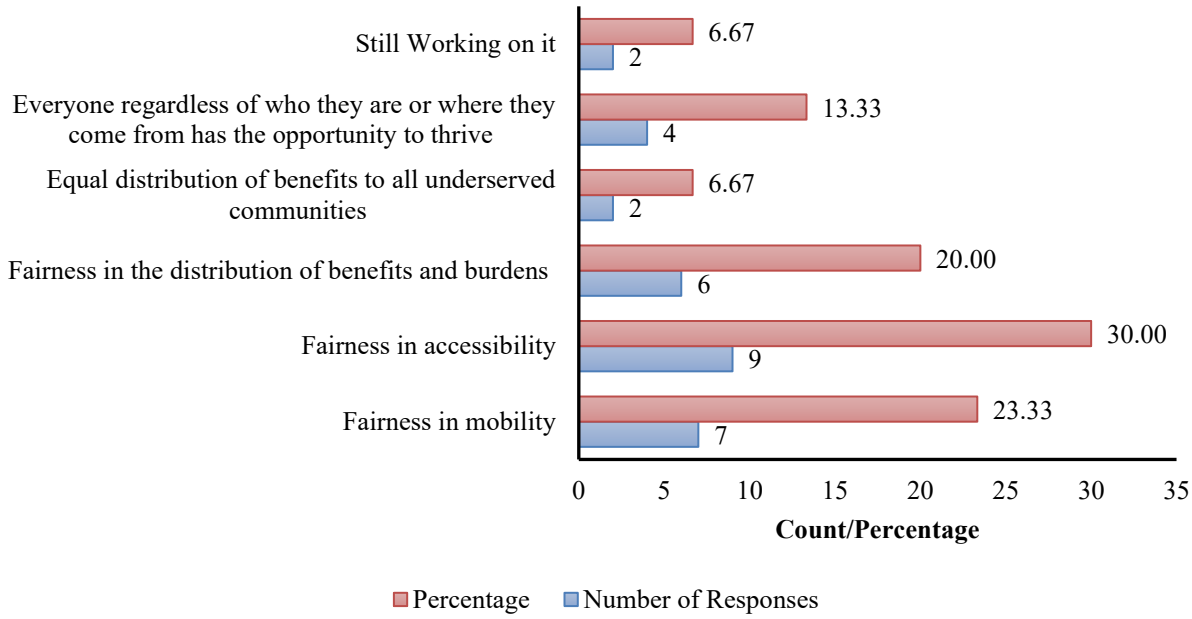


Figure 24. Defining Equity

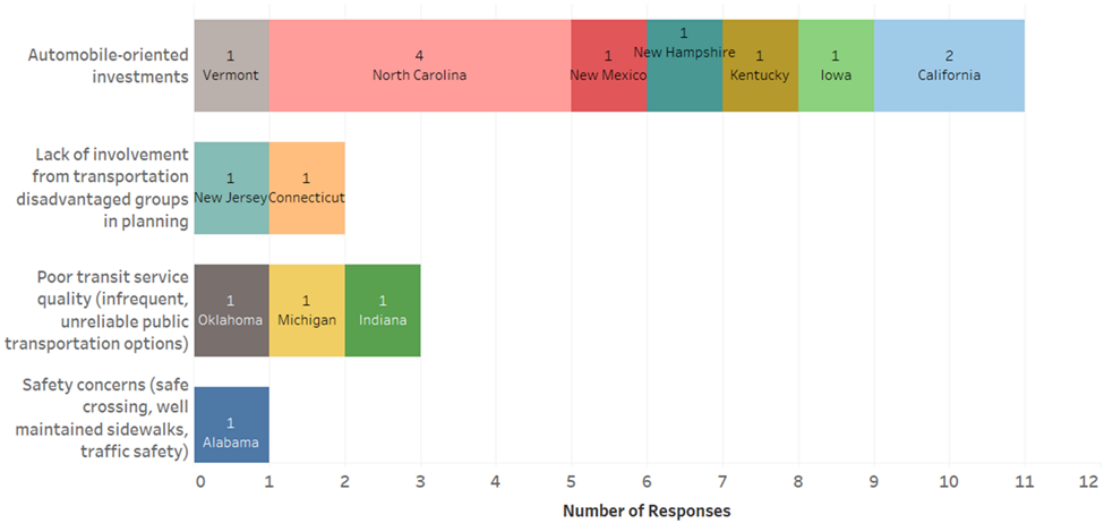


Figure 25. Barriers to People from Having Equal Access to Transportation

The survey results reveal a shared perspective among transportation professionals in Vermont, North Carolina, New Mexico, New Hampshire, Kentucky, Iowa, and California (Figure 25), where 64.7% of the respondents identified "Automobile-oriented investments" as the largest barrier to equal access to transportation. This consensus underscores a collective concern about prioritizing transportation investments that favor private automobiles, potentially leading to disparities in accessibility for other modes of transportation. Recognizing this shared emphasis on the challenges associated with automobile-centric planning practices provides valuable insights for targeted strategies and interventions to foster a more equitable and inclusive transportation system in these states. In states like Connecticut and New Jersey, 11.8% of respondents identified "Lack of involvement from transportation disadvantaged groups in planning" as the largest barrier to equal access to transportation. Similarly, in states such as Oklahoma, Michigan, and Indiana, respondents expressed concern about "Poor transit service quality."

Strategies to Improve Equity in Long Range Transportation Planning: The related survey question is to understand opinions on the potential effectiveness of specific strategies in enhancing equity within long range transportation planning. Actions that contribute most significantly to advancing equity in the planning process can be identified by gauging their agreement or disagreement with the statements provided. These strategies include providing more access to non-vehicle transportation in low-income neighborhoods, improving existing safety infrastructure, providing more on-demand transportation modes, focusing on individuals who do not have reliable access to personal vehicles (elderly, disabled, low-income), improving coordination between nearby communities, improved connectivity of bike lanes, sidewalks, etc.

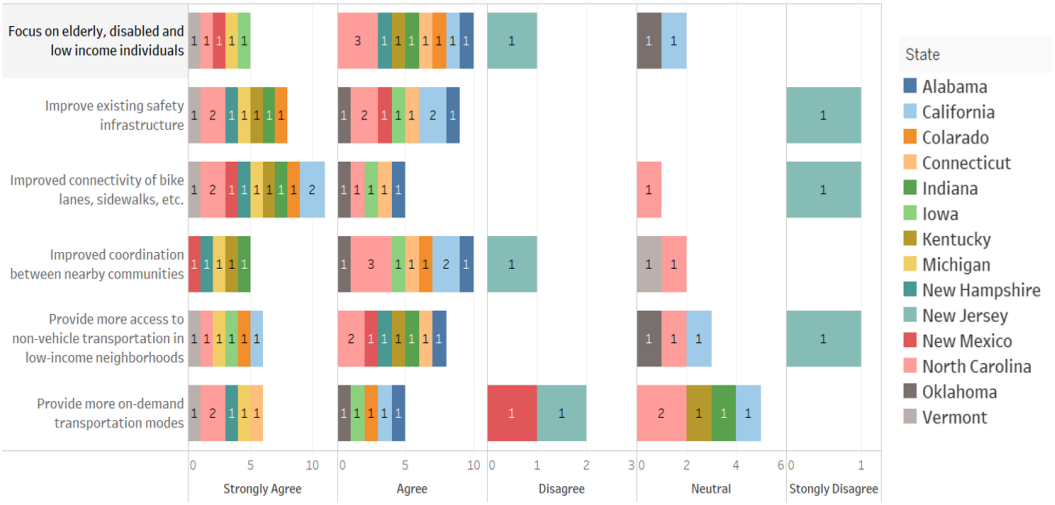


Figure 26. Strategies to Improve Equity in Long Range Transportation Planning

Survey respondents widely acknowledged the significance of specific strategies in enhancing equity within long range transportation planning. Notably, there is a strong consensus on the impact of focusing more on individuals who lack reliable access to personal vehicles, particularly the elderly, disabled, and low-income populations (Figure 26). This underscores a shared commitment to addressing the unique transportation challenges faced by these vulnerable groups, aiming to ensure their inclusion and accessibility in the broader transportation network. Another key strategy is improving connectivity through bike lanes, sidewalks, and related infrastructure. Respondents acknowledge that enhancing these elements contributes to creating a more accessible and interconnected transportation system catering to diverse modes of travel. Lastly, improving existing safety infrastructure, encompassing lighting, curb cuts, complete streets, and enhanced connectivity, is widely perceived as a crucial aspect of promoting equity.

A predominant trend in recent long range transportation planning across various DOTs is the thoughtful integration of equity strategies, focusing on three key pillars: multimodal planning, enhanced public engagement, and considerations for air quality and environmental justice (Figure 27). These strategies underscore a collective commitment to developing transportation systems prioritizing inclusivity and sustainability. Multimodal planning initiatives reflect a shift towards accommodating diverse transportation modes, acknowledging the varied needs of communities. Simultaneously, the emphasis on improving public engagement signifies a concerted effort to involve stakeholders and communities in decision-making processes, ensuring that transportation plans align with the specific needs and preferences of the people they serve. Moreover, incorporating air quality and environmental justice considerations demonstrates an integrated approach to long range transportation planning, addressing the broader environmental impacts and promoting equitable distribution of transportation benefits and burdens.

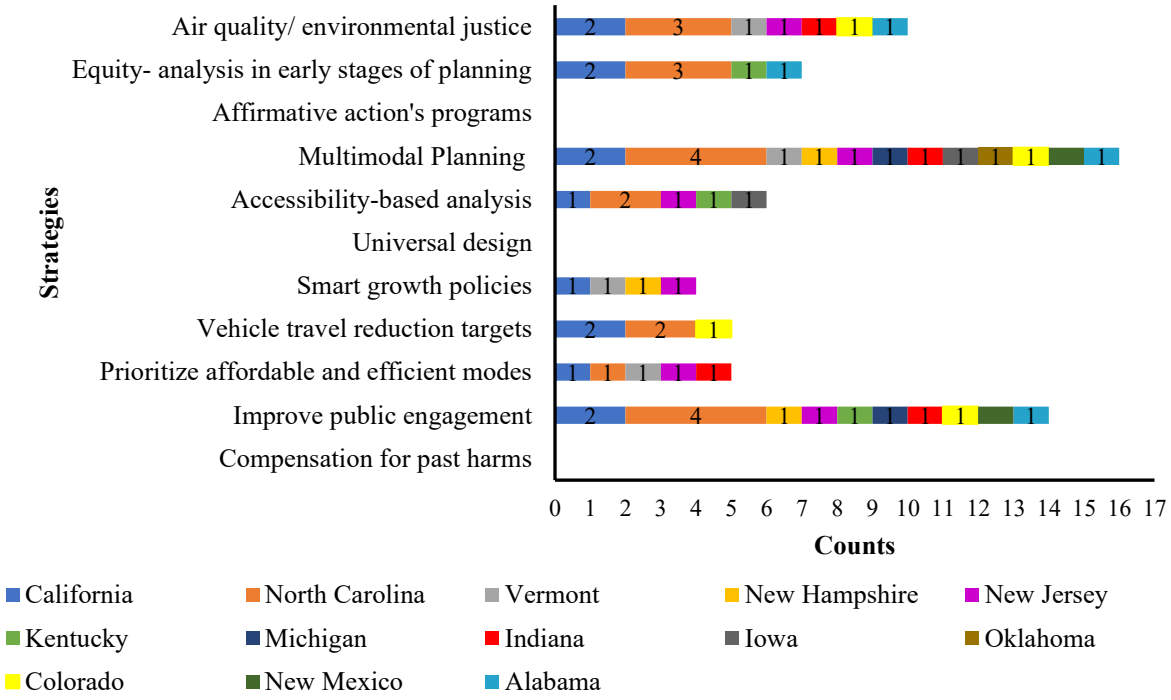


Figure 27. Strategies Employed in Current Long Range Transportation Planning by State

Disadvantaged Population: Term and Factors: The survey also sought to understand the diversity in terminology to understand the multifaceted nature of disadvantage within communities and how respondents define disadvantaged populations in the context of long-range transportation planning. The results indicate a diversity of terminology professionals use, reflecting nuanced perspectives. Most respondents (25.00%) employ the term "traditionally underserved," emphasizing a historical context in which certain communities have been consistently lacking in resources or attention (Figure 28). "Disadvantaged" (21.15%) and "minority" (19.23%) are also commonly used, highlighting populations facing demographic/socioeconomic challenges. "Socially underrepresented" (5.77%), "marginalized groups" (5.77%), and "communities of concern (COCs)" (7.69%) suggest a broader consideration of societal dynamics and community needs. The term "vulnerable" (15.38%) indicates a focus on populations with heightened susceptibility to adverse impacts.

The survey also focused on identifying factors based on which DOTs classify a population group as disadvantaged. The results reveal a comprehensive approach to addressing various groups of populations included in long range transportation planning processes. People living in rural areas are the top-priority population considered in these planning initiatives (Figure 29), reflecting a recognition of the unique transportation challenges residents face in less densely populated rural regions. Following closely, low-income or poverty-stricken populations are also prominently addressed, underscoring a commitment to addressing demographic/socioeconomic disparities. Non-drivers, disabled individuals, and the elderly are identified as key groups of citizens in the planning process, emphasizing the importance of inclusivity and accessibility for diverse mobility needs. Additionally, there is a concerted effort to address historically disadvantaged populations, acknowledging the impact of systemic inequalities on certain racial and ethnic minority groups.

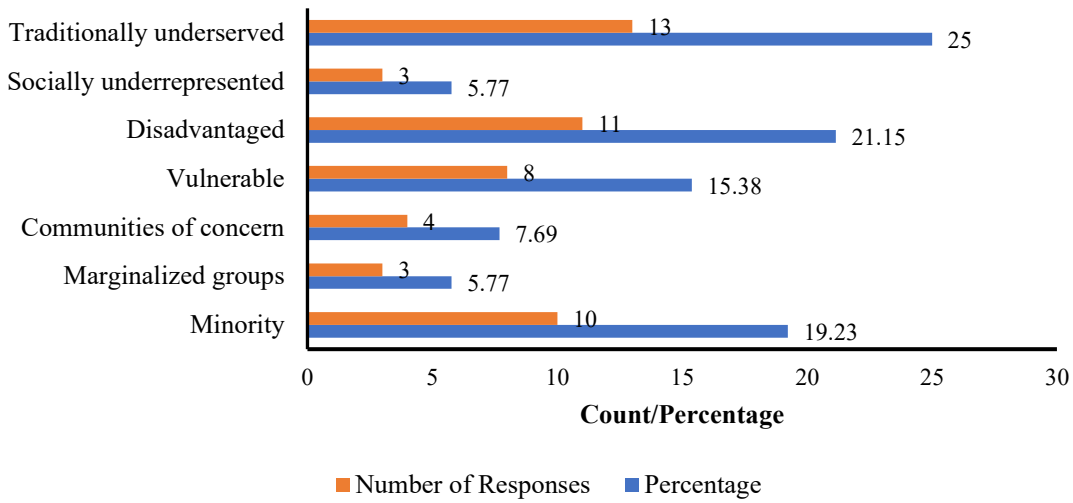


Figure 28. Disadvantaged Population: Other Terms Used in DOT

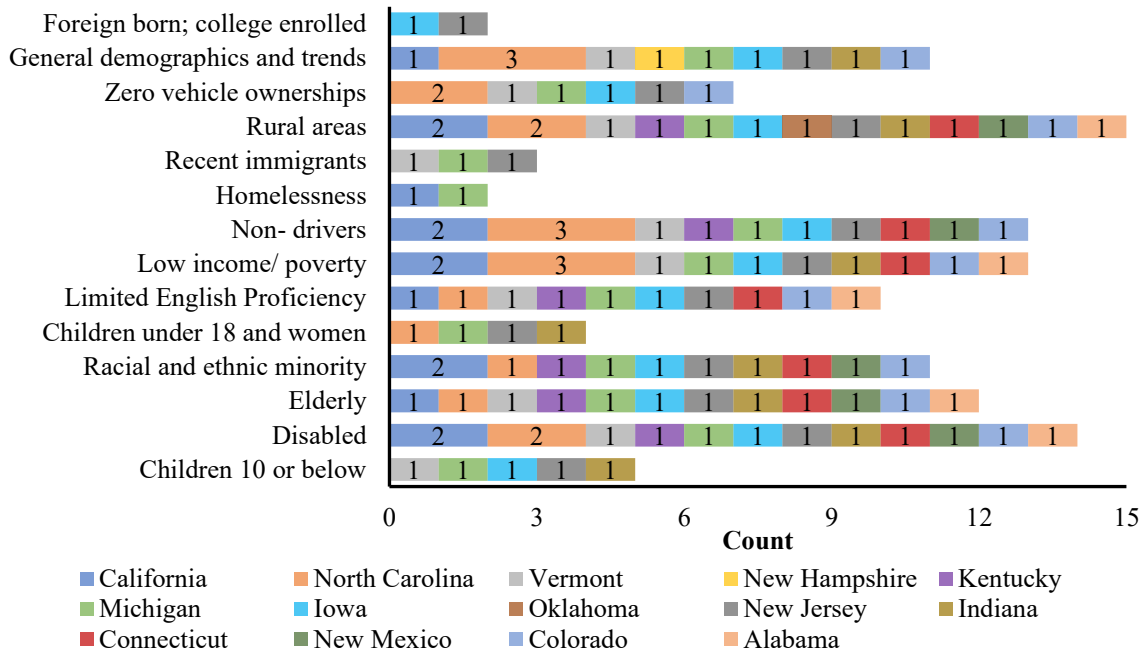


Figure 29. Factors used to Identify Disadvantaged Population by State

Incorporating Equity in Long Range Transportation Planning: The survey results illuminate key stages within the long-range transportation planning process where equity considerations were addressed. Notably, framing goals and objectives emerges as the stage where equity inputs were most extensively considered (Figure 30), underscoring the foundational importance of establishing inclusive and equitable guiding principles for transportation initiatives. The prioritization stage is identified as another critical juncture where equity considerations played a significant role, highlighting a deliberate effort to allocate resources and prioritize projects that address the needs of diverse and historically underserved communities. Additionally, the mode choice stage is a pivotal point in the planning process where equity inputs could be actively considered, reflecting a commitment to ensuring accessibility and inclusivity across various transportation modes. These findings underscore a strategic and comprehensive integration of equity

considerations throughout different stages of the planning process, reflecting the commitment to fostering equitable outcomes in developing and implementing LRTPs.

