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Defining and Measuring Equity in Public Transportation

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Report 23-18

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September 2023

A publication of the
Mineta Transportation Institute
Created by Congress in 1991
College of Business
San José State University
San José, CA 95192–0219

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. 23-18	**2. Government Accession No.**	**3. Recipient's Catalog No.**	
4. Title and Subtitle Defining and Measuring Equity in Public Transportation		**5. Report Date** September 2023	
		6. Performing Organization Code	
7. Authors Christopher E. Ferrell, PhD: 0000-0002-3285-1008 David B. Reinke, MRP, MS: 0000-0003-0969-2261 John M. Eells, MCP: 0000-0003-3564-2962 Matthew M. Schroeder, MUP: 0009-0002-4936-4502		**8. Performing Organization Report** CA-MTI-2100	
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San José, CA 95192–0219		**10. Work Unit No.**	
		11. Contract or Grant No. 65A0660	
12. Sponsoring Agency Name and Address California Department of Transportation 1120 N Street Sacramento, CA 95814		**13. Type of Report and Period Covered**	
		14. Sponsoring Agency Code	
15. Supplemental Notes			

16. Abstract

Transit should serve all users, regardless of age, race, ability, or any other identity. Policies and planning must be conscious of inequities when defining and measuring equity in public transportation. This study was done to aid the California Department of Transportation (Caltrans) and the state's transit agencies in assessing transit service equity and assisting with evaluating past, existing, and future inequities. This report identifies and evaluates policies and practices associated with equity measurement in public transit from extant academic and professional literature sources. These include the Federal laws and regulations addressing Title VI of the 1964 Civil Rights Act and the measurement tools (i.e., metrics) that are used to identify and evaluate equity impacts related to transit benefits and costs. The report identifies a list of candidate metrics and applies them to a test case in Santa Cruz County, California, and compares their results to those generated by the metrics required by Title VI (race and income) for transit equity analysis. From this comparison, the study evaluated the need for new metrics in transit equity. Findings suggest that these traditional Title VI measures do not correlate well with other potential measures of inequity. Hence, transit inequity is a multifaceted problem with several potential different measures, each revealing an aspect of inequity. Caltrans and other transit-related agencies need to reach beyond these traditional measures, finding metrics that address the specific, context-appropriate equity conditions of the communities they are measuring to ensure fair and equal public transportation for all.

17. Key Words Public Transportation; Transit; Equity; Metrics; Measurement; Title VI	**18. Distribution Statement** No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 144	**22. Price**

Form DOT F 1700.7 (8–72)

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DOI: 10.31979/mti.2023.2100

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ACKNOWLEDGMENTS

The authors would like to thank MTI Executive Director Dr. Karen Philbrick and Director of Research and Technology Transfer Dr. Hilary Nixon for their support and encouragement throughout this project.

Special thanks to Henry Mckay, Chad Riding, Andrew Furillo, Michael McHenry, Amar Cid, Eric Gudz, Tyler Monson of Caltrans and Sequoia Erasmus, and Brigitte Driller from the California Transportation Commission for their support and insights during this project. Finally, we are grateful to the board members and principals of Transportation Choices for Sustainable Communities Research and Policy Institute, a 501(c)(3) nonprofit, that provided additional support for the project.

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Executive Summary

The purpose of this report is to aid the California Department of Transportation (Caltrans) and the state's transit agencies in assessing transit service equity and assisting with the evaluation of potential solutions for past, existing, and future inequities. This report identifies and evaluates policies and practices associated with equity measurement in public transit from extant academic and professional literature sources. These include the federal laws and regulations addressing Title VI of the 1964 Civil Rights Act and the measurement tools (i.e., metrics) that are used to identify and evaluate equity impacts related to transit benefits and costs. Research and practice literature types reviewed include federal laws and regulations, metropolitan planning organization (MPO) and transit agency policy documents related to Title VI and other equity concerns, as well as academic research papers and reports regarding equity measurement. The report applies a series of possible metrics to a test case, public transportation in Santa Cruz County, California, and compares their results to those generated by the metrics required by Title VI (race and income) for transit equity analysis. From this comparison, the need for new metrics in transit equity analysis is tested and evaluated.

Additionally, Caltrans requested that the research team review issues surrounding secondary displacement and summarize how agencies can address community concerns regarding the effects of secondary displacement caused by capital investments. As such, the literature review also includes findings on evaluating neighborhood displacement risk and the potential for individual anti-displacement strategies to mitigate that risk.

The literature review in Chapter 2 presents and analyzes the existing state-of-the-practice knowledge on how transit and other transportation agencies currently evaluate transit equity, and how they and academic researchers are working to expand and improve on these practices. The following are the principal findings of the literature review:

- Title VI and its associated laws and regulations set forth the minimum requirements for transit agencies to address service inequities, but many researchers, advocacy groups, and transit agencies themselves have found some significant shortcomings in Title VI and its associated laws and regulations, including that they:
    - Only address inequities based on race and low-income status; they largely ignore several transportation-disadvantaged groups that often face inequities in transit service provision such as the elderly, handicapped, and single-parent households.
    - Do not directly address existing inequities. They only require that transit agencies address the equity effects of new actions.

    - Do not set standards for defining equity, nor do they prescribe any specific ways to measure equity. Instead, these measurements are left to the individual transit agencies. This leads to inconsistent and often ineffective implementation.

- There are many transit equity measures found in the literature. While many of these are of limited practical significance for most transit agencies, especially those whose budget constraints limit their capabilities for data collection, the sheer number and variety of metrics provide substantial opportunities for accurate, consistent, and effective measurement, while also potentially causing confusion as to which metrics are best to use.

- A number of transit agencies and advocacy groups have taken on the task of developing new tools for assessing equity in transit service provision. In one case (Los Angeles Metro), the transit provider has adopted the goal of making equity a prime consideration in every agency action, including planning, budgeting, and service management.

- The most well-developed methods for measuring and predicting secondary displacement focus on preventing gentrification. Although these methods are relatively straightforward and becoming an increasingly common practice for public agencies, the most difficult and important step is successfully integrating these tools into the policy and decision-making process so that they can lead to change.

- New capital investment in fixed guideway rail transit systems tends to increase nearby commercial and residential property values. That said, the degree to which property values change is highly context sensitive.

The literature review and analysis found that comparative methods for secondary housing displacement measurement could be useful for assessing displacement risk, while predictive methods/models lack certainty and require further development. Although predictive models are underdeveloped and should not be considered for use by Caltrans or other transportation agencies in California for the foreseeable future, there are numerous examples of comparative models that rate highly in our preliminary analysis across our three evaluation scales (understandability, workability, and effectiveness). In particular, the Regional Displacement Risk Index from the Puget Sound Regional Council and the Displacement Risk Indicators Matrix (DRIM) by Rutgers University show the most promise, each ranking high across nearly all preliminary evaluation scales compared to the other models evaluated.

These comparative methods pointed the research team to recommend the development of a suite of displacement-related indicators, specialized for the California context, that provide "red flags" to the user when they exceed empirically established thresholds of significance, most likely based on simple descriptive statistics (e.g., averages, standard deviations) of local, regional, or statewide data. Candidate indicators could be identified, tested, and evaluated for development and use by Caltrans for their Equity Index based on a review of the variables used in the methods found in our literature review and an assessment of data availability for those indicators statewide.

The research team conducted a case study that measured how well the Santa Cruz County Metropolitan Transit District (METRO) serves its county's most transit-dependent and underserved populations. Spatial analysis was performed by overlaying socio-demographic data from the American Community Survey (ACS) on METRO General Transit Feed Specification (GTFS) data to determine whether METRO service adequately meets the needs of the region's most disadvantaged groups. Results indicate that while there are meaningful and statistically significant correlations between the standard Title VI metrics (race and income) and the other metrics evaluated, these correlations are for the most part weak. This case study demonstrates that current Title VI guideline metrics may miss significant measures of transit equity for transportation-disadvantaged populations. These findings from both the literature review and the case study demonstrate that there is a compelling need for new metrics on both theoretical and empirical grounds.

1. Introduction

While the history of transit in the U.S. after World War II has largely been a story of declining ridership and increasing reliance on the automobile, many metropolitan areas, states, and the federal government have made significant investments in new transit capacity to attract new and retain current riders. These efforts have been aimed at attracting riders from two travel markets: commuters looking for relief from congested or otherwise inconvenient travel conditions on their way to work and transit-dependent populations who cannot afford to own a car. However, even though transit-dependent riders are generally a transit agency's most reliable customers, the U.S. transit industry has mostly focused on providing new, expensive high-speed and high-capacity rail and bus services for commuters hoping to lure them out of their cars, much to the frustration of those concerned with equity in transportation who see transit's primary purpose as a social service to our society's economically and socially disadvantaged.[1]

The relevance of social equity in transportation and transit services particularly has only increased since the COVID-19 pandemic reduced transit ridership, mostly among high-income commuters and shows no sign of coming back to pre-pandemic levels anytime soon.[2] Thus, with the collapse of commuter transit ridership, transit is faced with the need to reorient its services towards transit-dependent markets, which will require new and better methods of measuring transit service equity.

This report reviews existing policies and practices related to transit equity measurement which consider regulatory requirements addressing Title VI of the 1964 Civil Rights Act and specific metrics used for cost-benefit analysis. The sources and case studies reviewed include federal laws and regulations, metropolitan planning organization (MPO) and transit agency policy documents related to Title VI and other equity concerns, and academic research papers and reports on equity measurement.

The report summarizes current equity measurement best practices to help Caltrans and California's transit agencies develop solutions to social inequities. Agencies can leverage this information to improve their understanding and measurement of transit equity impacts. The research team conducted a literature review and interviews with several organizations and agencies to capture current thinking surrounding transit equity. Caltrans requested that the research team summarize the issues related to secondary displacement caused by capital investments and identify and review strategies for mitigating secondary displacement risk. The report identifies the need for new equity metrics related to transit service, operations, process, and secondary displacement.

2. Literature and State of the Practice Review

Transit equity measurement research and practice literature provide information on the different ways the transportation profession has defined equity.

2.1 Defining Equity and Implications for Measurement

The literature shows that just as there are many ways to define equity in transportation, there are many ways to measure it as well. A good example at how definitions are multifaceted and therefore, difficult to measure, is found in the definition used by Los Angeles Metro, the transit agency for Los Angeles County. They embrace the importance of developing a clear, measurable, and actionable definition that addresses the multifaceted nature of equity as relevant to both the procedures and outcomes of government:

> At Metro: Equity is both an outcome and a process to address racial, socio-economic and gender disparities, to ensure fair and just access—with respect to where one begins and the capacity to improve from that starting point—to opportunities, including jobs, housing, education, mobility options and healthier communities. Equity is achieved when one's outcomes in life are not predetermined, in a statistical or experiential sense, on their racial, economic or social identities; and it requires community-informed and needs-based provision, implementation and impact of services, programs and policies that reduce and ultimately prevent disparities.[3]

This and other definitions typically build on the definitions of equity and social justice as conceived by the federal government.

2.1.1 Title VI of the 1964 Civil Rights Act: The Federal Government's Functional Definition of Equity

To ensure federal regulatory and legal compliance, transit agencies, metropolitan transportation organizations (MPOs), state departments of transportation (DOTs), and the U.S. DOT are required to, at a minimum, adhere to the definition of equity in Title VI of the 1964 Civil Rights Act.[4] While the word equity is not explicitly used in this document, Title VI has served as the foundation for building equity definitions, measurement techniques, and policies for enhancing equity in the U.S. ever since. Based on this authorizing legislation and subsequent related executive orders,[5] the Federal Transit Administration (FTA) has defined the specific requirements for transit and associated agencies to comply with Title VI,[6] which says,

> No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving federal financial assistance.[7]

While Title VI is written in the language of a regulatory mandate, it also serves as a definition of equity by framing its key areas of concern: protection from discrimination from any program or activity receiving federal funding.

Specific to transportation, the U.S. DOT has stated that Title VI regulations require that recipients of federal transportation funding cannot use "criteria or methods of administering its program which have the effect of subjecting individuals to discrimination based on their race, color, or national origin."[8] Thus, Title VI and its related U.S. DOT regulations focus on equitable outcomes—if the effects of policies and practices are discriminatory, then they are in violation of Title VI.[9] Since discrimination can take many forms, Title VI's sole focus on "race, color, or national origin" seems narrow compared to subsequent equity-related definitions that have been articulated in the years since.

Title VI, Equity, and Environmental Justice

To address a wider range of equity concerns and impacts (and thereby expanding the definition of equity as well), President Bill Clinton's 1994 Executive Order (EO) 12898, focusing on environmental justice, is often seen to play a complementary role to Title VI, adding to the federal government's Title VI implicit definition of equity as described above. While Title VI focused on the disproportionate and discriminatory effects of federal funding, EO 12898 broadened the list of potential impacts to specify that the benefits of federally funded projects to a community should not be "purchased through the disproportionate allocation of its adverse environmental and health burdens on the community's minority."[10] In effect, this EO expands Title VI's definition of equity beyond the consideration of the disproportionate and discriminatory allocation of benefits from a project, program, or activities to include their adverse impacts as well. If there are disproportionate adverse impacts, the project sponsor must determine that there are no "practicable" alternatives for the project to continue.[11]

In part, it is the EO's definition of what is practicable that provides us with a clearer understanding of Title VI's definition of equity, how to evaluate it, and how to mitigate disproportionate (i.e., inequitable) impacts of federally funded activities.

> In determining whether a mitigation measure or an alternative is "practicable," the social, economic (including costs) and environmental effects of avoiding or mitigating the adverse effects will be taken into account.[12]

In effect, this EO requires federally funded agencies to measure the social, economic, and environmental effects of their policies, programs, and activities. If there is a disproportionate or discriminatory effect, then the social, economic, and environmental effects of alternatives must be measured and compared.

Nevertheless, the scope of who should be considered in equity-related policies and procedures remained narrow, mostly focusing on race, color, and national origin. Furthermore, in the years

leading up to Clinton's EO issuance, and in the years after, there was increasing criticism of the limitations of the federal government's definition and requirements for analysis of equity.

The Shortcomings of Title VI

The research and professional literature on Title VI (and its accompanying EOs and U.S. DOT regulations) have identified two ways that Title VI implementation tends to fall short of its original intent. First, Title VI allows for local agencies (hereafter referred to as "locals" or "recipients") to define and measure equity according to their own standards. This tends to cause confusion and allows locals to avoid actions that would reduce harm to underprivileged communities. Second, Title VI does not require locals to identify and address existing inequities, but only those resulting from federally funded policies and projects in the future. Therefore, it does not directly address past inequities, only focusing on preventing recipients from making things worse.

Title VI Shortcomings: Local Choice and the Ambiguity of Transit Equity

Because Title VI and the FTA allow transit agencies to design and conduct their own evaluation methods, implementation can fall short.[13] According to Buchanan and Rivera (2020), the mechanism that checks whether locals are evaluating equity impacts properly "is rife with flaws," including the "autonomy for agencies to decide when the check is needed and how to interpret the results."[14] Indeed, Section 602 of Title VI explicitly grants agencies the authority to implement the provisions of Title VI with their own methods for measuring equity as long as they are generally consistent with the statute.[15] Administrative requirements from the U.S. DOT on Title VI compliance confirm the broad scope of a local agency's discretion to define equity by explicitly requiring locals to perform analytical assessments of investment impact, but offer no specific guidance on how to conduct them.[16]

Therefore, Title VI effectively grants local agencies the ability to define equity as well. At times, this deference to locals has arguably served to undermine the original intent of Title VI.[17] According to Buchanan and Rivera (2020):

> For an industry where numbers drive most decisions, Title VI is a comfortable, rubber-stamped method to meet the federal equity mandate with handy population data. But Title VI also invites transit agencies to conduct one un-nuanced analysis and feel absolved from additional labor to achieve equity in their system—at the expense of their riders.[18]

Title VI requires transit agencies to define what constitutes a major (i.e., significant) service change that would warrant an equity review. Major service changes must be established through the identification of technical evaluation thresholds that are applied during the evaluation process to determine if a proposed project, policy, or activity will have a "disparate impact" on communities of color or economically disadvantaged communities.[19] However, Title VI does not specify any

quantitative thresholds for identifying disparities. Therefore, it is left up to locals to define their own thresholds.

According to Yan (2013), the FTA's 2007 Circular suggested recipients (e.g., transit agencies) should evaluate disproportionate effects on minorities (Black, Indigenous, and people of color, or "BIPOC"), potential mitigation measures for these effects, and project alternatives. Nevertheless, the 2007 Circular still lacked specificity and enforceability, and according to Yan, "allowed recipients to pass off meaningless statistics in the place of a true analysis."[20]

For example, Yan (2013) looked at the 2009 case of *Urban Habitat Program v. Bay Area Rapid Transit* (BART), where BART was in the process of designing its Oakland Airport Connector (OAC) rail extension between the Coliseum BART station and the airport's passenger terminals. The project's opponents challenged the project based on its high-cost relative to other equally effective alternatives and the fact that the project would run through a predominantly Black neighborhood without providing any primary benefits to it.[21]

To avoid this charge, BART's chosen evaluation procedure for their OAC project only compared the estimated travel times on the rail connector for minorities (BIPOC) and non-minorities.[22] This limited analysis framework suggests that BART used a definition of equity that was designed to meet the bare minimum of Title VI's requirements. In effect, they adopted a definition and associated evaluation methods that met the letter of the law but not the spirit.[23] Subsequently, the U.S. DOT issued updated guidelines in 2012 that sought to balance the original intent of Title VI with locally determined definitions and measurement techniques for equity. The FTA Circular 2012 mandates a "disparate impact test" that requires locals to "engage the public in the decision-making process to develop the disproportionate burden policy."[24] In doing so, the U.S. DOT effectively acknowledged that the definition and methods of equity are inherently flawed unless they are developed by and reflective of the values and concerns of the communities affected by the project.

However, Circular 2012 provides additional definitions related to equity that Title VI and the Environmental Justice EO do not. It explicitly defines the term "minority" as a person who is: "African American, Hispanic or Latin, Asian American, American Indian or Alaskan Native, or Native Hawaiian and other Pacific Islander." It also defines "low-income" as a person whose median household income is at or below the Department of Health and Human Services' poverty guidelines.[25] The Circular defines "adverse effects" as "the totality of significant individual or cumulative human health or environmental effects, including interrelated social and economic effects."[26] It also defines adverse impacts that result from a project or program that divides communities as "isolation, exclusion or separation of minority or low-income individuals within a given community or from the broader community."[27] Finally, it defines a "disproportionately high and adverse effect" as one that is either: "(1) [...] predominantly borne by a minority population and/or a low-income population, or (2) will be suffered by the minority population and/or

low-income population and is appreciably more severe or greater in magnitude than the adverse effect that will be suffered by the non-minority population and/or non-low-income population."[28]

Despite lingering criticism of Title VI and its associated policies and procedures, these FTA Circular documents manage to broaden the working definition of equity to include low-income populations. While this step forward is modest, it paves the way for the consideration of other disadvantaged groups that can and (some would say should) be considered in equity analyses.

