RESEARCH & DEVELOPMENT

RP 2019-16: Assessing Measures of Transportation Disadvantage for Public Transportation Project Prioritization

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16. Abstract

The Strategic Transportation Investment Act (STI) was passed by the NC Legislature in 2013, which "*allows the NC Department of Transportation to use its funding more efficiently and effectively to enhance North Carolina's infrastructure while supporting economic growth, job creation and a higher quality of life*" by allocating "*available revenues based on data-driven scoring and local input*" (NCDOT, 2018). The need for a metric that can represent the needs of transportation disadvantaged populations in transportation project funding was identified by the Prioritization 5.0 Workgroup. Transportation disadvantage is defined as barriers/conditions that make it difficult or impossible for individuals to access transportation services necessary to participate in essential activities outside of the home (including employment, health, education, shopping, etc.). Socially disadvantaged populations (i.e. transportation disadvantaged populations) face greater barriers to access to public transportation, which is necessary to participate in activities for daily living; for example, low-income populations, as well as individuals with a disability, may have difficulty accessing transportation. To identify potential metrics for use in the prioritization process, a literature review and content analysis was completed, as well as peer organization document analyses and interviews. As transportation disadvantage is multi-faceted in nature, the research team has set forth seven potential metrics that can best represent transportation disadvantage; the metrics are not mutually exclusive, and it is recommended to use several of the metrics for best representation of transportation disadvantage. It is recommended for the following metrics to be compiled into a single Transportation Disadvantage Rubric: (1) mapping transportation disadvantaged populations, (2) determining the level of access to points-of-interest, (3) transportation service provision in the context of an equity analysis, (4) existing transportation services and infrastructure, (5) improved connectivity/multimodality, and (6) alleviation of specific barriers to access (i.e. project barriers). Strategies for metric implementation are also discussed.

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Executive Summary

The Strategic Transportation Investment Act (STI) was passed by the NC Legislature in 2013, which "*allows the NC Department of Transportation to use its funding more efficiently and effectively to enhance North Carolina's infrastructure while supporting economic growth, job creation and a higher quality of life*" by allocating "*available revenues based on data-driven scoring and local input*" (NCDOT, 2018). During the Prioritization 5.0 funding cycle, the P5.0 Workgroup identified the need for a metric to represent the needs of transportation disadvantaged populations in future determinations of transportation project funding. As such, the purpose of this study is to identify metrics that represent transportation disadvantage and to use them to properly disburse public transportation funds within North Carolina. Transportation disadvantage can be defined as barriers/conditions that make it difficult or impossible for individuals to access transportation services necessary to participate in essential activities outside of the home (including employment, health, education, shopping, etc.). Socially disadvantaged populations face greater barriers to access to public transportation, which is necessary to participate in activities for daily living; for example, low-income populations, as well as individuals with a disability, may have difficulty accessing transportation. Currently, there is a lack of research on metrics representing transportation disadvantage for the purpose of integration into transportation funding decisions, and few states have an official system in which they consider the needs of disadvantaged populations in a quantitative manner. To identify potential metrics for use in the P6 prioritization process, a literature review and content analysis was completed, as well as peer organization document analyses and interviews. As transportation disadvantage is multi-faceted in nature, the research team has set forth seven promising metrics that can best represent transportation disadvantage; the metrics are not mutually exclusive, and it is recommended to use several of the metrics for best representation of transportation disadvantage. It is recommended for the following metrics to be combined into a single rubric/score sheet representing transportation disadvantage: (1) transportation disadvantaged populations, (2) access to points-of-interest, (3) transportation service provision, (4) need for service, (5) improved connectivity/multimodality, and (6) the alleviation of project-specific barriers to access. Strategies for implementation are also discussed.

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Background

Introduction

The Strategic Transportation Investment Act (STI) was passed by the NC Legislature in 2013 in order to facilitate the prioritization of transportation funding through the use of data-driven metrics and local input. The underlying formulas of the STI are reviewed every two years. During the Prioritization 5.0 process, a concern was raised by the Public Transportation/Transit committee that the current approach, which emphasizes the number of trips, fails to take into account which populations are utilizing the services as well as the value of the trips. In particular, a need was identified to find a way to integrate and quantify the needs of transportation disadvantaged populations when making transportation funding decisions. As such, this research examines both the academic literature and best practices from peer states, with special attention on states that prioritize their funding in a quantitative manner. The purpose of this study is to identify potential metrics that can be used within the existing STI law to represent transportation disadvantage, based on barriers to transportation and/or likelihood to be transportation disadvantaged based on belonging to particular socio-demographic groups, as reflected in the literature. The significance of this research is in its potential for implementation of a metric or combination of metrics identified during the course of the research during the P6 Prioritization Process disbursement of public transportation funds within North Carolina.

The ITRE research team worked closely with NCDOT stakeholders, including the SPOT Office, the NCDOT Research Committee, and the P5 and P6 Workgroup members during development of the research design, materials and analysis. The research team ensured consistent, regular, effective communication between stakeholders to anticipate any conflicts that could arise during the different potential approaches to the problem the research seeks to address (i.e. the need to identify metric(s) that represent the needs of transportation-disadvantaged individuals in state transportation project funding decisions).

Based on the information from the literature review, it has become apparent that the proposed research is timely. There have been few studies completed on calibrating a metric for transportation disadvantage, particularly in regards to project prioritization, and few states consider equity impacts of transportation funding decisions, although this is an area of emerging interest. Out of the studies that have discussed transportation disadvantage, most of them have focused on mapping out locations of transportation disadvantaged populations, but often not related to specific transportation projects. In contrast, the focus of the current study is to aid implementation of a metric used to signify transportation disadvantage that can be directly used by NCDOT. Metrics identified during the current study are developed for recommendation to be incorporated into North Carolina's STI Act for transportation project prioritization. This research represents a significant step towards developing a way to systematically represent the level of need associated with particular projects, particularly in terms of how disadvantaged populations are effected, which is consistent with transit agency goals as well as federal law outlining protections for vulnerable populations under Title VI of the Civil Rights Act of 1964.

Definitions

There are two main ways to address transportation equity concerns. One approach is to identify *transportation disadvantaged populations*, which are demographic groups more likely to experience difficulty accessing transportation. This approach is the most common one in the literature, in part due to demographic data being easily available from the US Census. The second approach is to focus on transportation and activity system barriers (i.e. *transportation disadvantage*), including the distance and time it takes to utilize existing infrastructure, affordability, etc. Transportation system barriers are related to the characteristics of the transportation system, including availability of service, frequency, level of service, and cost. Activity system barriers are related to land use characteristics, such as the location of employment centers, characteristics of rural areas, and housing affordability.

Much of the existing research does not explicitly state separate definitions of transportation disadvantage or transportation disadvantaged populations. Rather, the two distinct ideas are lumped together in their exploration of transportation disadvantage. Because the approaches to identifying and resolving the situation may be quite different, we make the distinction between transportation disadvantage and transportation disadvantaged populations for clarity. To define these terms, the 40 most relevant references analyzed during the literature review were systematically reviewed to find which barriers to accessing transportation networks were most often utilized by other researchers, as well as which populations are most often identified as transportation disadvantaged (a full list of these references is found in Appendix D).

Transportation Disadvantage

Transportation disadvantage refers to barriers/conditions that make it difficult or impossible for individuals to access transportation services necessary to participate in essential activities outside of the home (including employment, health care, education, shopping, etc.). The most commonly cited barriers to accessing transportation services/infrastructure are depicted in Table 1. Following the table, each barrier will be described in detail.

Table 1. *Barriers to accessing transportation infrastructure/services (i.e. "transportation disadvantage") as reflected in the 40 most relevant sources.*

Rank	Barrier	No. of Sources Citing	Percentage
1	Lack of adequate transportation facilities	24	60%
2	Rurality	20	50%
3	Mobility	19	48%
4	Accessibility	19	48%
5	Lack of equity	11	28%
6	Carless	8	20%
7	Affordability	6	15%
8	Time barriers	4	10%
9	Physical and/or psychological barriers	3	8%
10	Language barriers	2	5%
11	Lack of safety/inclusion	2	5%
12	Other/uncategorized	3	8%

For consistency, each definition has a similar format, as follows:

> **Term (number of mentions).** Definition (citation). Further description, explanation and examples. List measures used to represent this category in the literature.

Lack of adequate transportation facilities (24 mentions). The lack of transportation facilities and/or connectivity between different modes is the most common barrier associated with transportation disadvantage. This also includes studies that mentioned multimodal infrastructure specifically as it relates to system connectivity. Not only is it beneficial for multimodal infrastructure to be in place, but there must be sufficient connectivity between modes to meet community transportation needs.

Rurality (20 mentions). Living in a rural area, and the transportation challenges associated with it, was the second most commonly mentioned barrier associated with transportation disadvantage. In *Defining Rural at the US Census Bureau,* Ratcliffe et al. (2016) states that rural is:

> "*what is not urban—that is, after defining individual urban areas, rural is what is left… To define an area as urban, the Census Bureau uses criteria including total population thresholds, density, land use, and distance… In order for a block to qualify as urban, it must have a density of 1,000 people per square mile (ppsm)... Rural is defined as all population, housing, and territory not included within an urbanized area or urban cluster*" (p. 1-3).

While urban areas and urban clusters represent only about 3% of the land area in the US, 80.7% of the population is located within urban areas, as opposed to 19.3% of the population who reside in rural areas, as of the 2010 Census (Ratcliffe et al., 2016). North Carolina has a higher percentage of rural populations than the country as a whole, at 28.0% (US Census Bureau, 2018).

Mobility (19 mentions). Mobility was mentioned by 12 sources in the context of transportation disadvantage, sometimes without clear definitions. Litman (2011) described mobility as "*the movement of people or goods. It assumes that "travel" means person- or ton-miles, "trip" means person- or freight-vehicle trip. It assumes that any increase in travel mileage or speed benefits society… From this perspective, transport users are mainly motorists, since most person- and ton-miles are by motor vehicle, but recognizes that some people rely on non-automobile modes, and some areas have large numbers of transit, rideshare and cycling trips… "Mobility" refers to the movement of people and goods. This recognizes both automobile and transit modes, but still assumes that movement is an end in itself, rather than a means to an end. It tends to give little consideration to non-motorized modes or land use factors affecting accessibility*" (p. 4). Example measures of mobility include person-miles, door-to-door traffic time, ton-miles, frequency of route schedule, and whether public transportation infrastructure is wheelchair-accessible, among others.

Accessibility (19 mentions). Accessibility was mentioned in 19 out of the 40 references that focused on transportation disadvantage. Accessibility is defined as the ease with which an individual can reach public transportation services and/or points-of-interest through existing transportation infrastructure and/or services in terms of either a specific type of transportation mode, or multimodal transportation facilities (Barkley & Gomes-Pereira, 2015; Chandra et al., 2017; Lin et al., 2014; Zuo et al., 2018). Litman (2018) expands on this definition, explaining that accessibility includes *"the time and money that people and businesses must devote to transportation*" (Litman, 2018). Points-of-interest include destinations that need to be accessed in order to maintain an individual's quality of life, such as hospitals, schools, day care centers, places of employment, grocery stores, etc. Example measures of accessibility consist of access to points-of-interest, as well as access to transportation services/infrastructure (e.g. distance to bus stops).

Lack of equity (11 mentions). "*Equity (also called justice and fairness) refers to the distribution of impacts (benefits and costs) and whether that distribution is considered fair and appropriate*" (Litman, 2018). Examples of how to determine the level of equity include benefits, costs, and quality of social and economic opportunities; essentially any measure can be compared between transportation disadvantaged and non-transportation-disadvantaged groups (e.g. comparing distance to bus stops between high- and low-income groups).

Carless (8 mentions). Along with lacking a car, this category can also include individuals who cannot drive for some reason or whose licenses are revoked (temporarily or permanently). In North Carolina, there 693 out of 1,000 residents were licensed drivers in 2009. Nationally, 685 out of every 1,000 residents were licensed drivers, which is approximately 87% of the driving-age population, as of 2009 (FHWA, 2011). Additionally, the carless population includes people who choose not to drive, as this group is also reliant on public transportation.

Affordability (6 mentions). The lack of money or other resources necessary to access transportation infrastructure and services can serve as a barrier to access for disadvantaged populations. Refer to low-income and poverty-stricken populations in the "transportation disadvantaged populations" section as a proxy for the prevalence of this barrier. Affordability can be determined via an assessment of transportation costs, as related to low-income and homeless populations.

Time barriers (4 mentions). Travelers may be unable to access some forms of public transportation due to time barriers such as route schedules, frequency of buses, time-of-day issues, or the time it takes to travel to points-of-interest and between stops (if transferring). An example of this is night shift workers who are reliant on transit to get to and from their places of employment despite limited nighttime transit services. One way to calculate this is to determine the distance/time from transportation disadvantaged population neighborhoods to public transportation stops.

Physical and/or psychological barriers (3 mentions). Physical and psychological barriers relate to cognitive and/or cognitive disabilities/limitations that impede access to existing transportation infrastructure and services. Physical barriers can include a lack of ramps for physical disability access or audio instructions for blind travelers. Refer to the three disability categories (general/unspecified, physical, and psychological) in the *transportation disadvantaged populations* section to estimate the prevalence of these types of barriers. The lack of understandability of a public transportation route, for example, could be a barrier for someone even if they do not have a disability.

Language barriers (2 mentions). Individuals whose first language is not English may have a difficult time utilizing public transportation due to a difficulty with reading/comprehending route schedules or completing payment information. This category also includes individuals who are deaf and/or utilize sign language for communication. Based on the 2010 ACS (based on self-reported data of individuals 5 years and older), the estimated percentage of individuals who speak English less than "very well" in the US is around 8.6%, and in NC it is estimated to be around 4.7% (United States Census Bureau, 2016). To reduce language barriers, signs that include braille and Spanish/other translations could be posted.

Lack of safety/inclusion (2 mentions). A lack of safety or inclusion can be a barrier to transportation access. For example, women and children may need to take extra precautions while traveling alone due to safety reasons. If a public transportation stop is located in a high-crime area, there may be a fear of using a particular bus stop. Additionally, if public transportation infrastructure is located in an area with high crime and/or racial tensions, individuals of specific racial/ethnic groups may feel less safe, which could then prevent them from utilizing such services. Another example is if there is a lack of sidewalks connecting someone in a wheelchair between his/her home and a transportation stop, he/she may not feel safe enough to get to the nearest public transportation station/stop, even if the actual station is disabled-friendly. One way to measure this is to assess the crime rates surrounding bus stops, and steps could be taken to ensure rider safety between the bus stops and their home/destination.

Other/uncategorized responses (3 mentions). Uncategorized responses, only mentioned once each, include the limited capacity of existing transportation systems (Pareekh et al., 2017), employment opportunities that are spread out in part due to urban sprawl (Zhao & Gustafson, 2013), and caregiving responsibilities (Lane, 2013).

Transportation Disadvantaged Populations

Transportation equity concerns are prevalent among particular populations, and much of the existing research has relied upon demographic data as a way of identifying transportation disadvantaged populations. Table 2 depicts the socio-demographic groups that have been included in prior research as *transportation disadvantaged populations*. Following the table, each demographic group will be expanded upon in greater depth.

Table 2. *Socio-demographic groups included in the 40 most relevant sources as "transportation disadvantaged populations."*

Rank	Demographic Group Included	No. of Sources Citing	Percentage
1	Low-income	32	80%
2	Elderly	19	48%
3	Minorities	15	38%
4	Disabled - General	13	33%
5	Adolescents/Youth	11	28%
6	Carless	11	28%
7	Disabled - Physical	9	23%
8	Women	8	20%
9	Limited English Proficient (LEP)	7	18%
10	Age - General	6	15%
11	Disabled - Cognitive	6	15%
12	Foreign-born	3	8%
13	Rural	2	5%
14	Other/uncategorized	12	30%

For consistency, each definition has a similar format, as follows:

> **Term 1 (number of mentions).** Definition (citation). Further description, explanation and examples. List measures used to represent this category in the literature.