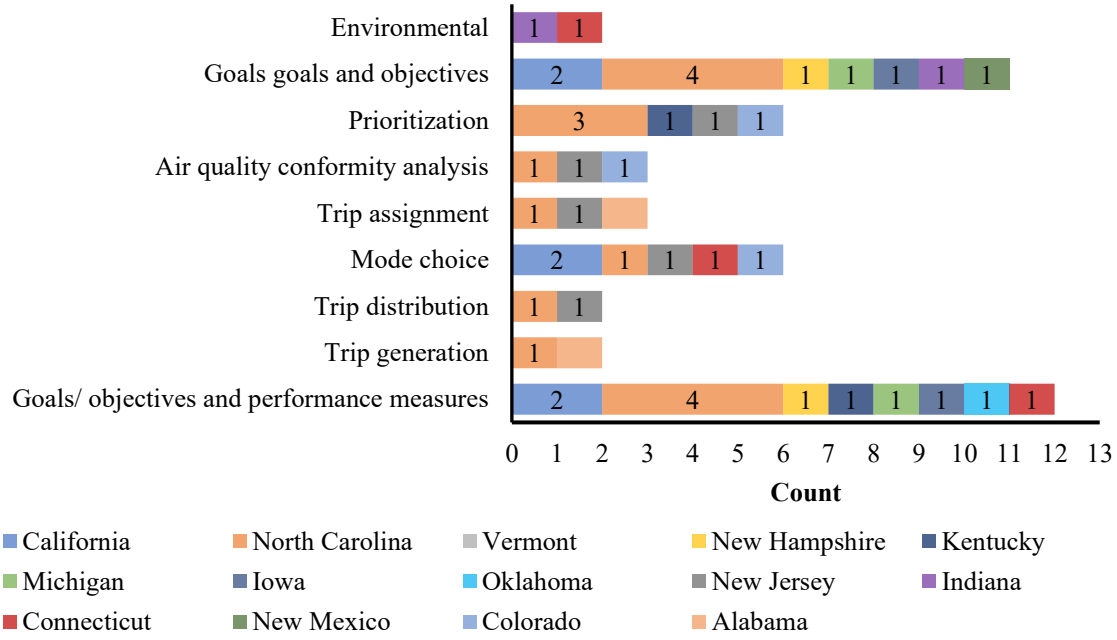


Figure 30. Equity in Planning Stages by State

Unit of Segmentation: The question about the unit of segmentation used for travel demand modeling and long-range transportation planning is crucial and pertinent for gaining insights into the methodology and granularity employed by State DOTs. Understanding the chosen units of segmentation provides valuable information about how transportation planners organize and analyze data to inform their decision-making processes. Different units, such as Traffic Analysis Zones (TAZ), census tracts, and census block groups, offer varying levels of detail and precision in capturing demographic/socioeconomic, geographic, and transportation-related information. The survey results shed light on the predominant units of segmentation utilized by State DOTs in travel demand modeling and long-range transportation planning. TAZ is the most commonly employed unit (Figure 31), indicating a widespread adoption of this segmentation approach for assessing transportation needs and demands. Notably, census block groups and census tracts also feature prominently as probable units of segmentation, emphasizing recognition of the significance of localized demographic/socioeconomic and geographic data in shaping effective transportation plans.

Travel Demand Modeling: Method and Software: The survey findings revealed diverse software preferences among State DOTs for travel demand modeling. TransCAD is the most widely used software across states (Figure 32), indicating its popularity as a versatile tool for transportation planning and demand modeling. However, there are exceptions, with New Mexico employing VISUM and highlighting a state-specific preference for a different modeling platform. Colorado uses an activity-based demand model, reflecting a nuanced approach that considers individual activities and travel patterns. Alabama employs Cube Voyager as its software of choice, demonstrating a unique selection that aligns with the state's specific modeling needs. These variations underscore the flexibility in software choices and the importance of selecting tools that align with the specific requirements and methodologies of each DOT.

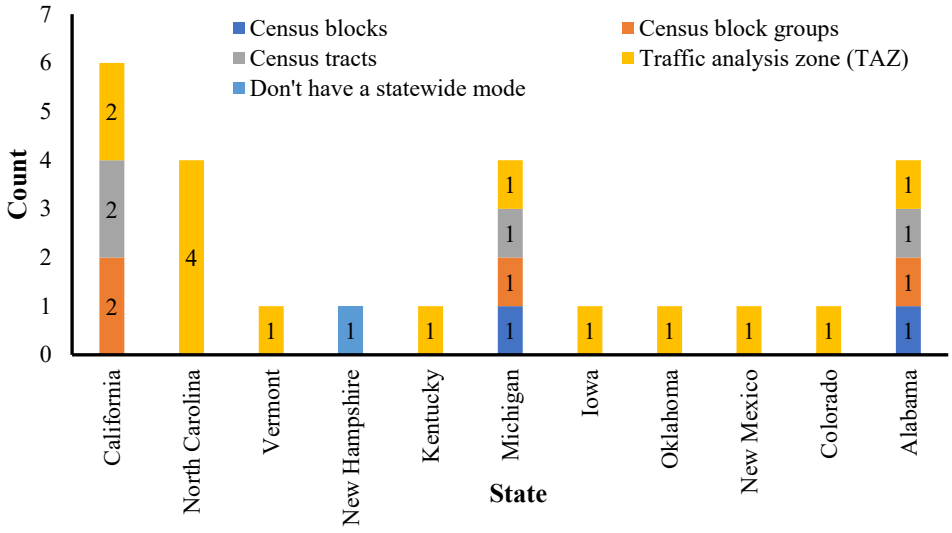


Figure 31. Unit of Segmentation Used by DOT by State

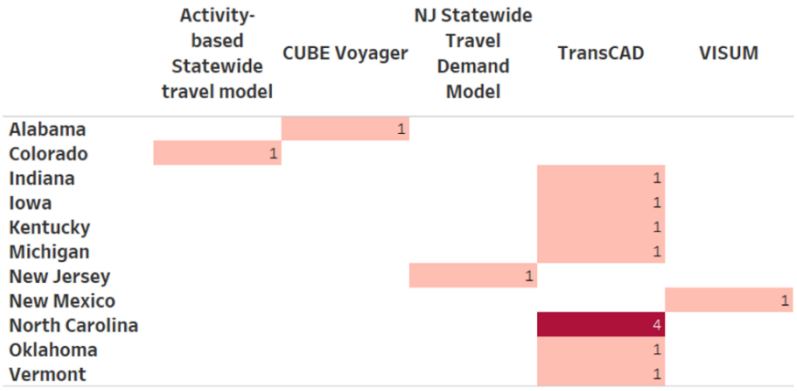


Figure 32. Software Used for Demand Modeling by DOT

Equity Concerns: The survey results underscore the key equity concerns that took precedence in recent long range transportation planning efforts. Foremost among these is safety (Figure 33), indicating a concentrated effort to address the severity of crashes, identify high-risk areas, and enhance the safety of vulnerable road users such as pedestrians and cyclists. Following this priority, the considerations of travel time and reliability emerge as significant equity concerns, emphasizing the importance of creating transportation systems that are not only efficient but also reliable for all users. Environmental impacts, reflecting a commitment to sustainable and eco-friendly transportation solutions, are also identified as an essential equity concern. Additionally, the accessibility of vital locations, including jobs, schools, and healthcare within a 45-minute radius, is acknowledged as a fundamental equity consideration. These findings reveal a comprehensive and nuanced approach to equity in long range transportation planning, spanning safety, reliability, environmental sustainability, and accessibility to essential services.

Strategies to Promote Equity and Diversity: The survey outcomes highlighted strategies employed by State DOTs in recent long range transportation planning processes to enhance diversity, equity, and inclusivity. Collaborating with community organizations is the most widely incorporated approach (Figure 34). Most respondents have been engaging in different communities through established local networks. Focus group meetings follow closely, indicating a commitment to facilitating interactive discussions to gather valuable input and perspectives. Additionally, collaborating with community organizations specifically to improve

survey responses from hard-to-reach populations underscores a targeted and collaborative approach to ensure representation and inclusivity. These findings illustrate a multifaceted and community-centric approach to promoting diversity, equity, and inclusivity in the planning process, emphasizing the importance of collaborative efforts and direct engagement with various community stakeholders for more inclusive and representative LRTPs.

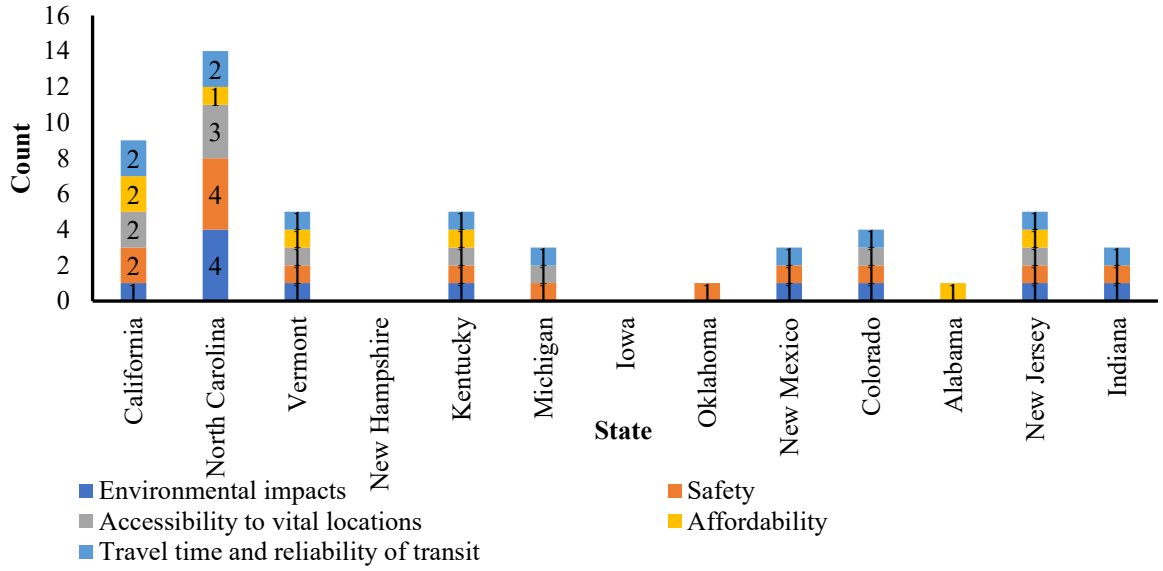


Figure 33. Equity Concerns Addressed across DOT

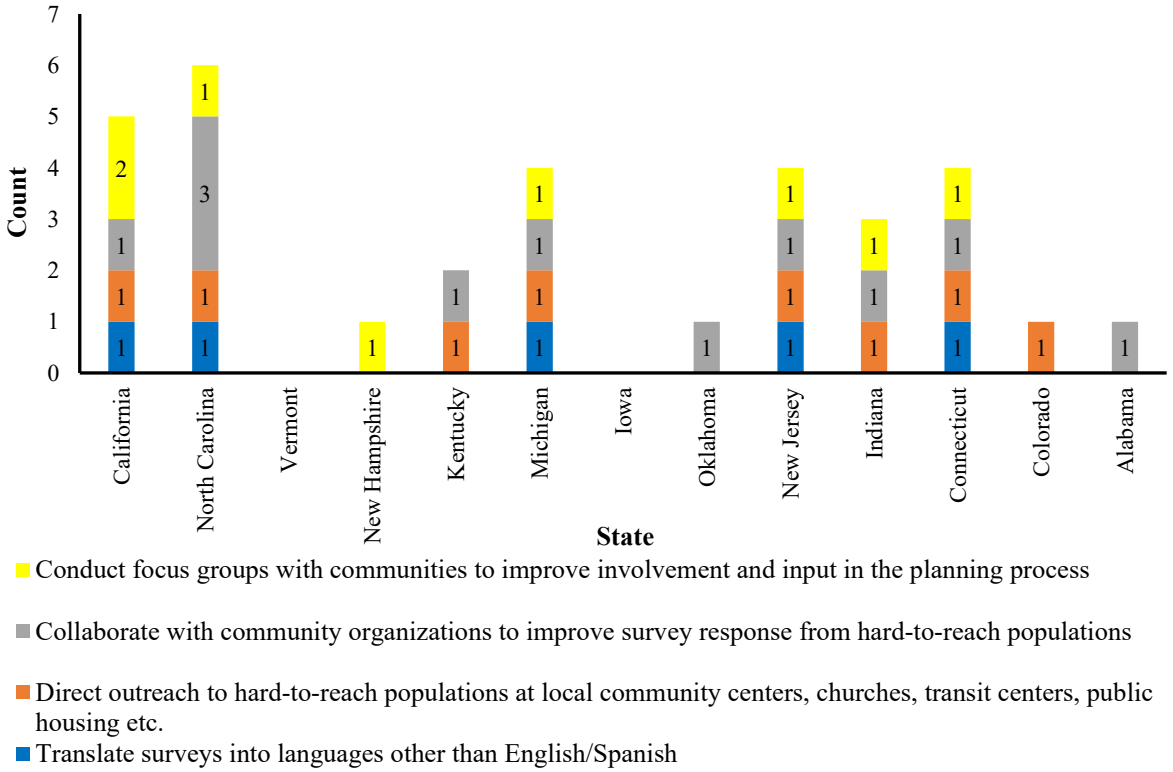


Figure 34. Strategies to Include Diversity in DOT Planning by State

Strategies for Prioritization: The survey results divulge a nuanced exploration of considerations inherent in the project prioritization processes of State DOTs during recent long range transportation planning initiatives. One salient strategy involved proactively identifying regions where historical underinvestment has contributed to safety issues, underscoring a commitment to rectifying enduring disparities in safety infrastructure (Figure 35). Simultaneously, prioritizing reliable transportation services for all users emerges as a pivotal focus, epitomizing a dedication to ensuring uniform and dependable transportation options for diverse communities. Furthermore, examining past projects through an equity lens, the targeted allocation of investments to enhance accessibility, and contemplating potential displacement and disruption from projects signify a comprehensive approach to equity and inclusivity. These findings illustrate a nuanced and strategic project prioritization process, displaying a commitment to addressing historical inequities, promoting reliable services, and striving for equitable outcomes for all users across diverse communities.

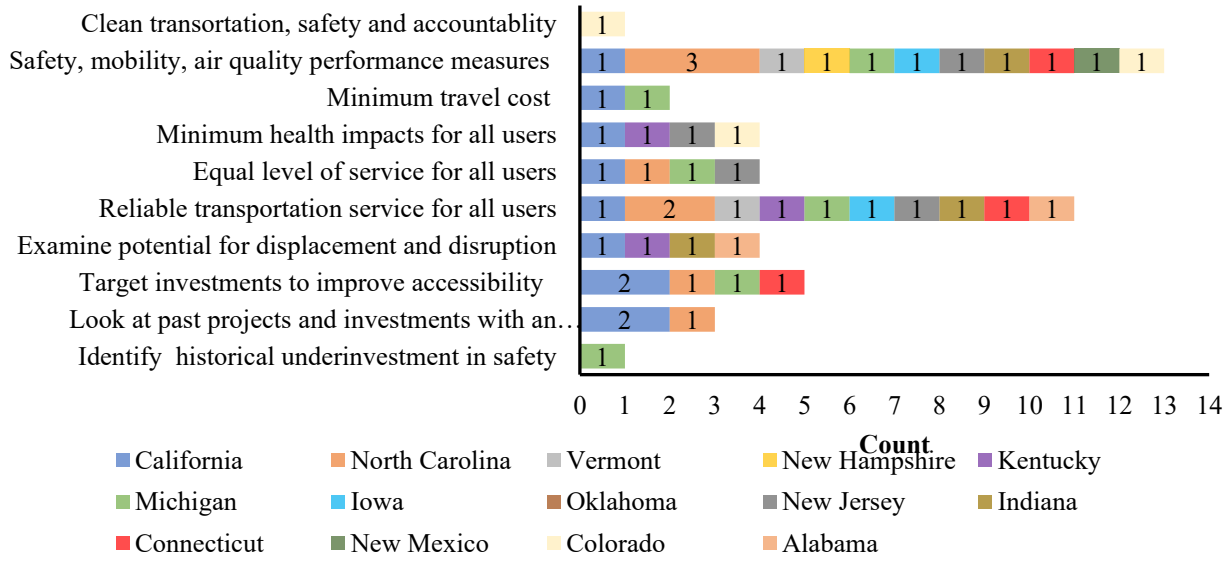


Figure 35. Strategies used in the Prioritization Process by DOT

Environmental and Health Equity Concerns: The question regarding including environmental and health equity concerns in their last LRTP serves a critical purpose in understanding the broader considerations and priorities of State DOTs. The survey outcomes shed light on incorporating environmental and health equity concerns within recent LRTPs formulated by State DOTs.

The focus revolved around addressing roadway congestion (Figure 36), reflecting a commitment to mitigating traffic-related issues and the associated environmental and health impacts. Additionally, a noteworthy emphasis on increasing the number of bike/pedestrian commutes highlights a dedication to promoting sustainable and active modes of transportation for improved environmental and public health outcomes. Moreover, strategies targeting improved access to the local economy and creating tourism destinations, activities, and opportunities demonstrate a comprehensive approach to environmental and health equity. These findings underscore a comprehensive and integrated perspective in addressing diverse equity dimensions within long range transportation planning, aligning with sustainability objectives and fostering healthier and more resilient communities.

Prioritization of Performance: This question on the relative importance assigned to various performance elements in transportation plans following community input assists in understanding the decision-making criteria that State DOTs prioritize based on community feedback. By assigning a ranking from 1 (most important) to 10 (least important) to elements such as accessibility, air quality, cost efficiency, community goals, congestion mitigation, connectivity, health impact, level of service of various modes, operating

cost/vehicle, safety, and sustainability, the survey seeks to unveil the values and preferences that guide transportation planning decisions.