Measuring the Ambiguous: Transit Equity is Hard to Quantify and Compare

Further complicating the picture of measurement for Title VI compliance is the ambiguity of transit benefits and costs compared to other services and infrastructure. The courts have made the importance of measurement clear: for plaintiffs to be successful in challenging Title VI compliance, they need to find a measure that appropriately assesses the disparate impact of the policy in question.[29]

However, the courts have mostly ruled in favor of transit agency defendants, partly due to the ambiguous nature of transit services, their benefits, and costs. According to Yan (2013), while the benefits of housing or jobs tend to be relatively uniform, transit services often bring a mixture of benefits and costs that vary from case to case and are also different for various groups.[30] This makes consistent and unbiased measurements of equity impacts difficult. Indeed, except for the Bus Riders Union case in Southern California (the rare case where the plaintiffs won), each side in these cases typically provides its own competing metrics to compare transit services and funding allocations. As a result, the courts have been largely skeptical about transit Title VI cases and typically rule for the defendant (i.e., the transit agency).[31]

As the plaintiff in the *Darensburg v. Metropolitan Transportation Commission* (MTC) case (where the plaintiffs lost) said, comparing the equity of transit services is "more an art than a science."[32] This case provides a useful illustration of the difficulties plaintiffs face when challenging transit agencies on the grounds of Title VI discrimination using equity metrics. The plaintiff's case compared the benefits of transit service expansions across the largest seven San Francisco Bay Area (MTC's jurisdiction) transit districts using a vehicle revenue-miles (VRM) metric. They claimed that since the districts with more minority ridership reduced services and those with less minority riders expanded them during the same period, there was a discriminatory disparity in the MTC's priorities in how it allocated transit funds. However, the court dismissed the claim, saying the VRM does not distinguish between the effects of the MTC's supposed discriminatory funding policies and practices, and other factors beyond the MTC's control, such as the service choices made by the operators, topography, and geographic/demographic changes within service areas—i.e., the context, as discussed below.[33]

Measuring the Ambiguous: Comparing Transit "Apples" and "Oranges"

It is notoriously hard to compare the equity impacts of different transit modes (e.g., buses versus rail) or even the same mode in different urban contexts. According to Accuardi (2018), this shortcoming is clearly illustrated in the nation's largest transit market, New York City. While New York's East Side Access project was estimated to attract 162,000 daily trips at a cost of $10 billion, the city's two million daily bus riders "compete for budgetary table scraps."[34] Accuardi suggests, therefore, that even with Title VI, federal tax dollars regularly flow to projects that tend to widen the transit service equity gap between high-income suburban rail commuters and low-income bus riders.[35]

The reach of Title VI can be relatively short as transportation systems across the country increasingly rely on state or local funding. Taylor (1991) points out that as federal funding subsidies for transit operations have fallen over time, supporting transit has increasingly fallen on local and state shoulders. As a result, the influence of Title VI and its protections for racial minorities (BIPOC) and low-income groups has eroded as well. Taylor provides an example of these correlated trends by evaluating the equity impacts of California's Transportation Development Act (TDA). While the TDA became a principal source of transit operating subsidies in California, Taylor shows that the TDA's per capita formulas favored suburban transit services over higher ridership services in California's more urban areas. For example, at the time when this study was conducted, San Francisco's transit riders received a TDA subsidy of $0.13 per trip, while Livermore's riders (a San Francisco suburb) received over $5.00 per trip. As a result, in post-TDA California, suburban transit operators were relatively well-funded and expanded their services, while high-ridership, urban transit providers faced funding shortfalls and were forced to cut service.[36]

A more recent study suggests that the passage of time has done little to rectify these inequities in the Bay Area. Mayer and Marcantonio (2010) claim that while MTC (the defendant in the Darensburg case) is aware of the historical racial and income disparities in the region's transit system, they (and by implication, the federal government's Title VI) perpetuate these inequities by giving wealthier, suburban rail riders a greater subsidy per trip (e.g., BART received a subsidy of $6.14 and Caltrain received $13.79 per trip) than it gave to inner city AC Transit bus riders ($2.78 per trip). As a result, while AC Transit services have declined over the years, even as fares have increased, services for the region's rail riders have continued to expand.[37]

Thus, just as the technical aspects of different modes and their benefits, costs, and subsidies are notoriously difficult to compare, the equity implications of these differences can become difficult to understand as well.

Title VI Shortcomings: The Past is the Past, Focus on the Future

Critics of Title VI claim that it focuses on future inequities and does not consistently address those from the past.[38] As a result, Title VI and the nation's transit agencies tend to turn a blind eye to

the history of inequitable transit services.[39] Since Title VI is primarily designed to limit further harm to disadvantaged communities rather than advancing equity by redressing past wrongs,[40] critics such as Accuardi (2018) say that transportation leaders have been allowed to turn "a blind eye" to the systemic inequities that their own programs and policies now perpetuate.[41]

This lack of focus on past inequities is likely the result of Title VI's previously mentioned deference to locals' definitions and consequent measurement approaches; without a clear and consistent definition that includes past inequities, they will not be measured and are unlikely to be addressed. Therefore, Marcantonio et al. (2017) recommend requiring a cumulative impact approach to equity analysis, wherein the effects of past transportation projects will be captured and allow analysts to highlight existing disparities, as well as how the current project or plan will play a role in improving them.[42]

Title VI Shortcomings: Overlooked Disadvantaged Groups

While Title VI represents a critical breakthrough in how the government addresses equity, it does not explicitly identify a comprehensive list of potentially disadvantaged groups. Title VI certainly took a big step forward by mandating the consideration of inequitable governmental actions towards minority groups; the FTA included a mandate for considering low-income groups as well. But there are other groups equally worthy of consideration and protection, groups such as senior, low-literacy, foreign-born, and disabled populations, and, specific to the transportation realm, transit-dependents.[43]

Fortunately, President Clinton's Environmental Justice Executive Order (12898) moved the government further towards addressing these groups overlooked by Title VI, directing federal agencies—specifically MPOs—to develop public participation plans that describe procedures, strategies, and desired outcomes addressing the needs of "traditionally underserved" populations such as those listed above.[44] However, these directives seem primarily focused on representative public participation in decision-making processes, and they have yet to be adopted into formal mandates from the FTA to transit agencies when analyzing the disparate (minority) and disproportionate (low-income) impacts of service changes, for instance. Therefore, these other traditionally underserved populations only receive analytic attention (using metrics) when there is a desire to do so on the part of transit agency staff, decision-makers, or outside activists/advocates. According to Accuardi (2018):

> Title VI provides a floor, not a ceiling. At transit agencies with a goal to make their cities and regions more inclusive places to live, board members should strive to ensure that social justice is central to their agency's everyday practices.[45]

In terms of measurement, Accuardi (2018) points out that while there are no clear mandates yet requiring transit agencies to analyze these and other traditionally underserved populations, transit agencies currently possess the tools and expertise required to do so—only political will is needed to make them.[46]

2.2 Definitions of Substantive and Procedural Equity

Title VI is focused on preventing disproportionate impacts (benefits and costs) which could create transit inequities in the future and is limited in its value because it does not directly address existing or past transit inequities, only the prevention of new ones.

Rather than trying to "fix" Title VI, it may be more productive to broaden the scope of the transit equity evaluation process to focus on identifying and measuring the inequities which currently exist in our transit systems and developing methods for reducing or eliminating them. These interventions can be approached from two angles: substantive and procedural equity.

2.2.1 Substantive Equity

According to Yan (2013), substantive equity is measured by the distribution of benefits and costs of the transit planning process. Therefore, substantive equity is the equitable distribution of transit benefits and costs (or negative impacts) on the community.[47]

Substantive equity can either be in the form of horizontal or vertical equity. Horizontal equity is a form of substantive equity where people with comparable needs are treated equally. Comparable individuals and groups are treated the same in the distribution of benefits and costs.[48] Vertical equity (also called environmental justice) is a form of substantive equity that allocates transit benefits and costs in a manner favoring disadvantaged people. Vertical equity in transit focuses on providing access and mobility to all users, including those with special needs.[49]

Horizontal and vertical equity in transit services pursue different goals. A primary goal of horizontal equity can be to achieve comparable shares of public investment for all transit riders, including both elective riders and transit-dependent riders. A primary goal of vertical equity can be to provide basic accessibility for physically, economically, or socially disadvantaged riders in a manner that is affordable to all disadvantaged riders. In addition, this vertical equity goal can also include ensuring the needs of riders with disabilities or other special needs are fully accommodated.

These goals for horizontal and vertical equity in transit can conflict with one another. For example, horizontal equity goals could necessitate that all transit riders share equally in the cost of transit services, while vertical equity goals could require that additional public subsidies be provided for transit services to disadvantaged riders.

2.2.2 Procedural Equity

Yan (2013) defines procedural equity as equal access to the decision-making process and the ability to participate in a meaningful way. Procedural equity therefore describes equal treatment in a decision-making process that is without discrimination and equal representation in the decision-making bodies that allocate transit resources.[50]

Striving to achieve procedural equity by providing equal access and treatment for physically, economically, or socially disadvantaged riders in the decision-making process for transit services can necessitate significant changes in the way that MPOs and transit agencies handle public outreach and involvement. However, providing equal representation for the decision-making bodies that allocate transit resources and govern transit services can be even more challenging. According to Yan (2013), disadvantaged transit riders are often underrepresented on the governing bodies for MPOs and transit agencies.[51] One study found that 92 percent of the central cities surveyed with more than 200,000 residents were underrepresented on MPO governing boards.[52] It would also appear that there is a similar level of underrepresentation of disadvantaged transit riders on the governing boards of transit agencies.[53]

Correcting these inequities can require changing the composition of the governing boards for MPOs and transit agencies, an effort that can prove quite difficult. Marcantonio et al. (2017), for example, recommend that MPO board members should be directly elected to make them accountable to regional constituencies, as opposed to the current practice of most MPOs that typically appoint one member for each constituent local government jurisdiction.[54]

2.2.3 Implications of Equity Definitions for Measuring Transit Equity

The definitions of substantive equity, including vertical and horizontal equity, are the best places to start when looking to identify methods for measuring substantive equity for transit services. For horizontal equity, the measurement tools or metrics must be useful in determining whether all transit users with comparable needs are treated equally. For vertical equity, the measurement tools must be useful in determining whether full transit accessibility has been provided for all physically, economically, or socially disadvantaged riders.

Defining procedural equity for transit riders as equal access to, equal ability to participate in, and equal representation in the decision-making process has significant implications for measuring procedural equity. In selecting tools for measuring procedural equity, analysts must determine how best to measure the effectiveness of public outreach, public engagement, and public input for disadvantaged communities and populations. More specifically, they need to determine:

1. Public Outreach:
    a) How to measure the effectiveness of public outreach to disadvantaged communities and populations.
    b) How to determine which methods of public outreach are working and which are not.
2. Public Engagement:
    a) How to measure the level of engagement from disadvantaged communities and populations.

b) How to determine which methods of public engagement are working and which are not.

c) How to determine whether advisory committees provide an effective means for public engagement.

d) How to measure the effectiveness of collaboration with community-based organizations.

3. Public Input:

a) How to measure public input provided by disadvantaged communities and populations.

b) How to measure the degree to which public input is taken into consideration.

c) How to measure the overall impact of the input from disadvantaged communities and populations on the decision-making process.

In addition, the measurement tools for procedural equity also must be able to determine whether disadvantaged communities and populations are equitably represented on the governing bodies or whether there are distinct voting power disparities. Are disadvantaged communities and populations underrepresented on governing bodies, and if so, how much?

2.3 Equity Measurement: Practical and Academic

This section begins with an overview of the state of the practice in transit equity measurement, with particular emphasis on the methods used to meet Title VI and its associated requirements. It then moves on to discuss several areas where practitioners and academics have gone beyond the Title VI requirements and have developed metrics to capture inequities that have not been reliably detected using standard methods. Finally, this section gives an overview of the inequities in the state of the practice's measuring procedures.

2.3.1 Transit Equity Metrics: State of the Practice

Martens et al. (2019) describe the key components of a transportation equity measure by first proposing a straightforward definition of equity as "the morally proper distribution of benefits and burdens over members of society."[55] Based on this definition, they identify three key components of equity that a measurement system should reflect, revised here to apply to transit:

1. The benefits and costs that are distributed by transit are identified and counted.

2. The populations and social groups that transit distributes its benefits and costs to are identified, differentiated, and counted.

3. The yardstick or distributive principle that determines whether or not a given transit service distribution is considered "morally proper" is identified and compared to the actual or forecasted distribution of transit if it is/will be an equitable distribution.[56]

The challenge confronting anyone attempting to measure equity—and specifically, transportation equity—is to create a measurement system that adequately captures each of these three components and, importantly, the interrelationships between them.[57] Each of the metrics that will be discussed here are organized into groups reflecting the first of Martens et al.'s (2019) three components: the benefit or burden being distributed.

Transit Service Supply Equity Metrics

There are many options available for metrics measuring transit supply because they have been developed and routinely used in transit agency planning and operations activities. As a result, it can be a relatively simple task to modify many of these metrics to focus on transit supply (and a lack thereof). According to Karner (2018), these commonly used measures of transit supply—such as average proximity to transit stops, service coverage, transit network coverage, and average transit vehicle headways—are easily combined with demographic data for the service area being analyzed to yield a useful transit equity metric.[58]

This literature review breaks transit supply equity metrics into three categories:

- Transit Needs Equity
- Transit Service Change Equity
- Transit Level of Service Equity

Transit Service Supply Equity Metrics: Transit Needs Equity

Identifying the need for transit for neighborhoods, corridors, cities, or other geographical areas is a long-standing practice in transit planning and operations. Increasingly, transit's benefits have been linked to positive economic, health, air quality, and climate outcomes that make identifying needs for transit an equity concern as well.[59] Therefore, one approach to linking equity to transit needs is to make these more traditional metrics more sensitive to equity.

Transit need is often correlated with poverty, the lack of access to other reliable forms of transportation, the lack of affordable housing, and discrimination-based indicators such as the concentration of ethnic minorities (BIPOC) in a neighborhood.[60] Therefore, the commonly used

and straightforward measures (and example metrics) for identifying transit needs within a community include:

- Zero-vehicle households: percentage of households with no vehicle available
- Poverty: percentage of households in poverty
- Unemployment: percentage of working age population unemployed
- Transit access: percentage of population within 0.5-mile of fixed-route transit stop/station
- Disability status: percentage of civilian non-institutionalized population with disability
- Housing cost burdened: percent of households spending >30 percent of income on housing[61]

While these metrics have the important advantage of being relatively easy to find data for and calculate, they also tend to be limited when it comes to capturing the nuance and complexity of how transit, urban form, and equity interact in the real world. Recognizing these shortcomings, practitioners and researchers have worked to develop more sophisticated and sensitive metrics capable of capturing these nuances.

For example, transit equity advocates in Houston, Texas developed the Transit Equity Demand Index (TEDI) for their "Equity in Transit: 2018" report. TEDI is designed to identify locations in need of further transit investment. These "high-demand areas" are identified by measuring fifteen different indicators, such as population density, vehicle availability, and the total number of households living in poverty. These fifteen socio-economic-environment indicators are evaluated at a census block group level and are categorized into three distinct categories: fundamental demographic demand, likely higher transit use, and human and built suitability. All indicators are weighted equally and standardized to a common scale of measurement,[62] indicating that the analysts consider each indicator to play an equal role in determining equity.

In an April 2018 resource paper intended to increase transit mode share in cities, the National Association of City Transportation Officials (NACTO) published a set of best practices for measuring transit performance. One of the paper's performance measures focused on how transit infrastructure impacts public places. NACTO titled this "Measures for Transit Streets as Public Space," and it included a metric that calculates the percentage of system-wide bus stops with shelters and other amenities. According to the paper, comfortable transit shelters and waiting areas are critical parts of the network and help define public spaces. As such, equity must be considered so that all communities are provided high-quality waiting areas in the public right of way. The metric can be used in conjunction with data on the demographic characteristics of the transit

system's riders, and in doing so, "is a simple and effective method to assess stop quality and equity."[63]

For its 2018 Regional Transportation Plan (RTP), Oregon Metro used five evaluation measures to assess its transportation investments strategy. One of the measures was Access to Travel Options—Systems Completeness and Connectivity. This measure focused primarily on access to active transportation infrastructure and roadway connectivity. That said, it also evaluated access to transit. Specifically, Oregon Metro used ArcGIS to "calculate the linear miles and percentage of sidewalks and bikeways completed within 1/2-mile from light rail stops, 1/3-mile from streetcar stops, and 1/4-mile from bus stops; existing and planned stops region-wide within the MPA boundary and in historically marginalized communities."[64] For its RTP investment strategy, Oregon Metro determined access to transit based on the amount of active transportation infrastructure in an area, and not transit coverage or frequency. Oregon Metro can leverage this Access to Travel Options measure to identify where there might be an inequitable distribution of infrastructure investment.[65]

Fan and Li (2019) combined and compared transit supply and demand in a single index score to help identify locations with transit need gaps. Their Transit Gap Index (TGI) measures transit supply by combining spatial (physical location) and temporal (time of day) transit services available in a neighborhood, combined with measures of local transit demand as measured by demographic features.[66]

The Boston region's MPO, the Metropolitan Area Planning Council (MAPC), developed the annual travel time disparity metric as part of the organization's Regional Indicators Project, which aims to measure the progress of long-range regional plan goals. This metric evaluates annual travel time disparity across different population groups for car drivers, as well as bus and subway riders. The metric is also used by the Livable Streets Alliance to emphasize that public transportation agencies must do more to address inequities that persist across the transit system.[67]

Pursuant to Martens et al.'s (2019) third "yardstick" component, one problem with the standard metrics discussed above is the lack of any threshold or standard of significance. In other words, it is difficult to tell when a metric score should be considered inequitable. To help address this need, several researchers have employed the use of needs gap analysis tools, which combine metrics of transit supply with metrics of transit demand to give an aggregated, unified transit need index score for populations and geographical areas.[68]

Carleton and Porter (2018) employ the three common equity analysis methods—needs gap, Lorenz curve, and Gini coefficient analysis.[69] Their findings highlight some of the pitfalls of transit equity analysis in general and needs gap analysis approaches in particular.

First, the aggregation of supply and demand metrics, geographic, and demographic groups into a single index score can hide bias and unknowingly lead to biased interpretations. Therefore, in terms of allowing practitioners and researchers to better understand the equity implications of transit-

related decision-making, a needs gap analysis cannot provide information on impacts to different population groups because "the equity experienced by the constituent disadvantaged groups cannot be separated, i.e., it could be that some groups experience greater inequity than others, but this information is lost in the aggregation."[70] Second, this bias can influence methodological and policy decision-making.[71]

Methods, such as the Lorenz curve and Gini coefficients, that graphically (Lorenz curve) and numerically (Gini coefficient) show the difference between the subject population and a reference population,[72] address some of the shortcomings of needs gap analysis. The Gini coefficient is a statistical measure of dispersion, often used to represent wealth inequalities and sometimes used in tandem with Lorenz curves. A Gini coefficient value of zero represents perfect equality, while a value of one represents maximum inequality.[73]

Lorenz curve analysis requires that "the cumulative proportion of a transit supply is mapped to the cumulative proportion of the disadvantaged population metric, thereby creating a Lorenz curve."[74] According to Carleton and Porter (2018), the benefit of a Lorenz curve method for transit equity analysis is that it is easy to measure the supply of transit services provided to different subgroups (percentiles) of the population. That said, "[a] limitation of the Lorenz curve method is that the results are spatially disassociated, and additional analysis is required to understand the spatial implications."[75] Therefore, an inspection of the Lorenz curve can tell you if there is an inequity but not tell you where it is located geographically. Overall, compared to a needs gap analysis, a Lorenz curve is more accurate at measuring the potential impacts on different population groups. According to Carleton and Porter, the best equity analyses incorporate both a needs gap and a Lorenz curve analysis.[76]

In comparing the Gini coefficient, Lorenz curve, and needs gap analysis methods, Carlton and Porter (2018) conclude that Gini/Lorenz methods are best if the analyst's goal is to make equity comparisons between groups or study areas, while needs gap methods are most effective when the detection of spatial patterns of inequity within a study area is required. However, their results indicate the fullest and most detailed description of transit equity seems to be possible with the combined use of the two methods.[77]

Mishra et al. (2018) used the Gini coefficient to compare study and reference populations in concert with a set of chosen equity metrics. Ultimately, the study's objective was to determine which communities had the greatest transit needs and to generate a plan to increase accessibility for transit-dependent riders. To evaluate equity, the researchers calculated a Gini coefficient based on four socioeconomic factors. The resulting metric is referred to as the Inequity Index and includes household income, vehicle ownership, employment density, and population density, while current and future (predicted) transit performance is measured by developing "connectivity indices at [the] stop, route, and zonal level by considering various factors such as speed, frequency, operational capacity, fare, route origins and destination, and urban form characteristics that serve the transit system."[78]

Transit Service Supply Equity Metrics: Transit Service Change Equity

While transit service changes—where routes are changed or service frequencies are increased or decreased—are often motivated by the perception of a change in transit needs, their outcomes can either help or hinder the cause of transit equity. As a result, the standard metrics used by transit operators to address the equity needs of a geographical area can be insensitive to the mobility and accessibility needs of low-income populations and communities of color (BIPOC communities). Therefore, recent years have seen the development of transit service change equity metrics that are sensitive to a broader array of equity impacts resulting from changes in transit services than those developed to meet the basic requirements of Title VI analysis.