Low-income populations (32 mentions). In North Carolina, the poverty rate was 18% at the peak of the recession in 2012, and has fallen to 14.7% in 2017. In 2017, the average median income in North Carolina was $52,752, which is lower than the overall average for the United States in the same year. Low-income populations are defined as 200% of the federal poverty threshold (US Department of Health & Human Services, 2018), while poverty-stricken populations equal the federal poverty threshold, which is configured based on family size. For reference, poverty guidelines by household size as published in 2018 by the US Department of Health & Human Services, a federal authority on the topic, are displayed in Table 3.

Table 3. *National poverty thresholds for 2018 by size of family and number of related children under 18 years old, in US 2017$.*

Size of family unit	Related children under 18 years								
	None	One	Two	Three	Four	Five	Six	Seven	Eight or more
One person (unrelated individual):									
Under age 65	13,064								
Aged 65 and older	12,043								
Two people:									
Householder under age 65	16,815	17,308							
Householder aged 65 and older	15,178	17,242							
Three people	19,642	20,212	20,231						
Four people	25,900	26,324	25,465	25,554					
Five people	31,234	31,689	30,718	29,967	29,509				
Six people	35,925	36,068	35,324	34,612	33,553	32,925			
Seven people	41,336	41,594	40,705	40,085	38,929	37,581	36,102		
Eight people	46,231	46,640	45,800	45,064	44,021	42,696	41,317	40,967	
Nine people or more	55,613	55,883	55,140	54,516	53,491	52,082	50,807	50,491	48,546

Source: U.S. Census Bureau.

Low-income and poverty-stricken populations may include individuals who are unemployed, partially employed or under-employed, seasonal or temporary workers, as well as some higher education students. In line with these definitions of low-income populations, the federal poverty line is indicative of individuals considered to be in poverty, while individuals at 200% of the federal poverty line are considered low-income.

Elderly populations[1] (19 mentions). The age of 65 is the traditional threshold for elderly populations and is used by the US Census Bureau, with 65-74 considered *early elderly* and 75 and up considered *late elderly* (Orimo et al., 2006). Compared to the 2013 US national average of 14.5% for the population 65 and older, North Carolina's share of the elderly population for the same year was similar, estimated at 14.3% (Tippett, 2015). Both of these values have increased over time and will continue to increase, in part due to the aging Baby Boomer generation (Tippett, 2015). In addition to age thresholds, the location of retirement communities/assisted living/nursing homes, etc. could be integrated into the analysis locating elderly populations.

Racial/ethnic minorities (15 mentions). Minority populations have been identified in the literature as more likely to be transportation disadvantaged. The categories of racial minorities tracked by the US Census are legislatively dictated by the 1997 Office of Management and Budget, and include the following groups:

- Black or African American – A person having origins in any of the Black racial groups of Africa.
- American Indian or Alaska Native – A person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment.

[1] It should be noted that age generally (not specifying young or old) was mentioned in six sources, including GAO, 2012; GAO, 2014; Gregg, Goodwill & Joslin, 2017; Litman, 2018; Manuagh, Badami, & El-Geneidy, 2015; Pyrialakou, Gkritza, & Fricker, 2016.

- Asian – A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
- Native Hawaiian or Other Pacific Islander – A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

In addition to these groups, the US Census also tracks the number of individuals who identify as White, and have origins in Europe, the Middle East, or North Africa. The US Census also tracks those who identify as Hispanic/Latino, but since this is considered an ethnicity, it is not broken down into specific regions or countries. There is also an option to identify as two or more races on the US Census. The 2017 US Census estimates are shown below.

Table 4. *2017 US Census summary of national racial statistics.*

Racial category	Percentage
White alone	76.6%
Black or African American alone	13.4%
American Indian and Alaska Native alone	1.3%
Asian alone	5.8%
Native Hawaiian and Other Pacific Islander alone	0.2%
Two or More Races	2.7%
Hispanic or Latino	18.1%
White alone, not Hispanic or Latino	60.7%

The above racial categories in Table 4 are derived from self-reported data collected by the US Census Bureau in which individuals can select the race(s) that best represent them.

Disabled - General (13 mentions). This category represents references that mentioned *disability* in a generic way, without specifying the type of disability (e.g. physical or cognitive). In 2016, 8.6% of adults age 18 and older in the US reported that they had a disability that made functioning difficult (CDC, 2017). The prevalence of disabilities increases with age, as evidenced by 18.2% of adults age 65 and older reported having a disability that made functioning difficult (CDC, 2017). Although the US Census collects data on disabilities, definitions of disability differ between localities and/or surveys. In addition, accepted definitions of disabilities have changed over the past 40 years, so caution should be taken when utilizing data on disabilities. As described on the US Census (n.d.) website:

> *"The Census Bureau collects data on disability primarily through the American Community Survey (ACS) and the Survey of Income and Program Participation (SIPP). The definitions of disability are not always alike so caution should be taken when making comparisons across surveys. Generally, the SIPP estimates of disability prevalence are broader and encompass a greater number of activities on which disability status is assessed. The ACS has a more narrow definition but is capable of producing estimates for states, counties, and metropolitan areas. Because the ACS has replaced the decennial long-form as the source for small area statistics, there is no disability data in the 2010 Census… In addition to these recent data sources, the Census Bureau has also produced disability estimates from the 2000 Census, and the Current Population Survey Annual Social and Economic Supplement (CPS ASEC). Other Federal*

agencies also collect and report disability statistics. Depending on your needs, one survey may be more suitable than another."

In 2008, the questions asked on the US Census regarding disabilities were changed, and are still current as of the date of this report. The six disability types for which data is collected include the following, verbatim from the US Census website (n.d.):

- **Hearing difficulty** – Deaf or having serious difficulty hearing
- **Vision difficulty** – Blind or having serious difficulty seeing, even when wearing glasses
- **Cognitive difficulty** – Because of a physical, mental, or emotional problem, having difficulty remembering, concentrating, or making decisions
- **Ambulatory difficulty** – Having serious difficulty walking or climbing stairs
- **Self-care difficulty** – Having difficulty bathing or dressing
- **Independent living difficulty** – Because of a physical, mental, or emotional problem, having difficulty doing errands alone such as visiting a doctor's office or shopping

Adolescents/Youth[2] (11 mentions). This category includes anyone who has not yet reached the age of 18, which is considered the age at which someone is legally recognized as an adult in the US. Adolescents/youth may be limited by their age to participate in available transportation services due to limitations or parental restrictions/dependence on parents. More specifically, this category may be limited to under 16 years old in the case of transportation disadvantage, since in most states 16 is the legal age at which someone can drive.

Carless populations (11 mentions). This category is defined as individuals who do not have access to a car. This category can include youth/adolescents who are too young to drive, low-income individuals who cannot afford such services, people who are physically or psychologically unable to drive, migrants who are restricted from legally driving, etc. Since the primary mode of transportation is by car, and a majority of transportation funding is invested in highway projects, lacking a car puts someone at a disadvantage in terms of access, particularly if he/she lives in a rural area with greater distances, time, and costs associated with travel to and from destinations and fewer alternative modes to choose from. This category includes individuals who may have the ability to travel by car but choose not to use one for whatever reason. In North Carolina, 693 out of 1,000 residents reported having a driver license in 2009. For comparison, in the United States as a whole, 685 out of every 1,000 residents are licensed drivers. Out of the driving-age population for the US, 87% of the population has a license (FHWA, 2011).

Disabled - Physical (9 mentions). In the United States in 2016, 16.1% of adults reported that they had a physical functioning disability which negatively impacted their life (CDC, 2017). The definition of a physical disability as followed by the US Census (n.d.) is as follows:

"According to the American Housing Survey, a person with a physical disability has serious difficulty walking or climbing stairs. This is defined as difficulty walking up to three city blocks or climbing one flight of stairs."

[2] It should be noted that age generally (not specifying young or old) was mentioned in six sources, including GAO, 2012; GAO, 2014; Gregg, Goodwill & Joslin, 2017; Litman, 2018; Manuagh, Badami, & El-Geneidy, 2015; Pyrialakou, Gkritza, & Fricker, 2016.

The categories displayed verbatim on the US Census website (n.d.) under information about disabilities that are indicative of a physical disability include the following:

- **Hearing difficulty** – Deaf or having serious difficulty hearing
- **Vision difficulty** – Blind or having serious difficulty seeing, even when wearing glasses
- **Ambulatory difficulty** – Having serious difficulty walking or climbing stairs
- **Self-care difficulty** – Having difficulty bathing or dressing
- **Independent living difficulty** – Because of a physical, mental, or emotional problem, having difficulty doing errands alone such as visiting a doctor's office or shopping

Women (8 mentions). Six references mentioned women as a sub-group of transportation disadvantaged populations. Women are more likely to report feeling unsafe walking alone at night, according to a 2011 Gallup Poll (see Table 5). As can be viewed from the table, the US has a larger gender safety perceptions gap compared to many other industrialized countries. Additionally, it can be inferred that women use a greater proportion of their income for transportation due to the gender pay gap, a worldwide phenomenon where women on average make less than men; these disparities are even more stark when broken down by racial categories, with women belonging to minority groups making even less than white women, for example.

Table 5. *Gendered responses by country to the question "In the city or area where you live, do you feel safe walking alone at night, or not?" as reflected in a 2011 Gallup poll.*

In the city or area where you live, do you feel safe walking alone at night, or not?

Percentage "yes, feel safe" among women and men in each country

	Women	Men	Gap
New Zealand	50%	85%	-35
Algeria	32%	66%	-34
Malta	48%	82%	-34
Cyprus	57%	85%	-28
Italy	40%	68%	-28
Albania	54%	81%	-27
France	51%	78%	-27
Australia	51%	78%	-27
United States	62%	89%	-27
Finland	66%	92%	-26
Sweden	65%	91%	-26
Ireland	58%	83%	-25
Portugal	51%	76%	-25
Yemen	56%	80%	-24
Belgium	52%	76%	-24
Malaysia	34%	58%	-24
Japan	57%	81%	-24
Estonia	46%	69%	-23
Czech Republic	48%	71%	-23
Slovakia	48%	70%	-22
Netherlands	69%	91%	-22
Latvia	39%	60%	-21
Moldova	40%	61%	-21
Germany	67%	88%	-21
United Kingdom	62%	82%	-20
Taiwan	54%	74%	-20
Poland	50%	70%	-20

Limited English Proficient (LEP) (7 mentions). The US Census definition of Limited English Proficiency refers to individuals over age 5 who self-reported to speak English less than "very well."

Age – General (6 mentions). Age was mentioned by six sources generally, not specifying young or old. When age was referred to generally, it is assumed that it included both youth and elderly populations.

Disabled - Cognitive (6 mentions). In the United States, 4.2% of people age 5-17, 4.5% of people age 18-64, and 8.9% of people 65 and over reported a cognitive disability in 2016; it is important to note that the prevalence disabilities increase with age (Kraus et al., 2018). Data collected by the US Census that indicate individuals with cognitive impairments include the following two categories, verbatim from the US Census website (n.d.):

- **Cognitive difficulty** – Because of a physical, mental, or emotional problem, having difficulty remembering, concentrating, or making decisions
- **Independent living difficulty** – Because of a physical, mental, or emotional problem, having difficulty doing errands alone such as visiting a doctor's office or shopping

Foreign-born populations (3 mentions). Also referred to as migrants/immigrants, "*the foreign-born population includes anyone who is not a U.S. citizen at birth. This includes those who have become U.S. citizens through naturalization… The U.S. Census Bureau uses the term foreign born to refer to anyone who is not a U.S. citizen at birth. This includes naturalized U.S. citizens, lawful permanent residents (immigrants), temporary migrants (such as foreign students), humanitarian migrants (such as refugees and asylees), and unauthorized migrants.*" as defined by the US Census (n.d.).

Migrants may face particular challenges after coming to the US, including language barriers, limited funds, and difficulty finding employment (Suphanchaimat et al., 2015). Migrants who do not have legal status in the US may face even greater challenges associated with lacking required identification, such as having difficulties using transportation services, obtaining stable and well-paying employment, and even finding suitable housing (Chaudry, et al., 2014). In 2016, immigrants made up 13.5% of the share of the US population (Zong et al., 2018).

Rural populations (2 mentions). Rural populations are defined as populations that reside in a rural area; if necessary, refer to the US Census' definition of rural as defined in the previous section entitled *Transportation Disadvantage*. Rural populations may be more likely to be transportation disadvantaged because of their isolation from points-of-interest (e.g. in terms of distance, travel time, etc.), which may be associated with greater travel costs. "*Rural areas cover 97% of the nation's land area but contain 19.3% of the population (about 60 million people)*," according to US Census Bureau Director John H. Thompson (US Census, n.d.). North Carolina has a large proportion of rural areas, with 59% of North Carolina's municipalities located within rural areas (Stanford, 2017). The US rural population percentage is significantly smaller than that of NC, which is approximately 40% (NC Department of Commerce, n.d.).

Other/uncategorized (12 mentions). Twelve stand-alone examples of transportation disadvantaged populations were identified through the content analysis, as follows: veterans, community college students, itinerant farm-workers, Mennonites, widows that do not drive (Lane, Bert & Heller, 2014), caregivers, individuals with medical obligations, law abiding drinkers, tourists/visitors/travelers (Litman,

2017), people who are unemployed (Pyrialakou, Gkritza, & Fricker, 2016), people living in the outskirts of cities/towns (Xiao, Wang & Wang, 2018), and environmentally impacted populations (EPA, 2011).

NCDOT Transportation Project Funding Prioritization Process

The Strategic Transportation Investment Act (STI) was passed by the NC Legislature in 2013 and directs "*the NC Department of Transportation to use its funding more efficiently and effectively to enhance North Carolina's infrastructure while supporting economic growth, job creation and a higher quality of life*" by allocating "*available revenues based on data-driven scoring and local input*" (NCDOT, 2018). The implementation phase of STI is termed *prioritization*, and most state capital funding goes through this multi-year process. The current study aims to provide a resource for future rounds of Prioritization in terms of providing a list of potential metrics that can be used to represent transportation disadvantage and/or transportation disadvantaged populations in transportation funding decisions.

For Prioritization 5.0, projects within each mode have distinct criteria and corresponding measures. Metropolitan planning organizations (MPOs), rural planning organizations (RPOs), and NCDOT division engineers are each able to submit transportation project proposals to be considered for funding. NCDOT division engineers, specifically, are each able to submit 14 proposals for every mode. In comparison, MPOs and RPOs are able to submit 12 proposals per mode, plus an additional proposal for every 50,000 people in population and an additional proposal for every 500 centerline miles. The Highway mode is legislated to receive at least 90% of the funding. Non-highway modes, which include Aviation, Bike/Pedestrian, Ferry, Rail, and Public Transportation, account for 6% of the funding. Highway and non-highway modes compete for the remaining 4%.

None of the non-Highway modes are guaranteed any level of funding. Instead, the 5 non-Highway modes compete for the 6% guaranteed funding amongst themselves and 4% flex funding amongst themselves and the Highway projects. A project that benefits multiple modes (e.g. roadway projects with bus lanes and sidewalks) can only be scored using the scoring methodology for a single mode. Interstate Maintenance, Bridges, and Safety Projects are scored using alternate criteria. There are other specific limits and allowances set by the legislature in the original and subsequent legislation.

All projects are initially assigned to one of three competition categories, depending upon their scope. The *Division Needs* projects are generally contained within one of North Carolina's 14 divisions and receive 30% of available project funds. *Regional Impact* projects can cross division boundaries within a single one of the North Carolina's 7 regions and also receive 30% of the available funds. *Statewide Mobility* projects generally cross multiple regions and only Highway, Aviation, and Rail projects are eligible; these projects receive 40% of the funding. However, the STI legislation contains overruling guidance on which competition levels projects are eligible. For instance, bicycle and pedestrian projects are only eligible for the Division level, regardless of scope. In addition, funding for projects within Regions and Divisions may be further limited because a previously funded project with a high price has been programmed over time and consumed subsequent funding amounts. Proposed projects are scored via the Strategic Mobility Formula (SMF), which varies between modes and is discussed below.