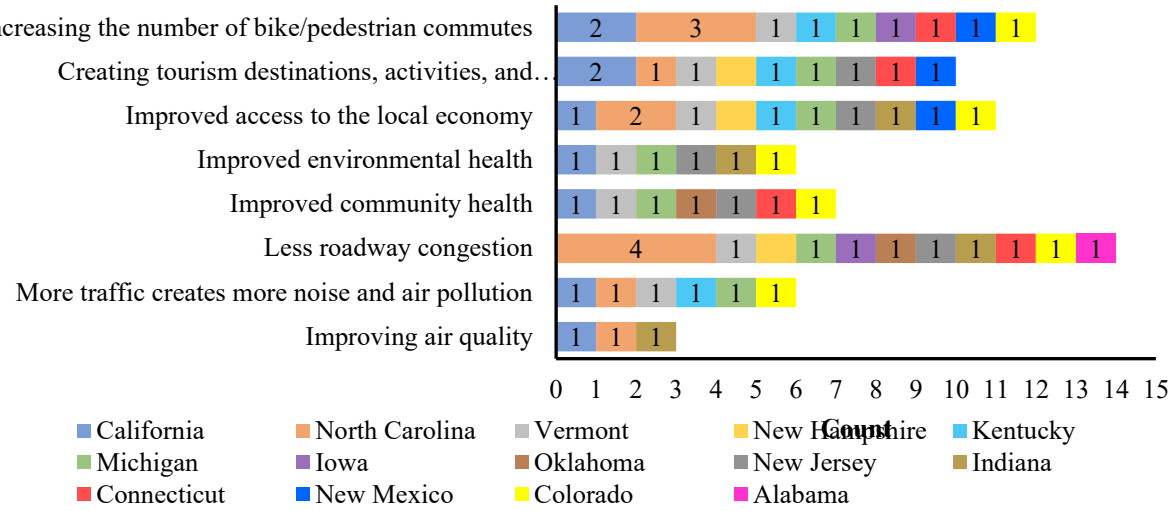


Figure 36. Environmental and Health Equity Concerns Included in Planning by DOT

The survey responses indicate a consistent trend across various states, with operating cost/vehicle (Figure 37) and the level of service receiving the highest rankings in transportation plans. This suggests a significant emphasis on cost-effectiveness and the efficiency of transportation services, aligning to maximize value for resources invested. Safety, accessibility, and connectivity also hold considerable importance, reflecting a balanced approach that addresses both operational efficiency and the broader community's needs. The prioritization of safety underscores a commitment to reducing crash risk for all road users, while accessibility and connectivity highlight the significance of creating inclusive and connected transportation networks.

The responses to this question provide valuable insights into the weight given to different factors in the decision-making process. It helps in understanding the extent to which community input influences priorities in transportation planning and whether there is an alignment between the goals of the community and the emphasis placed on specific elements in transportation plans.

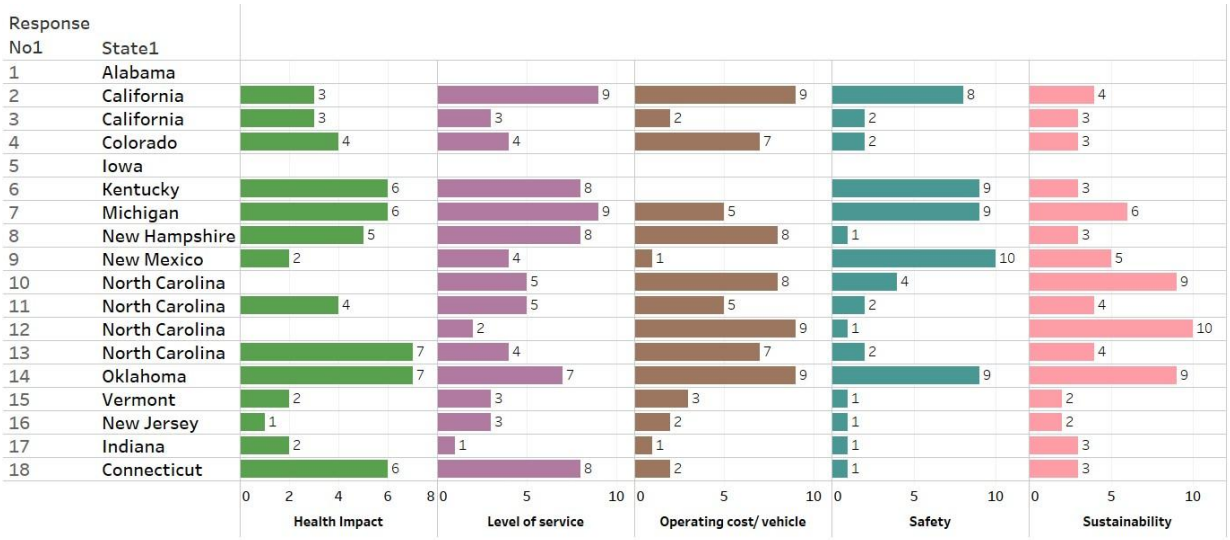


Figure 37. Rating on Elements of Prioritization

Familiarity with USDOT's Equitable Transportation Community (ETC) Explorer : Part 3 of the survey delves into participants' familiarity with the ETC Explorer tools. This section is designed to gather insights into respondents' awareness of and experiences with ETC tools, gauging their perceptions of their value, relevance, and potential for widespread adoption. The questions within this section aim to uncover the participants' perspectives on the ETC Explorer and assess its role in shaping equitable transportation practices. The results are presented in Figure 38.

Respondents from Connecticut, Iowa, Kentucky, Michigan, New Hampshire, New Jersey, New Mexico, North Carolina, and Vermont are aware of the recently released USDOT's ETC Explorer. However, a notable challenge identified across these states, particularly for smaller rural states, is the issue of data granularity. While many respondents are familiar with the ETC Explorer, a sizable portion have not utilized the tool. This indicates an awareness of the platform but suggests a need to overcome specific challenges, such as addressing data granularity issues, to enhance its widespread adoption and effectiveness in these states.

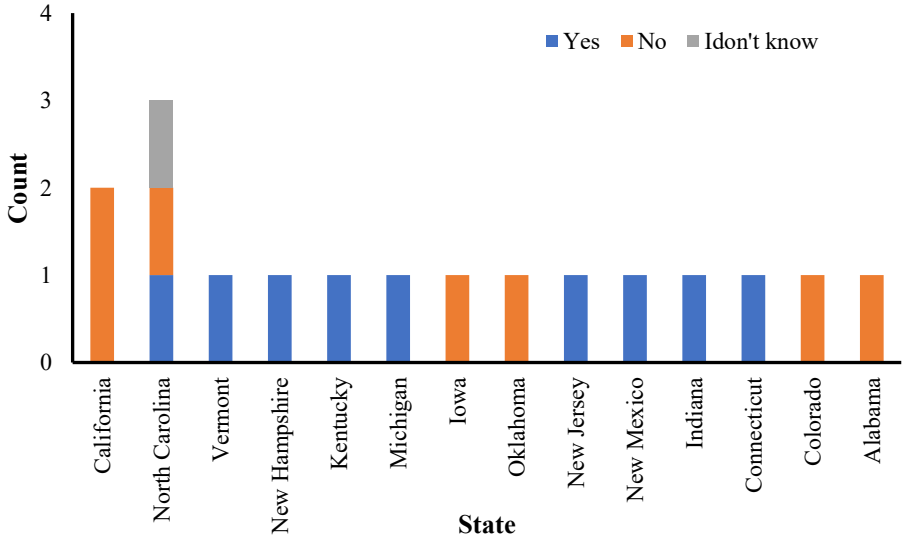


Figure 38. Familiarity with USDOT's ETC Explorer

GIS Tool Usage: Part 4 of the survey assesses participants' engagement with GIS tools within their transportation planning processes. This section delves into the adoption and effectiveness of GIS tools in identifying disadvantaged populations and addressing equity considerations. By exploring the prevalence of GIS tool usage among respondents, the survey aims to capture insights into how this technology is integrated into the transportation planning workflow and its impact on addressing equity-related concerns within the field.

Respondents from Colorado, Iowa, Indiana, Michigan, and Connecticut indicate that their DOTs have adopted GIS-based tools for assessing mobility options for transportation-disadvantaged individuals (Figure 39).

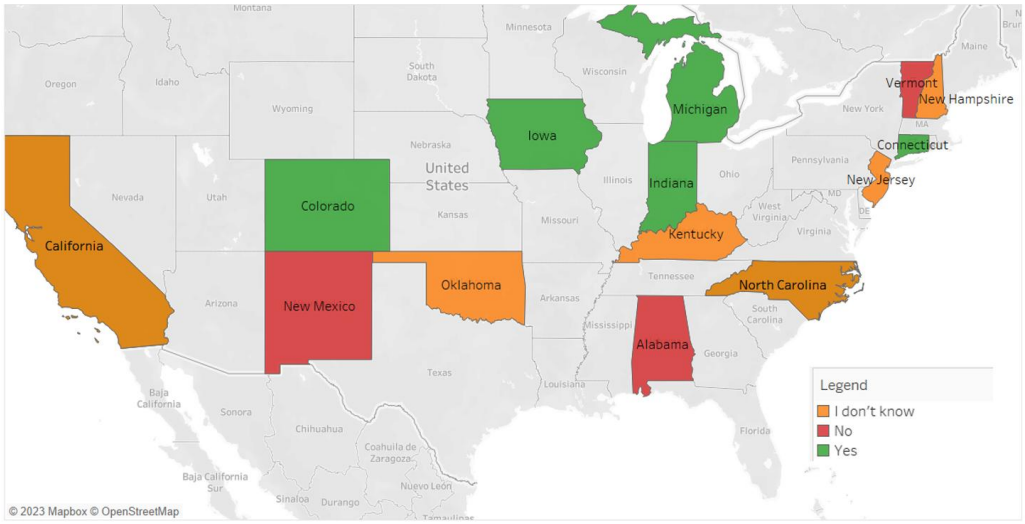


Figure 39. GIS Tool to Assess Mobility for Disadvantaged Populations across DOT

Disparities in Short-Term Delivery During the Pandemic: Part 5 of the survey is dedicated to exploring the impact of the pandemic on short-term delivery and addressing the disparities that emerged during this period. This section aims to gather valuable insights from practitioners on their perceptions and strategies in managing challenges related to the timely delivery of essential goods during the pandemic. By delving into survey participants' experiences, the survey seeks to uncover potential disparities during the pandemic and highlight innovative solutions to address these issues. This section offers a comprehensive examination of how transportation practitioners navigated the challenges posed by the pandemic in the context of short-term delivery, shedding light on both the challenges faced and the creative solutions implemented.

During the pandemic, Vermont Department of Transportation (DOT) proactively addressed access disparities related to the short-term delivery of essential perishable commodities, such as fresh fruits and medicine (Figure 40). Transportation departments across various states have implemented various initiatives to adapt to the challenges posed by the pandemic. Collaboration with transit agencies has been a common strategy to enhance the efficiency and coordination of transportation services. Additionally, virtual public engagement initiatives have been widely adopted to maintain community involvement and gather feedback while adhering to social distancing measures. Many departments have also made work-from-home arrangements to ensure the safety and well-being of their workforce during these unprecedented times. These initiatives collectively reflect an initiative-taking response from transportation departments to the evolving circumstances, demonstrating flexibility and innovation in adapting to the new normal brought about by the pandemic.

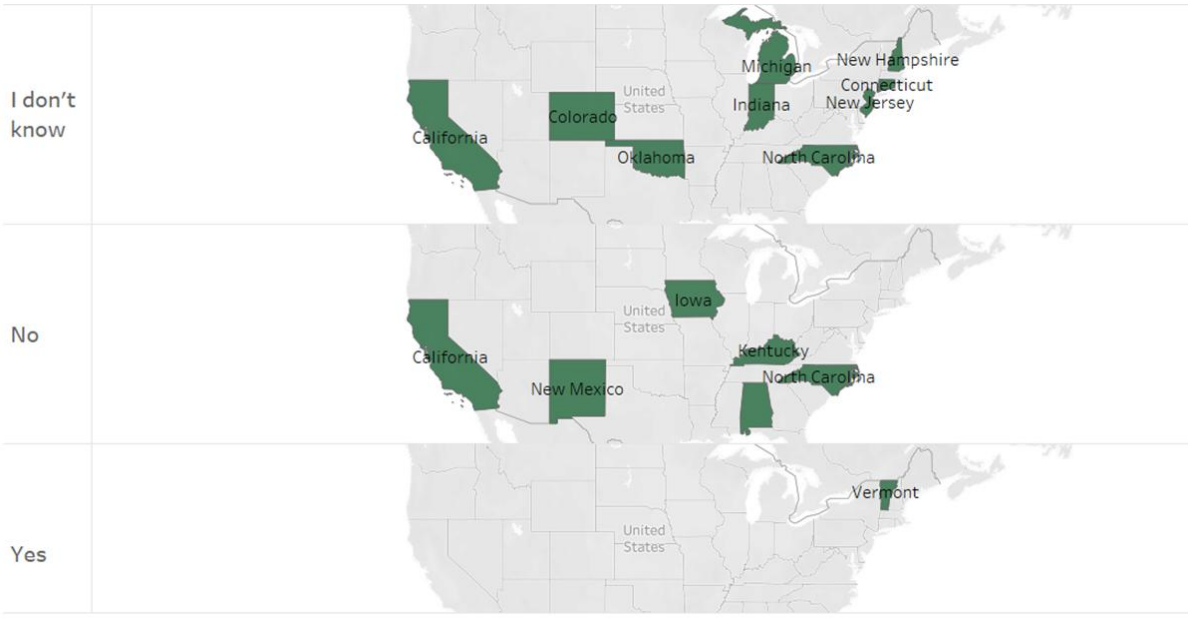


Figure 40. Addressing Disparities During Pandemic

Chapter 5. Findings from Focus Group Meetings and Interviews

This chapter focuses on findings from interviewing MPOs, RPOs, and transportation planners to identify their practices in addressing transportation equity.

Purpose: The focus groups were constructed in consultation with NCDOT. The meetings aimed to collect participants' detailed perspectives and observations about equity in long range transportation planning. Each meeting consisted of eight open-ended, exploratory questions, similar to those used in a previously administered survey, designed to elicit comprehensive insights. The questions focused on understanding participants' views on equity, what types of data organizations use, and how they integrate and incorporate equity in long range transportation planning. Additionally, the discussions addressed methods for overcoming challenges related to the short-term delivery of essential and perishable commodities across all areas of North Carolina. The insights collected from the focus groups provide valuable input for enhancing equity in transportation planning.

Participants and Interview Methodology: Three meetings were conducted via Zoom between September 19th and September 26th of 2023, complemented by four additional individual interviews between October 24th and November 3rd of 2023 to ensure underrepresented groups could share their perspectives. The findings from responses and insights from participants in each of the three virtual meetings are discussed in this chapter.

Participants were invited via email, with an attached Google Form for sign-up for their preferred meeting. Out of the twenty participants who confirmed their attendance, each meeting aimed to host 8-10 participants for 60-90 minutes. However, due to last-minute scheduling conflicts, participation was as follows: four in Meeting 1, six in Meeting 2, and four in Meeting 3.

All participants met the criteria for full participation, working in long range transportation planning. The NCDOT provided the email addresses of potential participants, which are public addresses for North Carolina Officials. Additional email addresses were collected through mutual contacts interested in participating. Most participants represented MPOs, RPOs, and various cities and towns. Efforts were made to include representatives from school districts, disability transportation officials/experts, and freight planning officials, though participation from these groups was lower.

To ensure diverse perspectives, individual interviews were conducted with community representatives from tribal areas, transportation disadvantaged groups, and the commercial sector (freight logistics companies) after the meetings. Despite repeated efforts, the team could not secure participation from a tribal community representative.

5.1. Focus Group Questions and Discussion

Question 1. What tools, metrics, or guidance are you already incorporating to ensure LRTP measures reflect equitable outcomes when they are put in place? Do practices appropriately address the needs of differing units of measurement and geographies, such as urban, suburban, and rural areas?

Participants across all groups described their experiences using various DOT tools and guidance, including the Environmental Justice tool, the TDI tool, and the Justice 40 initiative. Notable methods for ensuring equitable outcomes included ensuring an even spread of project submittals across regions and equal voting to increase project opportunities. Rural areas emphasized the importance of geographic equity when allocating resources and focused on mitigating the rural-urban divide in planning.

The focus groups discussed how current measurement tools may complicate planning efforts to create geographic equity. This complication arises partially because these tools are based on census block data, which fails to reflect a complete picture of a rural community’s needs. Participants expressed concerns that the local context is often lost in the process. Outcomes may not capture the meaningful variation between urban and rural communities or reflect how these differences dictate transportation equity needs.

A potential solution to improve the accuracy of these tools could be to incorporate more granularly scaled data. Additionally, all focus groups considered it a goal to increase regional projects to limit funding competition between urban and rural areas. Members of the groups agreed that considering a broader range of circumstances during project prioritization could achieve more equitable and inclusive outcomes for all community members.

Question 2. How do freight planning measures ensure future freight networks will serve the State's rural communities and address connectivity between rural and urban areas?

Although freight experts and officials did not participate in the three meetings, they were interviewed separately after they concluded. Therefore, this question was interpreted and addressed from the perspective of transportation planners working alongside freight networks.

All participants across the groups highlighted their organizations' efforts to incorporate and extend freight and passenger rail into rural regions. Common themes regarding opportunities for freight transportation initiatives emerged unanimously in all meetings. Participants emphasized that building and maintaining relationships is crucial for successful outcomes in freight and rail projects, especially since many freight networks are owned by private companies. Additionally, while communication with freight companies can be challenging, participants noted that positive outcomes are achievable through persistent and proactive engagement.

***Question 3. How do the current economic evaluation metrics of the LRTP costs and benefits reflect equitable planning and investment considerations? In addition, please share what is working, what is not* working.**

Similar to the first question, this question prompted discussions about the limited utility of the NCDOT prioritization and evaluation grading criteria. Participants noted that the existing metrics might be too broad to accurately capture the varying perceptions of costs and benefits across geographically diverse areas. Recognizing the unique needs of all communities is essential for ensuring equitable and accessible investments.