However, often, the choice of metrics is not as consequential for the equity impacts of service changes as is the selection of the significance thresholds and the methods used to determine their population of study. A rare example of a threshold set at the federal level can be seen in the FTA's regulations for Title VI service change analysis which require transit agencies that operate fifty or more peak service, fixed-route vehicles located in a Census-designated urbanized area (UZA) of 200,000 or more to perform an equity analysis for any major service change.[79] However, since Title VI and the FTA requirements for transit service change equity analysis cede the development of the definition, metrics, and impact thresholds for measuring and identifying discrimination to the locals,[80] there is a wide variety of approaches and metrics employed by practitioners. Transit agency approaches to equity measurement tend to favor metrics that give them the maximum flexibility to adjust their service levels to suit their policy goals, albeit within political constraints and responding to advocacy pressures of their local political environment.

According to research by Karner and Golob (2015), the choice of metrics and the data are critical to capturing and understanding transit service change equity impacts. Their findings suggest that Census-based (service area-based method) metrics are more likely to identify the discriminatory impacts of service cuts, while metrics based on onboard surveys (a ridership-based method) are better at revealing the discriminatory impacts of service improvements.[81]

Transit Service Change Equity: Ridership-Based Methods

Marin Transit in the San Francisco Bay Area—serving a largely transit-dependent ridership in a high-income, white, suburban county—uses the following metrics to determine disparate (race-based) or disproportionate (income-based) equity impacts of service changes:

- Change in *transit revenue hours* > 30 percent;
- Change in route > 40 percent route's path over a three-year period; or
- New service on streets not previously used by any route.[82]

Marin Transit uses these metrics to determine when a service change is likely to be "major," in compliance with FTA's requirements, and to determine whether those major changes will have disparate or disproportionate impacts. Before determining whether these impacts will occur, the transit agency must decide on what population it will measure. In Marin Transit's case, they prefer measuring impacts on their own riders using their regular onboard survey data, whenever possible. If survey data is unavailable or does not include data for riders of a proposed service expansion, Marin Transit will use U.S. Census data from their route service areas.[83]

The Valley Transportation Authority (VTA), the transit service provider for California's Santa Clara County, also uses riders (as found in their most recent onboard rider survey) as the basis for determining when a major service change is discriminatory. According to VTA's Title VI analysis policies, a major service change is identified and determined to be discriminatory when its impacts affect 10 percent more of their minority or low-income riders compared to the general population of riders, measured by the following metrics:[84]

- establishment or elimination of a transit line or service;
- route change affecting 25% or more of a line's *route-miles*;
- span of service or frequency changes affecting 25 percent or more of a line's *revenue vehicle-hours*;
- a series of changes on a single route that are included in the two-year Transit Service Plan and cumulatively meet any of the above criteria;
- proposed changes that are anticipated to be controversial with a particular community or interested parties based on public feedback; or
- a system-wide change concurrently affecting 5 percent or more of the *total system revenue-hours*.[85]

The Port Authority, the transit agency for the Pittsburgh, Pennsylvania metropolitan area, explicitly recognizes the significant implications of measuring ridership versus service area population. According to their Title VI analysis guidelines:[86]

> …the Authority may elect to establish comparison populations based upon either ridership data or the population data of a service area. Justification for selection of a ridership data comparison or a service area population comparison must be documented.[87]

The Port Authority uses the following metrics to determine what will be analyzed as a major service change, and then uses those same metrics to measure the disparate and disproportionate impacts on their ridership (or when the data is unavailable, their service area neighborhoods):[88]

- addition or removal of a route;
- addition or removal of a service day for a route;
- service changes that constitute an addition or reduction of more than 30% of the *weekly trips*, *service-hours*, or *service-miles* on a given route; and
- adding or removing more than 2,500 *annual hours of service* on a given route.[89]

Transit Service Change Equity: Service Area-Based Methods

Metrics that focus on measuring the effects of service changes on the minority and low-income people living, working, shopping, and recreating within their route service area neighborhoods can yield a very different picture of potential discriminatory effects from a transit agency's planned service changes.

For example, AC Transit in the San Francisco (East) Bay Area uses the following metrics, comparing people of color populations to non-Latino white populations in their route service areas (or riders):

- *Vehicle load (load factor)* for each mode: number of passengers divided by number of seats.
- *Vehicle headway* for each mode: weekday peak vehicle frequency.
- Service availability for each mode: the *hours of operation* for routes.[90]

When these metrics indicate that people of color (or low-income riders) experience 15 percent or more of the adverse effects of a service change to AC Transit operations compared to non-Latino white populations (or non-low-income riders), the proposed service change will be considered to have a disparate (or disproportionate) impact for Title VI purposes.[91]

The San Diego Metropolitan Transit System (MTS) also favors using service area-based methods for determining disparate and disproportionate impacts. Their analysis uses the following metrics to compare minority or low-income population percentages in the adversely affected service area to the minority or low-income percentages in the system service area:[92]

- A change that is greater than 25 percent of a route's *weekly in-service miles* or *hours*.
- An increase or reduction in the average *weekly span-of service* of more than 25 percent.
- The implementation of a new route or the discontinuation of an existing route.
- A routing change that affects more than 25% of a route's *directional route-miles* and more than 25% of the route's bus stops.

The Massachusetts Bay Transportation Authority's (MBTA's) 2017 policy memorandum summarizes the disparate impact/disproportionate burden policy for the Boston metropolitan region's transit agency. According to MBTA, a service change is considered "major" when it meets either of two criteria, using a standard transit industry metric—revenue vehicle-hours (RVH):[93]

- Major service change at the modal level: A change in RVH per week of at least 10 percent by mode.

- Major service change at the route level: For all routes, a change in route length of at least 25 percent or 3 miles; or for routes with at least 80 RVH per week, a change in RVH per week of at least 25 percent.

Once a service change triggers either of the above thresholds, the MBTA then performs a service equity analysis using RVH to determine the scope of the potential equity impacts.[94] It then states that "[i]f the ratio of the impact on minority to non-minority populations or low income to non-low-income populations is more than 1.20 (or 20%), then the proposed change would be determined to pose a potential disparate impact or disproportionate burden."[95]

Transit Fare Equity Analysis

FTA's regulations for Title VI fare change analysis require transit agencies that operate 50 or more peak service, fixed-route vehicles located in a Census-designated urbanized area (UZA) with a population of 200,000 or more to perform an equity analysis for any fare pricing change or change in fare media used (e.g., tickets, tokens, smart cards). Also, as with transit service change evaluations, Title VI and FTA allow transit agencies to determine their own evaluation policies and practices for fare changes. However, while service changes must be "major," any change in fare policies requires disparate and disproportionate burden analyses.[96] Furthermore, in contrast to service change evaluations where FTA guidance is essentially neutral when it comes to choosing between ridership (e.g., onboard surveys) and service area (i.e., census) data, in the case of fare change analysis, the FTA recommends using ridership survey data whenever possible.[97]

Most transit agencies use similar metrics and methods for fare changes to those they use for major service changes, with an analysis of the effects on racial minorities (BIPOC) and low-income populations. For example, Sacramento Regional Transit (RT) measures the effects of fare changes on riders using a 20 percent significance threshold,[98] while AC Transit and MBTA evaluate the equity impacts of fare changes on their riders with more stringent 15[99] and 10 percent[100] thresholds, respectively.

Furthermore, Sacramento RT's threshold uses a less stringent comparison group, measuring fare costs for minority (or low-income) riders compared to all riders,[101] while AC Transit compares minority (or low-income) riders to their white (or non-low-income) riders.[102] Since the average fare for a transit agency's white riders could be substantially different from the average fare for all actual riders, regardless of race, it seems likely that agencies using Sacramento RT's methods will

be less likely to find a significant difference in fare change impacts than an agency using AC Transit's more stringent methods of comparing minority (or low-income) to non-white (or non-low-income) riders.

Transit Fare Equity Analysis: Fare Payment System Change Equity

The FTA also requires transit agencies to perform equity analyses when they make changes to their fare media, even if those changes will have no prima facie effect on fares. Many transit agencies are transitioning from traditional fare media—such as cash, tickets, or tokens—to cashless smart card or smartphone technologies.[103] While these transitions are typically done separately from any change in fares, the research literature suggests that these transitions can have unintended and often unseen equity effects.

For example, Golub et al. (2021) looked at how low-income and senior riders have less access to smartphones, the Internet, and online banking, and therefore, may suffer financially from transitions to these media platforms that also phase out older fare media that disadvantaged groups depend on. Their use of focus groups, surveys, and a review of current transit agency practices found that a transition to a cashless fare system would create significant barriers for lower-income transit riders since many low-income and minority riders do not have access to bank services or reliable smartphone service that new payment technologies depend on.[104] They conclude that continuing to accept cash for fares—particularly onboard cash collection—is an important and effective means to keep transit equitable.[105]

Nancy Whelan Consulting (2013) provided an equity analysis for the Chicago Transit Authority (CTA) to evaluate their proposed conversion to a new fare payment system called Ventra. To evaluate the effects of the conversion, the consultants used a CTA customer satisfaction survey containing racial and income data linked to the CTA's existing fare card trip and transactions database. CTA used the following metrics to determine when the costs associated with changing their fare system are inequitable:

- 10 percent change in the average fare for minority compared to overall riders.
- 10 percent change in the average fare for low-income compared to overall riders.[106]

2.3.2 Transit Equity Metrics: Practical and Academic Advances

According to El-Geneidy et al. (2016), "[s]ocial equity is increasingly incorporated as a long-term objective into urban transportation plans." As such, there is an increasing demand for high-quality, low-cost, and easy-to-use transit equity metrics. There are many standard transit industry metrics that quantify the benefits and costs of transit,[107] but according to Kaplan et al. (2014), few of these adequately capture the dynamic interactions between land use, transit availability, and the geographic distribution of economically or socially disadvantaged populations.[108] To address these shortcomings, some researchers and practitioners have pursued improvements to traditional transit

metrics, expanding their capabilities to hone in on specific groups that previous analysis techniques overlooked or ignored. More common among academic researchers, considerable effort has also been devoted to developing comprehensive and often complex transit accessibility measures.[109]

Measuring Other Traditionally Underserved Populations

Caballero & Ng (2021) point out that it is a prima facia fact that today's transportation systems do not meet the needs of all people. They assert that this equity gap is caused by a lack of good performance metrics through which we can gauge the equity of today's transportation systems. As an example, they specifically focus on gender equity in transit, citing a metric used by the Los Angeles Metro, "… 20% of women avoid a new light rail line due to fear of harassment and other safety concerns."[110]

Aimen and Morris (2012) reviewed the Community Attributed Index (CAI) developed for the Atlanta Regional Commission (ARC) to identify traditionally underserved populations in the Atlanta metropolitan region. The CAI combines census track-level data from 165 variables by using principal components analysis to statistically reduce those variables into five dimensions: economic opportunity, poverty status, educational attainment, housing and population mix, and family stability. The most critical variables (metrics) used to determine these dimension scores were:[111]

- Economic opportunity:
    - Median household income
- Poverty status:
    - Percent female-headed household
    - Poverty rate
- Educational attainment:
    - Percent of 45–59 year olds with some education
    - Percent of people with associate degree
- Housing and population mix:
    - Total households
    - Total housing units
    - Total family housing units

- Family stability:
    - Percent of 45–59 (Age)
    - Percent married households

Gender differences in travel behavior and, as a result, in transit equity have been identified by a number of researchers as an important area for equity metrics and policy development. However, despite this growing attention, very few transportation agencies in the U.S. have developed metrics for analysis and, as a result, the policies, programs, and services to address gender inequities.[112]

Los Angeles Metro is one exception. Metro has placed an emphasis on identifying the transportation equity issues for women and girls by establishing a Women and Girls Governing Council to guide the agency's efforts to measure and understand the unique needs of females on their transit system.[113] Metro (2019) also undertook a study to understand the travel needs and behaviors of women in Los Angeles County, which used the following metrics to understand these unique needs:

- Female-to-male travel behavior comparisons:
    - Number of trips per day by sex/gender (all modes)
    - Average trip length by sex/gender (all modes)
    - Trip purpose by sex/gender (all modes)
    - Car availability by sex/gender (all modes)
    - Average number of trip chains by sex/gender (all modes)
    - Average trip chain length by sex/gender (all modes)
    - Peak period (time-of-day) for traveling by sex/gender (all modes)
- Female transit travel behavior:
    - Percent of riders riding transit 3 days per week or more on average by sex/gender
    - Percent of women riders who bring children on transit
    - Top reasons for women to ride transit
    - Trip purpose for women riding transit[114]

The TransitCenter, a non-profit institute working to "improve transit in order to make cities more just and environmentally sustainable,"[115] has developed a variety of tools to help transit agencies and advocates move beyond Title VI, in particular, by measuring transit equity impacts on single-mother households, essential workers, households below the poverty line, and households without cars. Their online tool for measuring transit equity in select metropolitan areas around the U.S. features several metrics to help transit provide greater levels of equity and sustainability by combining these demographic data with accessibility to jobs, supermarkets, hospitals, and parks (among others) by transit data in a user-defined GIS mapping format.[116]

Transit Accessibility Equity Metrics

Practitioner interest in accessibility metrics has been driven, in part, by dissatisfaction with traditional, less equity-sensitive mobility, and supply-based transportation performance metrics discussed above.[117] For example, Los Angeles Metro identifies equity in accessibility to opportunities as a crucial component of their goal to not only address the inequities of current and future transit projects but to address the inequities of the past:

> While we acknowledge many different definitions of "equity" exist, the Platform is explicit in its focus on the vast disparities in access to opportunity—jobs, housing, health care, and education, to name a few—among many people and communities within Los Angeles County.[118]

Accessibility metrics have similarly long attracted the interest of academic researchers to address the shortcomings of traditional transit equity metrics and methods since they measure how easily transit riders can reach a set of important destinations given their unique transportation and land use configurations.[119] In recent decades, researchers have developed ever more sophisticated accessibility metrics that are capable of capturing many of the factors that interact to determine transit needs equity. They do this by linking data on "the opportunities across space"—i.e., the distribution of important travel destinations such as employment, education, and health care—to measures of travel (in this case via transit) costs.[120] When calculated to specifically target disadvantaged demographic groups or communities, their particular needs (which destinations do they need to travel to), the specific costs they have to pay (both in travel time and fares), and their ability to pay those costs (i.e., income) accessibility metrics have proven themselves as uniquely powerful transit equity measurement tools.[121]

While researchers have developed more sophisticated accessibility metrics that can capture many of the factors that interact to determine transit needs equity, they typically rely on regional travel demand models for key data inputs that are difficult to develop and maintain. In response to this shortcoming, Kaplan et al. (2014) developed and tested an accessibility metric that was simple to calculate using easily obtained public datasets (i.e., the U.S. Census Bureau's Longitudinal Employer-Household Dynamics dataset and transit route and schedule information in the General Transit Feed Specification format).[122]

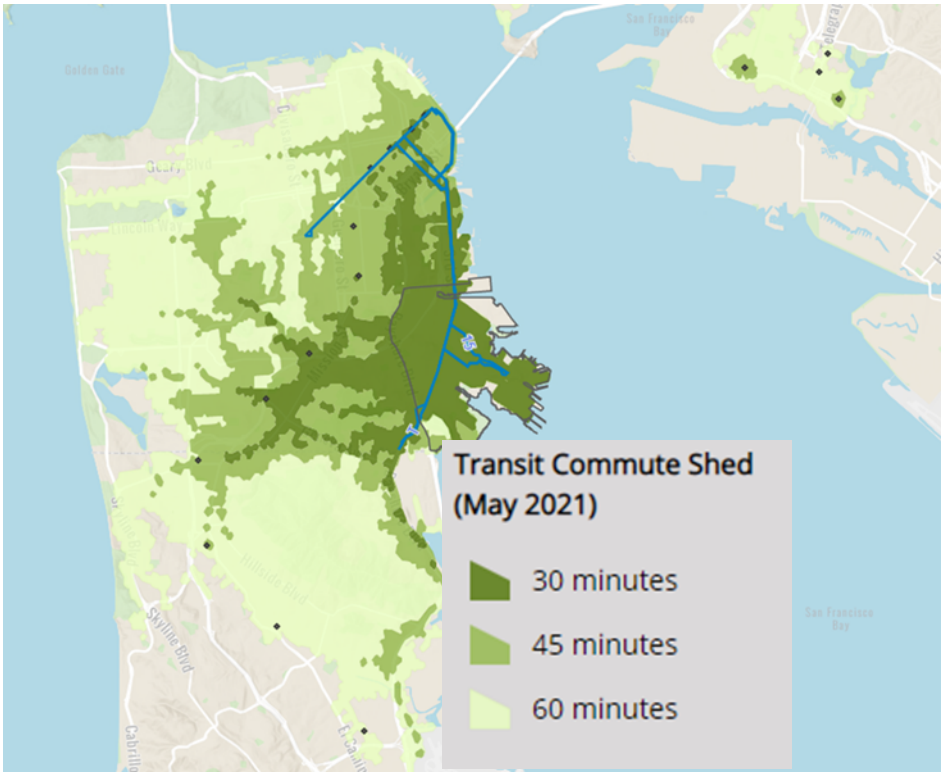
However, while noting the exceptions, like Kaplan et al.'s relatively simple approach, there are generally two types of accessibility metrics that typically rely on data from travel demand models: cumulative opportunity (sometimes called "isochronic") and gravity-based measures.[123] Research comparing the performance of these metrics has found that their performance characteristics are similar,[124] perhaps giving an advantage to the isochronic method since it is generally easier to obtain data for and calculate.

Accessibility Metrics: Isochronic (Cumulative Opportunity)

Isochronic accessibility metrics are calculated by adding all the destinations (either in terms of the number of establishments, building square footage, or number of employees) within a mode-specific, pre-determined travel time of a given origin point (e.g., 30-minutes). A set of lines, called *isochrons*, denote points within a fixed travel time of the given origin. This approach yields an intuitive and easily interpretable count of destinations reachable within a typical travel period.[125] Figure 1 shows an example of isochrons from the Bayview-Hunters Point neighborhood of San Francisco to destinations in the Bay Area. Note the different shadings that denote the various commute shed access times.

Isochronic metrics tend to be popular since they are easier to obtain data for, calculate,[126] and interpret than gravity-based measures.[127] Indeed, since transit agencies usually do not have primary access to a comprehensive travel demand model (which is often required for gravity-based models but may not be necessary for calculating an isochronic metric), they may find that isochronic metrics are more practical for their uses.