It is important to note that projects cascade down from Statewide to Regional to Division levels. Statewide projects are considered first and if one does not receive funding it is included in the next smaller pool. For instance, if a large rail project does not earn a high enough score to be funded within the Statewide Mobility category, it is then rescored by Regional Impact criteria and competes in that category. If it again receives an insufficient score, it is considered within the Division Needs pool. As shown in Table 6, the majority of scoring for projects is derived from the quantitative SMF, with the remainder coming from Local Input Points, divided equally between the MPO/RPO and the NCDOT Division Engineer. For example, 70% of the points for regional projects comes directly from the SMF (calculated by NCDOT staff), 15% from local input points submitted by the MPO/RPO and 15% from local input points submitted by the NCDOT Division Engineer. These points are discussed in the next section.

Table 6. *NC distribution of STI points allotment for all modes, by tier and distribution category.*

Tier	Strategic Mobility Formula	MPO/RPO Local Input Points	NCDOT Division Engineer Local Input Points	Total
Statewide	100	0	0	100
Region	70	15	15	100
Division	50	25	25	100

Local Input

While 100% of Statewide Mobility projects are scored on data-driven metrics, 30% of Regional Impact projects and 50% of division needs projects are based on local input, as indicated by local MPOs/RPOs and divisions. Each organization receives 1,000 points, with up to an additional 1,500 possible based on population. The same allocation is used for regional and divisional projects, with no more than 100 points per project per category. MPOs, RPOs and divisions create their own local input scoring methodologies. Each entity can come up with its own scoring process based on at least three of the following Standard Criteria (Non-Highway):

- **Quantitative Score** (NCDOT recommends assigning projects 0, 1, or 2 points): used by all 14 divisions
- **Local Support** (0 or 2 points): used by 11 divisions
- **Transportation Plan Consistency** (0 or 2 points): used by 11 divisions
- **Modal Stakeholder Support** (0, 1, or 2 points): used by 3 divisions
- **Project Development Activities Completed** (0, 1, or 2 points): used by 5 divisions
- **Cost of Project v. Available Division Category Funds** (0, 1, or 2 points): used 1 division

Different divisions may use the same criteria, but weight them differently. In addition, every division restricts how the local input points can be assigned. Although their methods vary, in practice every division dedicates at least 75% of its local input points to highway projects. Once the Division Engineer assigns local input points to the projects, she or he solicits input from the public before assigning final points. For each project, the local input points are divided equally between the MPO/RPO and the Division Engineer. Therefore, for a Regional Impact project, 70% of the final score comes from the Quantitative Score (calculated by the state office as discussed in the next section), 15% from MPO/RPO

Local Input Points, and 15% from Division Engineer Local Input Points (See Table 6 above). For Division Needs projects, the breakdown is 50%, 25%, and 25%. However, it should be noted that the quantitative score is included in many of the Local Input point calculations, giving it a greater influence on project selection. An analysis of the data shows that projects generally receive either 0 local input points or 100 (the maximum allowed per project). For example, out of all 909 Regional Impact projects across all modes in Prioritization 5.0, the MPO/RPOs assigned 0 points to 40% and 100 points to 54%.

Public Transportation Scoring

Within the Public Transportation mode in P5, there are three separate categories: Mobility, Demand-Response Transit (DRT), and Facilities. The general criteria and relative weighting for each quantitative score are presented in Table 7.

Table 7. *P5 criteria weighting for public transportation projects with the Strategic Mobility Formula.*

Criteria	**Mobility**		**Demand Response**		**Facilities**	
	Regional Impact	Division Needs	Regional Impact	Division Needs	Regional Impact	Division Needs
Impact	15%	10%	10%	10%	20%	15%
	Number of trips affected		Number of trips affected		Number of trips affected	
Demand/ Density	20%	10%	20%	15%	10%	10%
	Total trips/ Service population		Total hours/ Service population		Ridership Growth Trend	
Efficiency	10%	10%	15%	10%	15%	10%
	Total trips/ Total revenue seat hours		Vehicle Utilization Ratio		Efficiency Score*	
Cost Effectiveness	25%	20%	25%	15%	25%	15%
	Additional trips/ (NCDOT cost/Lifespan)		Additional trips/ (NCDOT cost/Lifespan)		Additional trips/ (NCDOT cost/Lifespan)	
Total	70%	50%	70%	50%	70%	50%

*While most of these criteria measure the actual raw data before ranking all the projects, each Facilities project receives an Efficiency Score of 0, 20, 40, 60, 80, or 100, depending upon number of trips, square footage, or vehicles per bay.

To determine the final score for each project, NCDOT compares the raw scores for each criterion across all the projects and scales accordingly based on rank. For instance, for Mobility projects, the criteria "Impact" is a measurement of the number of trips affected by the project. This raw number of trips for every Mobility project is collected from the submitter. These raw numbers are then compared to all the other projects and ranked. The top ranked project is given a score of 100 and the bottom one 0, with the remainder evenly spaced between 0 and 100 (skipping the lowest number after 0). If there were five projects with no ties, they would receive scaled rank scores of 0, 40, 60, 80, and 100 (if there were 90 projects, they would have scores of 0, 1.12, 2.5, 3.37....100). Scaling is conducted across all competition levels - Statewide, Regional, and Division.

Once each project has a scaled score for each individual criterion, that score is multiplied by the percentage weighting, as seen in Table 7. For instance, a Mobility-Regional Impact project with a rank score of 82.1 for Impact criteria is multiplied by 15% to obtain a criterion score of 12.32. The four

individual criterion scores are then summed to create the overall Quantitative Score. If a project is ranked at the top for every criterion, it would receive the maximum of 50 points for a Division Needs project, 70 points for a Regional Impact project, or 100 points for a Statewide Mobility project (N/A for public transportation). Local Input Points are then added in to make 100 the maximum for each project.

Programming

After scoring, the projects are funded through *programming*. Starting with the highest scoring projects in either Highway or Non-highway modes, Statewide Mobility projects (which account for 40% of the total funding) are selected until statewide funding is exhausted. In other words, if the top 35 scored projects exhaust all the Statewide Mobility funding, then the 36th is not chosen. However, the 36th project, along with all the other statewide projects are then added to the Regional Impact pool, with their initial scores weighted correctly for this pool. All the projects in this pool are then ranked by their scores and selected the same way. Once this category's funding is exhausted (30% of the total), the remaining projects are added to the Division Needs pool, and the final funds are allotted. There are other considerations that impact programming, such as limits on how much funding is available within a region/division and how much funding has been previously allocated. A costly project in P4, for instance, may reduce the amount of funding available in P5 for a region/division in the Highway/Non-Highway modes.

Applicable Scoring in Other Modes

Although, this study concentrates on the feasibility of adding TD metrics to the Public Transportation scoring, the possibility exists of adding it to other modes as well. Furthermore, NCDOT has experience with slightly different scoring mechanisms in other modes that may be applicable to TD metrics used in other parts of the country, as will be discussed in later sections.

In NCDOT's Bicycle & Pedestrian scoring, the Safety criterion accounts for 15% of the overall scoring at the Division-level. Within this category, one fifth of the scoring is based on the posted speed limit. There are five different categories of posted speed limits, each with its own assigned number of points. Another 20% of this criterion are allocated for Safety Benefits. Here the proposed project type is assigned a different number of categorical safety benefit points. For instance, a grade-separated facility (e.g., bridge/tunnel) is allotted 100 points while a multi-site bicycle facility (e.g., bicycle parking) is allotted 10 points. For the Connectivity criterion score (10% of total), NCDOT also utilizes a table to create a "Community Quality of Service" index for each endpoint. A similar table could be used for public transportation projects, although it more difficult to categorize all the types of public transportation projects that would needed to be included in such a table No such tables focusing on TD issues were discovered while researching other states' processes.

Bicycle & Pedestrian also has an *Access* criterion which accounts for 10% of its overall scoring. Similar to TD metrics that identify TD-relevant destinations, this criterion examines major centers (e.g., transit center) and secondary centers (e.g., schools) that are located near the proposed project. Major centers are assigned 10 points each and capped at 7 (70 total points), while secondary centers are worth 5 points and capped at 6 (30 total points). The other half of the access score is the distance to these centers, assuming a radius of 1.5 miles from the project for bicyclists and 0.5 miles for pedestrians. The Ferry Division has a similar criterion (Accessibility/Connectivity) and both divisions determine points-of-interest for these

projects by working in collaboration with the NC Department of Commerce. Incorporating a similar criterion for the goals of this study would involve a greater degree of sophistication in order to determine which major and secondary centers (or other destinations) would be of value specifically to transportation disadvantaged populations.

Finally, the Rail division has an Economic Competitiveness criterion worth 10% of its scoring at the Statewide and Regional levels and 5% for Division Needs. Economic Competitiveness is measured by calculating the number of full-time jobs estimated to be created in the 20 years after construction. It weights each county the project passes through by current unemployment and proximity to the project. This approach is similar to some possible TD metrics that try to predict improved job access for TD populations.

Methodology

The methodology for this research consisted of four main parts: (1) background knowledge acquisition (e.g. meetings with the SPOT Office), (2) literature review, (3) peer state interviews and analysis, (4) metrics assessment and recommendations for implementation. The methodology was established to find TD metrics that are supported by the literature as effective, as well as gather background information from stakeholders in the prioritization process in order to identify metric(s) that can be applied in the P6 Prioritization formula to represent the needs of transportation-disadvantaged individuals.

First, background information was obtained through regular meetings with the Research Committee as well as the SPOT Office and other stakeholders (e.g. from NCDOT) during the course of the research. This allowed for consistent communication between stakeholders involved the prioritization process to make sure that the product of the research (i.e. recommended list of metrics that can represent transportation disadvantage) is implementable and acceptable to the P6 Workgroup.

Second, a literature review and content analysis was completed of 40 references ranging from 1996 to 2018 using the search term *transportation disadvantage*; the vast majority of these sources were published after the year 2000. During the literature review, general background information related to transportation disadvantage was gathered, including methodologies used in the past to characterize transportation disadvantage. Additionally, the literature search yielded potential transportation disadvantage metrics (both quantitative and qualitative), as well as allowed the research team to identify potential peer states to interview.

Next, interviews with 14 individuals from seven selected peer states/organizations were completed, and an analysis/comparison was completed in which NC was compared with the selected peer states. These peer states were selected through recommendations from the Research Committee and the SPOT office, a TPCB peer exchange study from 2014, and a general literature review, which sought to identify states/ organizations that had similar prioritization processes to NC, had implemented TD metrics, or both. Peer states included in final analysis were North Carolina, Massachusetts, Virginia, California, Oregon, New Jersey, and the State Smart Transportation Initiative out of the University of Wisconsin. Additionally, information was gathered from publicly available documents and websites of other US states that were not interviewed. Refer to Appendix A for participating peer state interviews and Appendix B for peer

state interview questions; these questions were finalized based on unanswered questions following completion of the literature review (e.g. lack of other states with a similar transportation funding prioritization process to NC).

Finally, based on all data sources, a metrics assessment was completed, in which all promising metrics from the literature review, peer state analysis, and background information were compared on established criteria. The criteria that guided the metrics assessment was established based on practical considerations during internal research meetings as well as feedback from the Research Committee.

The criteria which guided the metrics assessment is as follows:

- Data requirements and availability
- Data ease of use/practicality
- Years for which data is available
- Accuracy of data source
- Data precision
- Effectiveness in reflecting transportation disadvantage
- Previous experience (whether the metric has been successfully implemented elsewhere)
- Pros and cons of each metric

Literature Review

In 2010, data from the US Census reveals that 13.5% of the population has some type of disability, 12.9% are of the age 65 or older, and 10.3% are at the poverty line or below it. While this list does not include all groups considered to be *transportation disadvantaged*, these groups typically face additional barriers in accessing transportation when compared to the general population. The purpose of the literature review is to thoroughly review research regarding transportation disadvantage and transportation disadvantaged populations; additionally, the literature review helped to identify peer states for interviews, as well as promising measures and metrics related to transportation disadvantage. Much of the existing literature is relatively recent and has been qualitative in nature. Furthermore, due to the emerging nature of this topic of focus, few states currently incorporate the needs of transportation disadvantaged populations in any systematic, data-driven way. This section will bring together the literatures on transportation disadvantage as well as the literature on accessibility generally.

Transportation Disadvantaged Populations

The concept of transportation disadvantage is multi-faceted. A lack of sufficient access to transportation services can have a strong negative impact on the rest of an individual's life (Cordes et al., 2016; Xiao, Wang & Wang, 2018), and social exclusion has been found to tie in heavily with transportation disadvantage (Farrington & Farrington, 2005; Lucas, 2012). In part due to some transportation disadvantaged populations that do not show up using conventional analysis methods (e.g. US Census data), a much larger portion of the population is transportation disadvantaged than commonly thought (Combs et al., 2016; Duvarci, 2007). The US Government Accountability Office (2013) also reported that the aging population has increased greatly the demand for paratransit. The location of an individual's residence heavily impacts their level of transportation disadvantage, with notable differences between living in inner cities, rural, or suburban areas (Hu, 2015; Litman, 2018).

Several predominant approaches to addressing transportation disadvantage were identified in the literature search. No specific research could be found about transportation disadvantage metrics and their inclusion in transportation project prioritization within North Carolina. More common but related topics within the literature included transportation project prioritization (Plaskon, Trainor & Grant, 2011), different types of goals of transit agencies (Plaskon et al., 2011), and using demographic data to identify geographic areas containing transportation disadvantaged populations (Combs et al., 2016; Lane et al., 2012; Shay et al., 2016). Using demographic data is the most commonly used and agreed-upon methodology in the literature and involves identifying disadvantaged groups from US Census data based on their inclusion in Title VI-protected populations (FTA, 2013; Combs et al., 2016; Lane et al., 2012; Litman, 2017b; Shay et al., 2016), including elderly, disabled, Limited-English-Proficient, low socio-economic status populations, as well as less-documented populations such as community college students, widows, migrants not included in the US Census, etc. (Combs et al., 2016; Lane et al., 2012; Shay et al., 2016). Assessing the level of connectivity of a transportation system is an indicator of accessibility, including for transportation disadvantaged populations. As cited by the US GAO (2014), connectivity has been negatively impacted by the lack of effective coordination.

Public transportation is essential for transportation disadvantaged populations, but has yet to be optimized, particularly in rural communities (Giuliano, 2005; Litman, 2017; Litman, 2018). The measures that have been used to analyze the needs of rural populations have been mainly grouped in two categories: (1) indicators of performance, and (2) indicators of levels of service (Hamby, 2012; Litman, 2017b). The ability to access particular points-of-interest, especially in terms of job accessibility, has the potential to improve the economic success of transportation disadvantaged communities (Barkley & Gomes-Pereira, 2015; Hu, 2015). The FTA suggested in 2013 to include the location of residences and places of employment to analyze transit systems.

Measures of Transportation Disadvantage

Litman (2018) recommended equity analyses to be completed in order to assist planners in making transportation planning decisions, pointing out potential benefits like reduced conflict and delays, in addition to expanding access to transportation disadvantaged populations. To meet the needs of the P6.0 Workgroup, the current study focused on metrics for which data can easily be obtained and analyzed. However, prior research on the topic tends to stress the importance of qualitative research in communities that are transportation disadvantaged, as well as a more precise analysis of neighborhoods than the more easily attainable census blocks (that may have small pockets of transportation disadvantaged populations even if these communities do not show up in the US Census). Specifically, Combs et al. (2016) recommended an analysis of informal transport networks (i.e. ways that individuals get from place to place that does not necessarily involve public transportation, such as rides to work from friends/family, etc.); this can help to identify transportation disadvantaged individuals who may not show up in conventional analyses. Research gaps specific to North Carolina include assessing the accessibility, affordability, availability and acceptability of state public transportation systems for transportation disadvantaged populations (Lane et al., 2014), as well as focusing on the intersection of design, place, mobility, class, and race in order to better understand structural inequalities and how to address them.