Participants highlighted the inequities in the current project funding process and the challenges it creates for both rural and urban core areas. Specifically, points assigned to regions for determining funding are not allocated equitably across geographic areas, leading to a geographically unequal distribution of projects. Many participants felt that their voices were diminishing in the process. Furthermore, local input points do not necessarily make projects more affordable in rural areas. While local input points may be directed towards a highway project at no cost to the local government, they often require monetary and administrative input when used for projects of need, such as sidewalks, resulting in poor funding for highly valued projects.

Metrics used to determine regional and divisional funding often place smaller divisions at a disadvantage, making it difficult for them to secure local matches for projects. As a result, some areas are forced to suspend projects due to budgetary limitations. Participants across the groups echoed these concerns about the evaluation tools and the data they rely on. They agreed that more equitable and inclusive outcomes could be achieved for all community members by considering a broader range of circumstances during project prioritization.

Question 4. What equitable outreach strategies have you incorporated as part of the LRTP to assist in bringing all voices to the conversation? For example, similar digital and non-digital methods, offering incentives, providing childcare, multilingual translation services, free transit passes, variable community/cultural meeting locations such as grocery stores, libraries, education facilities, recreation centers, faith-based centers, large housing complexes, and large employment centers?

Participants reported varying degrees of success in fostering active community involvement in the transportation planning process. Rural areas face significant barriers to conducting meaningful outreach due to limiting factors such as low staffing, limited resources, and the need for more technology to inform outreach efforts. In contrast, urban areas reported more success due to strategic partnerships with

community organizations and the use of data and technology to enhance their understanding of effective outreach strategies. Universal strategies employed by all groups to make involvement more convenient and accessible for citizens included conducting engagement meetings before or after other county meetings, utilizing virtual rooms for elderly and disabled groups, and relying on regional partners to improve understanding of regional challenges. Emphasis was placed on the need for more creativity, consideration, and awareness when exploring new ways of communicating and engaging with citizens.

Question 5. How do the outreach and engagement strategies of the LRTP ensure decision makers understand the need to address equitable measures in the near- and long-term horizon plan, programmatic funding, and implementation mechanisms?

Participants highlighted many difficulties in engaging with unfamiliar communities, often due to trust issues these communities' harbor. Stronger relationship-building with local officials, who can act as intermediaries, was identified as a critical need for improving effective information delivery. However, many local staff are already working beyond capacity. There was consensus that more local funds are needed for rural and grassroots outreach and capacity building. Trust is essential in these efforts and may diminish when there is a lengthy gap between public input at the project proposal stage and final implementation. This long 10–20-year gap without visible progress reflects poorly on the government's ability and willingness to accommodate citizens' voices and meet their needs. Participants suggested that smaller, near-term active transportation projects might alleviate this situation. However, achieving some of these goals may face pushback from elected officials with different priorities and less understanding of community transportation needs.

Question 6. How do you overcome any challenges related to implementing equitable LRTP and freight planning in your communication & outreach measures, the offering of service options, funding limitations, and governance & policy requirements?

Participants highlighted several challenges in project implementation, noting delays in timelines and a desire to place more urgency on addressing needs, such as the lack of overnight truck parking and pollution. Emphasis was placed on fostering collaboration for shared infrastructure investments, particularly regarding rail, freight, and transit connections. The importance of community engagement was underscored by using hybrid meetings for broader participation, ensuring language access, and improving website accessibility. Barriers to promoting localized conversations in larger counties, especially Mecklenburg, were noted, along with struggles with Justice 40 grant applications due to limited staff and low-tech options in rural areas. Despite the challenges both rural and urban areas face, available resources are used strategically to include diverse voices in transportation planning. Additionally, there is a call for plan updates considering factors such as truck parking access, pollution reduction, and harmonizing passenger and freight rail trips.

Question 7. If you had complete control and oversight, what are the top three measures, metrics, policies, regulations, or practices that you would change or improve upon to ensure equitable transportation planning outcomes?

Diversifying Funding

- Explore diverse funding resources, potentially targeting out-of-state contributions
- Advocate for a more equitable cost vs. benefit analysis to optimize fund allocation

Enhancing Local Input

- Emphasize the need for more local input in the planning process
- Promote proactive, rather than reactive, planning approaches

Coordination

- Call for better coordination between transportation agencies and localities
- Regionalized planning initiatives and transit systems for increased efficiency

Equitable Funding and Project Prioritization

- Advocate for more equitable funding distribution, especially for projects across geographically diverse areas
- Re-evaluate project prioritization criteria to ensure communities are receiving the resources and investments that match their unique needs

Universal Solutions

- Encourage a shift from a territorial mindset to a more universal approach to problem-solving
- Encourage communities to collaborate on initiatives that create mutual benefits and add value to all regions

Prioritizing Equity

- Call for a more integrative and direct approach to equity planning by NCDOT
- Emphasize the importance of implementing explicit and defined equity tools and metrics for effective decision-making

Multimodal Focus

- Shift the focus from highway projects to better connections between all transportation modes across regions
- Advocate for the implementation of complete streets for comprehensive and inclusive planning

Community Interaction

- Promote more direct interaction with small communities to understand their needs
- Emphasize the importance of listening to people rather than relying solely on traditional engagement methods like open houses

Consistent Funding for All Modes

- Highlight the potential cost savings by encouraging alternatives to car ownership
- Advocate for consistent and significant funding for all transportation modes

Multimodal Mobility Assessment

- Propose the inclusion of multimodal mobility assessments in local development reviews
- Advocate for the establishment of a governance structure that reflects local interests

Removing Caps on State Funds

- Call for the removal of caps on state funds for bike and pedestrian projects
- Propose the removal of the state cap on matching funds
- Suggest improvements in public input processes and increased data literacy

Public Safety and Consideration of Disability

- Emphasize the importance of public safety as a continuing message
- Highlight the need to consider the needs of individuals with disabilities in transportation planning

5.2. Individual Interviews

Urban County Department of Social Services: The discussion centered on the importance of transportation connectivity, community involvement, and how these factors directly impact quality of life improvements. Increasing route connectivity can improve access and affordability, allowing residents to live and work more optimally. However, extreme travel times impose limitations, resulting in inflexibility and restrictions for residents. To achieve these goals, North Carolina counties must adopt a more regional approach, moving beyond narrow planning perspectives. Collaboration with NCDOT and communities is essential for understanding and implementing equitable solutions. Fostering cooperation between rural counties and urbanized counties like Mecklenburg County can yield mutual benefits.

Concerns were raised about recent changes in gas tax-funded transportation and the implications of diversifying funding for vulnerable populations. While a supplemental sales tax might provide the necessary funding, it must consider the burden on vulnerable populations and explore alternative solutions, such as providing access at lower costs. Extending collaboration to include the Department of Health and Human Services (DHHS) was also discussed, recognizing DHHS as a valuable partner in transportation

planning. Consulting with DHHS can reduce extreme travel times for individuals without vehicles, particularly disadvantaged and vulnerable populations, including the elderly and disabled.

Participants emphasized the distinction between equal and equitable service provision. Providing equal shares of services and investments can result in some communities not getting what they need, while others receive services from which they do not benefit.

Regional Transportation Planning Organization: The lack of clear and defined metrics to assess equity was a significant theme during this discussion. Existing models for evaluating transportation investments and project allocation, such as cost-benefit analysis, often lack an equity component and primarily use monetary indicators like travel time savings and crash reduction benefits. Some models capture disparities in data collection but do not use equity as a metric to inform or assign resources effectively.

Improvements have been made by borrowing tools from other MPOs to ensure equitable distribution and allocation of funds across environmental justice populations. Greater emphasis has been placed on community outreach to solicit input from vulnerable populations, highlighting the importance of building trust through community involvement in planning.

Funding for projects was a recurrent topic, with participants noting that 90 percent of funds are allocated to roadway projects, which may not benefit all communities. Introducing more flexibility in the funding structure to consider diverse modes of transportation appropriate to different areas and communities was suggested as a potential improvement.

Freight Expert/Researcher: A principal concern was the need for clearer metrics to assess whether equity is being achieved in transportation and infrastructure projects. Evaluating equity in the freight context requires recognizing the close interrelation between freight investments and business initiatives. Understanding the business model approach can provide insight into the disconnect in rural road access coordination, often from prioritizing investments in large commercial enterprises over local job creation. Currently, preference is given to investing in large businesses, such as Amazon, which drains wealth from within, instead of developing local industries (agriculture, lumber, and mining) that retain and generate wealth in rural communities.

Rural communities face challenges in equitably delivering perishable items due to inadequate infrastructure for heavy-weight truck transportation. Implementing equity metrics to evaluate infrastructure projects, such as bridges with weight restrictions, could address these challenges. Promoting pluralistic decision-making in infrastructure investments, particularly from local businesses, could significantly improve outcomes. Providing subsidies, allowing communities to direct decision-making, and investing in local industries and regional partnerships could enhance economic participation and integration into the broader regional economy.

Disability Transportation Service Provider: This discussion provided insights into the process and costs of providing transportation services. Coordinating services with the State DOT and a local nonprofit faces challenge such as budget constraints, lack of cost transparency, vehicle maintenance, insurance standards, and the need for collaboration with other transportation units at regional/local levels and DHHS departments.

There is a continual need to explore partnerships with several companies and negotiate with these partners to secure the best rates for transportation services. However, budget inflexibility and the condition of vehicles limit the selection of vehicles eligible for transportation. These concerns are worsened by a lack of cost transparency and uniformity on a service-to-service basis that fails to outline potential additional charges in a timely manner.

Transporting individuals with disabilities can pose challenges, primarily due to the lack of available and eligible vehicles, resulting in inefficient methods of transporting these individuals. In terms of cost, there is a differential for transporting individuals with disabilities, but it is not consistent across persons or trips and is not known beforehand. More value would be added to the service provided if additional costs were clearly outlined for accommodating people with disabilities.

Ensuring fair pricing for services requires substantial and ongoing negotiation with transportation providers. To remain in compliance with maintenance standards set by the Department of State, confirmation that transportation providers are fully insured includes requesting information on vehicle age and maintenance status. Concerning the reliability and condition of vehicles may limit the vehicles eligible for use and the number of individuals who can receive the services. Transporting individuals with disabilities requires an ADA-compliant equipped vehicle, many of which are oversized relative to the number of people that require services.

Some issues related to inefficient transportation could be alleviated by establishing a relationship with the regional/local DOTs for access to buses accommodating individuals with disabilities. Particularly, more paratransit vehicles could enhance flexibility and efficiency in transporting people with disabilities or with special conditions. In terms of equity, services must emphasize the importance of flexibility in addressing the specific needs of individuals with disabilities. Smaller vehicles that can accommodate fewer passengers are a cost-effective and efficient transportation solution that meets the needs of all groups, especially those with disabilities.

Chapter 6. Equity in Long-Range Transportation Planning Framework

Before incorporating equity in long range transportation planning, it is necessary to define (a) equity and (b) target population and comparison groups. From the survey of state DOTs and literature review, it is evident that there is a lack of consensus in defining transportation equity.

Defining Transportation Equity: As one of the pivotal contributions, this study proposes transportation equity based on three important pillars: (a) concept, (b) dimensions, and (c) equity standard. They are discussed next.

Concept: This study uses the concept of equity proposed by Litman (2002). Transportation Equity refers to the "fair distribution of transportation costs and benefits between current and future members of society." The fairness in the distribution of costs and benefits is based on certain rules called "Equity standards." Transportation costs may include user and environmental costs resulting from transportation-related policy decisions and investments. Transportation benefits refer to improvements in accessibility, mobility, and economic viability due to transportation-related policy decisions and investments.

Dimensions: Transportation equity is defined along two dimensions: (a) horizontal equity and (b) vertical equity. Horizontal equity is the distribution of transportation-related costs and benefits across groups with similar abilities and needs. Vertical equity is the distribution of transportation-related costs and benefits between sub-populations that differ in needs and ability, such as income classes, age groups, car ownerships, etc.

Equity Standards: The fair distribution of costs and benefits is based on certain rules called equity standards. These standards provide an understanding of how costs and benefits are distributed and whether the distributions can be termed as fair. Multiple standards are proposed in the literature, and in this study, "equality," "proportionality," and "Rawls-utilitarianism" are used to assess fairness in the distribution of costs and benefits.

Given that this study aims to operationalize equity in long range transportation planning, the definition of transportation equity, as proposed above, is technical.

Population Segmentation: This step focused on segmenting the population into the target population and comparison groups. It requires the use of (a) one or more variables of segmentation (e.g., income, race, ethnicity, transportation disadvantage index, etc.) and (b) a unit of segmentation (e.g., individuals, households, census blocks, TAZs, census block groups, etc.). The target population or COCs are zones or blocks identified based on the concentration of different demographic/socioeconomic indicators. The term "target population" is designed to encompass a broad and varied array of populations and communities that may be deemed disadvantaged or vulnerable, considering their existing circumstances and the potential effects of future growth. This approach involves utilizing one or multiple segmentation variables, such as income, ethnicity, gender, or other relevant factors, and selecting a suitable unit of analysis, such as individuals, households, census blocks, or travel analysis zones.

NCDOT typically uses the TDI for identifying target populations at census block group levels. If the population threshold is greater than the specified percentage for any of the factors mentioned in Table 8, then the census block group is defined as a disadvantaged group/target population. Alternatively, if the population threshold is less than the specified percentage for any of the factors mentioned in Table 8, then the census block group is defined as a comparison group.

The TDI tool allows users to identify potential transportation-disadvantaged communities or target populations and enables a comparative analysis of the needs among neighboring communities. The TDI is a tailored methodology designed to facilitate a comprehensive evaluation of equity impacts at a higher level. This tool specifically concentrates on factors such as race (Black, Indigenous, and people of color), income, personal vehicle accessibility, individuals with mobility impairments, the elderly, youth, and populations

with LEP. The primary benefit of this tool lies in its scoring system, which is relative to various geographic scales such as MPO/RPO, county, division, and statewide.

Table 8. Transportation Disadvantaged Index Factors

S. No	Factor	Population Threshold
1	Low-income	23%
2	Zero car Household	6%
3	Black, indigenous and persons of color (BIPOC)	37%
4	Age less than 15	20%
5	Age over 65	16%
6	Disability	16%
7	Limited English proficiency (LEP)	4%

To identify the most suitable variable of segmentation, correlation analysis between demographic/socioeconomic indicators and equity-based performance measures, such as travel times, built environment, accessibility to employment, proximity to transit stops, and safety, should be assessed. The demographic/socioeconomic variables that exhibit (a) a higher degree of correlation with performance measures and (b) a higher degree of correlation between the demographic/socioeconomic variables are considered as the variables of segmentation. The unit of segmentation depends on the method adopted for transportation equity analysis.

The literature summarizes two high-level approaches: (a) non-modeling approach and (b) modeling approach to transportation equity analysis. The non-modeling approach examines data at census block groups or census tract levels. However, in the modeling approach, the model estimation technique used to develop a travel demand model (TDM) plays a key role in deciding at which unit of segmentation the analysis can be conducted. The activity-based model facilitates examining results at "individual levels." Similarly, trip-based, or hybrid-based models yield results at the TAZ level. Since the study focuses on using TDM for transportation equity analysis, TAZs are considered the most appropriate unit of segmentation.

Incorporating Equity in Long Range Transportation Planning: Equity can be considered primarily in four phases of long-range transportation planning, as shown in Figure 41. (A) defining the goals and objectives, (b) creating and planning scenarios, (c) travel demand modeling, and (d) evaluating scenarios for prioritization and decision-making. Among these four steps, incorporating equity in travel demand modeling and evaluating scenarios for decision-making is crucial.

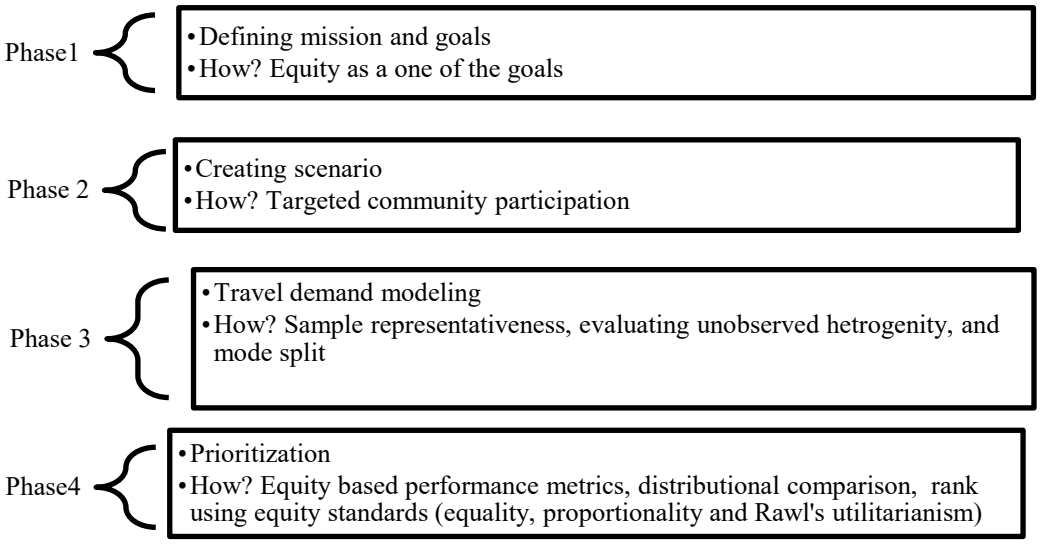


Figure 41. Equity in LRTP

6.1. Phase 1 - Equity in Defining Goals and Objectives

The formation of a scenario depends on the performing agency's identified goals and objectives. Agencies focus on developing performance metrics to reflect these goals. However, for incorporating equity, it is pivotal that the agencies consider equity as one of the goals/objectives and guiding principles to evaluate the policy impact of the different scenarios. For instance, one of the goals of the Charlotte Regional Transportation Planning Organization (CRTPO) 2045 Metropolitan Transportation Plan is to develop a framework for measuring the impacts and evaluating the trade-offs of different land-use, urban design, highway network, and transit network choices in the CRTPO planning area. However, equitable distribution of benefits, such as the distribution of costs and benefits between the target population and comparison groups, is not considered and should be considered. This has been addressed in the CRTPO 2050 Metropolitan Transportation Plan, where an equitable transportation option is one of the goals and objectives. Incorporating equity in defining the goals and objectives of an MTP serves two essential purposes. First, the objective evaluation of scenarios is fundamentally investigated from a perspective of transportation equity rather than just based on effectiveness. Second, ranking and prioritizing scenarios are based on effectiveness and equity.