Figure 1. Example Isochrons: Transit Commute Shed from Bayview-Hunters Point in San Francisco [128]



In a recent article analyzing transit accessibility equity in Chicago using an isochronic metric, Ermagun and Tilahun (2020) conclude that significant inequities persist across different population cohorts in the city. The research team made several refinements to the isochronic model to focus on equity concerns. First, it measured the complete travel time between origins and destinations, including walking (or other modes) travel times to and from the transit stops—an important consideration when assessing the true costs and burdens of travel, particularly for economically disadvantaged transit riders. Furthermore, instead of evaluating a single destination type (such as hospitals, retail, parks) or a couple of population cohorts, this research assessed six different destinations and nearly a dozen population cohorts. By measuring access to various opportunities such as jobs, parks, groceries, hospitals, schools, and libraries, the authors determined that Chicago's transit system serves some population groups more effectively than others. The most underserved cohort was low-income residents, but they also observed that areas with low accessibility tended to be located with communities with greater proportions of African Americans, Hispanics, Asians, low-income workers, low-educated citizens, and the elderly.[129]

Deboosere et al. (2016) offer a recent example of the potential for modifying isochronic metrics for use in equity analysis, which takes a new approach to measuring transit accessibility by examining financial access to transit and transit accessibility to jobs in Montreal, Canada. Even though fares can be a significant barrier for low-income riders, the inclusion of fares into a transit

accessibility model has historically been overlooked. By including transit fares into their accessibility metric, the authors claim that they have developed a metric that measures the total cost of transit and transit accessibility more accurately. The researchers chose to include transit fares in their model because failing to do so could potentially overestimate job accessibility for economically disadvantaged communities. Additionally, a variety of fares and time limits were analyzed for accessibility. For instance, the researchers calculated both a 60-minute radius with a monthly fare and a 60-minute radius with a single fare. Ultimately, this unique method allows planners to calculate "the performance of the transit and land use system, independently from the characteristics of the users and can then be used to conduct socio-spatial equity analyses."[130]

Deboosere et al. (2018) make further refinements to the isochronic metric by comparing accessibility to low-income jobs for vulnerable groups across 11 different Canadian metropolitan areas. Their approach allows planners to distinguish between finance and manufacturing jobs while building on existing accessibility research by calculating the average commute time for both vulnerable and non-vulnerable groups by mode.[131]

Griffin and Sener (2016) developed an isochronic measurement relying on readily available data from the EPA's Access to Jobs and Workers via Transit database. The data included in this database uses a 45-minute travel limit (an isochronic measure) to determine accessibility. The researchers also apply the local Moran's I statistic to their isochronic accessibility metric results, allowing them to identify statistically significant clusters and outliers of high and low transit accessibility for low-income populations.[132]

Accessibility Metrics: Gravity-Based

Gravity-based accessibility metrics are analogous to the law of gravity, where the attraction between objects is determined by the combination of the size of the objects and the distance between them. Gravity-based metrics assume that large destinations will be more attractive to potential travelers, but the further they are from a trip's origin (in terms of either travel time, cost, or distance), the less attractive they are.[133]

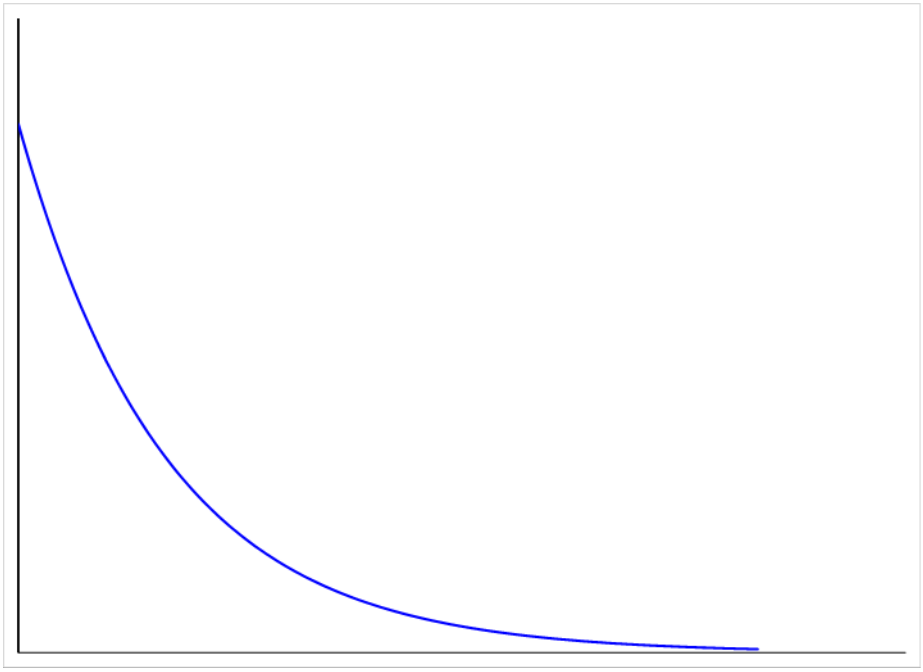
Gravity-based measures consider all destinations within a pre-defined study area (typically within a metropolitan region), summing all destinations for each trip origin to represent the accessibility rating of that origin. This can be shown in equation format below:

$$A_i = \sum_j D_j f(t_{ij})$$

where A_i is a weighted accessibility measure for an origin at location i; D_i is number of destinations (e.g., jobs, businesses, etc.) at location i; t_{ij} is the travel time between locations i and j; and $f(t_{ij})$ is a "friction factor" that decays with travel time, as shown in Figure 2 below; and the summation is taken over all destination zones j.[134]

Figure 2. Friction Factor Decay with Travel Time

$f(t_{ij})$



t_{ij}

An overall accessibility measure for a region can be obtained by summing up the above formula over all origin zones as follows:

$$A_T = \sum_i P_i A_i$$
$$= \sum_i \sum_j P_i D_j f(t_{ij})$$

where P_i is the population in zone i and the first summation is taken over all origins i.

However, if all destinations in the study area were simply summed, then every trip origin would have equal accessibility rankings. What is still needed is to account for the relative difficulty of traveling between that origin and each destination. Therefore, before the destination sum is undertaken, the raw count of destinations (and therefore, the attractiveness of each destination) is reduced according to the travel time required to go between each destination and the trip's origin.[135]

While gravity-based metrics are widely used in the transportation planning and research literature and have a long history,[136] a review of the literature suggests they are somewhat less-commonly used for equity analysis than their isochronic cousins. The sources reviewed here provide some examples of the uses of gravity-based metrics in transit equity analysis.

Stokes and Seto (2018) used a gravity-based metric to measure changes in transit and auto accessibility over time to jobs for low-income groups as an indicator for equity progress in U.S. urban areas from 2002 to 2014. Their findings suggest that while overall (auto and transit) accessibility increased in 74 percent of U.S. urban areas during the study period, these benefits were mostly achieved at the expense of low-income transit riders. While job accessibility by car increased for low-income populations, they did so at a much slower rate than for the urban area's population as a whole. Meanwhile, job accessibility for all residents by subway and transit increased by healthy amounts, it actually decreased for low-income residents.[137]

Ferguson et al. (2012) developed a formula to help planners design equitable transit services for low-income populations by integrating bus frequency data into a gravity-based accessibility metric, and the benefit of this formula is twofold. First, it can be applied to a variety of destinations to help planners evaluate access to not only jobs but also to things such as fresh food or hospitals. Second, this formula can be leveraged during land use analysis to help planners "consider the levels of access and mobility experienced by transit-dependent populations in multiple land use scenarios under a fixed transit budget."[138] The method also compares access via transit to an auto for selected destinations.[139]

An important challenge to the routine use of accessibility metrics by practitioners is that they typically rely on regional travel demand models for critical data inputs that are difficult to develop and maintain. In response to this shortcoming, Kaplan et al. (2014) developed and tested an accessibility metric that was simple to calculate using easily obtained public datasets (i.e., the U.S. Census Bureau's Longitudinal Employer-Household Dynamics dataset and transit route and schedule information in the General Transit Feed Specification format). While often relatively easy to calculate, transit service supply equity metrics tell us very little about how well transit links people to important destinations.[140]

Accessibility Metrics: Other

Most transit accessibility models rely on spatial or temporal coverage to calculate transit accessibility. The Transit Opportunity Index (TOI) developed by Mamun et al. (2013) expands on these existing metrics by including trip coverage into its accessibility model. Trip coverage is defined as "whether a public transit service is available for specific trip origin[s]/destinations."[141] According to the researchers, by integrating trip coverage into traditional accessibility metrics such as per capita service frequency, planners can better understand origin-destination and pair-wise connectivity. This comprehensive approach, which builds on existing models, allows service operators "to quantify the level of access provided by transit and the ability of this service to make

trips from [the] origin to [the] destination."[142] That said, one limitation of the TOI is that it can only account for a single transfer. Given that the case study examines a relatively small metropolitan area (New Haven, CT), this limitation could prove problematic when the TOI is applied to a more robust transit system. Lastly, because the TOI allows planners to quantify transit opportunity, TOI scores can be used to "identify service gaps and target investments to underserved communities."[143]

2.3.3 Transit Equity Metrics: Procedural Equity

McCahill and Ebeling (2015) define procedural equity in transportation as equity in "the processes through which transportation infrastructure and services are delivered and regulated."[144] Yan (2013) focuses on procedural versus substantive equity approaches, saying, "[r]ather than focusing on ultimate resource distribution, procedural equity seeks not so much an objectively fair solution, but rather a meaningful opportunity to influence decisions."[145]

By focusing on how decisions are made, procedural equity interventions hope to influence the equity of transportation outcomes. However, while planners have developed a plethora of transportation metrics that can be used to measure equity outcomes, less attention has been given to developing procedural equity metrics that can measure decision-making inputs. McCahill and Ebeling (2015) point out that this dimension of equity is more difficult to quantify,[146] and, therefore, is often measured using more qualitative tools, such as checklists or questionnaires.

The next section addresses two aspects of procedural equity measurement: (1) transit finance and decision-making equity and (2) public participation equity.

Procedural Equity: Transit Finance and Decision-Making Equity

Many of the industry standard equity finance metrics that have been in use for decades were designed to measure horizontal equity, where the goal is to achieve comparable shares of public investment for all transit riders,[147] rather than vertical equity, where the goal may be to benefit traditionally disadvantaged communities.[148]

For example, Litman (2021) discusses cost recovery analysis, where the assumption is that public investment expenditures or benefits should be distributed to communities according to their payments in fees or taxes.[149] While this may be equitable in "horizontal" terms, where the priority is on returning tax revenues to their original "source," it ignores and may perpetuate the plight of traditionally disadvantaged communities.

Since the end of World War II and the collapse of privately-owned, financed, and operated transit systems in the U.S., transit finance discourse has often focused on the amount of public subsidy required to provide transit services. Accordingly, industry-standard metrics tend to focus on measuring the average subsidy per passenger. Similar to cost recovery analysis, average subsidy per passenger metrics are typically designed and calculated to aid in allocating funds on a per rider (or

per capita) basis, thereby treating all riders equally without respect of their transit needs. Taylor (1991) evaluated California's Transportation Development Act (TDA) funding allocation formulas and found that their reliance on a per capita allocation method ignores the large differences between urban and suburban per capita transit ridership, effectively giving more money to suburban areas than they need.[150]

Nevertheless, even standard metrics originally designed to measure horizontal equity can often be augmented to measure vertical equity. Grengs (2002) recounts the important role that the subsidy per passenger metric served in the *Labor/Community Strategy Center v. Los Angeles County Metropolitan Transportation Authority* case of 1994. A rare and crucial case for transit equity advocates, the plaintiffs successfully argued that the Metropolitan Transportation Authority's (MTA's) plans to cut urban bus service and use the freed-up funds for building suburban rail transit lines was inequitable and in violation of Title VI. The plaintiff's case was based partially on subsidy per passenger calculations that compared subsidies given to urban versus suburban transit riders.[151]

Caltrans (2021) reviewed the Sacramento Area Council of Governments' (SACOG's) practice of identifying equitable transportation investment priorities based on a project's proximity to disadvantaged communities (DACs) and accessibility characteristics. SACOG uses its travel demand model to calculate accessibility metrics for projects and nearby DACs. They then calculate a project performance assessment metric that estimates a project's effects on the average accessibility of nearby DACs. Projects with higher Project Performance Assessment scores—and, therefore, with more equity benefits for DACs—are given higher priority in regional transportation finance plans.[152]

The Metropolitan Transportation Commission (MTC) uses its travel demand model to help identify equitable project funding priorities. In doing so, they can estimate the equity benefits of a project based on the forecasted use (demand) for the project, instead of simply relying on project location alone.[153]

Caltrans (2021) also reviewed a more qualitative method used by the Illinois DOT for evaluating the funding equity of proposed projects. Projects that are in or adjacent to a predominantly low-income or minority neighborhood are assumed to benefit them and, therefore, are more equitable and receive higher funding priority. Similarly, the Massachusetts Executive Office of Housing and Economic Development awards extra project selection scoring points to multimodal improvement projects that are within a half-mile of high concentrations of affordable housing (greater than the regional average).[154] However, it is important to note that proximity to a project can bring benefits as well as costs and, in some cases, a new road or highway facility may bring mobility benefits that may be overwhelmed by the health and property value costs imposed by the project on nearby residents and businesses. These costs would not be considered using the method of Illinois' DOT.

Manaugh et al. (2015) reviewed how North American metropolitan regions seek to balance multiple, and sometimes conflicting, goals, such as greenhouse gas emissions, automobile congestion, and equity, using performance measures. They found that equity metrics focused on process—or "inputs" to the transportation system—while important, are not necessarily sufficient. These procedural equity metrics are best used in tandem with measures of transportation system outputs. The New Orleans Regional Planning Commission, for example, sought to "ensure that the transportation system equitably serves all members of the community" by measuring "[p]rojects implemented and dollars invested in traditionally disadvantaged or underserved populations."[155] This process-oriented metric is a useful indicator of how equitable an agency's decision-making and project financing processes are, but does not measure how equitable the transportation system is from the user's perspective. Therefore, New Orleans used a measure of accessibility in tandem with this procedural metric to evaluate the equity of both inputs and outputs in their transportation system.[156]

Equitable representation among decision-makers is a necessary condition for consistent and equitable decision-making. Marcantonio et al. (2017) assert that MPO governing boards are often slanted in their representation to give more power to higher-income, predominantly white suburban jurisdictions, while giving less power to minority, lower-income urban cities. These representational inequities often lead to procedural inequities where transportation investment decisions favor suburban areas at the expense of urban jurisdictions. To identify and address these procedural inequities, Marcantonio et al. recommend monitoring MPO board representation using a metric designed to capture these inequities, such as MPO votes for a municipality per capita, to identify the number of residents each board member represents.[157]

Procedural Equity: Public Participation Equity

Community engagement and public outreach are vital steps in the public process. These steps are intended to inform and guide project decision-making and, when conducted effectively, can be powerful tools for achieving equitable outcomes. That said, when executed haphazardly, public participation can become just another box on a checklist.[158] Recently, many agencies and organizations have placed an increased emphasis on the need for enhanced procedural equity. Specifically, these organizations are refocusing their efforts on addressing procedural equity related to access and representation. Ultimately, the goal is for agencies to engage as many stakeholders as possible while also ensuring that these stakeholders are representative of the community or project area.[159]

With regard to access, two of the long-standing challenges that agencies face are identifying where and when public meetings should be held. Ensuring that meeting locations and times are designated appropriately is crucial in determining whether meeting attendees are representative of that specific community.

According to the Transportation Research Board (1999), public meetings that occur during the workday or where no childcare is available are the least convenient types of meetings. Conversely, meetings that are hosted at night, near transit, and have childcare are the most convenient types of meetings and experience the highest levels of participation.[160] Setting meeting times and locations that are accessible and convenient for all members of the public is an effective way to increase participation and increase the diversity of views represented. Furthermore, Kramer (2008) recommends that as a best practice, 60 percent of public involvement events should be held within 1/8 of a mile of a transit stop and within paratransit service areas:

> Although many resources point to a quarter mile as the maximum walking distance, it is suggested that a shorter distance be used as a target to accommodate elderly or disabled individuals who may have difficulty walking longer distances. In addition, the availability of paratransit service will help ensure that the elderly or disabled population can attend.[161]

When scheduling public meetings, agencies need to be mindful that certain population groups will likely prefer different meeting times based on their lifestyles and schedules. For instance, seniors would probably choose daytime meetings, whereas daytime meetings would be more challenging for individuals working 9–5 jobs. To assess whether a meeting time is convenient for all community members, agencies can conduct an anonymous post-meeting survey to determine if the meeting was, in fact, convenient. According to researchers at the University of Florida, if 75 percent of survey respondents state that the meeting time was convenient, then that time is considered an appropriate meeting time for future dates. That said, a post-meeting survey is limited in scope and potentially biased because it only measures convenience for those individuals who attended the meeting. It excludes individuals who might have wished to attend but could not. As a result, a post-meeting survey might not accurately determine the convenience of a meeting time for all community members.[162]

All members of the public, regardless of their abilities, have the right to participate in the planning process. Public agencies need to be inclusive and remember that some individuals experience more barriers to participation than others. One of these groups is persons with disabilities. To measure if disabled individuals feel that they are provided adequate accommodations, agencies can conduct post-meeting surveys to gauge their performance. Over time, survey information can help inform agencies on how to best accommodate persons with disabilities. Public agencies should strive to implement an outreach strategy where all individuals who need additional accommodation receive them adequately enough to participate.[163]

Another "major component of a successful process is clearly identifying all of the stakeholders affected by/interested in a project and then getting representatives of those groups to participate. In addition, concerns about environmental and social justice place a special emphasis on the ability of the process to involve minority or other traditionally under-represented stakeholder groups."[164] With this in mind, Portland Metro (2016) developed a Racial Equity Analysis and

Decision-Support Tool designed to identify unconscious biases and structural racism that might be present within the planning process. According to Metro, this tool is intended to ensure that planning is a collaborative and racially inclusive process. This support tool recognizes how minority groups have historically been excluded from the planning process and have suffered as a result. Metro claims that survey administrators need to receive proper training on how to apply the tool for it to be effective. The Racial Equity Analysis and Decision-Support Tool is an attempt at achieving racial equity in planning.[165]

In addition, public agencies should work to ensure that public meeting attendees are representative of that specific community. This can be measured by administering post-meeting surveys and leveraging geographic information system (GIS) analysis to cross-reference the survey responses against census demographic data. One indicator that can help increase equitable representation is geographic dispersion of involvement opportunities (Kramer 2008): "This indicator tracks whether public involvement opportunities have been reasonably distributed across the affected area. For example, are meetings always held in a central location or is the location alternated to capture higher rates of localized neighborhood participation?"[166] By alternating locations and accounting for different rates in community participation, agencies can deliver more equitable planning outcomes. This is especially true when agencies identify underrepresented groups and strategically target outreach campaigns to engage those specific groups.[167] Although post-meeting survey data might appear misleading by itself, cumulatively, this information can offer helpful insights into how to enhance procedural equity in planning.

On a regional level, one often overlooked component of procedural equity is the political composition of MPOs because they are usually constituted as a single government single vote system, which means that many MPO boards do not represent the region as a whole. As a result, what tends to occur is that mostly white suburban areas are overrepresented, and more diverse urban areas are often left without a representative on MPO boards, and therefore are without a voice. To account for this misrepresentation, Marcantonio (2017) recommends that MPO boards be determined by a primary election rather than by prior methods which favored suburban jurisdictions. By allowing for a primary election, an MPO board is more likely to accurately reflect the region's demographics and not a select few jurisdictions.[168]

2.4. New Directions in Transit Equity

This section presents several examples where transportation agencies and advocacy groups that have gone beyond the requirements of Title VI to look at transit equity in new ways, following two research paths: an evaluation of methods for measuring transit-induced secondary residential displacement, and an investigation of the performance of promising new transit equity metrics. Our work first focused on a request by the client (Caltrans) to evaluate methods for measuring and forecasting secondary displacement from transit improvements. Second, we examined several examples of how case study agencies and one advocacy group have worked to advance the cause of transit equity measurement and implementation.

2.4.1 New Directions: Transit Displacement

The potential relationship between transit equity and displacement seems intuitive, the assumption being that capital investments in a specific neighborhood will increase property values, attract infill developments, and apply excessive financial pressures on a community's most vulnerable residents. The literature suggests that the extent to which this occurs is immensely context-sensitive and varies depending on the scope of the investment.

Residential displacement can be categorized as either primary or secondary. Primary displacement, also referred to as direct displacement, occurs when a community's residents are evicted from their homes to allow for the construction of new development. Secondary displacement, also known as indirect displacement, or most commonly, gentrification, results when housing market dynamics gradually force residents (e.g., BIPOC groups) out of their neighborhoods. While primary displacement occurs when a new transportation or other infrastructure project displaces existing households from their residences so their properties can be used for the new facility's right-of-way, secondary displacement refers to the displacement "that occurs when low-income residents are forced out by economic or social forces, such as rising rents."[169]

Furthermore, secondary displacement effects are likely different depending on whether transit agencies and local governments use strategies, policies, and programs (i.e., mitigation measures such as the construction of affordable housing on transit property, fare reductions, the introduction of new services designed specifically to meet low-income people's access needs, etc.) to mitigate secondary displacement effects. Therefore, this project will study (among other metrics) the feasibility of Caltrans's and other transit stakeholders' use of metrics for measuring and predicting secondary displacement that results from the introduction of new transit services, as well as the effects of any mitigation measures used.