However, there have been challenges with implementing goals for transit in meeting the needs of the public. As stated by the US Government Accountability Office (2014), there has been a lack of coordination when it comes to administering non-emergency transportation services that assist transportation disadvantaged populations. State-level transportation agencies are not typically directly responsible for the administration of transit funds, as metropolitan areas usually handle these funds (Plaskon, et al., 2011). This can negatively impact system connectivity due to creating obstacles that impede coordination efforts across jurisdictions.

Accessibility

Accessibility has been defined by Owen et al. (2016) as "*the number of destinations reachable within a given travel time*." In his research focusing on accessibility and equity, the two major approaches set forth by Litman included identifying transit deserts as well as looking at the quality of transit options available to transportation disadvantaged groups (Litman, 2014; Litman, 2017a). Transportation disadvantage has also been measured via indices that have been created to combine multiple measures in an all-encompassing index, called the Transportation Dependency Index (TDI), which is obtained through demographic data (Lane et al., 2014). To help explain transportation disadvantage, Lucas (2012) analyzed transportation disadvantage within a social exclusion lens.

In the literature on accessibility, there are two main approaches: access to points-of-interest and access to transit. The use of gravity models is one common way to determine accessibility as reflected in the literature (Dong et al., 2006; Farber et al., 2015; Fu & Xin, 2005; Geurs & van Wee, 2004; Grengs, 2010; Horner & Downs, 2014; Lei & Church, 2010; Minocha et al., 2008; Transport for London, 2003; Widener et al., 2013; Widener et al., 2015). Gravity models differ based on the types of variables that are incorporated, but example parameters include: (a) walking/driving time between points-of-interest, transit stops, and residences; (b) transit travel time, (c) number of points-of-interest within a given area (jobs in particular), or accessible within a certain amount of time; (d) travel costs, and (e) levels of service and their reliability, among others.

The majority of approaches used to calculate access to and from particular origins/destinations, including transit, include points-of-interest. In one study, Public Transport Accessibility Measures (PTALS) were used to analyze the density of the public transportation system in London (Transport for London, 2003). These accessibility measures were calculated by factoring in walk access times to and from points-of-interest, as well as average waiting time, which were then added together for total access time (Transport for London, 2003). Another approach to calculating accessibility is to use the ability-based-accessibility (ABA) measure which is included in a gravity model to calculate access to particular activities; the ABA measure focuses on scheduling constraints and travel characteristics as opposed to trip-based measures of accessibility (Dong et al., 2006). Points-of-interest have also been utilized in existing research through the use of cumulative opportunity to measure the power of an accessibility measure mapped over time; cumulative opportunity counts the number of potential opportunities that are reachable in a set travel time or distance, with fifteen minutes as the threshold (El-Geneidy & Levinson, 2007). Similarly, Minocha et al. (2008) used the transit employment accessibility index (TEAI) for specific residential areas in a gravity model that inputs origin-destination transit trip and transit travel times (Minocha et al., 2008). Finally, Lei and Church (2010) used integral accessibility to calculate a measure of overall access with

regard to the number of possible destinations, which is defined mathematically in the gravity model mentioned employed in the study (Lei & Church, 2010).

The literature on accessibility has generally utilized a variety of methodologies, including spatial accessibility. Examples of different methodologies that have been analyzed or suggested in the literature for determining accessibility include:

- Studying the correlation between poor Los Angeles suburban communities and the spatial distribution of jobs (Hu, 2015).
- Determining the spatial accessibility of locations with healthy food for people that are transportation disadvantaged (Widener et al., 2013).
- Employing a gravity model to analyze the accessibility of the Detroit population to their destinations, as well as to identify spatial mismatch (Grengs, 2010).
- Using a combination of social, economic, infrastructure, location-based, person-based, and utility-based measures in combination with multiple gravity based models (Geurs and van Wee, 2004).
- Analyzing multiple factors, such as mobility, quality and affordability of transport options, transport system connectivity, mobility substitutes, and land use patterns in order to evaluate and understand issues that are ancillary to, and shaping, accessibility (Litman, 2008).
- Creating a social interaction potential (SIP) metric with interactions between different demographic groups, including income level, occupation, and race, among others (Farber et al., 2015).
- Integrating multiple measures into accessibility models through a suite of techniques, known as time geographic density estimation, to evaluate mobile objects (i.e. people or vehicles) interacting with opportunity locations (Horner & Downs, 2014).

Findings from the Literature Review

Following a review of the literature, several key points and insights have emerged. First, although the focus of the current study is on quantitative metrics representing transportation disadvantage, qualitative methodologies were generally more prevalent in the existing literature (Combs et al., 2016; Lane et al., 2014; Shay et al., 2016), as well as in reviews of governmental programs (e.g. many of the GAO reports). Specifically, completing surveys and/or semi-structured interviews to include stakeholders as well as members of transportation disadvantaged populations can yield information not evident from existing data (such as data from the US Census) (Combs et al., 2016; Lane et al., 2014; Shay et al., 2016). For example, US Census data is aggregated, with blocks and block groups as the finest level at which data is available; if the block group is a wealthy area but has several small low-income housing complexes within it, these scattered low-income groups may essentially be rendered invisible because of the lack of data precision needed for targeted intervention to improve access in transportation disadvantaged communities. Additionally, qualitative data enables feedback from parties involved in a proposed project and/or parties that would benefit or be adversely impacted by a particular project, which can uncover information such as the existence of informal transportation networks (e.g. carpooling) (Combs et al., 2016; Lane et al., 2014; Shay et al., 2016). The importance of incorporating the feedback of disadvantaged communities within the context of specific proposed projects/interventions that may impact such communities cannot be understated (Combs et al., 2016; Lane et al., 2014; Shay et al., 2016).

Another main finding from the literature review is that one way to assess the accessibility of an area is to identify valued points-of-interest, and complete an accessibility analysis between specific origins (e.g. residences or transit stops) and points-of-interest (e.g. employment, medical institutions, etc.); this type of analysis may include access to and from transit stops as well (Dong et al., 2006; Transport for London, 2003). Finally, due to the breadth of approaches to identifying and assessing a proposed project's impacts on the accessibility of an area, insights from the literature review has supported the idea of a multi-level analysis which incorporates several indicators (as opposed to using a single one). An example of how to do this is to compare several transportation service indicators between transportation disadvantaged populations and non-transportation disadvantaged populations in an equity analysis.

Several opportunities for future research were highlighted in the literature review. First, there is a need to develop a more accurate way of measuring service gaps with accessibility indicators (Lownes & Mamun, 2014). Next, policymakers need to be educated on the socioeconomic impacts of transit projects and their effects on transportation disadvantaged populations. For example, the addition of a new urban rail or bus rapid transit system could be beneficial for disadvantaged populations (Bardaka, Delgado & Florax, 2018). Specifically, raising the profile of research in policy sectors such as development studies, housing and planning, health, and social policy could aid the decision-making process within the transportation sector (Foth et al., 2013). The literature review provided the research team with the relevant background information necessary to complete the peer state analysis and metrics assessment.

Peer State Analysis

The purpose of the peer state analysis was to identify 3-5 leaders in the field of transportation funding in terms of their incorporation of transportation disadvantaged factors in order to identify best practices of project prioritization and promising metrics representative of transportation disadvantaged individuals.

Sampling and State Selection

Candidates for interviews were determined based on a literature review, including a report of a prior peer state exchange completed for the NCDOT entitled "Cross-modal project prioritization: A Transportation Planning Capacity Building Program" (Middleton & Regan, 2014), as well as SPOT Office/Research Committee recommendations. Once identified, the team conducted a thorough review of appropriate websites, as well as examining any documents or articles that might be of interest.

Peer states and organizations included in final interviews are displayed in Table 13. Out of the 14 individuals contacted for interviews, the response rate was effectively 100%, with peer state representatives either accepting the interview or referring the research team to someone more appropriate within their organization. Refer to Appendix B for peer state interview questions and Appendix C for a list of participating peer state interview participants (n= 14 interview participants, including 11 from peer states/organizations). Additionally, publicly available information (e.g. including websites and official documents) was gathered and analyzed for these 5 state and regional organizations.

The states were then selected based upon advice from these initial interviews and through examination of funding formulas and protocols discovered through the web review. States with funding structures somewhat similar to the one in North Carolina were prioritized due to time constraints. Because many states delegate much of their funding prioritization to regional or local levels, it was decided to include MPOs as well, specifically the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area in California and the North Jersey Transportation Planning Authority (NJTPA) in New Jersey. When at all possible, personal contacts were used to find the appropriate contacts at each agency, but agency websites were also good sources of contact information.

Interview Guide Development

The interview questions asked of the peer states were finalized based on unanswered questions following completion of the literature review. The interview questions were developed to correspond to the research questions guiding the current study (Appendix B). Although each interview was different based on the unique circumstances of each state, every agency was asked how they defined transportation disadvantage, how their prioritization process worked, how they incorporated transportation disadvantaged populations, and how well the process worked. A caveat to note is that many, if not most, states delegate much of the decision-making authority to the local or regional level; often it is a county government, MPO, or RPO that determines whether or not to include a metric indicating transportation disadvantage and, if so, what form it should take. While these hierarchies might be very different than that of North Carolina, the metrics they use might still be transferable. Furthermore, too often prioritization processes are not publicly or clearly explained, with some elements of the decision making process fairly opaque (SELC, 2017).

Peer State Findings

The states and organizations examined through literature and web searches included the following:

1. California
2. Houston-Galveston Area Council (TX)
3. Broward County (FL)
4. Capital Area Metropolitan Planning Organization (CAMPO) (NC)
5. Austin Capital Area Metropolitan Planning Organization (CAMPO) (TX)
6. Delaware
7. Florida
8. Genesee Transportation Council (NY GTC (NY)
9. Genessee County Metropolitan Planning Commission (MI)
10. Kalamazoo (MI)
11. Maryland
12. Massachusetts
13. Massachusetts Bay Transportation Authority (MBTA) (MA)
14. Metrolynx (ONT, CAN)
15. Metropolitan Transportation Commission (MTC) (CA)
16. Missouri
17. North Central Pennsylvania (PA)
18. North Central Texas Council of Governments (NCTCOG) (TX)
19. North Jersey Transportation Planning Authority (NJTPA) (NJ)
20. Ohio
21. Oregon
22. Puget Sound Regional Council (WA)
23. San Diego Association of Governments (SANDAG) CA)
24. Utah
25. Virginia
26. Wake Transit (NC)
27. WILMAPCO (MD, DE)
28. Winston-Salem (NC)
29. Wisconsin

Only about half of these states and organizations used a strictly data-driven metric. Many states instead stated a desire to recommend transportation projects that met TD-related goals, but might not have had strict data qualifications. Some states utilized "carve-outs," which generally took the form of specific grants or funding streams dedicated to specific purposes, such as aiding communities of concern or addressing other policy goals.

Metrics representing Transportation Disadvantaged Populations

An ideal metric would identify the TD populations that would be served by the proposed project *and* accurately predict the benefits those populations would accrue; while the former may be difficult, the latter is so resource-intensive to calculate that few states actually do it. Instead, the most common metrics the team discovered were those just identifying TD populations (as opposed to benefits). Table 8 shows a

summary of the 21 states or organizations that have implemented or plan to implement one or more quantitative measurement(s) for a transportation disadvantaged populations. Note that some of these are connected; for instance, once one California entity uses a TD metric it should not be surprising that other California entities do as well.

Table 8. *Peer state/organization population metrics comparison (n=21 peer organizations with comparable information regarding population metrics they use).*

	Boston	Broward County	California (Grants)	CAMPO NC	Delaware	GTC NY	Kalamazoo	MassDOT	MBTA	Metrolynx	MTC	Missouri	NJTPA	NCTCOG	Oregon	Puget Sound	SANDAG	Virginia	Wake Transit	WILMAPCO	Winston-Salem
Environmental Justice (General)	X		X		X		X	X						X		X					
Minority						X			X		X			X	X			X	X		X
Low Income			X	X		X			X	X	X			X	X		X	X	X	X	X
Elderly				X						X	X			X	X		X			X	
Disabled				X							X			X	X		X				
Low English Proficiency						X					X							X			
Carless		X		X							X	X		X					X		
Affordable Housing											X				X				X		
Single Parent											X										
Distressed Communities												X	X								
Threshold					X	X							X								
Population Range	X	X	X	X			X	X		X				X	X				X	X	

Of these groups, seven use a general *environmental justice* metric; environmental justice in this case refers to minority and low-income populations, as identified by President Clinton's Executive Order 12898 in 1994. Environmental justice metrics generally compare the percentage of minority and low-income populations to national or state averages. Eight organizations specifically mention minority populations, while 13 specifically include a metric for low-income populations. Elderly and disabled are the next most common groups, along with carless. The Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area in California used the most metrics, but they do not specifically assign weights to any of their metrics; instead, they have found it to be more politically feasible to present all the data in a transparent manner to their board.

The bottom of Table 8 shows which organizations calculated their metric along a range of scores versus on a binary scale. The majority of organizations choose to look at the range of population data, meaning that the larger the population of TD individuals or else the larger percentage of TD individuals, the more

points are awarded to that metric. Other organization use a yes or no threshold, whereby a project is awarded points in this metric only if the population of TD individuals (however defined) passes a certain threshold, generally based upon the percentage of TD individuals across the region or the state. Finally, some states require projects to be within an area that has a TD population above a certain threshold in order to qualify for benefits-based metrics, as described in the next section.

Population-based Metrics

Population-based metrics can also vary wildly in what proportion of the overall score they account for. Making this problem even more complex is the fact that some funding authorities use the prioritization scores more as recommendations or starting points. While in some cases this may lead to a TD-positive score being discounted, in our interviews we learned of cases where this additional layer to the process could help a TD-oriented project.

In Massachusetts, for instance, the planning staff will look deep into the numbers to see which sub-groups are hurt or helped by a proposed project; their analyses are different for every project and so cannot be easily turned into a general metric. In addition, many organizations may consider TD populations as part of a larger metric, but do not clearly delineate what each component is worth. For organizations with clearly explained population-specific metrics, these metrics were worth from 2% to 12.5% of the total project scoring. It is important to note however, that those entities scoring in the 2% to 3% range (e.g., California, NJTPA) had additional benefits-based metrics, which increased the overall value of TD-positive projects.

Using Population Data to make Decisions

The main advantage of population-based metrics is that the data are often simple to obtain. Most of the peer states and organizations use the US Census and the American Community Survey. It is beyond the scope of this report to discuss the strengths and weaknesses of these sources, but it should be noted that these data are proxies. Many low-income individuals, minorities, and other classified individuals are not transportation disadvantaged and may never use the proposed project, but planners may need to make assumptions that they are more likely to use them. However, relying solely on population-based metrics may end up in a project receiving *TD points*, simply because it is located in an area with high percentage of certain communities, even if the project actually harms that community.

As previously mentioned, many organizations will measure TD populations along a sliding scale, while others will require a project to meet a certain threshold population percentage in order to qualify. The MTC provides an illustrative example, as they consider the more types of TD individuals than any other organization in this study. As shown in Table 9, the MTC examined populations across their nine-county region. For each type of population, they assigned a concentration threshold that was somewhat higher to define *communities of concern*, which is another term for transportation disadvantaged populations.

Table 9. *MTC Communities of Concern Thresholds.*

Disadvantage Factor	% of Regional Population	Concentration Threshold
Minority Population	54%	70%
Low Income (<200% of Poverty) Population	23%	30%
Limited English Proficiency Population	9%	20%
Zero-Vehicle Households	9%	10%
Seniors Aged 75 and Older	6%	10%
Population with a Disability	18%	25%
Single-Parent Families	14%	20%
Rent-Burdened Households	10%	15%

Source: https://mtc.ca.gov/our-work/fund-invest/tip/tip-appendices

For California's Active Transportation Program, they allow project proposers to identify TD communities in various ways. These include using median household income, the CalEnviroScreen, percentage of free or reduced priced school meals, or a method of their choosing. In New Jersey, the Department of Community Affairs has defined some areas as *distressed municipalities*. For NJTPA, if a project is in one of these areas it gets an additional 38 points out of the 1,000 possible across all metrics.