6.2. Phase 2 - Equity in Creating Planning Scenarios Through Advanced and Targeted Community Participations

Creating scenarios is one of the crucial steps in the scenario planning process and is one of the major steps where equity should be considered. The future scenario is a future state of the world influenced by different driving forces (pandemic, technological innovation, demographic change, political change, and funding for transportation), which may not necessarily reflect the agency's proposed policies (Shaheen et al., 2013). Participatory discussions, such as discussions within agencies, focused groups with experts, and collective input from citizens, significantly determine the outcome of the scenario composition process. Particularly involving participants from the target population is essential for incorporating equity in composing scenarios, as it will enable discussion on how certain populations and groups benefit or are hurt by different scenarios.

6.3. Phase 3 - Incorporating Equity in Travel Demand Modeling

TDM serves as the primary transportation planning tool for measuring and forecasting the changes in travel behavior resulting from transportation investments. TDM measures the effect of transportation systems,

land-use changes, and demographic/socioeconomic, residential, and travel cost changes on travel behavior (mode, destination, and time of the day). The TDM forecasts the changes in travel behavior of the population in response to the scenarios. These scenarios reflect changes in the transportation system (e.g., highway expansion, transit extension, etc.), transportation policies (fare changes, pricing, etc.), and land-use policies. The general step-by-step framework of a regional travel demand model is illustrated in Figure 42.

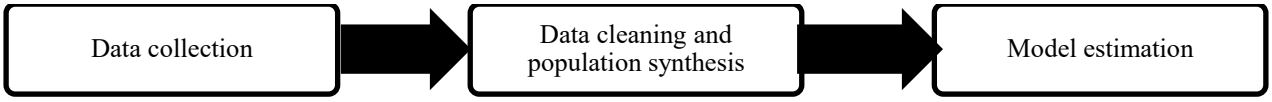


Figure 42. General Regional Travel Demand Modeling Framework

The first step begins with collecting data related to travel behavior using household travel surveys (HHTSs). The data collected at the household level using standard representative sampling strategies include household demographic/socioeconomic information and household members' reported travel activities for one day. The collected samples are then cleaned and expanded using population/household synthesis techniques. This data synthesis technique expands the sample to the population. The synthesized population is then used to develop regional TDMs. In practice, trip-based, hybrid, and activity-based approaches are used to develop regional TDMs.

Recent research argues that planning agencies have little guidance in terms of performing equity analyses using the TDM (Bills, 2022; Williams & Golub, 2017). If one carefully examines the general framework of the TDM, as illustrated in Figure 42, it can be understood that equity can be incorporated into the TDM at two stages: (a) data collection and (b) model development.

Step 1: Incorporating Equity in Data Collection for TDM: The samples collected at the household level play a significant role in developing a TDM that can accurately predict the behavior of travelers. The representativeness of samples in terms of travel and population characteristics plays a vital role in the development of TDM. The literature documents that sampling error is more likely for disadvantaged populations (Lievanos et al., 2019). However, the severity and ramifications of under-representativeness on model estimation and performance are unknown. Theoretically, it can be understood that poor representativeness (more samples from one group compared to another) would result in a biased TDM that may not accurately predict the behavior of travelers. Therefore, samples from disadvantaged populations must be collected to develop a representative TDM that can accurately predict travelers' behavior. The typical solution to include representativeness in samples is to develop a pooled dataset (a combination of standard HHTS conducted by agencies and target HHTS like special surveys covering disadvantaged populations). In addition to conducting standard HHTS, agencies should also conduct target HHTS specifically for disadvantaged populations to incorporate their behavior in developing a region-wide TDM. Methods such as target stratified sampling and a mix of survey modes (outreach, community workshops, etc.) can be used to collect travel behavior samples from disadvantaged populations. The targeted HHTS and the standard HHTS can be combined to develop a pooled sample for TDM development that can estimate travelers' realistic behavior.

If targeted HHTS cannot be collected, then generating synthetic data that statistically mirrors the desired population characteristics, including those of disadvantaged groups, and re-weighting the weighting of existing data points could be another way to ensure equity in HHTSs. For example, if a survey underrepresents a particular racial group, their responses can be given greater weight in the analysis.

Step 2: Incorporating Equity in Estimating TDM: Accurate representation of travel preferences and the model structure (unobserved heterogeneity) defined to capture the travel preferences are critical to an accurate and realistic representation of travel behavior. The question related to the accurate representation of travel preference can be addressed to a larger extent using the pooled data (data from standard HHTS

and target HHTS). This pooled data can be used to jointly estimate the preferences of the majority of travelers and disadvantaged travelers.

In addition to the travel preferences, the model structure (how unobserved heterogeneity is defined) used to predict these travel preferences is also important. For instance, the mode choice model, as illustrated in Figure 43, is a two-level nested choice model with the upper level having three classifications: auto, transit, and non-motorized, whereas there is a lower level for each choice. Choices such as drive-alone and shared-ride are nested in the auto nest.

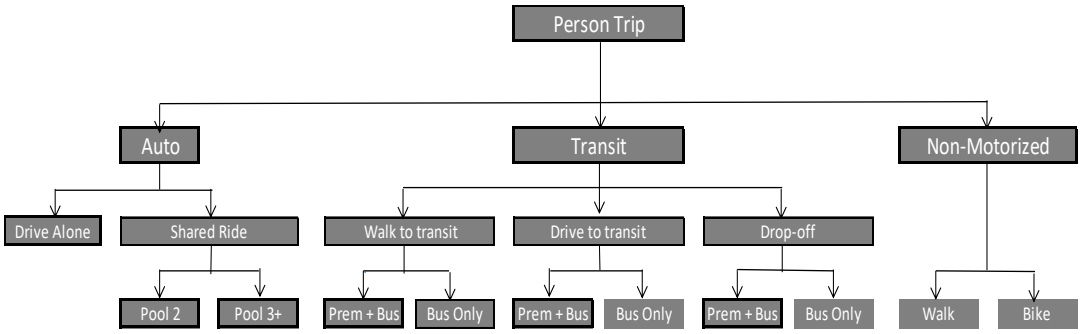


Figure 43. Nested Mode Choice Model (Illustrative Purpose)

The estimation of a discrete choice model is based on random utility theory, which states that an individual, if provided with alternatives, will assign utility to each alternative and will choose the alternative with maximum utility. For an individual *i,* the utility (*U)* of the alternative *j* is equal to the measurable utility (V_{ij}) and the random component (ε_{ij}), capturing the unobserved heterogeneity. Mathematically, it is represented as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (2)$$

The structure of the random components or the error governs the performance of the model. When considering the nested logit model, . However, if the unobserved heterogeneity between the shared ride and drive to transit is assumed to be correlated (refer to Figure 44), model performance would change significantly. Similarly, some individuals do not have access to alternatives or choices and are constrained to choose a particular mode; incorporating this constrained behavior in estimating mode choice will significantly alter the model performance and the predictions of the model.

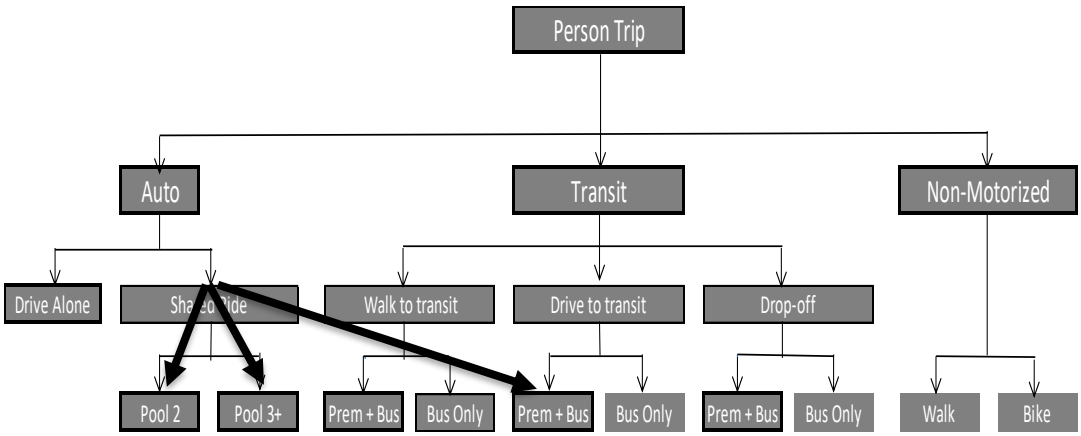


Figure 44. Correlated Nested Logit Model for Mode Choice

TDMs are developed based on different approaches: trip-based, tour-based, activity-based, or hybrid. Several mathematical or statistical models are used to predict travel behavior for any approach.

Therefore, an accurate description of the discrete choice model structure is primarily pivotal for two reasons. First, it will enable an accurate representation of travel preferences and a realistic prediction of travel behavior. Second, if the benefits of any scenario are estimated using TDM, an accurate and more realistic model structure will enable accurate estimation of costs and benefits between the target population and comparison groups. For example, *logsums* measures are most commonly used to understand the costs and benefits of transportation projects and policies (De Palma and Lindsey, 2006; Geurs et al., 2010; Bills and Walker, 2017; Dixit and Sivakumar, 2020). Logsum measures such as "logsum accessibility" and "consumer surplus" are estimated using the discrete choice model used in the TDM. Therefore, an accurate and realistic discrete choice model structure will enable (a) accurate estimation of costs and benefits and (b) realistic evaluation of scenarios from an equity perspective.

One of the potential solutions to define model structure would be to employ a hybrid modeling approach, wherein a discrete choice model can be used for modeling mode choice preferences, and a machine learning or deep learning model can be used to define the model structure by understanding the linear and non-linear correlation and effects from the data.

6.4. Phase 4 - Incorporating Equity in Project Prioritization: Scenario Analysis and Decision-Making

If providing equitable transportation is considered one of the objectives of long-range transportation planning, the objective evaluation of scenarios needs to be done from an equity perspective. This framework or methodological approach states that instead of evaluating scenarios only in terms of effectiveness or benefits at the aggregate or regional level, they should also be evaluated in terms of fairness in the distribution of costs and benefits between the target population and comparison groups based on certain equity criteria. The scenarios can then be ranked based on (a) effectiveness and (b) equity. The overall methodology for Phase II is presented in Figure 45.

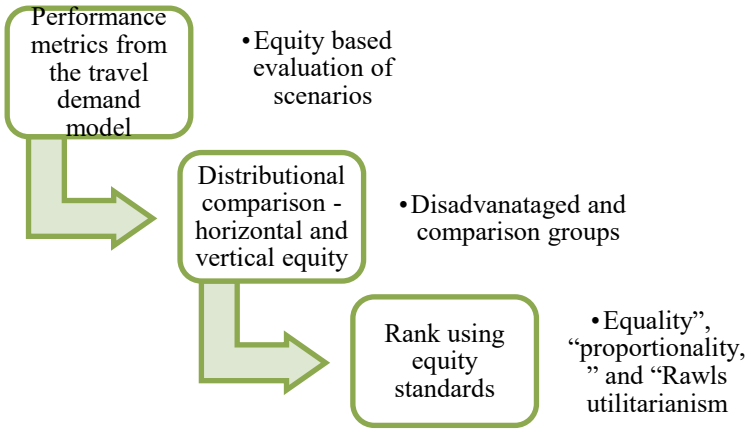


Figure 45. Methodology for Phase III

Step 1: Simulating Scenarios using the Travel Demand Model (TDM): This step involves using TDM to simulate different scenarios and project and evaluate the impacts of these scenarios from an equity perspective. The Metrolina Region TDM (MRTDM) is applied to forecast the potential impacts of implementing hypothetical scenarios as defined in the agency's long range transportation planning. A conventional framework for travel forecasting in transportation planning is followed, where an existing TDM is used to forecast the impacts of a hypothetical scenario that does not exist in reality. It is important to note that scenarios are hypothetical, and the expected behavioral response to the scenario is empirically estimated using the TDM, preserving travelers' real-world preferences and behaviors. This reflects the "best guess" as to how travelers are likely to be impacted by a hypothetical future scenario as defined in the long-range transportation planning.

Various model input data need to be adjusted to simulate a scenario. For instance, in the transit extension scenario, where the transit is added to the region that previously did not have transit, the scenario is simulated by adjusting the mode choice alternatives to represent the availability of new transit for additional links in the networks. However, in the case of MRTDM, the mode choice model assumes that everyone has access to all modes, and therefore, to simulate the transit extension scenario in MRTDM, only the transit network layer needs to be updated. The transit travel times are then computed using the highway and transit network layer data. Once the scenarios are simulated, the TDM is run to generate model outputs for the scenario. Link volumes, travel times by mode, number of tours/trips, number of tour stops, mode share, etc. are some of the model outputs that can be obtained using the TDM.

Step 2: Calculating Performance Metrics for Equity-Based Evaluation of Scenarios: There is no clear consensus in the literature on which performance metrics are appropriate for reflecting equity impacts. It is important to consider performance metrics representing the true benefits and costs of transportation. In other words, performance metrics sensitive to level-of-service changes, lane-use changes, and individual preferences are more desirable for transportation equity analysis. For instance, travel time only captures a portion of the transportation benefits due to transportation system and land-use changes (Giuliano and Agarwal, 2004). Accessibility, which captures the effect of land-use changes, transportation system changes, and individual preference changes, is one of the most desirable performance metrics for transportation equity analysis. In particular, "logsum" accessibility will be used as a performance metric. Logsums can be forecasted over time, as they are artifacts of estimated changes in travel and land-use attributes and can be easily estimated using the TDM. Similarly, walk access, percentage of non-motorized and transit trips, and average commute time by mode are other performance metrics that could be used for assessment. The performance metrics are computed for each scenario and then compared between the target population and comparison groups by scenario to conduct transportation equity analysis.

Step 3: Conduct Equity Analysis: Analyzing Horizontal and Vertical Equity and Scenario Robustness: In this step, the performance metrics between the target population and comparison groups, such as improved job access, reduced travel times, enhanced safety, and minimized negative externalities like air pollution and noise, are compared by scenarios for vertical equity analysis. For horizontal equity analysis, the performance metrics are compared by scenario over space for the target population. Instead of comparing at an average level, distributional comparisons are performed to evaluate benefits from different scenarios or mobility plans (Pan et al., 2024). Moreover, the distribution of "individual differences," i.e., differences in performance metrics between scenarios by the target population and comparison groups, is also performed for fine-grained transportation equity analysis. The distributions of the performance metrics are then assessed based on selected equity criteria of proportionality and equality to comment on the robustness of different scenarios in achieving equitable transportation.

Step 4: Ranking and Selecting Strategic Scenarios: The results of the previous step should be integrated into ranking scenarios. The scenarios are ranked based on their effectiveness and fairness in the distribution of costs and benefits. A sum-of-the-ranks method could be used to rank scenarios in ascending order. The scenario with the lowest rank could be considered as the optimal scenario.

Chapter 7. Illustrations and Data Gaps

It is recommended that equity be incorporated in various stages of the long-range planning process. Firstly, it should be considered when defining goals for the study region. Secondly, it should be considered in scenario planning and decision-making (when prioritizing implementation of projects, more as an afterthought). Thirdly, it should be considered in the modeling process (trip generation step, destination choice models, etc.). Example illustrations and data gaps are discussed next in this chapter.

7.1. Equity Goals in Long Range Transportation Planning

Agencies often establish performance metrics aligned with their primary objectives. Nevertheless, many planning agencies produce equity planning documents that are ambiguous in terms of equity criteria/goals (Martens and Golub, 2021, Loh and Kim 2020). However, to ensure equitable outcomes, it is essential to prioritize equity as a core goal alongside other goals such as improved accessibility and safety etc. By explicitly incorporating equity into the foundational framework of the long-range transportation planning process, agencies can establish a clear mandate for evaluating the distributional impacts of transportation policies on diverse communities. This proactive approach ensures that equity is not merely an afterthought but is woven into the very fabric of the planning process, guiding the development and assessment of scenarios toward a more just and equitable transportation future.

7.2. Equity in Scenario Planning - Illustration

In this scenario planning example, walk accessibility to bus stops is chosen to perform equity analysis. Data was gathered from multiple sources. Demographic/socioeconomic data was obtained from the American Community Survey (ACS) 5-year estimates (2018-2022) for 624 census block groups in Mecklenburg County, North Carolina. The ACS data was used to assess transit access for transportation disadvantaged and comparison groups. Transit supply data was gathered from the City of Charlotte data portal, providing detailed information on the spatial configuration of bus stops and routes. Additionally, job accessibility data was acquired from the Smart Location Database (SLD), which offers insights into the number of jobs accessible within a 45-minute travel time by public transit.

Variables like income and BIPOC were used to segment the population into transportation disadvantaged and comparison groups at the census block group level, with thresholds estimated based on the 25th and 75th percentiles of median income and the percentage of the BIPOC population.

Disadvantaged groups (DG) include DG1, defined as low-income individuals (earning less than 69,000 USD) living in areas with more than 81% of the BIPOC population, highlighting significant economic and racial barriers to transit access. DG2 consists of low-income individuals in areas with less than 25% non-BIPOC population, indicating economic challenges without significant racial barriers. Comparison groups (CG) include CG1, characterized by high-income individuals (earning more than 143,000 USD) in areas with less than 25% non-BIPOC, representing affluent populations with minimal racial barriers. CG2 includes high-income individuals in areas with more than 81% of the BIPOC population, suggesting affluence but potential racial barriers.

Leveraging the defined thresholds for income and BIPOC status, 86, 8, 97, and 4 census block groups fall under DG1, DG2, CG1, and CG2, respectively. This distribution highlights that low income is more commonly associated with BIPOC populations, whereas high income is found among White populations.

The spatial distribution of transportation disadvantaged and comparison groups is illustrated in Figure 46. DG1 and DG2 are located in central areas, whereas CG1 and CG2 are more scattered in central areas, extending to peripheral regions. The other groups, represented in yellow, are distributed throughout the study area.