The most common methods for secondary displacement risk assessment can be categorized as using one or more of three approaches: descriptive, comparative, and predictive. While municipalities, transit agencies, and non-profits may employ different techniques for measuring displacement risk, the indicators or variables used for determining risk are generally a combination of housing market datasets and socioeconomic information based in part on census (American Community Survey) data.

This review presents the existing state-of-the-practice methods that organizations currently use to evaluate secondary displacement risk and how they use these assessments to develop anti-displacement strategies.

Secondary Displacement as an Equity Issue

Secondary displacement (also known as gentrification and exclusionary displacement) is a significant equity issue because, in addition to transforming the social fabric of local communities, this process disproportionately occurs in either low-income or predominately BIPOC

neighborhoods. Furthermore, most places that have either gentrified, are undergoing gentrification, or are most vulnerable to future gentrification are also communities previously affected by de facto segregation and decades of exclusionary housing policies. Due to these former policies, many high-risk neighborhoods still suffer from lower land values resulting from older and under-maintained development that are nonetheless in urban areas with excellent access to jobs and transit, thus making them highly appealing to house hunters and developers.

While many developers will argue that neighborhood investments are positive engines for encouraging economic growth, most community leaders will remind their neighbors that redevelopment can also produce unwanted changes to a community's cultural and physical character.

Secondary Displacement as Transit Equity

Transit equity planning needs to consider secondary displacement because if a neighborhood's demographic composition shifts, the ridership base for the existing transit supply will also change. This might mean, in certain scenarios, that a line that previously served transit-dependents now serves elective or "choice" riders—something with clear equity and operational implications since choice riders require commuter service, while dependents rely on lifeline service. Furthermore, changes to transit operations and infrastructure can also affect secondary displacement.

Although most of the existing academic literature on gentrification examines the role of private sector agents in causing neighborhood change, researchers have also studied how public agencies shape the nation's neighborhoods. Chapple et al. (2017) sought to accomplish this in a report prepared for the California Air Resources Board and California Environmental Protection Agency. In it, they concluded that secondary displacement is extremely context-sensitive and that any attempt to identify the root causes of neighborhood change should be performed on a case-by-case basis.

The literature suggests that there are at least two important factors determining the effects of new transit services on property values and secondary displacement. First, numerous sources have found that the type of transit improvement made plays an important role. For example, when examining secondary displacement within the context of transit capital investments, Chapple et al. (2017) concluded that even though new-fixed rail transit generally tends to increase residential and commercial values, "this positive effect varies substantially according to context."[170] Nevertheless, studies suggest that while context effects vary, they are positive in most cases. This finding is consistent with a 2001 report published by WSP USA, formerly Parsons Brinckerhoff, that states, "it is clear that in most cases access to rail systems is valued by property owners and there is little support for the suggestion that proximity to rail actually decreases property values."[171]

However, lower-investment, non-rail transit modes such as bus rapid transit (BRT), local, and express commuter bus services that do not have fixed guideways tend to have little or no detectable influences on property values and, by implication, on displacement as well.[172] That said, the

exception is in cases where improvements to BRT system performance increase accessibility to levels comparable to those of fixed rail service.[173]

Measuring Transit Effects on Secondary Displacement

Today, public agencies often want to avoid repeating previous urban renewal-style planning decisions that uprooted families and destroyed communities.[174] As such, many organizations have worked to develop methods for measuring, predicting, preventing, and mitigating displacement. Since the causes of primary displacement are relatively clear and identifiable, this study focuses on methods that measure, predict, prevent, and mitigate secondary displacement.

A heightened focus on displacement prevention has prompted researchers and practitioners to develop various methodologies to help policymakers understand which neighborhoods have gentrified, which are actively gentrifying, and which are most vulnerable to future change.

Displacement Measurement Methods

Currently, the most well-developed methods for measuring and predicting displacement focus on preventing gentrification. Specifically, these methods measure gentrification risk by summarizing demographic and housing market data into an index, or by comparing neighborhood-scale data to citywide averages. The purpose of these methods is to avoid secondary displacement outcomes resulting from socio-demographic conditions coupled with specific planning, management, investment, or operational decisions. That said, given the recent interest in anti-displacement research, there are a range of different types of displacement vulnerability measurement methods available for use.

A search of the academic and practice literature identified the following methods:

- Displacement Alert Portal (DAP): Developed by the Association for Neighborhood and Housing Development, New York City Council, and New York State.
- Heightened Displacement Risk Indicators: Developed by the City of Seattle.
- Area Deprivation Index: Developed by the University of Wisconsin-Madison.
- Displacement Risk Indicators Matrix (DRIM): Developed by the Rutgers Center on Law, Inequality, and Metropolitan Equity.
- Gentrification Measurement: Developed by Chapple et al. (2017).
- Regional Displacement Risk Index: Developed by the Puget Sound Regional Council.

- Urban Displacement Typology Map: Developed by the Urban Displacement Project at University of California, Berkeley.

- Mapping Displacement Pressure: Developed by the Institute for Housing Studies at DePaul University.

- Gentrification and Displacement Neighborhood Typology Assessment: Developed by the Portland Bureau of Planning and Sustainability.

- Change Model: Developed by the City of Denver.

- Off-Model Displacement Assessment—UrbanSim and PECAS: Developed by Chapple et al. (2017).

The City of Seattle's Heightened Displacement Risk Indicators method measures displacement risk by evaluating housing market dynamics in terms of decreases in the total number of available affordable and rental housing units. Relying on data from the U.S. Census Bureau, King County Department of Assessments, and the Seattle Department of Construction and Inspections, the City of Seattle believes that tenant relocation cases, condo conversions, and foreclosures are appropriate indicators for measuring primary displacement. The City of Seattle has determined that early design guidance applications, construction permits, increases in sale prices, and home flipping are useful indicators for secondary displacement, stating that these indicators "suggest the potential for secondary economic displacement and exclusionary neighborhood change."[175]

In addition to the development of risk-based indicators, displacement typology maps are also a commonly accepted method for assessing gentrification risk. That said, many of these methods tend to fall short when attempting to clearly identify and examine the causes of gentrification, which limits their overall effectiveness and ability to forecast gentrification.[176] The City of Portland employs a version of this methodology in its 2018 Gentrification and Displacement Neighborhood Typology Assessment. Rather than simply looking for the presence of specific indicators, Portland compares tract-level values to city averages. Specifically, the

- share of households that are renters greater than the Portland average,

- share of population that are communities of color greater than the Portland average,

- share of adults (25 or older) without a four-year degree greater than the Portland average, and

- share of households that are low-income (below 80% median family income) greater than the Portland average.[177]

According to the Portland Bureau of Planning, "These socioeconomic factors indicate a reduced ability to withstand housing market price increases caused by gentrification."[178] Decennial Census and American Community Survey (ACS) data used in this method, such as race and total household income, are commonly accepted indicators that serve as red flags for evaluating displacement risk.

While it was not specifically designed to measure potential displacement risk, the Area Deprivation Index (ADI) can serve as a proxy for displacement risk because it identifies the locations of disadvantaged communities nationwide. Using many of the same indicators as displacement-specific measurement methods, the ADI is a public health tool developed by the University of Wisconsin-Madison to evaluate health disparities across the county: "The ADI is composed of 17 education, employment, housing-quality, and poverty measures originally drawn from long-form Census data and updated by our team to incorporate more recent American Community Survey (ACS) data."[179] This approach "allows for rankings of neighborhoods by socioeconomic disadvantage in a region of interest (e.g., at the state or national level). It includes factors for the theoretical domains of income, education, employment, and housing quality. It can be used to inform health delivery and policy, especially for the most disadvantaged neighborhood groups."[180] The ADI could serve as an effective first step for identifying neighborhood displacement risk and can complement traditional displacement risk assessment methods.

One of the main challenges facing the field of displacement measurement is that there is no consensus on the best indicators for assessing displacement risk. Some agencies have attempted to resolve this uncertainty by incorporating a more comprehensive range of indicators in their method. For instance, Puget Sound Regional Council developed a method that consists of fifteen indicators, while the Rutgers Center for Law, Inequality, and Metropolitan Equity uses nine. This difference in approach illustrates the fact that "Previous studies have failed to build a cumulative understanding of displacement because they have utilized different definitions, compared different populations, and adopted a relatively short timeframe."[181]

Chapple et al. (2017) aimed to go beyond simple measurement and developed two separate models for forecasting secondary displacement, one for the Bay Area and one for Los Angeles. For this purpose, they first ran logit and linear regression models to determine statistically significant "neighborhood indicators from readily available, tract-level ACS data in order to facilitate [the] assessment of displacement risk by city or regional agency staff in a simple spreadsheet analysis."[182] Independent variables for future conditions were then estimated using two different micro-simulation models. Bay Area independent variables were estimated using Paul Waddell's UrbanSim model, while Los Angeles independent variables were estimated using SCAG's PECAS model.

The final models developed by Chapple et al. (2017) are useful for identifying key variables that cause, or are related to, displacement but are of limited or no predictive value since they explained relatively small shares of the overall variation in displacement data and produced high levels of

false positives and false negatives when used for prediction. They conclude that "[t]herefore, we should be very cautious on how to use these models."[183]

While agencies and planners have historically taken a reactionary approach to transportation equity, addressing it after the equity impacts have already taken hold, some are beginning to recognize that equity must be embedded throughout the entirety of the planning process. This holistic and proactive way of thinking is especially evident in how some planners and policy-makers are addressing the issue of secondary displacement. In particular, the cities of Austin, Texas and Denver, Colorado have each taken unique approaches to mitigate gentrification risk. These innovative tactics have drawn national recognition and been applauded for their forward-thinking and data-driven methods.[184] The City of Denver also desires to better understand how capital investments, both public and private, might affect displacement by using a consultant-developed "change model" to forecast future community property values post-construction.

Unlike Denver's approach, which is project-focused, the City of Austin's approach focuses on guaranteeing that development review begins with equity and continues to consider equity throughout the project's life cycle. To achieve this, the City of Austin developed what it refers to as the Neighborhood Stabilization Strategy Tool, which maps displacement vulnerability based on demographic factors to help policymakers understand the locations of the city's most vulnerable population groups.[185] The purpose of mapping at-risk neighborhoods is so that city officials can better implement anti-displacement strategies to protect community character. The Neighborhood Stabilization Strategy Tool was created as part of CapMetro and the City of Austin's Project Connect, which is the name for the region's long-term transit plan.

These are two examples of unique approaches in the emerging field of anti-displacement, and as such, there is limited published technical documentation on these methods. That said, given the recent interest in anti-displacement research, there are a range of different types of displacement vulnerability measurement methods available for use, which we review in Chapter 4 of this report.

2.4.2 New Directions: Enhanced Title VI Practice Case Studies

In addition to the issue of displacement, there are a number of examples of how transit agencies and advocacy organizations have been working to enhance their measurement and policy toolboxes beyond the traditional methods employed to address Title VI requirements.

Two of the nation's largest transit agencies have recently implemented strategies that place equity at the forefront of organizational operations. The San Francisco Municipal Transportation Agency (SFMTA) has decided to leverage demographic mapping to help design a more equitable transit service plan, and the Los Angeles County Metropolitan Transportation Authority (LA Metro) has incorporated equity into the budget process to ensure that its financial commitments are consistent with its social policy goals. Both strategies are grounded in thorough community outreach efforts that focus on better understanding community needs by directly engaging with riders themselves.

Private organizations are also embracing and advancing these emerging approaches to transportation equity planning. One example of this is the Equity Dashboard developed by TransitCenter. This tool is unique because it not only measures how well some of America's largest transit operators currently serve their riders, but it also gauges how potential service adjustments might impact individuals with the greatest transit needs.

The case studies are summarized and briefly described below:

- **San Francisco Municipal Transportation Agency (SFMTA/Muni)** has initiated the Muni Service Equity Strategy that looks at transit service equity in terms of how well transit serves nine designated neighborhoods within San Francisco. The Muni Service Equity Strategy aims to identify and address high-priority transit needs in neighborhoods that rely on transit service the most with tangible solutions that can be implemented quickly (within one to two years) and deliver measurable improvements. The program includes an extensive outreach effort to the designated neighborhoods, development of an Equity Toolkit to assess service equity, and periodic reporting on progress.

- **Los Angeles Metro** has a new Office of Equity and Race that is tasked with promoting equity within Metro and equity in transit service. The office has worked to make equity analysis a part of the agency's budgeting process. As part of its equity strategy, Metro is conducting extensive outreach efforts through community-based organizations and has also incorporated equity into its new NextGen Bus Plan.

- **TransitCenter** is an advocacy group based in New York that works with transit agencies and advocacy groups to promote equity in transit. They have developed an Equity Dashboard that provides graphic and mapping tools to look at transit equity in seven major urban areas: Boston (forthcoming), Chicago, Los Angeles, New York, Philadelphia, San Francisco–Oakland, and Washington, D.C.

The San Francisco Municipal Transportation Agency

The Muni Service Equity Strategy is aimed at improving transit performance in San Francisco neighborhoods with a high percentage of households with low income and people of color.[186] The Equity Policy adopted by SFMTA calls for the agency to:[187]

- "Select neighborhoods based on percentage of low-income households, private vehicle availability, race/ethnicity demographics, and disability status.

- "Analyze transit performance metrics for Muni routes serving these neighborhoods compared to peer Muni route performance including *on-time performance*, *service gaps*, *crowding*, *capacity utilization*, *travel times to key destinations*, and *customer satisfaction* information (emphasis added).

- "Establish a performance baseline for Muni routes serving each neighborhood.
- "Outline the top two to three Muni challenges and strategies to improve service performance.
- "Conduct outreach to community stakeholders to confirm key Muni service issues.
- "Prioritize resources to implement strategies as needed in conjunction with a two-year budget cycle.
- "Implement identified strategies.
- "Repeat these steps over the course of a two-year cycle linked to the biannual budget process, updating the neighborhoods, performance baseline, challenges, and strategies to improve service performance."[188]

The Equity Strategy was developed with the help of the Equity Working Group, which was formed by the SFMTA and includes the following government and community-based organizations:

- Chinatown Community Development Center
- Council of Community Housing Organizations
- San Francisco Bicycle Coalition
- San Francisco County Transportation Authority
- San Francisco Transit Riders Union
- Senior Disability Action
- Tenderloin Neighborhood Development Corporation
- Urban Habitat[189]

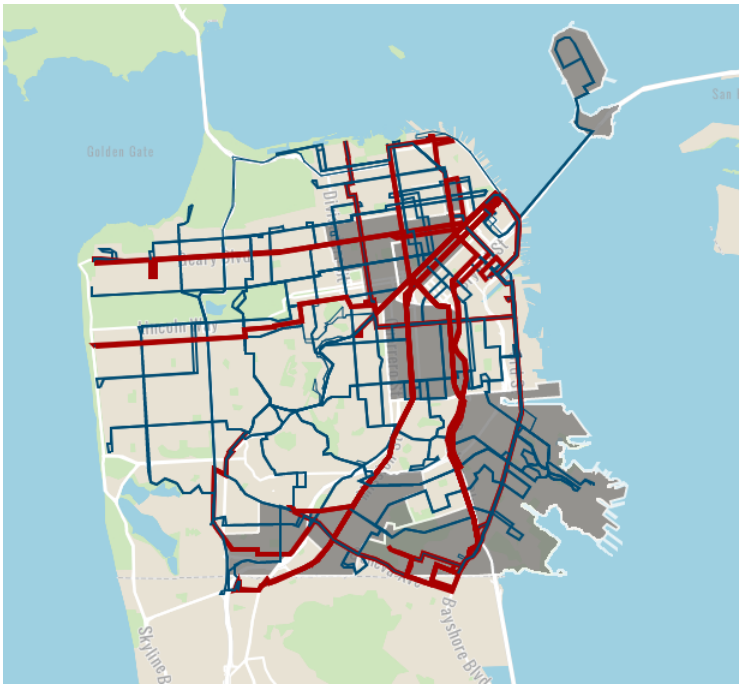
Muni identified transit equity neighborhoods based on:

- Percentage of households with low incomes
- Private vehicle ownership
- Race and ethnicity demographics

- Affordable and public housing development concentrations[190]

Muni also reviewed data from senior and handicapped electronic card use to identify the routes most used by seniors and people with disabilities. Figure 3 shows the nine transit equity neighborhoods identified as part of the analysis.

Figure 3. Muni-Designated Equity Areas



Data used to inform the equity analysis include:[191]

- *Headway adherence*: percent of trips with gaps
- *Crowding*: percent of trips over capacity
- *On-time performance*
- *Transit-auto travel time ratio* to key destinations
- *Service delivery*: percent of scheduled service hours delivered

Work on the Equity Strategy included the development of the Transit Equity Toolkit, a web-based mapping tool to show specific performance measures.[192] Figures 4 and 5 show an example of one such measure: access to jobs by transit from a particular neighborhood (Western Addition), where Figure 4 shows the map itself and Figure 5 shows the accompanying data on the number of jobs accessed.