Metrics Indicating Transportation Disadvantage/Barriers to Access

Metrics indicating transportation disadvantage measure the reduction of transportation and activity system barriers and give credit for the benefits of a proposed project. Many peer states and organizations only assign this metric to projects in a TD area, but it is possible for a project in a non-TD area to benefit TD individuals; for example, a multimodal transfer site might greatly increase the mobility of TD individuals who live a bus ride away. Many funding authorities couple their benefit-based metric with an analysis of the local TD population, either requiring a certain population or assigning it weights based on population.

Table 10 summarizes the benefits-based metrics of the twelve organizations the research team found that most clearly defined their quantitative metrics. The most common metric was a catch-all solution that assigned points based on impact on, improvement for, or simply benefits to TD populations. As discussed in the literature review, access to points-of-interest (POIs) is a metric that is often recommended by experts. In terms of TD specific metrics however, the only destination generally used was jobs. Oregon has the widest range of metrics, but in their case these metrics were actually just ones that were presented as possible ones that regional funding authorities were encouraged to use; in reality, most of these regional entities would only use the more general impact/improvement metric.

Table 10. *Peer state/organizations comparison of metrics reflecting barriers/benefits to transportation system access (n=14 peer organizations with comparable information on metrics used to reduce transportation disadvantage).*

	Delaware	GTC NY	MBTA	MTC	Mississippi	NJTPA	NCTCOG	Oregon	Puget Sound	Virginia	Winston-Salem	Ohio	Houston-Galveston	Maryland
Impact/ Improvement	X		X		X	X	X	X	X		X		X	
POIs (Jobs)		X		X		X		X	X	X		X		X
Travel Time/ User Cost								X						
Disabled Access								X						
Affordable Housing				X				X						
Health Benefits								X						
Supports Policy			X							X				

Impact/Improvement has the advantage of being a very flexible metric, one that can reward projects helping TD populations in different ways. It is generally scored by staff or a committee of reviewers who rate it on such scales as -1 to 7 points (Massachusetts), 0 or 21 or 36 points (NJTPA), or 0 to 2 points (WILMAPCO, MD/DE). However, its main disadvantage is that it can be too flexible; without clear rubrics, reviewers may not score projects consistently.

For Oregon's Statewide Transportation Improvement Fund (STIF) discretionary fund, submitters must "*[d]escribe how the project supports and improves access for vulnerable populations*" (ODOT, 2018). Each submitting agency can come up with their own rationale, but some possible indicators suggested are:

- The share of the population in the project area who are seniors, limited English proficiency, low-income, or other vulnerable populations.
- The portion of the project benefiting a vulnerable population as compared to the portion of Oregon's population that the vulnerable population represents.
- The proportion of agency ridership comprising vulnerable populations before and after implementation of the project.

ODOT also provides some examples:

- Describe improvements to transit service or infrastructure serving vulnerable populations.
- Describe the project's outreach to vulnerable populations or communications to notify potential vulnerable transit users about availability of reduced transit fare programs.
- Describe planning related to improved service to neighborhoods with vulnerable populations or travel training programs with a focus on vulnerable populations.

As can be seen, there is a large variety of worthwhile answers that a submitting agency could give here, all in 2,500 characters or fewer. Reviewers then have to rate the answers and score them up to 30 points, which will be 10% or 20% of the total score, depending upon the program.

The Massachusetts Bay Transportation Authority (MBTA) has a *Social Equity* metric that they use across modes, which is worth 10% of the final score (5% for aeronautics). As seen in Table 11, reviewers score projects based on how positively they impact two overlapping groups, Environmental Justice communities and Title VI communities. It should be noted the scores are based on proximity of communities ("in an EJ area" is better than "within a ¼ mile") and significance of impact, allowing a possible "-1" for having a negative impact. *Regional Equity* is generally independent of equity for TD populations, instead mostly rewarding submissions for projects in areas that have not recently been rewarded projects. One point is given to projects in rural areas, which are sometimes considered as TD populations. However, in interviews with Massachusetts, the team learned that the regional equity component has had little effect in the long term.

Table 11. *MBTA social equity metric rubric.*

F	SOCIAL EQUITY			Project #	
	The extent to which the project provides economic, social, and health benefits to residents and local businesses.				
	This section is worth 10% of the final score			**Maximum Points for this Section:**	**10**
	Criterion	**Factor**	**Points**	**Note**	**Score**
1	**Environmental Justice** (Score based on the project's positive environmental impacts targeting an EJ community; examples include improved transit stops, sidewalks, ramps, accommodations to 40R Districts, Sustainable Development Principles #2,6, & 8)	Project is located within an Environmental Justice area, and elements of the project significantly improve the safety, sustainability, health, or mobility of the EJ community	3		8
		Project is located within an EJ area and will have a minor positive impact on the EJ community	2		
		Project is located within a 1/4 mile of an EJ area and will have positive impacts on a nearby EJ community	1		
		Project is not located in an EJ area or no known impacts	0		
		Project will have a negative impact on nearby EJ communities	-1		
2	**Title VI** (Score based on how the project positively impacts and addresses the needs of Title VI communities)	Project is located within a Title VI area and elements of the project are specifically designed to have a positive impact on the Title VI community	3		0
		Project is located in a Title VI area and elements of the project are anticipated to have a positive impact on the Title VI community	2		
		Project is located within a 1/4 mile of a Title VI area and is anticipated to have a positive impact on a nearby Title VI community	1		
		Project is located in a Title VI area but there are no impacts to the community or impacts are unknown -OR- Project is not located in a Title VI area	0		
3	**Regional Equity** (Score based on how the project positively contributes to regional equity and equitable sharing) (Note: "Other projects" in this section are in reference to municipally initiated or designed projects)	Municipality has neither initiated nor constructed any other projects seeking Federal Funding in the last 5 years	4		0
		Municipality has neither initiated nor constructed any other projects seeking Federal Funding in the last 3 years	3		
		Municipality has not had a Federally Funded project under construction in the last 3 years -OR- Municipality has not initiated a Federally Funded project in the last 3 years	2		
		Project is located in a rural area and is deemed of vital importance to the region	1		
		No regional equity considerations	0		
				Total Score:	**8 out of 10**

Source: Massachusetts Bay Transportation Authority Highway Project Scoresheet (2018).

The Puget Sound Regional Council in Washington state assigns 40% of their scoring a metric titled *Benefit to Regional Growth, Manufacturing/Industrial and/or Locally Identified Center*. One of eight questions asks the submitter to describe how the project will benefit Environmental Justice groups, including seniors and people with disabilities, as well as areas with high impact or unemployment. With so many questions assigned to one metric, it is makes it relatively easy to ignore any one subset of questions, if other questions have a clear positive impact.

As mentioned above, points-of-interest, particularly jobs, was the only other benefits-based metric that was used broadly by peer states and organizations. Since improving access to jobs is a goal that appeals to many stakeholders and because at least limited job information is often available, many states have a job-

based metric, often under an economic performance category. These are often for jobs in general, as opposed to TD-specific jobs; this is most likely because while many mapping programs will output job locations, it is more difficult to determine which jobs are likely to be of use to TD populations. For instance, in their recently proposed prioritization updates (2018), the Virginia Department of Rail & Public Transportation had under their Accessibility Measure, an Access to Jobs metric (defined as "*projected improvement in transit travel time to jobs and workforce development*") and a companion Access to Disadvantaged Communities (defined as "*disadvantaged population (low-income, minority, or limited English proficiency) within walking distance of project (¼ mile)*").

The Puget Sound *Benefit to Regional Growth, Manufacturing/Industrial and/or Locally Identified Center* metric discussed has support for new and existing jobs as one of its indicators, but not specifically for TD populations. Finally, the State of Maryland, has a direct metric to measure job accessibility and economic development for some TD populations, as shown in Table 12. Note that the first part is directly calculable with certain mapping software programs (e.g. Sugar Access), but dependent on the accuracy of the underlying data, while the second part requires further analysis by the submitter and/or reviewer.

Table 12. *Maryland TD Jobs Access Metric.*

3.7. Goal 7: Equitable Access to Transportation

The Chapter 30 goal of Equitable Access to Transportation includes two measures that evaluate how the project will impact job accessibility and economic development for disadvantaged or low-income populations. The measures and their weights are given below in Table 3.7.

Table 3.7 Equitable Access to Transportation Measures and Weights

Measure ID	Description	Weight
G7 M1	The expected increase in job accessibility for disadvantaged populations within an approximately 60-minute commute for projects.	53%
G7 M2	The projected economic development impact on low-income communities.	47%

(Source: Maryland DOT, 2017, http://www.mdot.maryland.gov/newMDOT/Planning/Chapter_30_Score/Images_and_Documents/MDOT_TechnicalGuide_Final_12292017.pdf)

Peer State Interviews

The next part of the peer state analysis consisted of interviewing persons involved in transportation funding prioritization in three to five states; see Table 13 for a complete list of interviewees. The initial interviews were with NCDOT personnel to get a more complete picture of the needs and gaps involving funding for transportation disadvantaged projects in North Carolina and to help identify other states and organizations that could prove useful for other interviews. Another initial interview was with Jeff Sundquist of the State Smart Transportation Initiative in Madison, WI. He has worked with numerous state DOTs and other organizations and helped provide a broad framework for examining this problem.

Table 13. Peer state/organization list of completed interviews (n=14 participants).

Name	Title	Affiliation
Debra Collins	Public Transportation Director	North Carolina DOT
Sarah Lee	Senior Transportation Engineer	
Eric Sundquist	Director	State Smart Transportation Initiative
Jennifer Slesinger	Transportation Planner, Office of Transportation & Planning	Massachusetts DOT
Quinn Molloy	GIS Analyst/Transportation Planner, Office of Transportation & Planning	
Craig Sobczynski	Title VI Specialist, Office of Diversity & Civil Rights	
Ann Ludwig	Manager, Capital Programming	North Jersey Transportation Planning Authority (NJ)
Zenobia Fields	Department Director of Planning	
Dave Vautin	Principal Planner/Analyst	Metropolitan Transportation Commission (CA)
Anup Tapase	Planning Department	
Neil I. Sherman	Director of Statewide Transit Programs, Department of Rail & Public Transportation	Virginia DOT
Mary McGowan	Senior Transportation Planner, Transportation Planning Unit	Oregon DOT
Michael Rock	Unit Manager, Transportation Development Division	
Naomi Zwerdling	Transit Program and Policy Lead	

Transportation Disadvantaged Population Metrics

All the agencies interviewed utilized data on TD populations in their scoring. Often a threshold percentage was used, sometimes to assign points to a proposed project and sometimes to allow an additional metric to be considered. In New Jersey, they look at populations in the bottom 25% of the census for minority, low-income, elderly, and mobility-impaired, while in Massachusetts they compare the population in the project area to the statewide average. MTC's concentration thresholds were presented above in Table 9; they have a wide variety of TD factors and tend to set thresholds above regional averages.

Transportation Disadvantage Considerations

Every organization attempted, to varying degrees, to predict what effects a proposed project would have on TD populations in the area. Sometimes this involved quantitative scoring on specific metrics. For instance, as one of 28 different metrics, NJTPA projects are scored based on if each project provides "benefits or reduce burdens to low-income, minority, elderly or mobility-impaired communities" and then are assigned 0, 21, or 36 points. Similarly, in Massachusetts, reviewers scored projects from -1 to 3 on whether a project would hurt or help an environmental justice community.

These scoring mechanisms generally required substantial staff hours to review proposals, especially as each proposal needed multiple scorers for transparency. The proposer and other stakeholders were then allowed to challenge or appeal scores, which added to the time necessary, but also served to keep the community better involved. At the MTC in California, they analyze projects across a wide array of metrics, but do not relatively weight scoring at all between them. This was decided upon because it proved too difficult and not politically viable to choose between competing goals, such as the environment, TD populations, affordable housing, and regional equity. Instead, reports are made to the commission, along with public input, who then tries to make decisions in as transparent a way as possible. This has led to a greater percentage of funds being spent on high-demand transit corridors than before, rather than being spread more throughout the nine-county region.

This geographical equity is an issue that several states brought up in the interviews. Massachusetts tried a formula where regions received more points the longer it had been since they had federal or similar funding; they are considering dropping this metric, partly because it has had decreasing effect over time. In Virginia, different regions weight their metrics quite differently, particularly in areas like Northern Virginia, where congestion mitigation is the driving concern. In Oregon, when asked about any urban-rural (and tribal) divide, the interviewees said that both regions have similar levels of concerns about serving TD and that transit was a better unifier between these areas than anyone predicted.

Stakeholder Input

All the interviewees spoke about the importance of generating stakeholder input. NJPTA and MassDOT work with local proposing entities to help them connect to TD communities as they create their proposals. In Oregon, where much of the prioritization is done locally, there is a great deal of public involvement. While this level of involvement helps create much-needed local support, they stated that sometimes the immediate goals of the local agency do not always match the long-term plans of the state.

The other type of input occurs after the scoring is completed. Internally, the funding authority will often make recommendations that are based off the calculated scores, but factor in other issues such as public input and specific circumstances of each unique proposal. These decisions are often then returned to the local agencies for feedback, including an appeal process. Most states do not have such a strongly data-driven model of prioritization as North Carolina, but they do try to rely on quality data when they can. It is usually only when there is a unique situation with a proposing project that they try to supply additional context in order to help make the funding decision. For instance, would the construction of a new light rail station that is intended to help the local TD community actually cause gentrification and a loss for that

community? In some cases, such as MTC mentioned above, the actual data along with recommendations is presented instead of numerical scores.

Recommendations by Peer Organizations

Finally, each agency was asked if they had any recommendations for North Carolina. MassDOT and NJTPA said to watch out for redundant metrics that led to double counting of some factors; for instance, a metric measuring access to jobs might overlap with a metric for economic improvement. Both these agencies were in the process of streamlining their processes, in order to reduce the overall number of metrics. In Virginia, it was felt that the different needs in different regions necessitated different weighting systems, while Massachusetts felt that the every-region-gets-its-turn model was not helpful. Under the MTC model, transit projects tended to go to where there was the most people, perhaps leaving some less-populated areas out of the running.

Most of the agencies had some specialized monies dedicated to grants for TD populations. Some of these are with federally funded dollars, but Oregon recently began to employ a payroll tax. This is to help fund discretionary projects and transportation equity is one of the stated goals. One final item that was stated by both statewide and regional agencies was the importance of all the proposing agencies knowing how the prioritization process works and being given the tools to navigate it successfully. Virginia has a very detailed manual of how the scoring process works, detailing each step. The Oregon DOT has created the Mosaic model to give guidance to regional and local agencies as they come up with their own scoring schemes, although it has not been utilized as much as was projected. Virginia is in the process of updating their prioritization process as well and part of their plan is to rollout the changes gradually, perhaps starting with guidance in the first year and not implementing all the changes until later.

Metrics Assessment Findings

The purpose of the metrics assessment was to fit the needs of the NCDOT P6 Workgroup in their attempt to better incorporate the transportation needs of disadvantaged individuals. Potential metrics were identified from the literature review, peer organization documents, interviews and online content. Following this step, a metrics assessment was completed in which all promising metrics were compared based on the following criteria:

- Data requirements and availability
- Data ease of use/practicality
- Years for which data is available
- Accuracy of data source
- Data precision
- Effectiveness in reflecting transportation disadvantage
- Previous experience (whether the metric has been successfully implemented elsewhere)
- Pros and cons of each metric

The criteria that guided the metrics assessment was established based on practical considerations during internal research meetings as well as feedback from the Research Committee. The seven metrics recommended by the research team include the following: (1) transportation disadvantaged populations, (2) access to points-of-interest, (3) transportation service provision, (4) need for service, (5) improved connectivity, (6) general impact improvement, and (7) alleviation of specific barriers to access (i.e. project barriers).