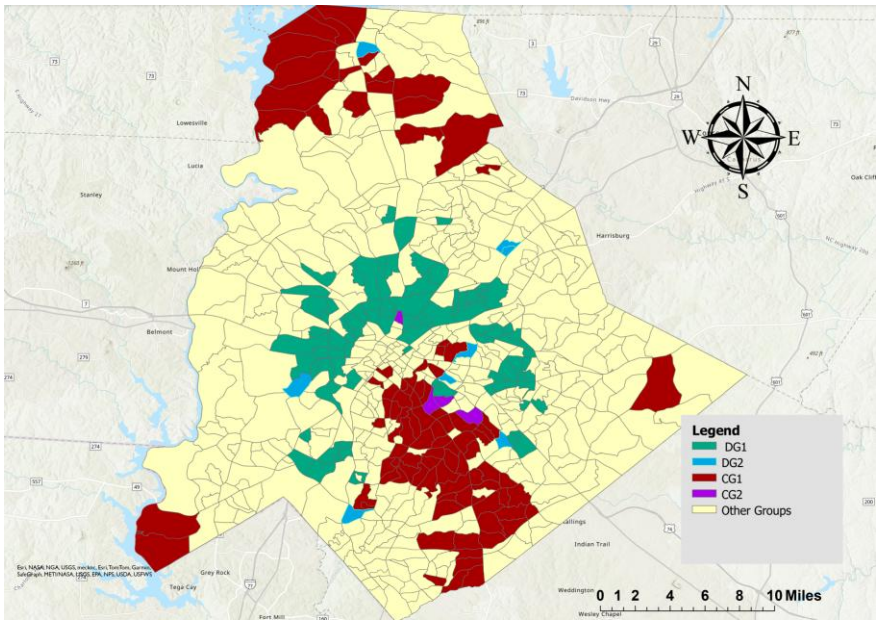


Figure 46. Spatial Distribution of Transportation Disadvantaged Groups

Computing Equity Indicator: Transit Accessibility

Two key factors, connectivity to the network and connectivity to the destinations, are used to measure transit accessibility. These factors capture the level of transit system accessibility by considering both spatial proximity to transit infrastructure and the system's ability to connect users with key destinations efficiently *(*Aman and Colin, 2020*)*. Each factor also has an associated set of indicators and is explained next.

Connectivity to the Network

Transit networks (transit stops and routes) should be easily accessible to the population as they shorten the travel time by transit and encourage individuals to use public transportation. Three different indicators were used to measure the connectivity to the network: (a) walk access to transit stops, (b) bus stop density, and (c) route coverage.

Walk Access to Transit Stops: This measure quantifies the geographical coverage of transit services within walking distance of residents. The walk accessible area within a given census block group is estimated by using Equation (1).

$$W_{CBGi} = \frac{\sum_{n=1}^{n} AT_n}{A_{CBGi}} \quad (1)$$

where W_{CBGi} represents a measure of walk accessible area, CBG_i denotes the ith census block group, A_{CBGi} is the total area of the ith census block group, AT is the accessible area by walk to transit for the census, n is the number of bus stops in ith census block group.

The walk accessible area is a key indicator of how well a transit system is integrated with its surrounding urban fabric. A higher percentage suggests that more people can easily walk to transit stops, which leads to higher transit ridership and supports more sustainable urban development patterns.

To estimate the accessible area by walking to transit, a GIS-based approach using ArcGIS Pro's Network Analyst was explored to delineate service area polygons around transit stops, representing areas accessible within a 0.5-mile walking distance. The "Generate Service Areas" tool calculated the accessible areas around each transit stop, producing service area polygons that delineate zones within a 0.5-mile walking distance. These polygons visually and quantitatively represent pedestrian accessibility to transit stops, providing a basis for assessing public transportation services' reach. High-precision street network

data ensures an accurate depiction of pedestrian routes, which is crucial for capturing the nuances of urban walkability, including street connectivity and pedestrian infrastructure.

Bus Stop Density: Bus stop density is a metric used to assess the availability and distribution of public transit access points within a specific area. It provides insight into the spatial distribution and concentration of bus stops relative to the size of the census block. A higher density suggests more abundant transit options and potentially better accessibility for residents, while a lower density may indicate areas where transit access could be improved. Bus stop density can be estimated using Equation 2.

$$BD_{CBGi} = \frac{n}{A_{CBGi}} \quad (2)$$

where BD_{CBGi}represents the bus stop density for ith census block group, n is the total number of bus stops within the given census block group, and A_{CBGi} is the total area of the ith census block group.

Route Coverage: Route coverage is a metric used to evaluate the extent and reach of transit routes throughout a region. This metric provides insight into how comprehensively the bus routes serve the street network of a given census block group. It determines the proportion of the street network that is accessible via public transit, highlighting the areas that are well-served by transit routes and those that may be underserved. Route coverage is estimated using Equation 3.

$$R_{CBG_i} = \frac{\sum L_j}{\sum S_{iCBG}} \quad (3)$$

where R_{CBG_i} represents the measure of route coverage for the ith census block group, L denotes the total length of jth bus route j within ith census block group, and S_{iCBG} indicates the total length of the entire street network in the census ith census block group.

Connectivity to Destinations

Effective transit systems must enable users to reach their desired destinations. The number of jobs accessible within 45 minutes of travel time by transit was used to measure the connectivity to the destination. This indicator assesses the effectiveness of the transit system in connecting residents to employment opportunities. The SLD was leveraged to compute the connectivity to the destination in terms of jobs accessible within 45 minutes of travel time by transit. The SLD utilizes General Transit Feed Specification (GTFS) data from transit agencies, including transit stop locations, routes, and schedules. It models transit travel times by incorporating walking times to and from transit stops, waiting times, and in-vehicle travel times. The analysis identifies all job locations reachable within the specified travel time from the centroid of each CBG. Finally, the total number of accessible jobs within this travel time threshold is aggregated for each block group, providing a clear measure of job accessibility that can inform urban planning and policy decisions aimed at improving transit accessibility and promoting equitable access to employment opportunities.

Composite Transit Accessibility Index (CTAI)

The composite transit accessibility (CTAI) score is introduced here for a comprehensive evaluation of transit accessibility. This index provides a holistic assessment of how well a transit system serves different areas and populations. CTAI effectively integrates all four indicators and can be estimated using Equation (4).

$$CTAI_{CBGi} = w1 * W_{CBGi} + w2 * BD_{CBGi} + w3 * R_{CBG_i} + w4 * JA_{CBGi} \quad (4)$$

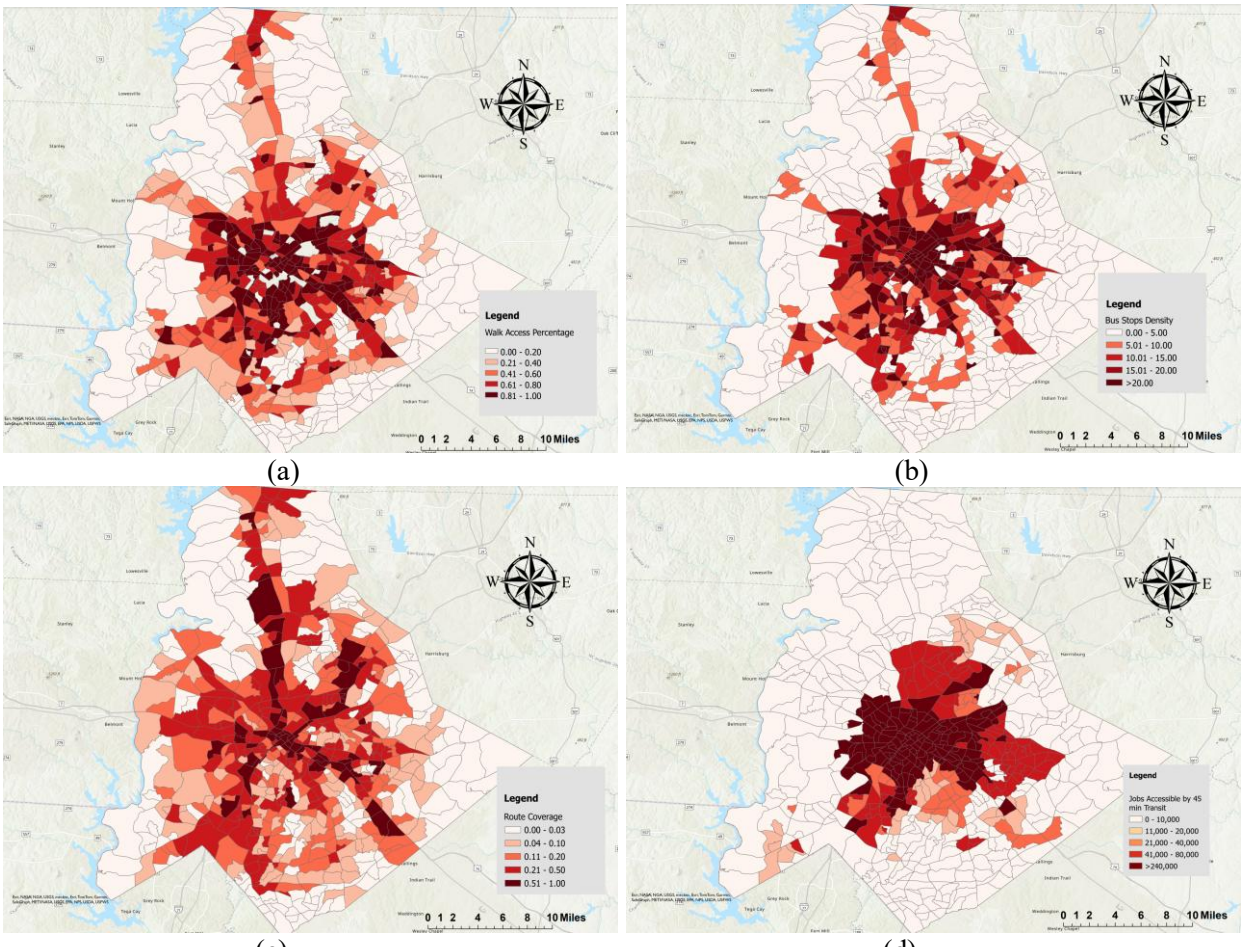
The weights for each indicator are computed based on the inverse coefficient of variation technique. This method assigns higher weights to indicators with lower variability and vice versa, ensuring that more consistent indicators have a greater influence on the CTAI. The coefficient of variation (CV) is calculated for each indicator, and the inverse of CV is used to determine the weights. This is expressed mathematically as

$$w_i = \frac{1/CV_i}{\sum_{j^{i=1}}^{n}(1/CV_j)} \quad (5)$$

where W_i is the weight for indicator i, CV is the coefficient of variation for that indicator, and n is the total number of indicators.

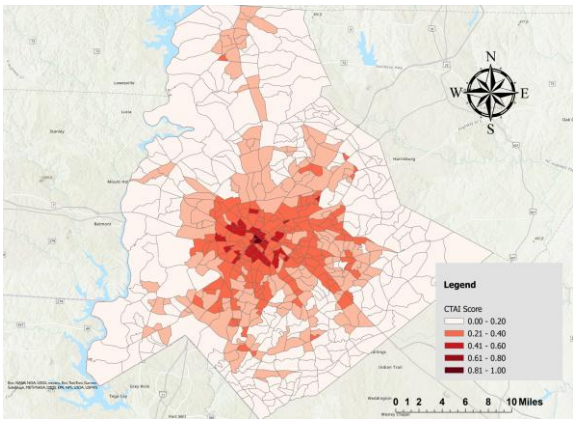
For computing CTAI, each indicator was rescaled and normalized between 0 to 1 to ensure comparability. The rescaled indicators were then used to estimate weights and CTAI. The CTAI offers a robust framework for evaluating transit accessibility, capturing multiple dimensions of access and service quality. By considering proximity, frequency, coverage, and job accessibility, the CTAI provides a nuanced understanding of how well the transit system serves different populations. Higher CTAI values indicate better overall accessibility, while lower CTAI values highlight areas that require improvements in transit services. This comprehensive measure can inform urban planning, transportation policy, and infrastructure investment decisions aimed at enhancing transit accessibility and promoting equitable access to essential services and opportunities.

As an example, Figure 47 presents the spatial distribution of walk access to transit stops, bus stop density, route coverage, connectivity to the destination, and CTAI.



(a) (b)

(c) (d)



(e)

Figure 47. Spatial Distribution of (a) Walk Access to Transit Stations, (b) Bus Stop Density, (c) Route Coverage, (d) Connectivity to the Destination, and (e) CTAI

Figure 47 reveals that all indicators of transit accessibility—walk access, bus stop density, route coverage, and job accessibility are highest in the central areas of Charlotte. This results in higher CTAI scores, reflecting superior transit service quality and access. Downtown areas (central part of Charlotte) typically have higher population and employment densities, which justifies a greater concentration of bus stops to serve more people within a smaller area (Figure 47). Downtown Charlotte contains many important destinations, such as offices, government buildings, entertainment venues, and shopping centers, which attract more transit riders. Higher land values and parking costs in downtown areas make public transit more attractive, supporting frequent service and stops. In contrast, peripheral areas have lower scores across all transit accessibility indicators. These regions exhibit less walk access, lower bus stop density, limited route coverage, and fewer accessible jobs within a 45-minute transit commute. Consequently, these areas have lower CTAI scores, indicating poorer overall transit accessibility.

The spatial distribution of transit accessibility indicators (Figure 47) correlates closely with the distribution of transportation disadvantaged (DG1 and DG2) and comparison groups (CG1 and CG2) (refer to Figure 46). Transportation disadvantaged groups, primarily located in central areas, benefit from higher walk access, bus stop density, route coverage, and job accessibility, resulting in higher CTAI scores. This central concentration ensures that DG1 and DG2 have better access to transit services, reflecting a more equitable distribution of transit resources. Conversely, comparison groups (CG1 and CG2) are more dispersed and often found in peripheral areas. These regions exhibit lower scores across all transit accessibility indicators, indicating that despite their economic advantages, these groups have less access to comprehensive transit services due to their residential locations. This spatial analysis highlights the inequity of transit accessibility, favoring central, disadvantaged groups and emphasizing the need for targeted improvements in peripheral areas to ensure equitable transit access for all population segments.

Distributional Comparison: Assessing Both Horizontal and Vertical Equity

The distributional comparison involves plotting the distribution of the CTAI for different groups. This visual approach allows for simultaneous analysis of horizontal and vertical equity. Examining the spread and central tendencies of CTAI levels across different groups makes it possible to identify disparities and assess whether transit services are equitably distributed *(Bills, 2024)*.

In the context of a distributional comparison, horizontal equity is assessed by comparing the distributions of CTAI for DG1 and DG2 and CG1 and CG2. The standard deviation or variability in CTAI for each group reflects the extent of horizontal inequity, where a high variability indicates more inequity. For vertical equity, the distribution of CTAI (mean and standard deviation) is compared between DG and CG based on equality and proportionality.

- In a distributional comparison, equality in vertical equity is assessed by examining whether transportation disadvantaged groups (DG1 and DG2) have the same level of access (ratio of mean and standard deviation of CTAI) to transit services as comparison groups (CG1 and CG2).
- In a distributional comparison, proportionality in vertical equity is measured as the ratio of the mean and standard deviation of CTAI for transportation disadvantaged groups (DG1 and DG2) and comparison groups (CG1 and CG2) to the average and standard deviation of CTAI for the full population. This approach assesses whether the level of transit access provided to disadvantaged and comparison groups is proportionate to the overall access levels in the population, ensuring that those with greater needs receive a commensurate share of resources.

As an example, Figure 48 illustrates the variation in CTAI for different groups. The distribution of CTAI for low-income whites (DG2) shows a moderate median CTAI that is widespread, indicating considerable differences in transit access within this group. This variability suggests that while some DG2 individuals have good access to transit, others experience much poorer access, reflecting significant horizontal inequity. In contrast, low-income non-Whites (DG1) exhibit a higher median CTAI than DG2 and show less variability. The narrower interquartile range suggests more consistent transit access within the group, indicating better horizontal equity. However, the presence of outliers indicates that some groups still face poor transit access, although these are exceptions rather than the norm. High-income whites (CG1) have a lower median CTAI with significant variability, indicating lower and highly inconsistent transit access within this group, which leads to substantial horizontal inequity. High-income non-Whites (CG2), on the other hand, show a slightly higher median CTAI than high-income Whites with less variability, suggesting higher and uniform transit access and better horizontal equity compared to CG1.

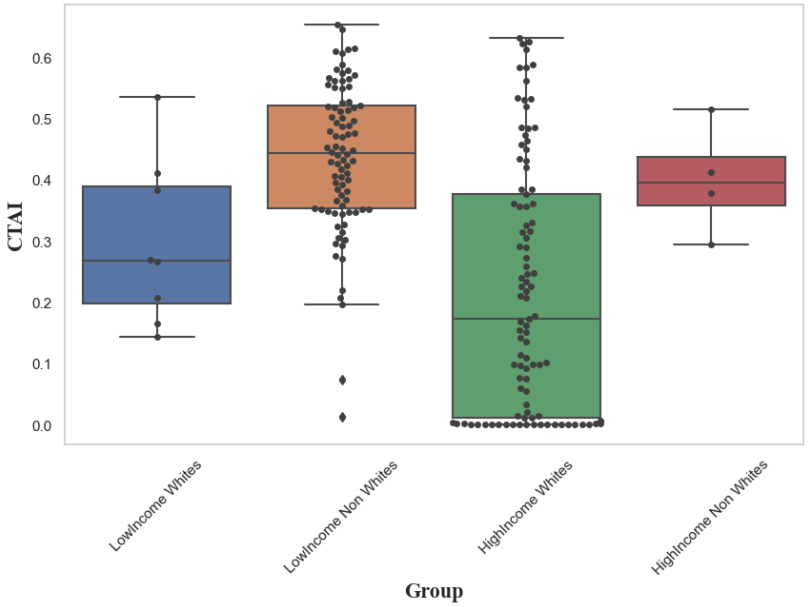


Figure 48. Variation in CTAI among Different Groups

Likewise, Table 9 summarizes the equality and proportionality results.