Figure 4. Jobs Access by Transit from the San Francisco Western Addition

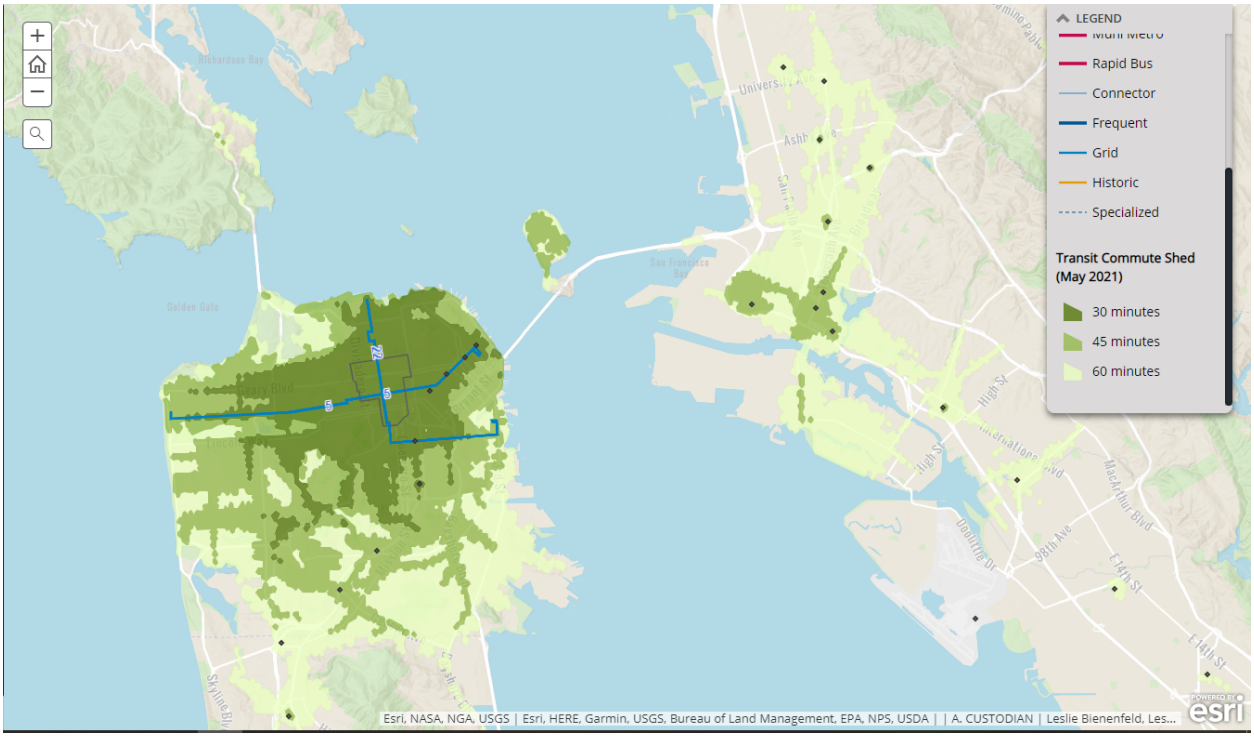
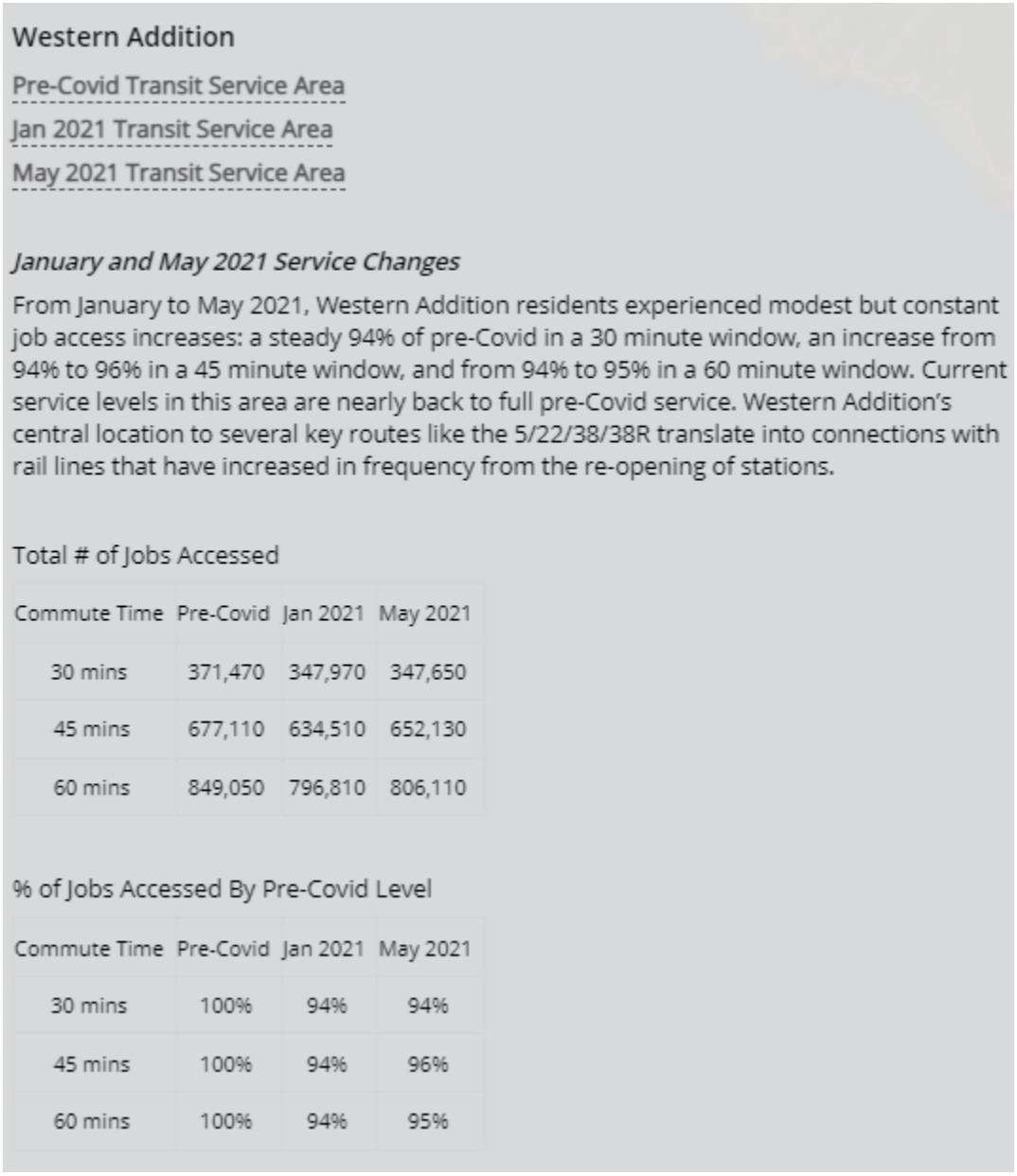


Figure 5. Jobs Access from the San Francisco Western Addition



The policy of the SFMTA is to have its Equity Strategy inform all aspects of service planning:

- Service and operations decisions
- Community engagement and response
- Feedback from riders
- Capital and quick build projects[193]

These planning considerations include all hours and days of service, with the objective of ensuring the same or better service outcomes. Service recommendations are made on a neighborhood-by-neighborhood basis.[194] Neighborhood input was solicited to vet the recommendations of SFMTA staff through extensive outreach efforts. These included:

- public workshops in individual neighborhoods to focus on recommended improvements in those neighborhoods,
- direct feedback from community-based organizations, and
- distribution of recommendations to over 700 riders signed up for email/text message updates.[195]

The following are some of the specific actions that have already been taken as a result of the Equity Strategy:

- implementation of new rapid bus service along some formerly under-served corridors,
- increased service along some lines,
- bus stop improvements,
- upsizing equipment on some routes to articulated buses with higher capacity, and
- extending bus contraflow lanes.[196]

Los Angeles Metro[197]

LA Metro has a new Office of Equity and Race that is tasked with promoting equity within the administration and planning activities of Metro and equity in the transit services they provide.[198] The office has worked to make equity analysis a part of the agency's budgeting process, thereby providing incentives to rank-and-file staff to take equity concerns seriously and integrate them into their everyday work.

Los Angeles Metro has made equity analysis a part of all planning and budgeting decisions in the organization. Each proposed action is accompanied by a Rapid Equity Assessment, which is included in a report to the Board on the proposed action.[199] The Rapid Equity Assessment includes a set of questions intended to guide staff in evaluating the equity impacts of their routine projects and procedures:

- Which groups would be affected:
    - Metro employees

    - Public
        - Black, Indigenous, or people of color
        - Low-income households
        - People with disabilities
        - Equity-focus communities that meet thresholds of income, percentage non-white, and zero car ownership
        - Other marginalized communities such as those with limited English proficiency, LGBTQ+, women, and elderly
        - Minority or women-owned businesses
- Who would benefit
- Who would be harmed
- How this would improve equity outcomes
- Identification of strategies to mitigate potential negative consequences
- Which community engagement and data informed this analysis?[200]

The Office of Equity and Race has also established an equity rating system for individual departments within Metro. Each department is asked to conduct a self-assessment on various aspects of equity. Staff from the Office of Equity and Race then review the self-assessment with each department and discuss possible actions to work toward equity goals.

As part of its equity strategy, Metro also conducts extensive outreach efforts through community-based organizations (CBOs). Their Community-Based Organization Plan lays out specific steps for developing partnerships with CBOs to further its equity strategy.[201] For example:

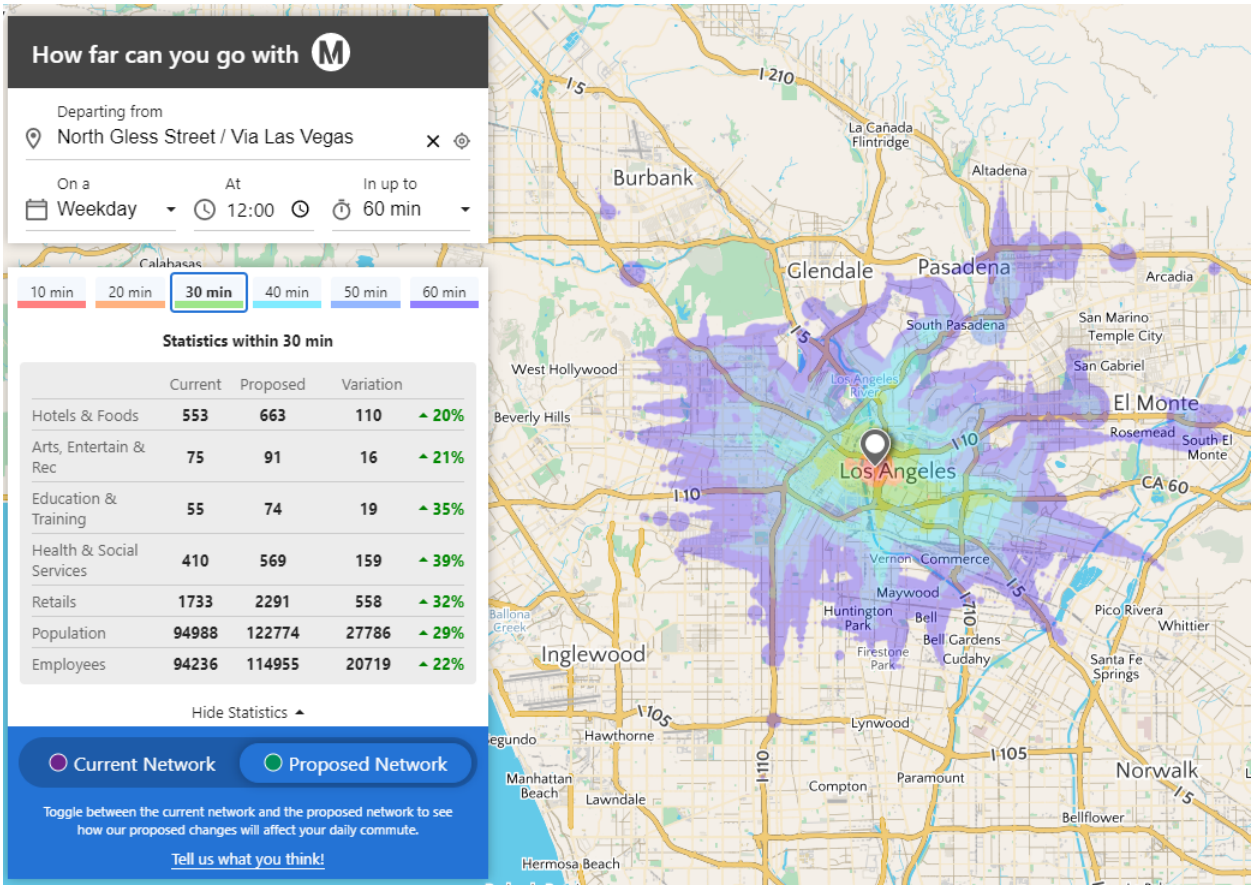
- Metro worked in collaboration with CBOs to conduct a door-to-door walking campaign on the Purple Line (Subway) Extension Project.
- Partnerships with CBOs included having CBOs serve as contractors or subcontractors on Metro's A Line (Blue) First/Last Mile: A Community-Based Process and Plan.

Metro recently completed a new bus plan, designated as NextGen, which was aimed at improving access to the bus system and increasing the number of trip opportunities reachable by transit within a given time. Service equity has been a key element in developing the NextGen Bus Plan.[202] Work

on the plan included development of an interactive online Reach Map that shows how the new network improves access to jobs, education, shopping, and other opportunities.[203]

Figure 6 shows an example of one Reach Map from NextGen. The user can move the origin (indicated by the white circle in the center) anywhere within the region. The user can select the time period within which he/she wants to travel. The resulting map shows geographic accessibility and the number of destination opportunities accessible within the given time period.

Figure 6. An Example Reach Map from Nextgen Showing How the Proposed Bus Network Improves Reachable Opportunities



TransitCenter[204]

TransitCenter is an advocacy group based in New York that works with transit agencies and advocacy groups to promote equity in transit.[205] They engage in several activities to promote equity in transit:

- Conducting applied research to develop equity measures and analyze transit equity in metropolitan areas.
- Working to improve transit agency governance, planning, and operations.

- Partnering with other transit advocates to campaign for better transit.
- Providing grants to designated 501c3 organizations that work to improve transit.

A key feature of the TransitCenter's website is its Equity Dashboard, which provides graphic and mapping tools to look at transit equity in seven major urban areas: Boston (forthcoming), Chicago, Los Angeles, New York, Philadelphia, San Francisco–Oakland, and Washington, D.C.[206] Data can be downloaded from the dashboard as needed, which provides data on the following:[207]

- Accessibility
- Comparison between transit and auto travel times
- Demographic overlays

Data can be displayed by type of access, time period (morning and evening weekday peaks, weekends), and length of the trip.

Accessibility information is provided for the following:

- Jobs
- Low-wage jobs
- Grocery stores and supermarkets
- Hospitals
- Urgent care
- Pharmacies
- Parks and greenspace
- Colleges and universities
- Transit service intensity (i.e., accessibility to transit service)

Overlays can be added for the following groups:

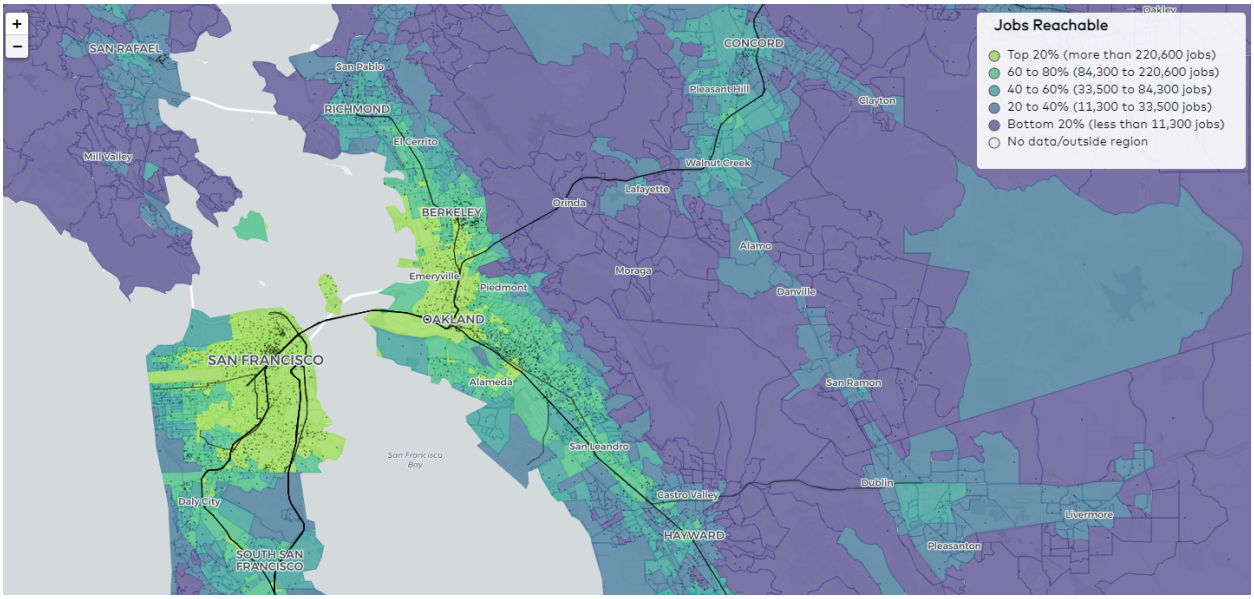
- Asian and Pacific Islander
- Black

- Hispanic/Latinx
- White
- Living at or below poverty level
- Essential workers (at their place of residence)
- Single-mother households
- No-car households

The user also has the option to show accessibility only for affordable trips, i.e., trips where the transit fare is $4 or less.

Figure 7 shows an example of a map of the San Francisco Bay Area generated by the TransitCenter equity dashboard. The map shows jobs accessible within 45 minutes by transit during the AM peak period. The small dots in the map show an overlay of low-income households. Major transit lines are overlaid on the map.

Figure 7. TransitCenter Dashboard Map Showing Jobs Accessibility (Dots Represent Low-Income Households)



New Directions Case Studies: Summary and Conclusions

The examples in this section illustrate how two transit agencies and one advocacy group have gone well beyond the confines of Title VI to look at equity and, in the case of transit agencies, incorporate equity into planning, budgeting, and decision-making.

Table 1. Summary of Equity Definitions and Processes

	San Francisco MTA	Los Angeles Metro	TransitCenter
Group definitions	Race Low income Car ownership Seniors/disabled	Race Low income Disabled Language barrier Elderly LGBTQ+ Women	Race Income Car ownership Household structure
Equity measures	Accessibility Service quality	Accessibility Service quality	N/A
Outreach	Community groups Workshops	Community groups	N/A
Inclusion in agency	Entire planning, budgeting process	Entire planning, budgeting process	N/A
Tools & metrics	Equity analysis tool (mapping)	Equity analysis tool (mapping) Rapid equity assessment checklist	Mapping tools

Several key features distinguish these efforts from the way transit agencies traditionally address Title VI requirements:

- **Inclusion of equity in all agency activities**: Rather than considering equity analysis separately, San Francisco and Los Angeles both include equity in all phases of planning, budgeting, and decision-making.

- **A focus on geography:** San Francisco and Los Angeles have worked to identify specific geographic areas where efforts to improve equity can be directed. The focus on geography has aided in the development of web-based mapping tools that not only help Metro plan better but can communicate with the public on various needs for addressing equity.

- **Looking beyond race:** San Francisco, Los Angeles, and TransitCenter have taken a broad perspective on equity to include all groups that might be transit-disadvantaged, including those with disabilities, limited auto ownership, and family structure that may limit mobility.

- **Measurement**: These agencies have defined equity metrics that focus on accessibility to transit, accessibility to destinations, and transit service quality such as crowding. Metrics are also area-specific and time-specific.

- **Public input**: This differs in two significant ways:

- Public input is sought throughout planning, budgeting, and decision-making. This differs from past practices where public input was sought only at the very end.

- Public input is sought through multiple sources, including workshops and other public events. Community-based organizations are a key means of soliciting input from disadvantaged groups.

- **Presentation**: Interactive web-based mapping tools allow agency constituents to view service metrics for themselves.

2.5 Literature and State of the Practice Review: Summary and Conclusions

This literature review presents and analyzes the existing state-of-the-practice knowledge on how transit and other transportation agencies currently evaluate transit equity, and how they and academic researchers are working to expand and improve on these practices.

The following are the principal findings of our review:

- Title VI and its associated laws and regulations set forth the minimum requirements for transit agencies to address and improve equity. However, many researchers, advocacy groups, and transit agencies have found some significant shortcomings of Title VI, including:

    - Title VI and its associated laws and regulations only address inequities based on race and low-income status; they largely ignore a number of transportation-disadvantaged groups that often face inequities in transit service provision such as the elderly, handicapped, and single-parent households.

    - Title VI and its associated laws and regulations do not directly address existing inequities. They only require that transit agencies address the equity effects of new actions.

    - Title VI and its associated laws and regulations do not set standards for defining equity, nor do they prescribe any specific ways to measure equity. Instead, these measurements are left to the individual transit agencies. This leads to inconsistent and often ineffective implementation.

- There are many transit equity measures found in the literature. While many of these are of limited practical significance for most transit agencies, especially those whose budget constraints limit their capabilities for data collection, the sheer number and variety of metrics provide substantial opportunities for accurate, consistent, and effective measurement, while also potentially causing confusion as to which metrics are best to use.

- The most well-developed methods for measuring and predicting secondary displacement focus on preventing gentrification. Although these methods are relatively straightforward and becoming an increasingly common practice for public agencies, the most difficult and important step is successfully integrating these tools into the policy and decision-making process so that they can be used to effect change.

- New capital investment in fixed guideway rail transit systems tends to increase nearby commercial and residential property values, making affordable housing scarce. That said, the degree to which property values change is highly context sensitive.

- A number of transit agencies and advocacy groups have taken on the task of developing new tools for assessing equity in transit service provision. In one case (Los Angeles Metro), the transit provider has adopted the goal of making equity a prime consideration in every agency action, including planning, budgeting, and service management.

These findings suggest a clear need for metrics and methods of measuring transit equity that go beyond race and income as required by Title VI and FTA guidance. Chapter 3 employs a preliminary needs analysis for Santa Cruz County, California, to establish an empirically based argument for employing other metrics that can identify a more complete picture of transit equity in the practice of equity analysis in California.

3. Transit Equity Metrics Needs Evaluation: How Well Do Title VI Metrics Represent Transportation-disadvantaged Populations?