Metric 1: Transportation Disadvantaged (TD) Populations

Transportation disadvantaged populations refer to demographic groups that are statistically more likely to face barriers in accessing transportation infrastructure as well as destinations. Population data is typically used as the basis for an equity analysis, where various benefits can be analyzed and compared between TD and non-TD groups. The following demographic groups are included in TD populations in the literature, from most to least common:

- Low-income (can use Federal Poverty Line normalized to NC/Dept. of Housing)
- Elderly (65+)
- Minorities
- Disabled (physical/cognitive)
- Carless populations, including youth unable to drive
- Women
- Limited English Proficient (LEP)
- Migrants
- Rural populations
- Other - e.g. single parent households

Data Source: US Census; American Community Survey (ACS); Dept. of Housing
Scoring Options: Scoring options include the following: (1) Threshold comparison - y/n (e.g. state average); (2) Range (ranked based on TD populations in project area; based on percentages); (3) Tiers/zones of geographic areas (e.g. 1-3, 1-100; reflect level of economic distress); (4) Project submitter explains how the project benefits TD populations

Peer State Implementation:

- Low-income (13)
- Minorities (9)
- TD/EJ general (7)
- Elderly (6)
- Carless (6)
- Disabled (physical/cognitive) (5)
- Geographic designations (includes tiers - disadvantaged communities, distressed municipalities/counties, tribal lands; 5)
- Limited English Proficient (LEP) (2)
- Single parent households (1)
- Women, youth, migrants, rural (standalone; 0)

Pros & Cons: Advantages to using population data include the following: (1) the data are easily available (US Census, American Community Survey); (2) this is the most common method used in the literature as well as implemented in other states, so it has been implemented and has acceptability; (3) the metric would need to be included either by itself or in conjunction with another metric to verify that the submitted project is affecting the target demographic. A disadvantage to utilizing population data is that population characteristics included in this list are largely proxies, with the exception of low-income and carless populations, which are more directly linked to being transportation disadvantaged (e.g. being a racial minority does not necessarily mean that person is transportation disadvantaged, but being low-income is more directly linked to being transportation disadvantaged). Another disadvantage is that a project may be in a TD area but have a negative effect on the TD population; for example, if that project involves building a road through a disadvantaged community, as well as raising property values, this project could do more harm than good, in that it is disrupting or displacing disadvantaged communities.

Metric 2: Access to Points-of-Interest (POIs)

Evaluating the ability of TD populations to access points-of-interest is another way to address the needs of disadvantaged populations. If a project improves connection between a disadvantaged area and a hospital, for example, the project may be deemed to be more beneficial when compared to a project that does not do this. Points-of-interest that may be included are as follows:

- Employment (can specify low-income jobs) (Lucas, 2012; Tsai, 2003)
- Locations for job searching and/or job training (Tsai, 2003)
- Social services and/or other governmental services (e.g. DMV) (Tsai, 2003)
- Central Business Districts (CBDs) and/or "central city" (Grengs, 2010)
- Medical facilities (Farrington & Farrington, 2005; Giuliano, 2005; Litman, 2008)
- Rehabilitation centers
- Educational facilities (Farrington & Farrington, 2005; Lucas, 2012)
- Food stores, supermarkets, healthy food (Widener et al., 2013)
- Child care centers
- Recreational facilities/public parks (Giuliano, 2005; Litman, 2008; Lucas, 2012)

- Safety facilities (e.g. police departments, domestic violence shelters, etc.)
- Homeless shelters
- Transit accessibility (e.g. 0.25-0.50-mile buffer around stops)
- "Shops and leisure" (Lucas, 2012)
- Cultural activities (Lucas, 2012)
- Rail services and/or access to stops for public transportation (Farrington & Farrington, 2005)
- Errands (Litman, 2008)
- Other as specified

Data Source: Origin-destination (agency); US Census; American Community Survey, commercial databases (e.g., SUGAR Access is a tool that can assist with accessibility analyses)

Scoring Options:

- Jobs (or other POIs) located with ½ or ¾ miles of target corridor
- Additional jobs created (Ohio, PA North Central)
- Is it within an area with dense job centers (CA MTC, MN)
- Is it an area (e.g., county) that is identified as under economic distress (Indiana), distressed municipality (NJ), such as NC's economic tiers?
- Scored based on description
- If you choose to use several different points-of-interest, a checklist may be useful

Peer State Implementation:

- Access to jobs is included by the following areas: Oregon, Wake County (NC), MTC (CA), Richmond (VA), Virginia, NJTPA (NJ), Indiana, Ohio, NCP (PA), Maryland, Minnesota
- Many states and local organizations score based on "benefits" to TD populations, which can include increased access to various POIs

Pros & Cons: Advantages of including access to points-of-interest in the prioritization process include the following: (1) jobs are a major generator of trips and a robust public transportation system will serve these trips; (2) serving these job sites/POIs helps the greater community; (3) increased access to points-of-interest. Disadvantages include (1) one size does not fit all - different communities have different needs and a too strict formula may miss much nuance. For instance, not all jobs are TD jobs and a certain area may have a great need to serve a shopping center, while another needs better access to medical facilities; (2) it is difficult to predict what jobs/POIs will be accessed by the TD population, as opposed to the general population; and (3) it is difficult to predict what jobs will exist in what locations decades in the future, particularly for a subset of the population. MTC in California has reduced their reliance on new jobs as a metric because of this.

Metric 3: Transportation Service Provision (Equity Analysis)

The quality of transportation service provision can be evaluated, particularly in the context of an equity analysis, where transportation disadvantaged groups are compared to non-transportation disadvantaged groups; this is consistent with the literature, where a transit service indicator has been recommended (Fu & Xin, 2005). One way to evaluate transportation service provision for transportation disadvantaged populations is to weight indicators between TD and non-TD groups in an equity analysis.

Below are some indicators that can be compared between the two demographic groups:

- Transit travel time (try to include all travel, including wait time and reliability, between origin and destination)
- Average distance to the nearest transit stop
- Availability of night time service
- Availability of low-cost transit options
- Frequency of service
- Degree of crowding
- Number and quality of bus shelters
- Service (Annual per capita vehicle hours)
- Ridership (Annual per capita passenger trips)
- Transit productivity - example measures below:
    - Average weekday transit boardings per vehicle revenue hour
    - Average transit boardings per vehicle revenue mile
    - Average annual transit boardings per route mile
    - Passenger miles traveled per vehicle revenue mile

Data Source: Transportation service provider
Scoring Options: A scoresheet could be presented which awards additional points for service improvements (e.g., reduced crowding, increased frequency).
Peer State Implementation: Many states and local organizations score based on benefits to TD populations, which can include improved service provisions. Oregon specifically asks for each project to describe benefits to low-income communities on whether the project increases frequency of bus service schedules, expands bus routes, reduces fairs, improves reliability, and reduces fragmentation.
Pros & Cons: The advantages of using metrics representing features of transportation service provision is that it would improve the quality of service for all transit riders as well as the fact that it is based on agency data, which is already a part of the process. Disadvantages of using transportation agency data include the following: (1) it is difficult to distinguish between the benefits accrued to TD populations as opposed to non-TD populations unless a comparison/equity analysis is completed; (2) it is difficult to weight different types of service improvement; and (3) projections may be needed in some cases.

Metric 4: Lack of Adequate Transportation Facilities

A metric can be included that represents whether or not adequate transit services are available in a particular project area. It may be a more valued project if it serves an area that lacks existing transit infrastructure as compared to a proposed project in an area with adequate public transportation in place already. This metric is trying to assess whether an area is underserved by rating on a scale or a yes/no basis, based on the presence or absence of existing transportation infrastructure or how well the existing infrastructure adequately meets stated policy goals.

Data Source: NCDOT GIS data of transportation infrastructure and networks, together with community input through surveys and/or interviews

Scoring Options: This could be presented as a yes/no (0 or 1), or the quality of existing infrastructure can be ranked on a scale based on goals for quality/connectivity/ multimodality.
Peer State Implementation: Mississippi asks about the need for service, and has a specific metric dedicated to the presence/absence of existing transportation infrastructure.
Pros & Cons: This metric is based on the belief that we should work to make sure that most people have at least a minimum access to public transportation. Therefore, a new project in an unserved area or an area that has substandard service may be preferred to expanding an existing system, even if the expansion would serve a greater number of people.

Metric 5: Improved Network Connectivity (can specify Multimodal)

The degree of connectivity between and within public transportation systems and other modes is an important consideration that can be taken to address the needs of disadvantaged populations. Connectivity is defined as the degree to which multiple transportation systems connect to facilitate transit accessibility (between and within modes). For this approach, a GIS connectivity analysis could be completed across the state, for which submitted projects could be assessed based on this data. If a project is found to increase connectivity between public transportation systems, it could be scored higher than a project that does not improve transportation system connectivity. Connectivity indicators can include frequency of service, number of stops, distance between stops, complementary scheduling, etc. These indicators can also be combined into a single number to create a *connectivity index*.

Data Source: NCDOT GIS data
Scoring Options: This could be presented as a yes/no (0 or 1) in terms of whether the project would improve connectivity, or a scale could be presented (1-5, with 1 being no improvement and 5 being the greatest level of improvement). Another option is a look-up table similar to the one used by the NCDOT Bike/Pedestrian department.
Peer State Implementation: California Active Transportation Program; South Carolina; Virginia Smart Scale Scoring Approach for Multimodal Choices
Pros & Cons: Improved connectivity is advantageous because it can greatly increase the benefits of any one particular mode of transportation. Disadvantages to utilizing a connectivity measure include the following: (1) connectivity is not necessarily targeted towards transportation disadvantaged populations; (2) it may not be sufficient as a stand-alone metric – for example, two transportation systems may be connected, but have such infrequent service that few people will use it.

Metric 6: Impact Improvement (General)

Another approach to integrating the needs of TD populations in transportation funding decisions is to compile all measures deemed relevant/desirable, and to score each project on all attributes which can then be compiled into an overall TD-benefit score. This could also be combined with an open-ended explanation provided by a project submitter or local practitioner (e.g. local planner) in which the degree to which a proposed project benefits TD populations is presented and justified with supporting evidence; this explanation could be ranked based on a scale of 1-5 (1 is no benefit, 5 is the greatest benefit). Alternatively, some states include “harm to TD populations” in this scale at the lower end to represent projects that may lead to gentrification of an area, thus indirectly harming the TD population (e.g. if an

area is gentrified, housing becomes more expensive, pushing out low-income populations who are then forced to move). One benefit to relying on local practitioners to submit such information is that they may be more familiar with TD populations not included in the US Census (e.g. homeless populations, low-income areas surrounded by higher-income areas, thus getting drowned out in the US Census data).

Data Source: All data sources would be combined - Origin-destination (agency); US Census; American Community Survey; NCDOT GIS data; US Dept. of Housing
Scoring Options: A score sheet would be provided in which measures of benefit to TD populations are evaluated on a project-by-project basis which can then be combined into a single TD-benefit score. An explanation of how a proposed project benefits TD populations can be integrated, along with requiring justification/evidence of the scoring decisions.
Peer State Implementation: Used by many states, including Delaware, Oregon, California (San Diego & MTC), Massachusetts, and New Jersey
Pros & Cons: An advantage to this approach is that it provides an opportunity to compile all TD measures deemed to be relevant, which simplifies decision making. There is a wide variety of transportation projects, each of which may have unique benefits or opportunities for TD communities; a general metric can capture these benefits without having to determine all the possibilities beforehand. A disadvantage to this approach is that some of the measures may not be determinable without local knowledge. Both the project submitter and the funding agency may have to analyze each situation individually, potentially making the process more time-consuming and subjective.

Metric 7: Alleviation of specific barriers to access (Project Features)

It may be desirable to incentivize specific project features that benefit TD populations. Examples include additional lighting/blue lights/emergency areas, ADA accessible infrastructure, Spanish/Braille translations, low-cost fares or non-monetary payments for transit, easier-to-understand or access public transportation schedule information, off-hour time schedules, hiring assistants that can help confused or cognitively disabled people, providing security around bus stops in dangerous areas to walk people home if needed (i.e. high crime areas), providing more parking around transit boarding areas, etc.

Data Source: This metric would depend of project-related data that is submitted by project submitters for proposed transportation projects.
Scoring Options: Specific project features that benefit disadvantaged peoples can be integrated into the prioritization process through bonus points or by other means.
Peer State Implementation: There are specific programs for this, but not integrated as a part of prioritization (e.g. ADA access)
Pros & Cons: An advantage to utilize this metric is that it would provide an incentive to improve project features to be more inclusive for disadvantaged communities. One disadvantage is the uncertainty involved in implementation, since it is not widely used as a specific metric.

Discussion

In line with the purpose of the study, promising metrics that can be used to represent transportation and/or transportation disadvantaged populations in the STI prioritization process are identified based on a review of the literature and a peer state analysis. To recap, the seven metrics recommended by the research team include the following: (1) transportation disadvantaged populations, (2) access to points-of-interest, (3) transportation service provision, (4) need for service, (5) improved connectivity, (6) general impact improvement, and (7) alleviation of specific barriers to access (i.e. project barriers). Unlike the other recommended metrics, general impact improvement is a way to consolidate the metrics into a checklist and/or scoring system; this is a common way that other states use to integrate measures of transportation disadvantage and associated populations into a single category. Each of the recommended metrics will be described in relation to how they can be used in tandem with each other for a more robust analysis. Metrics not recommended tended to be ones that did not accurately represent transportation disadvantage/populations, or were too general to be implemented.

It is also important to remember that no existing or proposed metric operates in a vacuum. Adding an additional criterion necessitates the elimination or reduction in scope of another criterion. Furthermore, it is advisable that a TD metric be utilized by *all* the modes as they prioritize funding. If not, then a public transportation project that is exemplary on all other criteria will lose points compared to a highway or aviation project, where TD factors are not considered.

Mapping Transportation Disadvantaged Populations

The metrics recommended by this study work best when they overlap and complement each other instead of being implemented individually A more thorough approach combines multiple measures to come up with a more accurate picture of the current level of accessibility for transportation disadvantaged populations, and how to improve their accessibility. The first recommended metric - transportation disadvantaged populations – is important to provide a geographic picture of where such populations reside in order to better serve them. Mapping out transportation disadvantaged populations is recommended as a base layer for any type of analysis, but it is more impactful when combined with other measures. For example, examining differences in transportation service provision (e.g. average distance from the nearest transit stop, transit travel time, etc.) between transportation disadvantaged and non-transportation disadvantaged groups can form the basis of an equity analysis; the outcome of the equity analysis can then guide decisions regarding investment in transportation infrastructure and services.

Access to and from Points-of-Interest

As improved accessibility of transportation disadvantaged populations is a main goal when applying an equity analysis in the context of transportation funding, calculating the level of access to points-of-interest, particularly for disadvantaged populations, is another approach that can be used with demographic/population data. The only point-of-interest that we found to be used by peer states is access to jobs, although it is possible to integrate other points-of-interest in the analysis, such as health care facilities, educational institutions, governmental/social service centers, etc. It should also be noted that points-of-interest can be applied not only in the form of destinations, but also from departure locations – e.g. if there is an area where affordable housing is located, it may be desirable to evaluate access to employment centers from areas with affordable housing, homeless shelters, etc. Another example is if there is a neighborhood or housing complex where many workers are known to travel to a particular

employer and lack transit access, this area may become a priority for transportation planners. Total travel time (including time to walk to and from transit stops), frequency of service, and distance from destinations all may be used to calculate the level of access to points-of-interest, particularly for disadvantaged populations.

Equity Analysis of Transportation Service Provision

Measures of transportation service provision are already widely used within the STI Prioritization funding formula (mainly in the form of ridership, which could be weighted based on the proportion of riders that are considered transportation disadvantaged). Among others, examples of measures of transportation service provision may include transit travel time, average distance to the nearest transit stop, availability of night time service, availability of low-cost transit options, frequency of service, number and quality of bus shelters, and service (i.e. annual per capita vehicle hours, which can also be weighted based on the proportion of transportation disadvantaged riders). It is particularly important to ensure that some off-peak hour travel times are available to accommodate night shift workers, who may also be considered low-income or otherwise transportation disadvantaged. Instead of examining these measures in isolation, however, it is recommended that measures of transportation service provision to be used together with population data within the context of an accessibility/connectivity/equity analysis. Specifically, comparing travel time to specific destinations between transportation disadvantaged populations and non-transportation disadvantaged populations is one way to integrate accessibility and transportation service provision within an equity analysis. If not enough data is available to determine the amount of transportation service provision is adequate, a targeted survey in a specific area lacking transportation infrastructure could be completed to gain additional information specific to the geographic area of interest.