Table 9. Equality and Proportionality Results

Group	Mean	SD	Group	Mean	SD
Equality			Proportionality		
DG1/CG1	2	0.6	DG1/Total	1.63	0.57
DG1/CG2	1.13	1.71	DG2/Total	1.07	0.62
DG2/CG1	1.32	0.65	CG1/Total	0.81	0.95
DG2/CG1	0.74	1.86	CG2/Total	1.44	0.33

Equality (Vertical Equity): DG1 has a higher median CTAI and a more concentrated distribution than CG1. The mean CTAI ratio of 2.00 and the standard deviation ratio of 0.60 indicate better and more consistent access to transit services for DG1. In contrast, CG1 exhibits a lower median CTAI and significant variability, suggesting that these groups have inconsistent and poorer transit access. DG1 has a higher median CTAI than CG2, with a mean ratio of 1.13 and a standard deviation ratio of 1.71. This implies that while DG1 enjoys good transit access, CG2 has a narrower and higher CTAI range, reflecting particularly good and uniform transit access. The box plot (Figure 48) shows that CG2 experiences high accessibility with less variability, highlighting an advantage in consistent transit access for high-income non-Whites. DG2 shows a higher median CTAI with more variability than CG1, with a mean ratio of 1.32 and a standard deviation ratio of 0.65. This suggests that despite being a transportation-disadvantaged group, DG2 has better transit access than CG1, though with greater inconsistency in access. DG2 has a lower median CTAI and greater variability than CG2, with a mean ratio of 0.74 and a much higher standard deviation ratio of 1.86. The box plot (Figure 48) indicates that CG2 enjoys superior and more consistent transit access, highlighting significant vertical inequity where economic and racial factors influence accessibility.

Proportionality (Horizontal Equity): DG1 shows a mean ratio of 1.63 and a standard deviation ratio of 0.57, indicating significantly better and more consistent transit access than the overall population. This suggests that low-income non-Whites have relatively equitable transit access. DG2 has a mean ratio of 1.07 and a standard deviation ratio of 0.62, indicating slightly better and more consistent transit access than the overall population. However, the variability suggests some inconsistencies in access within this group. CG1 shows a mean ratio of 0.81 and a higher standard deviation ratio of 0.95, indicating poorer and more inconsistent transit access than the overall population, highlighting horizontal inequity among high-income Whites. CG2 has a mean ratio of 1.44 and a standard deviation ratio of 0.33, indicating significantly better and more consistent transit access than the overall population, reflecting the high and uniform transit accessibility experienced by high-income non-Whites.

In summary, the vertical equity analysis revealed that transportation disadvantaged groups, particularly DG1, enjoy better transit accessibility than CG1, reflecting relative equity. However, the significant advantage in transit access experienced by CG2 over DG2 highlights the disparities influenced by economic and racial factors. The proportionality analysis further confirms that DG1 and CG2 have better and more consistent transit access than the overall population. In contrast, CG1 faces more challenges in transit accessibility.

7.3. Incorporating Equity in the Modeling Process

Traditional trip generation models rely on aggregated demographic/socioeconomic data (for example, household size or car ownership). However, this can mask significant differences in travel behavior across different demographic/socioeconomic groups. This is because trip production rates often differ based on income, access to employment, access to transportation, and other demographic/socioeconomic factors. For instance, low-income households may generate fewer trips overall because of limited access to transportation options. Disaggregating data based on factors such as ethnicity, income, age, disability, and geographic location, thus, allows for a more nuanced understanding of an individual's trip-making behavior.

Land use characteristics play a significant role in trip generation, as they are associated with the availability of jobs, services, and amenities. Transportation disadvantaged populations may live in areas with fewer employment opportunities, healthcare, or educational facilities, which limits their trip generation potential. Agencies could use granular land use characteristics data (say, at parcel level) that reflects the disparities in access to services and amenities across different neighborhoods. This allows trip generation models to capture how inequities in land use planning (for example, fewer commercial and service centers in low-income areas) affect an individual's trip-making behavior.

Correlations between demographic/socioeconomic variables or land use characteristics and redundancy are another crucial factor that should be taken into consideration. To illustrate this effect, age less than 15, the percent of low-income population, age over 65, zero-car households, BIPOC, disability,

and LEP used in the TDI tool at census block group level for North Carolina were analyzed. Table 10 summarizes the Pearson correlation coefficients obtained from the analysis.

A strong positive correlation (greater than 0.5) was observed between low income and BIPOC, as well as between low income and zero-car households. Likewise, a significant correlation was observed between BIPOC and LEP. To minimize multicollinearity and redundancy, low income, age less than 15, age over 65, and disability could be considered when identifying transportation disadvantaged populations and incorporating their needs in the long-range transportation planning process.

Table 10. Correlation Analysis – Example

Variables	Age <15	Low Income	Age >65	BIPOC	Zero Car Households	Disability	LEP
Age <15	1.000						
Low Income	0.231	1.000					
Age >65	-0.120	-0.179	1.000				
BIPOC	0.268	0.614	-0.272	1.000			
Zero Car Households	0.026	0.501	0.073	0.372	1.000		
Disability	0.029	0.270	0.346	0.214	0.374	1.000	
LEP	0.284	0.448	-0.201	0.504	0.202	0.017	1.000

Attempts were made to conduct preliminary tests using TransCAD and available non-MPO models data for Carteret County and Jackson County to develop trip generation models and account for variations in trip production and attraction rates among transportation disadvantaged populations. While some issues were resolved with support from NCDOT, others, such as requiring TransCAD version 5.0 to run and generate output for the Jackson County non-MPO model, could not be resolved. In particular, the lack of survey data to examine variations in trip production and attraction rates among transportation-disadvantaged populations was a major limitation. This emphasizes the need for collecting detailed statistically large samples of data from individuals for modeling purposes.

7.4. Data Gaps for Modeling

Different datasets are available for modeling but with limitations when non-MPOs are taken into consideration. In general, data could be aggregated, analyzed, and modeled at census tract, census block group, census block, or TAZ levels. However, the sample size may be small if data are considered at census tract or census block group levels for examining relationships and incorporating equity in long range transportation planning. The size (in terms of area) of a census tract or census block group may also limit accurately capturing the role of equity and incorporating it in long range transportation planning (destination choice, mode, etc.). To illustrate this limitation, Table 11 summarizes the number of census tracts, census block groups, census blocks, and TAZs in Carteret County and Jackson County.

Table 11. Number of Units

County	# of Census Tracts	# of Census Block Groups	# of Census Blocks	# of TAZs
Carteret	39	72	2,881	279
Jackson	9	26	1,660	277

Data available in aggregated datasets for modeling is another factor that needs to be considered. Table 12 summarizes demographic/socioeconomic variables in census tracts, census block groups, and census blocks related datasets. Variables in bold were considered as equity-related or transportation disadvantage-related variables in the past by practitioners and researchers. As can be seen from the table, fewer details are available for analysis and modeling when explored at a census block level. Any benefits from a large sample size are offset by the lack of details in this dataset.

Table 13 summarizes demographic/socioeconomic variables in regional and non-MPO datasets for Metrolina region, Carteret County, and Jackson County. Variables in bold were considered as equity-related

or transportation disadvantage-related variables in the past by practitioners and researchers. Many variables were available for the Metrolina region dataset, but only a few variables are available in Carteret County and Jackson County datasets. They are not particularly adequate for incorporating equity into long range transportation planning. This emphasizes the need for collecting detailed demographic/socioeconomic details. The data should meet minimum sample size requirements for various transportation disadvantaged populations (by applying a stratified sampling technique or similar) while also accounting for spatial distribution (spatial segmentation units).

Table 12. Demographic/Socioeconomic Variables in Census Datasets

Variable	Census Tract	Census Block Group	Census Block
Auto-ownership	X		
Income	X	X	
Disability	X		
Age <15	X	X	X
Age >65	X	X	X
BIPOC	X	X	X
Limited English proficiency (LEP)	X		
Means of transportation to work	X	X	
School enrollment	X	X	
Employment status	X	X	
Household size	X	X	X
Travel time to work		X	
Total population	X	X	
Time of departure to go to work		X	
Households by type	X	X	
Housing units	X	X	
Occupancy status	X	X	
Family type	X	X	

Table 13. Demographic/Socioeconomic Variables in Planning Model Datasets

Variable	Metrolina	Carteret	Jackson
Population		X	X
# of households		X	X
Household size	X		
# of students	X	X	X
Age	X		
Gender	X		
# of license drivers	X		
Race/ethnicity	X		
Hispanic	X		
# of students			
# of vehicles		X	X
# of vehicles per household		X	X
# of commercial vehicles	X		
Drive commercial vehicle	X		
# employed	X	X	X
Income	X		
Service		X	X
Office		X	X
Highway retail		X	X
Retail		X	X
Industry	X	X	X
Occupation	X		
Employer TAZ	X		
Employer city	X		
Employer state	X		
Employer zip	X		

Full- or part-time	X		
Self-employed	X		
More than one job	X		
Regularly work at tome	X		
Work at home today	X		
If pay to park at work - how much	X		
Start place	X		
End place	X		
Type of home	X		
Beach acre		X	X
Military-base			X
Other		X	X

Synthetic Data and Modeling

In addition to the smaller sample size, detailed datasets are not available for non-MPOs or smaller regions. Resource limitations further limit agencies from collecting large samples of data. However, more granular data helps explore and develop disaggregate models. One solution to address this problem is to create synthetic datasets. The process involves generating a complete set of demographic/socioeconomic variables data, preferably at an individual level, for a given modeling region. This concept is often applied in a tour-based model. It should be noted that the details should be designed to reflect the distribution of important variables in the study area, ensuring they align with observed aggregate marginal distributions.

The tour-based model seems more appropriate for incorporating equity into long range transportation planning. The model aims to estimate the likelihood of an individual making 0, 1, 2, or more round-trip tours by purpose and mode on a typical weekday. A multinomial logit model is often employed, where utility is influenced by the individual's characteristics, the attributes of the home zone, and the number of tours for specific purposes. Unlike traditional trip generation models, attractions are not estimated during this stage. Instead, destination choice models and production models are used at the individual level. This approach incorporates detailed data about each individual, along with their demographic/socioeconomic characteristics and geographic location, to make predictions. Considering the penetration of micromobility and microtransit as travel modes in the future, the process could also be expanded by taking the mode of travel into consideration.

Chapter 8. Conclusions

Incorporating equity into the transportation planning process is vital. Literature documents a range of equity definitions and indicators. It is different and means something different in different places. Intersectionality between equity factors, effects of transportation policies and projects on communities, travel behavior data, assessing the effectiveness of interventions and approaches in addition to a widely accepted equity definition, indicator and modeling framework will assist practitioners in North Carolina with better incorporating equity and accomplishing the goals and objectives.

In the current context, equity is means accessibility and mobility to transportation for all residents of North Carolina. Improving access to non-motorized modes, considering low-income, elderly and disabled people, would help address the gap in accessibility and mobility limitations. Funding priorities, plans, and long-range transportation planning goals should be oriented to develop an equitable, healthy and affordable regional transportation network. Promoting sustainable and walkable communities with effective transit options, as well as bikeways that connect communities is the key. This should be complemented with coordination between regional/local agencies and DOT field offices to fully understand how tools are being utilized and if data needs to be updated based on community responses to the data.

The study emphasizes the need for an equitable design of transportation network. The findings from the focus group meetings recommend the allocation of adequate funds to multimodal options and active transportation, potentially benefiting the transportation disadvantaged populations. State and regional/local agencies need to have near/short-term smaller active transportation and microtransit options to get people to work, school, play, and healthcare instead of or while waiting 10 to 20 years for implementing large-scale transportation projects.

The existing equity tools do not account for rural area and urban core low-income pockets. Their needs are watered down typically in census block group data, emphasizing the need to conduct grass roots data collection for analysis and modeling as well as for outreach.

8.1. Implementation Plan

State and regional/local agencies should:

- consider equity in all stages of the transportation planning process - when defining goals/objectives, in scenario planning, and when prioritizing implementation of projects and in the modeling process.
- explore GIS-based tools are appropriate to assess the needs and select projects based on their potential impact.
- collect geographically-distributed detailed data (household/individual surveys) in each study area for analysis and modeling; and,
- explore tour-based models taking trip generations and destination choices into consideration for each study area (including non-MPOs and RPOs).

References

Allahviranloo, M., and W. Recker. Daily Activity Pattern Recognition by Using Support Vector Machines with Multiple Classes. Transportation Research Part B: Methodological, 2013, 58, 16-43.

Altshuler, A. Equity, Pricing, and Surface Transportation Politics. Urban Affairs Review, 2010, https://onlinepubs.trb.org/onlinepubs/sr/sr303Altshuler.pdf.

Aman, J. J. C. and J. Smith-Colin. Transit Deserts: Equity Analysis of Public Transit Accessibility. Journal of Transport Geography, 2020. 89:102869. https://doi.org/10.1016/j.jtrangeo.2020.102869

Atlanta Regional Commission (ARC). The ARC Transportation Improvement Program (TIP) Project Evaluation Framework, 2016, https://documents.atlantaregional.com/transportation/projsolicitation/2017/project_eval_documentation.pdf.

Atlanta Regional Commission (ARC). The Atlanta Region's Plan. 2018, https://cdn.atlantaregional.org/wp-content/uploads/arc-equity-methodology-june2019.pdf.

Baltimore Regional Transportation Board. Maximize 2040: A Performance-based Transportation Plan for a Greater Baltimore Region. 2016, https://baltometro.org/sites/default/files/bmc_documents/general/transportation/longrange/2040/maximize2040.pdf.

Beiler, M., and M. Mohammed. Exploring Transportation Equity: Development and Application of a Transportation Justice Framework. Transportation Research Part D: Transport and Environment, 2016, 47, 285-298. DOI: 10.1016/j.trd.2016.06.007.

Bills, T. Advancing the Practice of Regional Transportation Equity Analysis: A San Francisco Bay Area Case Study. Transportation, 2022. https://doi.org/10.1007/s11116-022-10355-z.

Bills, T. S., and J. L. Walker. Looking Beyond the Mean for Equity Analysis: Examining Distributional Impacts of Transportation Improvements. Transport Policy, 2017, 54, 61-69. https://doi.org/10.1016/j.tranpol.2016.08.003.

Biran, B. N., N. Sharaby, and Y. Shiftan. Equity Aspects in Transportation Projects: Case Study of Transit Fare Change in Haifa. International Journal of Sustainable Transportation, 2014, 8(1), 69-83, DOI: 10.1080/15568318.2012.758525.

Boucher, D., and P. J. Kelly. Social Justice: From Hume to Walzer. Routledge: Psychology Press, 1998.

Brody, S. D., S. Zahran, A. Vedlitz, and H. Grover. Examining the Relationship Between Physical Vulnerability and Public Perceptions of Global Climate Change in the United States. Environment and Behavior, 2008, 40(1), 72-95.

Bullard, R. D., G. S. Johnson, and A. O. Torres. Highway Robbery: Transportation Racism & New Routes to Equity. South End Press, 2004.

Bureau of Labor Statistics. The Economics Daily, Consumer Spending on Public Transportation Rebounded in 2021 After Large Decline in 2020. U. S. Department of Labor, 2022, https://www.bls.gov/opub/ted/2022/consumer-spending-on-public-transportation-rebounded-in-2021-after-large-decline-in-2020.htm.

Caldwell, D. Equity Indicators. 2022, https://www.letstalkhouston.org/equity?tool=brainstormer#tool_tab.

Cantarella, G. E, and S. de Luca. Multilayer Feedforward Networks for Transportation Mode Choice Analysis: An Analysis and a Comparison with Random Utility Models. Transportation Research Part C: Emerging Technologies, 2005, 13(2), 121-55.

Cantilina, K., S. R. Daly, M. P. Reed, and R. C. Hampshire. Approaches and Barriers to Addressing Equity in Transportation: Experiences of Transportation Practitioners. Transportation Research Record, 2021, 2675(10), 972–985. https://doi.org/10.1177/03611981211014533.

Cao, X., P. Mokhtarian and S. Handy. Neighborhood Design and the Accessibility of the Elderly: An Empirical Analysis in Northern California. International Journal of Sustainable Transportation, 2010, 4(6), 347-371. DOI: 10.1080/15568310903145212.

Carleton, P. R., and J. D. Porter. A Comparative Analysis of the Challenges in Measuring Transit Equity: Definitions, Interpretations, and Limitations. Journal of Transport Geography, 2018, 72, 64-75. https://doi.org/10.1016/j.jtrangeo.2018.08.012.

Castiglione, J., M. Bradley, and J. Gliebe. Activity-Based Travel Demand Models: A Primer, SHRP 2 Report S2-C46-RR-1, 2015.

Castiglione, J., R. Hiatt, T. Chang, and B. Charlton. Application of Travel Demand Microsimulation Model for Equity Analysis. Transportation Research Record, 2006, 1977(1), 35–42.

Chudyk, A. M., M. Winters, M. D. Moniruzzaman, M. C. Ashe, J. S. Gould, and H. McKay. Destinations Matter: The Association Between Where Older Adults Live and Their Travel Behavior. Journal of Transport & Health, 2015, 2(1), 50-57. https://doi.org/10.1016/j.jth.2014.09.008.

City of Dallas. Connect Dallas Strategic Mobility Plan. Final Report, 2021, https://dallascityhall.com/departments/transportation/Documents/DSMP_FinalReport_041921.pdf.

Cui, Z., and G. Gong. The Effect of Machine Learning Regression Algorithms and Sample Size on Individualized Behavioral Prediction with Functional Connectivity Features. Neuroimage, 2018, 178, 622-37.

Cutler, D. M., E. L. Glaeser, and J. L. Vigdor. When are Ghettos Bad? Lessons from Immigrant Segregation in the United States. Journal of Urban Economics, 2008, 63(3), 759-74.

De Palma, A., and R. Lindsey. Modelling and evaluation of road pricing in Paris. Transport Policy, 2006, 13 (2), 115–126.

Delavega, E., J. Meiman, C. C. Malone, M. Hirschi, A. L. Hunter, and S. L. Neely-Barnes. The Two Pandemics: the Disparate Impact of the COVID-19 Pandemic and the K-Shaped Recovery. Journal of Policy Practice & Research, 2022, 3(1), 36–51. DOI: 10.1007/s42972-022-00048-3. Epub 2022. PMCID: PMC8880298.