3.1 Introduction

As described in Chapter 2, the original Title VI guidelines were based solely on race. Subsequent environmental justice guidelines incorporated into FTA guidelines include income. These guidelines do not specifically mention other characteristics that could realistically indicate transportation-disadvantaged populations.

Before evaluating new metrics in a future, second phase of this research project, the research team was able to determine the answers to a preliminary research question: are Title VI's required metrics (race and income) sufficient for measuring the equity impacts of transit service changes? By comparing the performance of "new" metrics to that of the traditional Title VI metrics in a case study area in California, the research team sought to answer this question and determine the need and potential for additional metrics for use in studying transit equity.

Examples of characteristics of transportation-disadvantaged populations (derived from the literature reviewed in Chapter 2 and the researchers' professional experience) include the following:

- Households without a car.
- Single-parent households with a female head of house and children.
- Households without internet access.
- Persons who work late at night without access to late-night transit service.

Using this preliminary list of new metrics, the research team performed a needs analysis by comparing their performance with the performance of traditional Title VI metrics (race and income) in Santa Cruz County in California. Santa Cruz was selected because it: (1) has a combination of substantial urban and rural areas within it; (2) has a single transit provider that serves the entire county, making the acquisition and analysis of their transit operational data relatively easy; and (3) has a diverse population in terms of income, race, and other demographic characteristics.

The team evaluated the need for new transit equity metrics in Santa Cruz County by: (1) visual inspection of thematic GIS maps in comparison to those generated from traditional metrics; and (2) statistical analysis (correlations) of the performance of various metrics, indicating to what degree new metrics detect equity conditions that are and are not captured by Title VI metrics.

3.2 Case Study: Santa Cruz County

This section presents a case study that demonstrates that the measures typically used based on the existing Title VI guidelines (i.e., race and income) may not fully capture some transportation-disadvantaged populations.

3.2.1 County Characteristics

Santa Cruz County is located immediately south of the nine-county San Francisco Bay Area. The county has a population of 270,000 and includes four incorporated cities: Santa Cruz, Capitola, Watsonville, and Scotts Valley. The county is a mixture of rural and urban areas. The economy is a mixture of agriculture, high-tech, tourism, and education, including the Santa Cruz campus of the University of California. In addition to its own high-tech industries, the county also serves as a bedroom community for Silicon Valley to the north.[208] Transit service in the county is provided by Santa Cruz Transit. Average pre-pandemic patronage on local buses was about 16,000 per day.[209]

3.2.2 The Geography of Title VI and Transit-disadvantaged Populations

This section presents several maps of the county that demonstrate some significant geographic differences between Title VI guideline definitions of equity and associated metrics and other potential definitions and metrics of transit-disadvantaged populations. Demographic data are from the American Community Survey, years 2015–2019.[210] Transit routes are also shown to indicate the extent of service coverage in the county.

Figure 8. Block Groups in Santa Cruz County by Percent Non-White

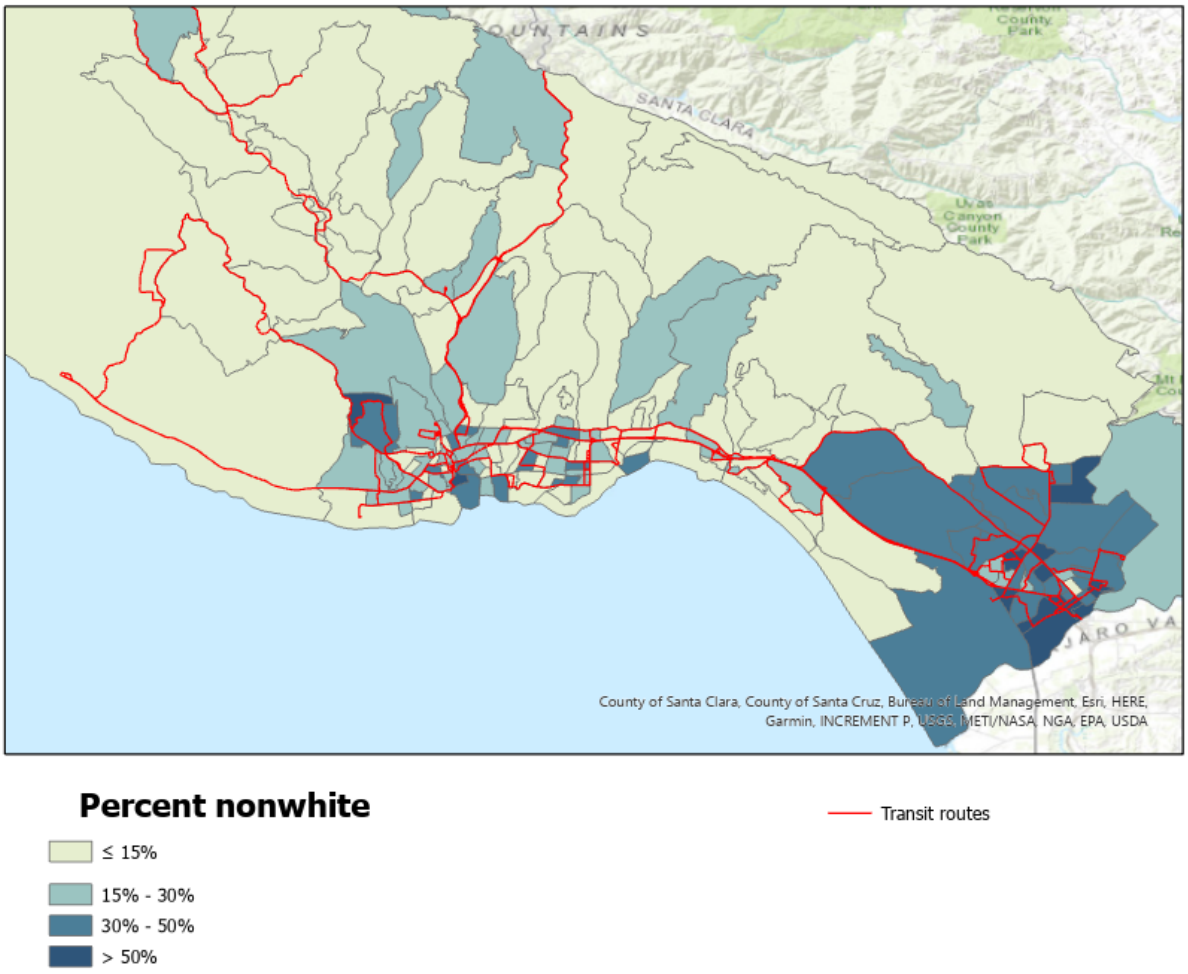


Figure 8 shows the percentages of non-white households by block group in the county and represents a typical Title VI-required metric used by transit agencies to test for equity impacts resulting from service changes. Note that the highest concentrations of non-white populations are in the southeast and south-central parts of the county.

Figure 9. Block Groups in Santa Cruz County by Percent Households Below Twice the Poverty Level

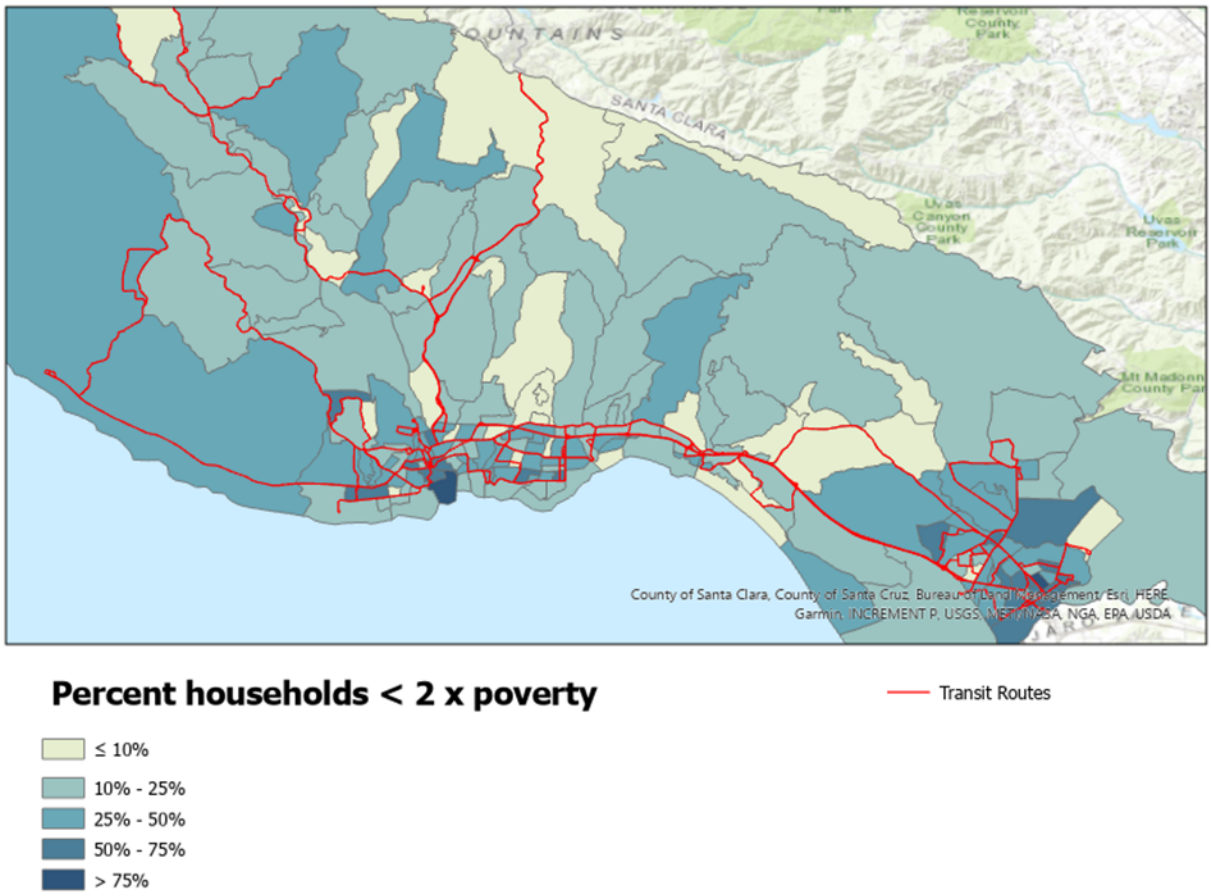
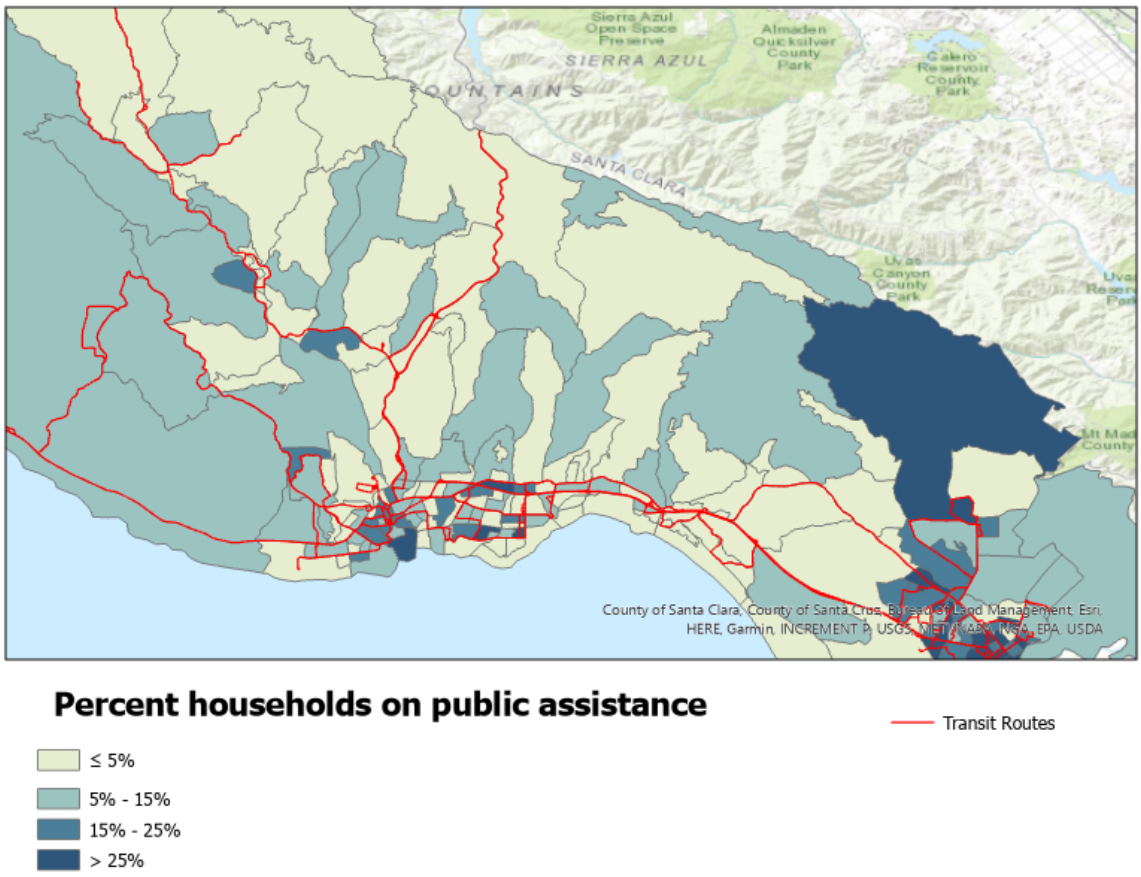


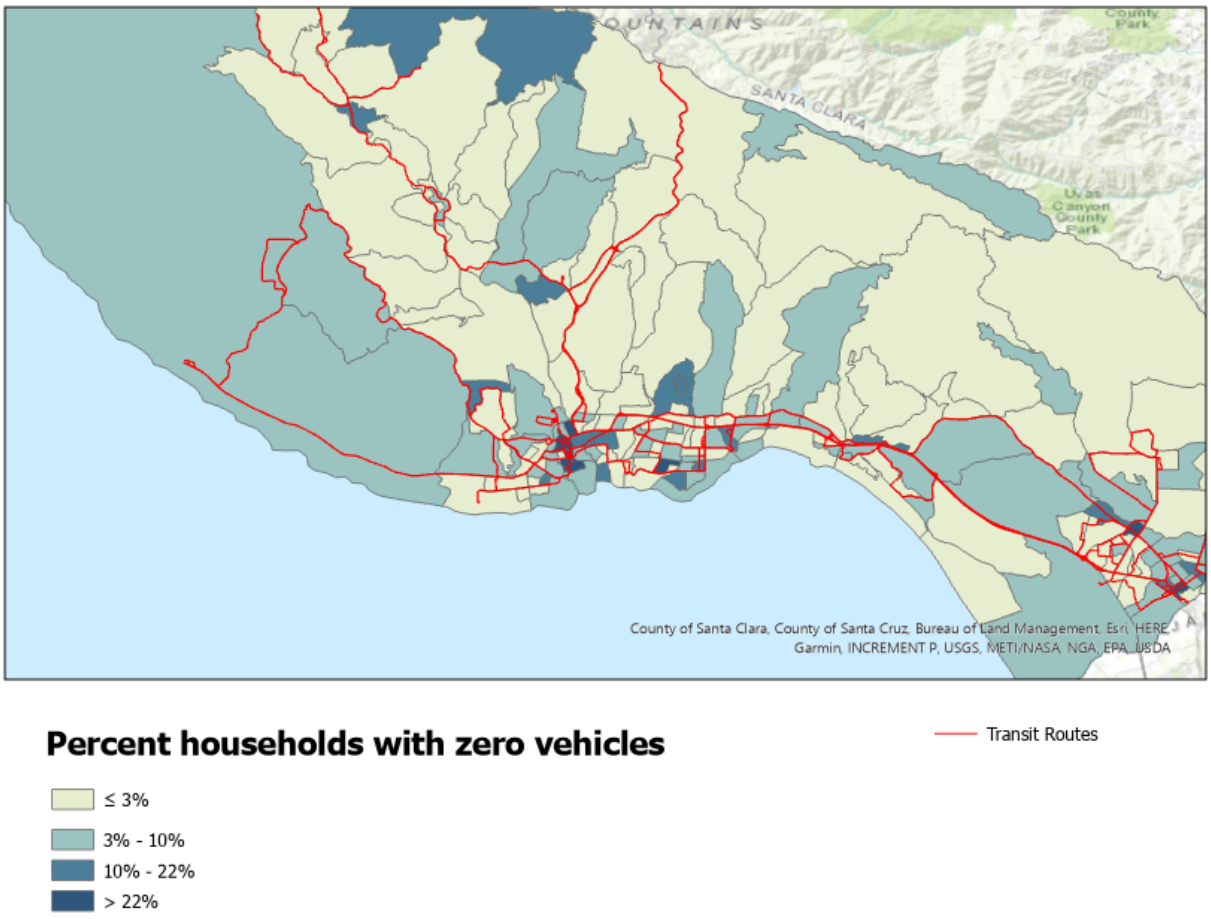
Figure 9 shows low-income households (incomes below twice the poverty level) and, similar to race shown in Figure 8, represents a typical Title VI required metric used by transit agencies to test for equity impacts resulting from service changes.

Figure 10. Block Groups in Santa Cruz County by Percent Households on Public Assistance



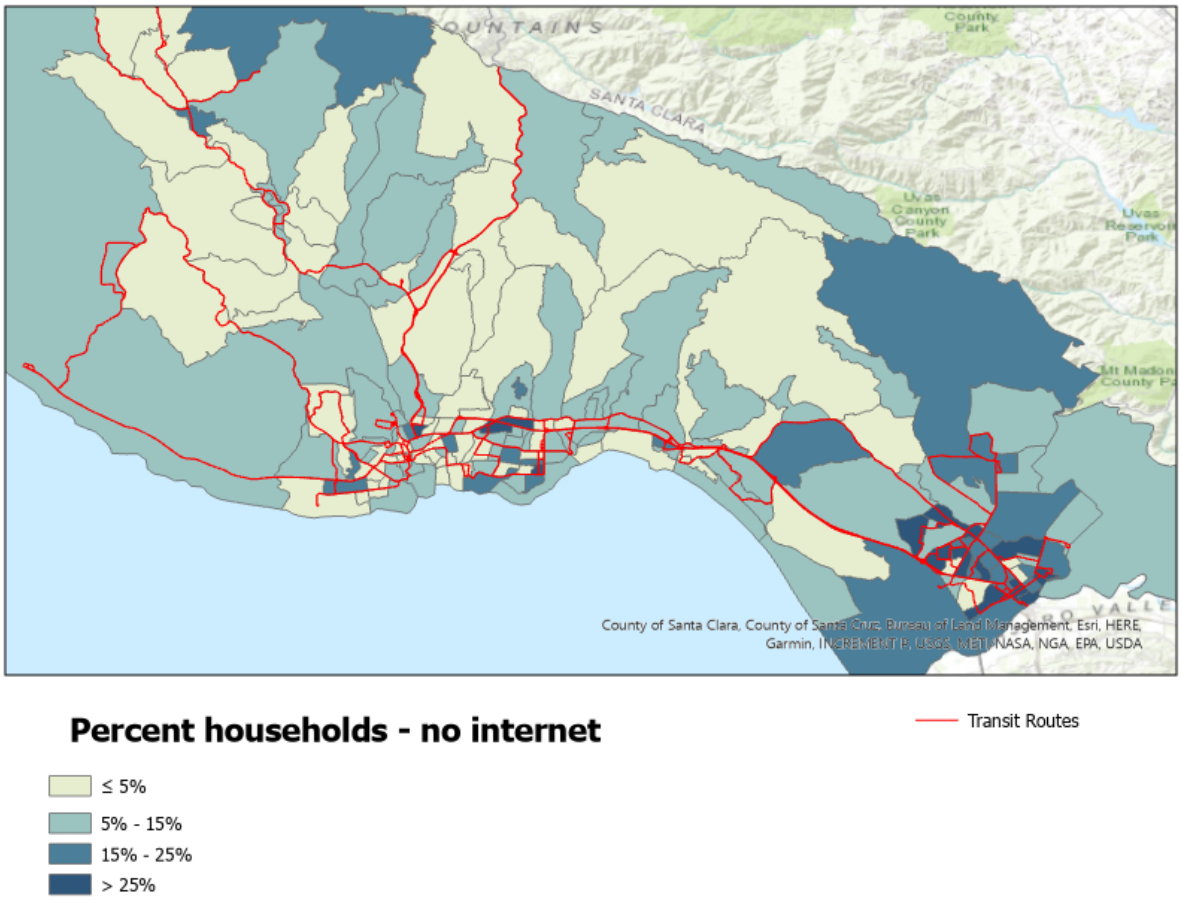
Figures 9 and 10 show low-income households from two perspectives: incomes below twice the poverty level, and public assistance. In comparison with Figure 8, note that although there are some similarities in concentrations of non-white and low-income populations, there are also some significant differences; and even between Figures 9 and 10 there appear to be some differences between households on public assistance and households with incomes below twice the poverty level.