Lack of Existing Transportation Infrastructure/Services

When used together with population data showing the locations of disadvantaged groups, the need for service can be gauged by also mapping out existing transportation infrastructure and services, with an urgency placed on areas lacking such infrastructure that is located within disadvantaged neighborhoods. The lack of transit, together with the presence of transportation disadvantaged populations, could work together as proxies in place of a direct measurement of individuals who are transportation disadvantaged-which could only be reliably measured by collecting data from individuals via qualitative surveys. The level of what is considered to be adequate public transportation provision would have to be established by area, as acceptable levels of access differ between different land uses. Existing employment data (including origin and destination linkages), together with the times of day at which people in different areas need to get to and from work, can help to establish what would be considered appropriate levels of transportation infrastructure/services.

Connectivity

Sufficient connectivity across modes, as well as within a particular mode, is imperative if the goal is to improve accessibility for individuals who rely on transit for travel (e.g. acceptable distance between bus stops, or between bus stops and rail stops, complementarity of transit schedules, etc.). It should be noted that NCDOT currently has measures of connectivity integrated within bicycle/pedestrian project scoring via a look-up table. The degree of connectivity within and between modes would need to be established prior to this analysis, and models such as SUGAR, an ArcGIS add-in focusing on accessibility, can assist

in determining existing levels of connectivity as well as levels of connectivity that would be present with the incorporation of a proposed project/route. The SUGAR model is cited near the end of this report. Similar to the need for service (i.e. the existing availability of public transportation), the level of acceptable connectivity within the transit system may differ between land uses. If used as a metric rather than a model, connectivity could be configured by calculating the improved access to the number of additional stops/services that were less accessible prior to addition of the proposed project, as well as the calculated distance and/or travel time to other transit stops from the proposed route. Another way to increase multimodal connectivity and overall mobility is to reduce the 1st mile/last mile transportation cost in terms of time and/or money by making electric scooters, bicycles, or other personal mobility devices available around transit stops. One way NCDOT could facilitate this solution is by working together with private companies and/or legislators to come up with a transit pass that would include access to rentable bicycles and scooters. Under the current SMF, such a project could theoretically score well by increasing the number of trips in the adjacent system, but NCDOT would have expand its allowable project types.

General Impact Improvement Rubrics/Score Sheets

General impact improvement is the most commonly used and cohesive strategy used by peer states to integrate varied measures related to transportation disadvantage, but care would have to be taken in North Carolina to ensure that any general scoresheets remain objective and quantitative in order to comply with NCDOT law. Also worth noting is that even the findings from a model, such as one used to assess levels of connectivity, could be integrated into such a checklist. All measures could then further be simplified into a transportation disadvantaged score as established by parties responsible for implementation. An example is a scale from 1 to 5, ranging from 1 (very harmful to transportation disadvantaged populations) to 5 (very beneficial for transportation disadvantaged populations); conversely, the scale may be focused only on the level of benefit without including costs, although this is a less comprehensive way of assessing projects, as costs may be a part of a particular project, and missing such costs could skew the analyses.

Table *14* shows an example of a metric that could be employed by NCDOT within the SMF. Details (e.g., scoring values, which criteria to include) could be modified based upon preferred policy goals, but the framework could provide a starting point for further development. It incorporates both *transportation disadvantaged population* criteria (1 & 2) and *transportation disadvantage* barriers criteria (3-6). Point values are kept low (i.e., 0-4 rather than 0-100) in order to ensure consistent scoring; the rubric can allow a reviewer to delineate what is a 3 versus a 4 better than what is a 90 versus 91. It addresses all of the metric types discussed above to some degree, using metrics derived from peer states and organizations. Finally, it maximizes flexibility while still relying on data-driven, quantitative calculations.

Alleviation of Project-Specific Barriers to Access

The final avenue for integrating the needs of transportation disadvantaged populations recommended in the current study focuses on the alleviation of project-specific barriers to access. Addressing project-specific barriers to access is a direct way of reducing barriers to access, especially for disadvantaged populations. This could be addressed by offering extra project points to projects that work to reduce barriers likely to adversely impact disadvantaged populations; a few examples of project-specific barriers to access include: emergency lighting/call systems, off-hour time schedules, translations of information required for travel, providing more parking around transit boarding locations, hiring assistants that can help confused or cognitively disabled people, providing security around bus stops in areas with high crime to walk people home if needed (particularly women or children).

Table 14. *Example Rubric of Transportation Disadvantage Metrics.*

Impact Category: Transportation Disadvantage				
	Criterion	Scoring Factor	Points	Score
1	**1. TD Population** What percentage of the population within ½ mile of access points (e.g., transit stops) are *Low-Income, Minority, Elderly, Disabled,* or *Other (*please explain)?	Determine the percentage of largest TD population. Take this number and add on half of the percentage of any other TD population (up to four total groups). Multiply this number (which may not exceed 100%) by 4.	4	
	OR (if higher)			
	If the project is expanding a current project, what is the percentage of TD individuals currently using the existing project?			
	OR (if higher)			
	If the project creates a network connection to a current project, what is the percentage of TD individuals currently using the existing project?			
2	**2. NC County Distress Rankings (Economic Tiers)** What is the most recent tier designation of the county where the project predominantly will take place?	Tier 1 = 2 points Tier 2 = 1 points Tier 3 = 0 points	2	
3	**3. Impact** Will the project improve or expand service for TD populations, such as extending routes, increasing hours, or reducing travel times?	The application **clearly and convincingly**: explains how the project will improve or expand service *specifically* for TD populations	3	
		The application **convincingly**: explains how the project will improve or expand service *including* for TD populations	2	
		The application **minimally**: explains how the project will improve or expand service *including* for TD populations	1	
		The application does not adequately make an argument that it will improve or expand service for TD populations.	0	
4	**4. Destinations** Will the project increase the accessibility to TD-relevant destinations, including jobs, medical facilities, and education centers? (If the project was *intentionally* proposed in order to increase the access of TD populations to another type of destination, it may be listed and described under "Other destinations.")	The application **clearly and convincingly**: explains how the project will increase accessibility to high volume or multiple TD-relevant destinations	3	
		The application **convincingly**: explains how the project will increase accessibility to medium volume or some TD-relevant destinations	2	
		The application **minimally**: explains how the project will increase accessibility to low volume or a low number of TD-relevant destinations	1	
		The application does not adequately make an argument that it will increase accessibility to TD-relevant destinations.	0	
5	**5. Need** Will the project address a *need* or *gap* specific to TD populations, that was identified by the local TD community?	The application **clearly and convincingly**: explains how the local TD community identified the need or gap **and how** the project will address it	3	
		The application **convincingly**: explains how the local TD community identified the need or gap **and how** the project will address it	2	
		The application **minimally**: explains the need or gap **and how** the project will address it	0	
		The application does not adequately make an argument that it will address any needs or gaps for the TD community	0	
6	**6. Negative Effects** Is there a risk that the project could have unintended negative effects on the TD population? These could include: • Reducing service or accessibility for TD populations by altering or replacing current services • altering the physical layout or infrastructure of a TD neighborhood (either long-term or during construction) • the replacement of TD residents or businesses by non-TD residents or businesses (i.e., gentrification)	The application **clearly and convincingly** explains how there are no predictable negative effects	0	
		The project is likely to have substantial negative effects on local TD communities	-3	
		The project is likely to have some negative effects on local TD communities	-2	
		The project may possibly have negative effects on local TD communities	-1	
		Raw Total Points	**15**	

Conclusions and Recommendations

The current study sought to review the existing literature, as well as information from peer states, to identify the most promising metrics and approaches used to integrate the needs of transportation disadvantaged populations within state transportation funding decisions. Based on the findings in this report, the research team recommends that NCDOT develop a single form (i.e. referred to as "General Impact Improvement" in the report) that compiles multiple metrics representing transportation disadvantage to facilitate a more comprehensive way of making transportation funding decisions. General impact improvement is a common approach used by peer states to consolidate the transportation disadvantage metrics and associated populations into a single checklist and/or scoring system. This approach is flexible, even allowing for the integration of quantitative and qualitative measures. Metrics recommended for inclusion into an overarching rubric include the following: (1) the location and distribution of transportation disadvantaged populations, (2) calculating access to and from points-of-interest, (3) transportation service provision in the context of an equity analysis, (4) identifying areas that lack adequate public transportation infrastructure, (5) finding ways to improve connectivity, and (6) alleviating specific barriers to access (i.e. project barriers).

It is recommended for all relevant data necessary for an analysis of transportation disadvantage be entered into the NCDOT computer system, at the most precise and most recent data levels (e.g. smallest data level available with the US Census, at the most recent year available), but also gathering data going back to the year 2000 or earlier to allow for viewing trends within their historical context for all data. When possible, data gathered for analysis should facilitate project-level comparisons, although supplementary information may need to be gathered directly from project submitters. This data on transportation disadvantage should also be connected to GIS data displaying multi-modal transportation networks as a whole, to indicate the need for service in particular areas. Where the data intersect is indicative of transportation disadvantaged hotspots, where transportation projects should be prioritized, especially if there is evidence that it connects a disadvantaged community to valued points-of-interest (e.g. hospital, major employment center, grocery/clothing stores, etc.). An example of a transportation disadvantaged hotspot is an area that is demographically likely to be transportation disadvantaged based on US Census data, but it also overlaps with a lack of transportation infrastructure/service provision, and low levels of connectivity and transportation service provision (e.g. infrequent service), that together indicates a need for service.

During the course of the current study, gaps in knowledge were identified that support future opportunities for research support related to future cycles of prioritization. First, a follow-up study focusing on how best to apply the recommended metrics in a way that is tailored to specific regions of the state, and continually updating this data, will be helpful in future decision making regarding transportation funding allocations. Ways to integrate such metrics into other transportation categories, such as bicycle/pedestrian modes, highways, ferry, rail and aviation could also be explored within the context of the difference of each mode as well as within the existing STI law structure. Additionally, discussions with the P6.0 Workgroup revealed not just the desire to encourage projects that meet the needs of underserved areas and populations, but also the need for a metric that serves to encourage projects that facilitate increased transit ridership regardless of demographics. Following from this need, future research could also focus on the development/identification of promising environmental metric(s) that can encourage both increased transit ridership as well as reduced carbon emissions and incentives;

similarly, this research should focus specifically on the North Carolina needs and context of the STI law. Finally, another research need was identified during discussions with the project NCDOT Research Committee – specifically, future research could explore why existing transportation services are not always utilized, particularly in areas where reliance on transit would be expected due to lack of personal vehicles, the presence of disadvantaged populations, etc. This research question would likely need to be explored qualitatively, via interviews or a targeted survey.

References (Except for the 40 references used for the content analysis)

1. Barkley, B. & Gomes-Pereira, A. (2015). A Long Ride to Work: Job Access and Public Transportation in Northeast Ohio. Federal Reserve Bank of Cleveland, 6(1).
2. Centers for Disease Control and Prevention. (2017). *Disability and Functioning (Noninstitutionalized Adults Aged 18 and Over)*. Retrieved from: https://www.cdc.gov/nchs/fastats/disability.htm
3. Chandra, S., Jimenez, J. & Radhakrishnan, R. (2017). Accessibility evaluations for nighttime walking and bicycling for low-income shift workers. Journal of Transport Geography, 64.
4. Dong, X., Ben-Akiva, M., Bowman, J., & Walker, J. (2006). Moving from trip-based to activity-based measures of accessibility. Transportation Research Part A: Policy and Practice, 40(2).
5. El-Geneidy, A. & Levinson, D. (2007). Mapping accessibility over time. Journal of Maps, 3(1).
6. Farber, S., O'Kelly, M., Miller, H., & Neutens, T. (2015). Measuring segregation using patterns of daily travel behavior: A social interaction based model of exposure. Journal of Transport Geography, 49.
7. Farrington, J. & Farrington, C. (2005). Rural accessibility, social inclusion and social justice: towards conceptualisation. Journal of Transport Geography, 13(1).
8. FHWA. (2011). *Highway Finance Data Collection.* Retrieved from: https://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/chapter4.cfm
9. Geurs, K. & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. Journal of Transport Geography, 12(2).
10. Giuliano, G. (2005). Low income, public transit, and mobility. Transportation Research Record: Journal of the Transportation Research Board, 1927.
11. Horner, M. & Downs, J. (2014). Integrating people and place: A density-based measure for assessing accessibility to opportunities. Journal of Transport and Land Use, 7(2).
12. Hu, L. (2015). Job accessibility of the poor in Los Angeles. Journal of the American Planning Association, 81(1).
13. Kraus, L., Lauer, E., Coleman, R., & Houtenville, A. (2018). *2017 Disability Statistics Annual Report*. University of New Hampshire: Durham, NH.
14. Lane, L.B., Bert, S.A., & Heller, A.E. (2012). *Defining North Carolina's transportation disadvantaged populations* (NCDOT report no. NCDOT/NC/2012-0731).
15. Lei, T. & Church, R. (2010). Mapping transit-based access: Integrating GIS, routes and schedules. International Journal of Geographical Information Science, 24(2).
16. Lin, T., Xia, J., Robinson, T., Goulias, K., Church, R., Olaru, D., Tapin, J., & Han, R. (2014). Spatial analysis of access to and accessibility surrounding train stations: a case study of accessibility for the elderly in Perth, Western Australia. Journal of Transport Geography, 39.
17. Litman, T. (2011). *Traffic, Mobility and Accessibility*. Victoria Transport Policy Institute: Victoria, BC, Canada.
18. Middleton, S. & Regan, T. (2014). Cross-Modal Project Prioritization: A TPCB Peer Exchange. USDOT: Washington, D.C.
19. Minocha, I., Sriraj, P., Metaxatos, P., & Thakuriah, P. (2008). Analysis of transit quality of service and employment accessibility for the greater Chicago, Illinois region. Transportation Research Record: Journal of the Transportation Research Board, 2042(1).
20. Oregon Department of Transportation (ODOT) Rail and Public Transit Division. (2018). *Formula Fund: Statewide Transportation Improvement Fund (STIF) Guidance and Application*

Instructions. Retrieved from https://www.oregon.gov/ODOT/RPTD/RPTD%20Committee%20Meeting%20Documents/STIF-Application-Guidance.pdf.

21. Orimo, H., Ito, H., Suzuki, T., Araki, A., Hosoi, T., & Sawabe, M. (2006). Reviewing the definition of "elderly." *Geriatrics and Gerontology International, 6*(3). doi:10.1111/j.1447-0594.2006.00341.x
22. Owen, A., Murphy, B., & Levinson, D. (2016). Access across America: Transit 2016 Final Report. Accessibility Observatory. University of Minnesota: Minneapolis, MN.
23. Plaskon, T., Trainor, S., & Grant, M. (2011). *Statewide transit goal setting*. The National Academies Press: Washington D.C.
24. Ratcliffe, M., Burd, C., Holder, K. & Fields, A. (2016). *Defining Rural at the US Census Bureau: American Community Survey and Geography Brief*. US Census Bureau: Suitland, MD.
25. Southern Environmental Law Center (2017). *Report Highlights Georgia DOT's Opaque Decision-Making Process*. Retrieved from https://www.southernenvironment.org/news-and-press/news-feed/report-highlights-georgia-dots-opaque-decision-making-process.
26. Stanford, J. (2017). *NC in Focus: Revisiting the 2016 Population Estimates.* Retrieved from: *https://demography.cpc.unc.edu/2017/12/12/nc-in-focus-revisiting-the-2016-population-estimates*
27. Suphanchaimat, et al. (2015). *Challenges in the provision of healthcare services for migrants: a systematic review through providers' lens.* BioMed Central Health Services Research.
28. Tippett, R. (2015). *NC in Focus: Population Proportion 65 and Older, 2010-2035.* Retrieved from: *https://demography.cpc.unc.edu/2015/05/14/nc-in-focus-population-proportion-65-and-older-2010-2035/*
29. United States Census Bureau. (2016). *Language Use.* Retrieved from: *https://www.census.gov/hhes/socdemo/language/data/other/usernote.html*
30. United States Census Bureau. (2016). *New Census Data Show Differences Between Urban and Rural Populations.* Retrieved from: *https://www.census.gov/newsroom/press-releases/2016/cb16-210.html*
31. US Department of Health & Human Services (USDHHS). (2018). (poverty guidelines table)
32. Widener, M., Farber, S., Neutens, T., & Horner, M. (2013). Using urban commuting data to calculate a spatiotemporal accessibility measure for food environment studies. Health & Place, 21.
33. Widener, M., Farber, S., Neutens, T., & Horner, M. (2015). Spatiotemporal accessibility to supermarkets using public transit: An interaction potential approach in Cincinnati, Ohio. Journal of Transport Geography, 42.
34. Zong et al. (2018). *Frequently Requested Statistics on Immigrants and Immigration in the United States.* Retrieved from: *https://www.migrationpolicy.org/article/frequently-requested-statistics-immigrants-and-immigration-united-states*

Zuo, T., Wei, H. & Rohne, A. (2018). Determining transit service coverage by non-motorized accessibility to transit: Case study of applying GPS data in Cincinnati metropolitan area. Journal of Transport Geography, 67.