Delaware Valley Regional Planning Commission. Connections 2050 LRTP, 2021, https://www.dvrpc.org/reports/21027.pdf.

Di Ciommo, F., and Y. Shiftan. Transport Equity Analysis. Transport Reviews, 2017, 139-151.

District Department of Transportation (DDOT). Equity Statement. 2021, https://ddot.dc.gov/node/1520176.

Dixit, M., and A. Sivakumar. Capturing the impact of individual characteristics on transport accessibility and equity analysis. Transportation Research Part D: Transport and Environment, 2020, 87, 102473.

Dobbs, L. Wedded to the Car: Women, Employment and the Importance of Private Transport. Transport Policy, 2005, 12(30), 266-278. https://doi.org/10.1016/j.tranpol.2005.02.004.

Duvarci, Y., and T. Yigitcanlar. Integrated Modeling Approach for the Transportation Disadvantaged. Journal of Urban Planning and Development, 2007, 133(3), 188-200.

El-Geneidy, A., D. Levinson, E. Diab, G. Boisjoly, D. Verbich, and C. Loong. The Cost of Equity: Assessing Transit Accessibility and Social Disparity Using Total Travel Cost. Transportation Research Part A: Policy and Practice, 2016, 91, 302-316. https://doi.org/10.1016/j.tra.2016.07.003.

Emond, C. R., W. Tang, and S. L. Handy. Explaining Gender Difference in Bicycling Behavior. Transportation Research Record. 2009, 2125(1), 16-25. https://doi.org/10.3141/2125-03.

Ezike, R., P. Tation, and G. Velasco. Defining “Communities of Concern” in Transportation Planning. The Urban Institute, Washington DC, 2020, https://www.urban.org/sites/default/files/publication/102746/defining-communities-of-concern-in-transportation-planning_1.pdf.

Fan, Y., and A. Huang. How Affordable is Transportation? A Context-Sensitive Framework. Humphrey School of Public Affairs, University of Minnesota, 2011, https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.226.3142&rep=rep1&type=pdf.

Federal Highway Administration (FHWA). Environmental Justice. 2012, https://www.environment.fhwa.dot.gov/env_topics/environmental_justice.aspx.

Geurs, K. T., W. Boon, and B. Van Wee. Social Impacts of Transport: Literature Review and the State of the Practice of Transport Appraisal in the Netherlands and the United Kingdom. Transport Reviews, 2009, 29(1), 69-90.

Geurs, K., and B. Van Wee. Accessibility Evaluation of Land-Use and Transport Strategies: Review and Research Directions. Journal of Transport Geography, 2004, 12, 127-140. DOI: 10.1016/j.jtrangeo.2003.10.005.

Geurs, K., B. Zondag, G. De Jong, and M. de Bok. Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings. Transportation Research Part D: Transport and Environment, 2010, 15 (7), 382–393.

Gibb, J. K., L. Z. DuBois, S. Williams, L. McKerracher, R. P. Juster, and J. Fields. Sexual and Gender Minority Health Vulnerabilities During the COVID-19 Health Crisis. American Journal of Human Biology, 2020, 32(5), e23499.

Giuliano, G., and A. Agarwal. Land use impacts of transportation investments. *The Geography of Urban Transportation*, 2004, *3*, 237-273.

Grengs, J., J. Levine, and Q. Shen. Evaluating Transportation Equity: An Intermetropolitan Comparison of Regional Accessibility and Urban Form. U. S. Federal Transit Administration, Office of Civil Rights, 2013.

Guo, Y., Z. Chen, A. Stuart, X. Li, and Y. Zhang. A Systematic Overview of Transportation Equity in terms of Accessibility, Traffic Emissions, and Safety Outcomes: From Conventional to Emerging Technologies. Transportation Research Interdisciplinary Perspectives, 2020, 4, 100091. https://doi.org/10.1016/j.trip.2020.100091.

Guthrie, A., F. Burga, and Y. Fan. Collaboration in Mitigating Spatial and Skills Mismatch. Journal of Transport and Land Use, 2018, 11(1), 1081-100. http://dx.doi.org/10.5198/jtlu.2018.985.

Hu, L. Changing Effects of Job Accessibility on Employment and Commute: A Case Study of Los Angeles. The Professional Geographer. 2014, 67, 141217122811001. DOI: 10.1080/00330124.2014.886920.

Iroz-Elardo, N., J. Schoner, E. H. Fox, A. Brookes, and L. D. Frank. Active Travel and Social Justice: Addressing Disparities and Promoting Health Equity Through a Novel Approach to Regional Transportation Planning. Social Science & Medicine, 2020, 261, 113211.

Johnston, R. A., C. J. Rodier, J. E. Abraham, J. D. Hunt, and G. J. Tonkin. Applying an Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region. MTI Report 01-03, Mineta Transportation Institute Publications, 2001.

Jones, P., and S. Wixey. Measuring Accessibility as Experienced by Different Socially Disadvantaged Groups. Project Summary Report to the EPSRC, 2005.

Kane, M., J. Oloka-Onyango, and A. Tejan-Cole. Reassessing Customary Law Systems as a Vehicle for Providing Equitable Access to Justice for the Poor. In Arusha Conference "New Frontiers of Social Policy", 2005, 12-15.

Kaplan, S., D. Popoks, C. G. Prato, and A. A. Ceder. Using Connectivity for Measuring Equity in Transit Provision. Journal of Transport Geography, 2014, 37, 82-92.

Karner, A., and D. Niemeier. Civil Rights Guidance and Equity Analysis Methods for Regional Transportation Plans: A Critical Review of Literature and Practice. Journal of Transport Geography, 2013, 33, 126–34.

Karner, A., J. London, D. Rowangould, and K. Manaugh. From Transportation Equity to Transportation Justice: Within, Through, and Beyond the State. Journal of Planning Literature, 2020, 35(4), 440-59.

Kocak, T. K, S. Gurram, R. L. Bertini, and A. L. Stuart. Impacts of a Metropolitan-Scale Freeway Expansion Program on Air Pollution and Equity. Journal of Transport & Health, 2021.

Lane, L. B., S. A Bert, and A. Heller. Defining North Carolina's Transportation Disadvantaged Populations. Report No. NCDOT/NC/2012-0731), North Carolina Dept. of Transportation, 2014.

Litman, D., S. Young, M. Gales, K. Knill, K. Ottewell, R. van Dalen, and D. Vandyke. Towards Using Conversations with Spoken Dialogue Systems in the Automated Assessment of Non-Native Speakers of English. Proceedings of the 17th Annual Meeting of the Special Interest Group on Discourse and Dialogue, Association for Computational Linguistics, 2016, 270-275.

Litman, T. Evaluating transportation equity. *World Transport Policy & Practice*, 2002, *8*(2), 50-65.

Litman, T. Evaluating Transportation Equity: Guidance for Incorporating Distributional Impacts in Transportation Planning. Victoria Transport Policy Institute, Victoria, BC: 2023. https://www.vtpi.org/equity.pdf.

Liévanos RS, Lubitow A, McGee JA. Misrecognition in a Sustainability Capital: Race, Representation, and Transportation Survey Response Rates in the Portland Metropolitan Area. *Sustainability*. 2019; 11(16):4336. https://doi.org/10.3390/su11164336.

Loh, C. G. and Kim, R. 'Are We Planning for Equity? Equity Goals and Recommendations in Local Comprehensive Plans', Journal of the American Planning Association, 87(2), 2020, pp. 181–196. DOI: 10.1080/01944363.2020.1829498.

Madison Area Transportation Planning Board (MATPB) 2035 RTP. 2012, http://www.madisonareampo.org/planning/documents/RTPFINAL_Web.pdf.

Madison Area Transportation Planning Board (MATPB). 2023-2027 Transportation Improvement Program. 2022, https://www.greatermadisonmpo.org/planning/documents/TIPFinal23.pdf.

Manaugh, K., M. G. Badami, and A. M. El-Geneidy. Integrating Social Equity into Urban Transportation Planning: A Critical Evaluation of Equity Objectives and Measures in Transportation Plans in North America. Transport Policy, 2015, 37, 167-176. https://doi.org/10.1016/j.tranpol.2014.09.013.

Marshall, W., and N. Ferenchak. Assessing Equity and Urban/Rural Road Safety Disparities in the US. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 2017, 10, 1-20. DOI: 10.1080/17549175.2017.1310748.

Martens, K., and F. Di Ciommo. Travel Time Savings, Accessibility Gains and Equity Effects in Cost–Benefit Analysis. Transport Reviews, 2017, 37(2), 152-169.

Martens, K. and Golub, A. A Fair Distribution of Accessibility: Interpreting Civil Rights Regulations for Regional Transportation Plans. Journal of Planning Education and Research, 41(4), 2021, pp. 425-444.

Maurici, R., M. Joana, and M. Jaume. Improving Bus Service Levels and Social Equity Through Bus Frequency Modelling. Journal of Transport Geography, 2017, 58, 220-233. https://doi.org/10.1016/j.jtrangeo.2016.12.005.

Memphis Metropolitan Planning Organization (MPO). 2040 Regional Transportation Plan 2040. 2016, https://memphismpo.org/sites/default/files/documents/resources/trends/performance-measures/livability-2040-all-chapters.pdf.

Metropolitan Area Planning Agency (MAPA). 2050 Travel Demand Model. 2018, http://mapacog.org/wp-content/uploads/2015/10/MAPA_2040MTP-as-amended-8-31- 2017.pdf.

Metropolitan Council. Thrive MSP 2040. 2014, https://metrocouncil.org/Planning/Thrive-2040/Thrive-MSP-2040-Plan.aspx.

Metropolitan Transportation Commission (MTC). 2017 TIP Investment Analysis. 2016, https://mtc.ca.gov/sites/default/files/Final_2017_TIP_Investment_Analysis.pdf.

Metropolitan Transportation Commission (MTC). California Transportation Plan 2050. 2021b, https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/ctp-2050-v3-a11y.pdf.

Mid America Regional Council (MARC). Outlook 2040, LRTP Citizen-Friendly Best Practices. 2020, https://www.browardmpo.org/images/WhatWeDo/LRTP/Packet-2040LRTP-SteeringCommittee-No10.pdf.

Mid-America Regional Council (MARC). Transportation Improvement Program 2020–2024. 2015, https://www.marc.org/sites/default/files/2022-05/TIP_2020-2024.pdf

Mid-Ohio Regional Planning Commission (MORPC). 2020- 2050 Columbus Area Metropolitan Transportation Plan. 2016, https://www.morpc.org/wordpress/wp-content/uploads/2022/11/Cover_TOC.pdf.

Minnesota DOT. Statewide Multimodal Transportation Plan, 2022, https://edocspublic.dot.state.mn.us/edocs_public/DMResultSet/download?docId=27025399.

Nashville Area Metropolitan Planning Organization (MPO). Middle Tennessee Connected Regional Transportation Plan. 2016, https://online.flippingbook.com/view/1030522283/2/.

North Central Texas Council of Governments (NCTCOG). Mobility 2040. 2016, https://www.nctcog.org/getmedia/e3995727-95f9-46c0-8205-9c9c276e3584/M2040-ES.pdf.
Ohio Department of Transportation (DOT). Access Ohio 2045. 2020, https://www.transportation.ohio.gov/wps/wcm/connect/gov/369f5c73-12f1-4d24-8b88-fc66717a268e/AO45_OhiosTransportationPlan_8.5x11_LowRes_12012020.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_K9I401S01H7F40QBNJU3SO1F56-369f5c73-12f1-4d24-8b88-fc66717a268e-nsvU8Nn.
Oregon Metro Council. 2018 Regional Transportation Plan. 2018, https://www.oregonmetro.gov/sites/default/fles/2020/07/29/Adopted-2018-RTP-allchapters.pdf.
Owen, A., and D. Levinson. Modeling the Commute Mode Share of Transit Using Continuous Accessibility to Jobs. Transportation Research Part A: Policy and Practice, 2015, 74. DOI: 10.1016/j.tra.2015.02.002.
Pereira, R. H. M. and A. Karner. Transportation Equity. In R. Vickerman (Ed.), International Encyclopedia of Transportation, 1st Edition, Elsevier, 2021.
Presidential Documents. Executive Order 12898 of February 11, 1994, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. Federal Register, 1994, 59(32), https://www.archives.gov/files/federal-register/executive-orders/pdf/12898.pdf.
Presidential Documents. Executive Order 13985 of January 20, 2021, Advancing Racial Equity and Support for Underserved Communities Through the Federal Government. Federal Register, 2021, 86(14), https://www.govinfo.gov/content/pkg/FR-2021-01-25/pdf/2021-01753.pdf.
Puckett, T. S. Maryland Special Education Due Process Decisions: A Closer Look at the Issues and Outcomes. 2016, https://www.ideals.illinois.edu/items/93264.
Pyrialakou V. D, K. Gkritza, and J. D. Fricker. Accessibility, Mobility, and Realized Travel Behavior: Assessing Transport Disadvantage from a Policy Perspective. Journal of Transport Geography, 2016, 51, 252-269. https://doi.org/10.1016/j.jtrangeo.2016.02.001.
Ricciardi, J. A. M, C. Xia, and G. Currie., Exploring Public Transport Equity Between Separate Disadvantaged Cohorts: A Case Study in Perth, Australia. Journal of Transport Geography, 2015, 43, 111-122. https://doi.org/10.1016/j.jtrangeo.2015.01.011.
Rodier, C. J., R. A. Johnston, and J. E. Abraham. Heuristic Policy Analysis of Regional Land Use, Transit, and Travel Pricing Scenarios Using Two Urban Models. Transportation Research Part D: Transportation Environment, 2002, 7(4), 243– 254.
Rogalsky, J. The Working Poor and What GIS Reveals About the Possibilities of Public Transit. Journal of Transport Geography, 18, 2010, 226-237. DOI: 10.1016/j.jtrangeo.2009.06.008.
Sanchez, T. W, and J. F. Wolf. Environmental Justice and Transportation Equity: A Review of Metropolitan Planning Organizations. Cambridge, MA: The Civil Rights Project at Harvard University, 2005.
Schaeffer, K. 1 in 10 Americans rarely or never drive a car. 2024, Pew Research Center. https://www.pewresearch.org/short-reads/2024/11/14/1-in-10-americans-rarely-or-never-drive-a-car/.
Seattle DOT. Transportation Equity Framework. 2022, https://www.seattle.gov/documents/Departments/SDOT/TransportationEquity/TransportationEquity_Framework_Report_41422.pdf.
Shaheen, S., M. Camel, and K. Lee. Exploring the future of integrated transportation systems in the United States from 2030 to 2050: Application of a scenario planning tool. UC Berkeley: Transportation Sustainability Research Center, 2013. https://escholarship.org/uc/item/8qg3p02f
Shamsher, R., and M. N. Abdullah. Traffic Congestion in Bangladesh- Causes and Solutions: A Study of Chittagong Metropolitan City. Asian Business Review, 2013, 2(1), 13-8.
Shiftan, Y., and J. Suhrbier. The Analysis of Travel and Emission Impacts of Travel Demand Management Strategies Using Activity-based Models. Transportation, 2002, 29, 145–168. https://doi.org/10.1023/A:1014267003243.
Shih, P., C. C. Huang, CS. C. Pan, T. L. Chiang, and Y. L. Guo. Hyperactivity Disorder in Children Related to Traffic-based Air Pollution During Pregnancy. Environmental Research. 2020, 188, 109588.

Southern California Association of Governments (SCAG). Connect So Cal. 2016, https://www.fhbp.org/PDFs/Resources/Resources/Regional/SCAG-Proposed-Final-ConnectSoCal-2020.pdf.

Spielman, S. E., and J.-C. Thill. Social Area Analysis, Data Mining, and GIS. Computers, Environment and Urban Systems, 2008, 32(2), 110-22.

State of North Carolina, Executive Order No. 292 Advancing Environmental Justice for North Carolina, October 24, 2023, https://governor.nc.gov/executive-order-no-292/open.

USDOT Federal Highway Administration (FHWA), and Federal Transit Administration (FTA), Transportation Planning Capacity Building Program. The Transportation Planning Process Briefing Book: Key Issues for Transportation Decision-makers, Officials, and Staff., 2019, https://www.fhwa.dot.gov/planning/publications/briefing_book/fhwahep18015.pdf.

Van Wee, G. P., and K. Geurs. Discussing Equity and Social Exclusion in Accessibility Evaluations. European Journal of Transport and Infrastructure Research, 2011, 11(4). https://doi.org/10.18757/ejtir.2011.11.4.2940.

Van Zandt, S., W. G. Peacock, D. W. Henry, H. Grover, W. E. Highfield, and S. D. Brody. Mapping Social Vulnerability to Enhance Housing and Neighborhood Resilience. Housing Policy Debate, 2012, 22(1), 29-55.

Vanessa, C., P. Manual, and M. Wander. An Agenda for Equity: A Framework for Building a Just Transportation System in Los Angeles County. 2013, https://dornsife.usc.edu/assets/sites/242/docs/Executive_Summary_Agenda_for_Equity_PERE_A.pdf.

Wang, S., J. Cao, and P. Yu. Deep Learning for Spatio-Temporal Data Mining: A Survey. IEEE Transactions on Knowledge and Data Engineering, 2020.

Williams, H. C. W. L. On the Formation of Travel Demand Models and Economic Evaluation Measures of User Benefit. Environment and Planning A: Economy and Space, 1977, 9(3), 285–344. https://doi.org/10.1068/a090285.

Williams, L. MassDOT Resources to Address Equity. 2021, https://onlinepubs.trb.org/onlinepubs/excomm/21-07-Williams.pdf.

Wu, Y., D. Rowangould, J. K. London, and A. Karner. Modeling Health Equity in Active Transportation Planning. Transportation Research Part D: Transport and Environment, 2019, 67(2019), 528-540. https://doi.org/10.1016/j.trd.2019.01.011.

Xu, M., J. Wu, L. Huang, R. Zhou, T. Wang, and D. Hu. Network-wide Traffic Signal Control based on the Discovery of Critical Nodes and Deep Reinforcement Learning. Journal of Intelligent Transportation Systems, 2020, 24(1), 1-0.

Xu, W., Y. Li, and H. Wang. Transit Accessibility for Commuters Considering the Demand Elasticities of Distance and Transfer. Journal of Transport Geography, 2016, 56(C), 138-156.