Appendices

Appendix A: List of Interviews Completed

Table #. List of interviews completed for this research (n=14).

No.	Name	Title	Affiliation	Interview type	Date	Duration	Medium	Interviewers
1	Debra Collins	Public Transportation Director	NCDOT	Guidance	9/6/2018	~60 min	In person	Brittany & Waugh
2	Sarah Lee	Senior Transportation Engineer	NCDOT	Guidance	9/6/2018	~60 min	In person	Brittany & Waugh
3	Eric Sundquist	Director	State Smart Transportation	Guidance	9/24/2018	~45 min	Telephone	Waugh
4	Jennifer Slesinger	Transportation Planner, Office of Transportation & Planning	MassDOT	Peer state	10/12/2018	65 min	Telephone	Brittany & Waugh
5	Quinn Molloy	GIS Analyst/Transportation Planner, Office of Transportation & Planning	MassDOT	Peer state	10/12/2018	66 min	Telephone	Brittany & Waugh
6	Craig Sobczynski	Title VI Specialist, Office of Diversity & Civil Rights	MassDOT	Peer state	10/12/2018	67 min	Telephone	Brittany & Waugh
7	Ann Ludwig	Manager, Capital Programming	NJTPA	Peer state	10/18/2018	44 min	Telephone	Brittany & Waugh
8	Zenobia Fields	Department Director of Planning	NJTPA	Peer state	Pending	n/a	Email	Waugh
9	Dave Vautin	Principal Planner/Analyst	MTC	Peer state	10/23/2018	~60 min	Telephone	Brittany & Waugh
10	Anup Tapase	Planning Department	MTC	Peer state	10/23/2018	~60 min	Telephone	Brittany & Waugh
11	Neil I. Sherman	Director of Statewide Transit Programs, Department of Rail & Public Transportation	VADOT	Peer state	10/30/2018	~60 min	Telephone	Brittany & Waugh
12	Mary McGowan	Senior Transportation Planner, Transportation Planning Unit	ODOT	Peer state	11/29/2018	50 min	Telephone	Waugh
13	Michael Rock	Unit Manager, Transportation Development Division	ODOT	Peer state	11/29/2018	50 min	Telephone	Waugh
14	Naomi Zwerdling	Transit Program and Policy Lead	ODOT	Peer state	11/29/2018	50 min	Telephone	Waugh

Appendix B: Peer State Interview Questions

Defining & Measuring Transportation Disadvantage & Transportation Disadvantaged Populations

1. What populations are identified by your state/organization as being transportation disadvantaged?

Population	Included?	How defined/measured?	Data used?
Low-income			
Age - e.g. youth, elderly			
Disability (general) - physical, cognitive			
Minorities			
Immigrants			
Limited English Proficient			
Carless/reliance on public transportation			
Women			
Rural			
Other (list)			

2. What barriers to transportation access are assessed by your state/organization?

Barrier	Included?	How defined/measured?	Data used?
Lack of multimodal transportation facilities/ connectivity			
Accessibility			
Lack of equity			
Time barriers			
Language barriers			
Safety barriers			
Other (list) - e.g. mobility			

3. Are points-of-interest (POIs) taken into consideration? If yes, what types of POIs are taken into account? (e.g. jobs, types, of jobs, low-income housing, health centers, grocery stores, etc.)

Transportation Project Selection Process/Prioritization

4. Are projects that reduce transportation disadvantage or improve accessibility to transportation for disadvantaged populations prioritized? How are they measured? How are they weighted, if at all? (e.g. Quantitative metric or qualitative?)
    i. (Are trips taken by individuals who face transportation disadvantage valued differently than trips taken by someone who is not transportation disadvantaged?)
5. How is feedback from public participation processes incorporated into project selection? Who does the scoring (e.g., state, commission, MPO/RPO)?
6. What software/tools are used to prioritize transportation projects and is it used across the state? How was it developed? Price? Pros & cons?

Implementation-Related

7. What groups benefit the most from the project selection process? Least?
8. How has the current funding/prioritization process worked in practice? Is there any type of practical assessment of its effectiveness (e.g. a study)?

9. What are some areas for improvement? Are any changes being considered? (e.g. difficulties with particular metrics in representing transportation disadvantage)

Referrals

10. Recommendations for other contacts - in your state or outside of your state - who are knowledgeable about meeting the transportation needs of transportation disadvantaged populations? (can be governmental or non-governmental/non-profits, etc.)
11. Do you have any supplementary documents describing state transportation project selection and/or any documents pertaining to transportation disadvantage or transportation disadvantaged populations?
12. Anything else?

- *Note: Additional questions may be asked that are unique to the specific peer state organization being interviewed.*

Overall Interview Goals:

1. Obtain information on metrics representing transportation disadvantage (barriers) and transportation disadvantaged populations (demographic information)
   ii. Who/what is included
   iii. How defined - e.g. disability, elderly, etc.
2. Obtain information on how transportation disadvantaged needs are incorporated into transportation project funding processes
3. Lessons learned/how it has worked in practice

Appendix C: Sample Open-Ended Scoring Sheet

These would be evaluated with a rubric to convert to numerical scores.

1. Please describe the TD populations within the project area and how the proposed project will impact them. Be specific about local communities that might not be captured in larger Census tract data (e.g. a small TD community within a wealthy area would not show up in the US Census)
2. What are the potential adverse impacts to the TD populations associated with the proposed project? (both during construction and after)
3. Which of the following locations does the proposed project facilitate access to?
    a. Employment (e.g. low-income jobs)
    b. Central Business Districts (CBDs)
    c. Medical facilities
    d. Rehabilitation centers
    e. Educational facilities
    f. Grocery stores (can specify access to healthy foods in particular)
    g. Child care centers
    h. Recreational facilities/public parks
    i. Safety facilities (e.g. police departments, domestic violence shelters)
    j. Governmental services (e.g. social services, DMV)
    k. Homeless shelters and/or affordable housing communities
    l. Transit accessibility
    m. Other as specified
4. Please describe how your proposed project will connect TD populations to specific destinations and/or improve transit service for these populations (e.g. connecting an affordable housing community with business districts/social services/health services).
5. Please describe how the proposed project will facilitate connectivity between transportation systems, with special emphasis on the TD population (e.g. can mention frequency, number of stops, complementary scheduling, etc.).
6. Describe the need for service in the project area, particularly for TD populations (e.g. existing public transportation infrastructure in the project area).
7. Please describe the overall benefits to TD populations that this proposed project would provide.
8. What project features are included that may benefit disadvantaged communities? (Examples include additional lighting/blue lights/emergency areas, ADA accessible infrastructure, Spanish/Braille translations, low-cost fares or use plastic bottles to pay for transit, easier-to-understand or access public transportation schedule information, off-hour time schedules, hiring assistants that can help confused or cognitively disabled people, providing security around bus stops in high crime areas, providing more parking around transit boarding areas, etc.)
9. Please describe and document the level of support by the disadvantaged community residents within the project area, as well as specific examples of how their feedback and concerns were integrated into the project proposal.
10. Please describe the specific project goals to improve mobility and accessibility for TD populations.

Appendix D: List of 40 References used for the Content Analysis of the terms
Transportation Disadvantage & Transportation Disadvantaged Populations

1. Attoh, K.A. (2012). The transportation disadvantaged and the right to the city in Syracuse, New York. *The Geographical Bulletin, 53*, 1-19.
2. Bardaka, E., Delgado, M.S. & Florax, R.J.G.M. (2018). Causal identification of transit-induced gentrification and spatial spillover effects: The case of the Denver light rail. *Journal of Transport Geography, 71*, 15-31.
3. Combs, T., Shay, E., Salvesen, D., Kolosna, C., & Madeley, M. (2016). Understanding the multiple dimensions of transportation disadvantage: The case of rural North Carolina. *Case Studies on Transport Policy, 4*(2), 68-77.
4. Cordes, S.A., Schwartz, A.E., Stiefel, L. & Zabel, J. (2016). Is neighborhood destiny? Exploring the link between neighborhood mobility and student outcomes. *Urban Studies, 53*(2), 400-417.
5. Duvarci, Y., & Mizokami, S. (2009). A suppressed demand analysis method of the transportation disadvantaged in policy making. *Transportation Planning and Technology, 32*(2), 187-214.
6. Duvarci, Y., & Yigitcanlar, T. (2007). Integrated Modeling Approach for the Transportation Disadvantaged. *Journal of Urban Planning and Development, 133*(3).
7. Environmental Protection Agency (EPA). (2011). *Guide to Sustainable Transportation Performance Measures*. Retrieved from https://www.epa.gov/sites/production/files/2014-01/documents/sustainable_transpo_performance.pdf
8. Foth, N., Manaugh, K. & El-Geneidy, A. (2013). Towards equitable transit: Examining transit accessibility and social need in Toronto, Canada, 1996-2006. *Journal of Transport Geography, 29*.
9. Friedman, C. & Rizzolo, M.C. (2016). The state of transportation for people with intellectual and developmental disabilities in Medicaid home and community-based services 1915(c) waivers. *Journal of Disability Policy Studies, 27*(3), 168-177. doi:10.1177/1044207316644413
10. Giuliano, G. (2005). Low income, public transit, and mobility. Transportation Research Record: *Journal of the Transportation Research Board*, 1927.
11. Government Accountability Office. (2003). *Transportation disadvantaged populations: Some coordination efforts among programs providing transportation services, but obstacles persist* (Report no. GAO-03-697). US Government Accountability Office: Washington, D.C.
12. Government Accountability Office. (2012). *Transportation Disadvantaged Populations: Federal Coordination Efforts Could Be Further Strengthened*. Retrieved from https://www.gao.gov/assets/600/591707.pdf
13. Government Accountability Office. (2013). *Transportation-disadvantaged populations: Coordination efforts are underway, but challenges continue*. Statement for the record by Dave Wise, Director, Physical Infrastructure Issues (Report no. GAO-14-154T). US Government Accountability Office: Washington, D.C.
14. Government Accountability Office. (2014). *Transportation Disadvantaged Populations: Nonemergency medical transportation not well coordinated, and additional federal leadership needed*. (Report no. GAO-15-110). US Government Accountability Office: Washington, D.C.
15. Gregg, R., Goodwill, J., & Joslin, A. (2017). *Transportation Disadvantaged State-Wide Service Analysis*. Retrieved from https://sites.stlucie.k12.fl.us/fdlrs/files/2018/01/Final-Transportation-Task-Force-Report.pdf

16. Grengs, J. (2010). Job accessibility and the modal mismatch in Detroit. *Journal of Transport Geography, 18*(1).
17. Hamby, B. (2012). *Data needs for assessing rural transit needs, benefits, and levels of service*. The National Academies Press: Washington D.C.
18. Hu, L. (2015). Job accessibility of the poor in Los Angeles. *Journal of the American Planning Association, 81*(1).
19. Lane, L. (2013). *Defining North Carolina's transportation disadvantaged populations: NCDOT Research Project 2013-12: Technical Memorandum 1*.
20. Lane, L.B., Bert, S.A., & Heller, A.E. (2014). *Defining North Carolina's transportation disadvantaged populations* (NCDOT report no. NCDOT/NC/2012-0731).
21. Lee County. (2012). *Transportation Disadvantaged Service Plan: A Five-year Plan for the Lee County Service Area*. Retrieved from http://www.fdot.gov/ctd/docs/TDSP/Lee Minor TDSP 2012 Final Adopted.pdf
22. Litman, T. (2010). *Evaluating public transportation health benefits*. Victoria Transport Policy Institute: Victoria, BC, Canada.
23. Litman, T. (2018a). *Evaluating accessibility for transport planning: Measuring people's ability to reach desired goods and activities*. Victoria Transport Policy Institute: Victoria, BC, Canada.
24. Litman, T. (2018b). *Evaluating transportation equity: Guidance for incorporating distributional impacts in transportation planning*. Victoria Transport Policy Institute: Victoria, BC, Canada.
25. Litman, T. (2018c). *Public transportation's impact on rural and small towns: A vital mobility link*. The American Public Transportation Association: Washington D.C.
26. Lownes, N. & Mamun, S. (2014). *Assessing and Quantifying Public Transit Access*.
27. Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy, 20*.
28. Manaugh, K., Badami, M.G. & El-Geneidy, A.M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport Policy, 37*, 167-176.
29. Martens, K. (2006). *Basing Transport Planning on Principles of Social Justice*. UC Berkeley.
30. Mattson, J. (2012). *Travel behavior and mobility of transportation-disadvantaged populations: Evidence from the National Household Travel Survey*. North Dakota State University: Fargo, ND.
31. Mjedle, J., Dudensing, R., Brooks, J., Battista, G., Carillo, M., Counsil, B., Ullerich, S., Giri, A., Kim, A.K., Pyrialakou, V.D. (2017). *Economics of Transportation Research Needs for Rural Elderly and Transportation Disadvantaged Populations*.
32. Nutley, S. (1996). Rural transport problems and non-car populations in the USA: A UK perspective. *Journal of Transport Geography, 4*(2), 93-106.
33. Pareekh, P., Mitra, S., & Majumdar, B. (2017). Quantifying dimensions of Transportation Diversity: A City-Based Comparative Approach. *Transportation Research Procedia, 25*, 3174-3187.
34. Purifoye, G.Y. (2017). Transporting urban inequality through public transit designs & systems. *City & Community, 16*(4), 364-368. https://doi.org/10.1111/cico.12266
35. Pyrialakou, V.D., Gkritza, K. & Fricker, J.D. (2016). Accessibility, mobility, and realized travel behavior: Assessing transport disadvantage from a policy perspective. *Journal of Transport Geography, 51*, 252-269.

36. Shay, E., Combs, T.S., Findley, D., Kolosna, C., Madeley, M., & Salvesen, D. (2016). Identifying transportation disadvantage: Mixed-methods analysis combining GIS mapping with qualitative data. *Transport Policy, 48*, 129-138.
37. U.S. Department of Health and Human Services (USDHHS). (2004). *Getting There: Helping People with Mental Illnesses Access Transportation*. Retrieved from https://store.samhsa.gov/shin/content/SMA04-3948/SMA04-3948.pdf
38. Widener, M., Farber, S., Neutens, T., & Horner, M. (2013). Using urban commuting data to calculate a spatiotemporal accessibility measure for food environment studies. Health & Place, 21.
39. Xiao, R., Wang, G. & Wang, M. (2018). Transportation disadvantage and neighborhood sociodemographics: A composite indicator approach to examining social inequalities. *Social Indicators Research, 137*(1), 29-43.
40. Zhao, F., & Gustafson, T. (2013). *Transportation Needs of Disadvantaged Populations: Where, When, and How?* Retrieved from https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0030.pdf