Figure 11. Block Groups in Santa Cruz County by Percent Households with Zero Vehicles



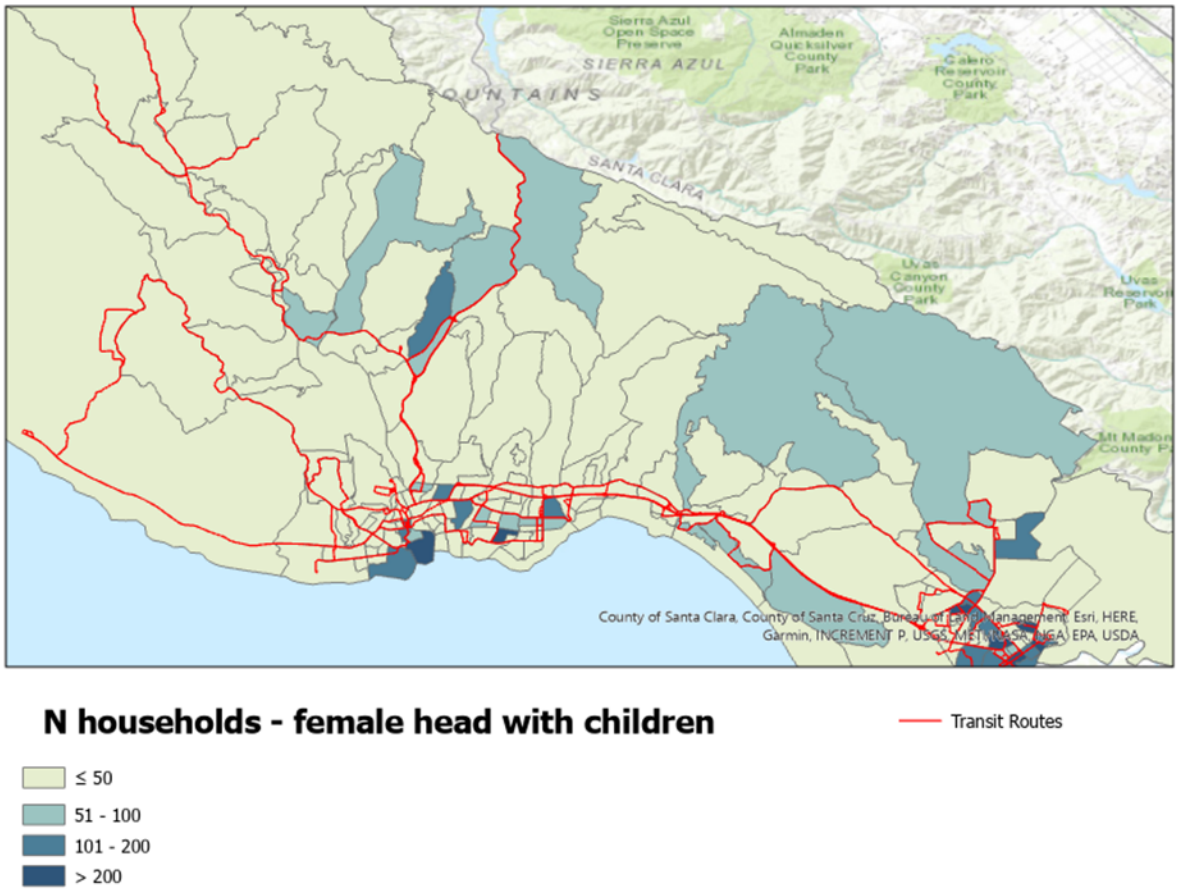
Absence of a vehicle in the household is yet another indicator of transit disadvantage. Yet, comparing Figure 11 with the previous two figures, there appear to be significant differences between zero vehicle ownership and race or low income.

Figure 12. Block Groups in Santa Cruz County by Percent Households with No Internet Service



The distribution of households without internet service (Figure 12) appears somewhat similar to that of low-income households. But again, there are also some slight differences.

Figure 13. Block Groups in Santa Cruz County by Number of Single-Parent Households with Female Head and Children



Santa Cruz County also shows some areas with significant concentrations of households with children that are headed by women (Figure 13). These concentrations somewhat overlap with low-income and non-white households, but there are some differences as well.

Figure 14. Block Groups in Santa Cruz County by Number of Workers Who Work at Night

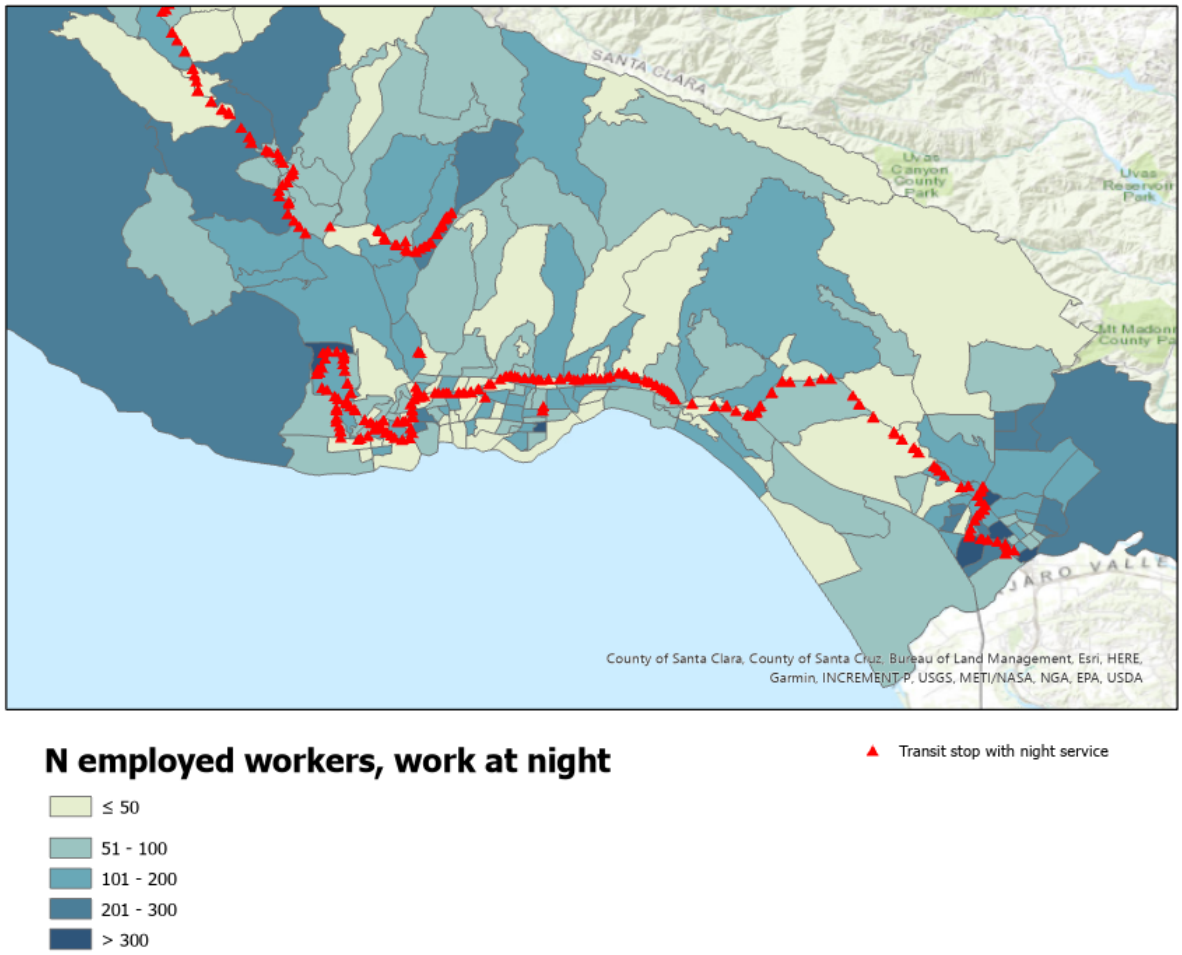


Figure 14 shows the number of workers who work at night by block group, juxtaposed against transit stops with night service (headways of one hour or less). As shown on the map, although there appears to be nighttime service along the main corridors in the county, there are several block groups with large numbers of nighttime workers but no nighttime transit service.

A number of nonparametric correlations were run to assess how well the Title VI guideline criteria (race and income) correlate with other measures of transportation disadvantage. All correlations were significant at the 5 percent level or better using the Kendal's tau coefficient method, a nonparametric measure of rank-order correlation between two variables .[211]

Table 2. Block Group Correlations: Percentages [212]

	% HH with public assistance	% HH with zero vehicles	% HH with income under twice the poverty level	% HH with no internet
% non-white population	0.33	0.16	0.29	0.26
% HH with public assistance		0.12	0.44	0.17
% HH with zero vehicles			0.18	0.25
% HH with income under twice the poverty level				0.23

Table 3. Block Group Correlations: Number of Households

	# HH with female head with children	# HH with public assistance	# HH with zero vehicles	# HH under twice the poverty level	# HH with no internet
Non-white population	0.24	0.40	0.21	0.46	0.33
# HH with female head with children		0.34	0.12	0.34	0.14
# HH with public assistance			0.21	0.52	0.26
# HH with zero vehicles				0.26	0.35
# HH under twice the poverty level					0.36

These correlations show that, although there is some relationship between Title VI guideline metrics and other measures, the relationships are weak at best. Hence, it appears that Title VI guideline metrics appear to miss some significant measures of transportation disadvantage.

3.3 Summary and Conclusions

As discussed earlier, the research in this report addresses equity from the perspective of ensuring access to all those who might be transportation-disadvantaged. Race and income are only part of the story. We also looked at transportation disadvantage with regard to several other metrics, such as:

- Income
- Race

- Zero car availability
- Lack of internet service
- Single-parent households headed by females with children
- Persons who work late at night, and may therefore have less access to transit service

The results of the case study suggest the following preliminary conclusions:

- There appear to be some correlations between race, income, and the other proposed metrics listed above.
- These correlations, though significant, are for the most part very weak, suggesting the new metrics capture aspects of transit service equity that are overlooked by race and income metrics.

We therefore conclude that this example demonstrates that current Title VI guideline metrics may miss out on other significant measures of transit equity.

4. Secondary Displacement Feasibility Analysis Findings

A determination was made based on discussions with Caltrans that the research team would also identify and evaluate equity metrics for secondary housing displacement caused by transit, potentially for use in the Caltrans Equity Index.[213] While primary displacement occurs when a new transportation or other infrastructure project displaces existing households from their residences so their properties can be used for the new facility's right-of-way, secondary displacement refers to the displacement "that occurs when low-income residents are forced out by economic or social forces, such as rising rents."[214] Furthermore, secondary displacement effects are likely different depending on whether transit agencies and local governments use strategies, policies, and programs (i.e., mitigation measures such as the construction of affordable housing on transit property, fare reductions, the introduction of new services designed specifically to meet low-income people's access needs, etc.) to mitigate secondary displacement effects. Therefore, this project studied (among other metrics) the feasibility of Caltrans and other transit stakeholders to use metrics for secondary displacement that may result from the introduction of new transit services, as well as the effects of any mitigation measures.

Many organizations have worked to develop methods for measuring, predicting, preventing, and mitigating displacement. This study presents and evaluates these methods based on a survey of the literature.

4.1 Displacement Measurement Methods and Tools

As described in the Chapter 2 literature review, most displacement measurement methods can be organized into three categories: descriptive, comparative, or predictive.

Method 1: Descriptive Secondary Displacement Measurements

A descriptive method summarizes demographic data to help determine potential displacement risk by looking for the presence of specific high-risk indicators within a given area. However, unlike comparative methods (described below), they do not compare those indicators to citywide standard or "benchmark" values (e.g., averages).

A search of the academic and practice literature identified the following descriptive methods:

- **Displacement Alert Portal (DAP):** Developed by the Association for Neighborhood and Housing Development, New York City Council, and New York State
- **Heightened Displacement Risk Indicators**: Developed by the City of Seattle.
- **Area Deprivation Index:** Developed by the University of Wisconsin-Madison.

The City of Seattle's Heightened Displacement Risk Indicators is an example of a descriptive method.[215] This approach measures displacement risk by evaluating housing market dynamics in terms of decreases in the total number of available affordable and rental housing units. Relying on data from the U.S. Census Bureau, King County Department of Assessments, and the Seattle Department of Construction and Inspections, the City of Seattle believes that early design guidance applications, construction permits, increases in sale prices, and home flipping are useful indicators for secondary displacement, stating that these indicators "suggest the potential for secondary economic displacement and exclusionary neighborhood change."[216]

While it was not specifically designed for the purpose of measuring potential displacement risk, the Area Deprivation Index (ADI) can serve as a proxy for displacement risk because it identifies the locations of disadvantaged communities nationwide. Using many of the same indicators as displacement-specific measurement methods, the ADI is a public health tool developed by the University of Wisconsin-Madison to evaluate health disparities across the county. "The ADI is composed of 17 education, employment, housing-quality, and poverty measures originally drawn from long-form Census data and updated by our team to incorporate more recent American Community Survey (ACS) data."[217] This approach "allows for rankings of neighborhoods by socioeconomic disadvantage in a region of interest (e.g., at the state or national level). It includes factors for the theoretical domains of income, education, employment, and housing quality. It can be used to inform health delivery and policy, especially for the most disadvantaged neighborhood groups."[218]

Based on these findings, the research team concludes that while the Heightened Displacement Risk Indicators method is well-developed and capable, it is developed by and for the Seattle region, and therefore would require substantial effort to configure for California use. However, the ADI is a relatively "off-the-shelf" method that could readily serve as an effective first step for identifying neighborhood displacement risk and can be used to complement traditional displacement risk assessment methods.

Method 2: Comparative Secondary Displacement Measurements

The comparative method is the most common method found in the literature. These methods compare displacement vulnerability indicators to city or regional benchmarks (typically average values). Individual neighborhoods are considered higher risk when vulnerability indicators vary substantially compared to citywide averages.

A review of the academic and practice literature identified the following comparative methods:

- **Displacement Risk Indicators Matrix (DRIM):** Developed by the Rutgers Center on Law, Inequality, and Metropolitan Equity.

- **Gentrification Measurement:** Developed by Chapple et al. (2017).

- **Regional Displacement Risk Index:** Developed by the Puget Sound Regional Council.
- **Urban Displacement Typology Map:** Developed by the Urban Displacement Project at UC Berkeley.
- **Mapping Displacement Pressure:** Developed by the Institute for Housing Studies at DePaul University.
- **Gentrification and Displacement Neighborhood Typology Assessment**: Developed by the Portland Bureau of Planning and Sustainability.

The City of Portland's methods provide a useful example of a comparative model. They employ a version of a comparative methodology in its 2018 Gentrification and Displacement Neighborhood Typology Assessment. Rather than simply looking for the presence of specific indicators, Portland then compares those tract-level values to city averages. Specifically:

- share of households that are renters greater than Portland's average,
- share of population that are communities of color greater than Portland's average,
- share of adults (25 or older) without a four-year degree greater than Portland's average, and
- share of households that are low-income (below 80% MFI) greater than Portland's average.[219]

According to the City's Bureau of Planning, "These socioeconomic factors indicate a reduced ability to withstand housing market price increases caused by gentrification."[220]

One challenge facing the development of a method (or, as seen described below, a model) capable of accurately forecasting displacement is that there is no consensus on the best indicators for measuring displacement risk. Some agencies have attempted to resolve this uncertainty by incorporating a more comprehensive range of indicators in their method. For instance, Puget Sound Regional Council developed a method that consists of fifteen indicators, while the Rutgers Center for Law, Inequality, and Metropolitan Equity uses nine. This difference in approach illustrates the fact that "Previous studies have failed to build a cumulative understanding of displacement because they have utilized different definitions, compared different populations, and adopted a relatively short timeframe."[221]

Method 3: Predictive Secondary Displacement Measurements

The third and least common is the predictive method designed to forecast secondary displacement outcomes resulting from socio-demographic conditions coupled with specific planning,

management, investment, or operational decisions. As seen with the descriptive and comparative methods described previously, Census/American Community Survey (ACS) data, such as race and total household income, are commonly accepted indicators that serve as red flags for the evaluation of displacement risk.

In addition to the development of risk-based indicators, displacement typology maps are also a commonly accepted method for assessing gentrification risk. That said, many of these methods tend to fall short when attempting to clearly identify and examine the causes of gentrification, which limits their overall effectiveness and ability to forecast gentrification.[222] Predictive methods seek to overcome these shortcomings and provide actionable policy forecasts of future displacement outcomes.

A search of the academic and practice literature identified the following predictive methods:

- **Change Model**: Developed by the City of Denver.
- **Off-Model Displacement Assessment**—UrbanSim and PECAS: Developed by Chapple et al. (2017).

While the research team could not find any technical information on Denvery's Change Model, Chapple et al. (2017) provide a useful example of the challenges involved in creating a predictive model of displacement and gentrification. They aimed to develop two predictive models, one for the Bay Area and one for Los Angeles. To achieve this, Chapple et al. first ran logit and linear regression models to determine statistically significant "neighborhood indicators from readily available, tract-level ACS data in order to facilitate assessment of displacement risk by city or regional agency staff in a simple spreadsheet analysis."[223] Independent variables for future conditions were then estimated using two different micro-simulation models. Bay Area independent variables were estimated using Paul Waddell's UrbanSim model, while Los Angeles independent variables were estimated using SCAG's PECAS model.

The final models developed by Chapple et al. (2017) are useful for identifying key variables that cause or are related to displacement but were of limited or no predictive value since they explained relatively small shares of the overall variation in displacement data and produced high levels of false positives and negatives when used for prediction. They conclude that "[t]herefore, we should be very cautious on how to use these models."[224]

4.2 Secondary Displacement: Evaluation Conclusions

Based on the information collected and analysis of secondary displacement measurement techniques, the research team reached the following conclusions: (1) predictive methods and models are "not ready for prime-time", and (2) comparative methods show promise, as described in greater detail below.

4.2.1 Predictive Methods and Models are "Not Ready for Prime-Time"

The predictive value of Chapple et al.'s (2017) model was determined to be unreliable, and therefore, not very useful at this stage of its development. As a result, the literature review and analysis determined that predictive models are still underdeveloped and should not be considered for use by Caltrans or other transportation agencies in California for the foreseeable future.

4.2.2 Comparative Methods Show Promise

While predictive models do not hold promise for now, there are numerous examples of comparative models that rate highly in our analysis across our three preliminary evaluation scales (understandability, workability, and effectiveness). In particular, the Regional Displacement Risk Index by the Puget Sound Regional Council and the Displacement Risk Indicators Matrix (DRIM) by Rutgers University show the most promise, each ranking very high across nearly all preliminary evaluation scales. These comparative methods point the research team in the direction of recommending the development of a suite of displacement-related indicators, specialized for the California context, that provide "red flags" to the user when they exceed empirically established thresholds of significance, most likely based on simple descriptive statistics (e.g., averages, standard deviations) of local, regional, or statewide data. Candidate indicators could be identified, tested, and evaluated for development and use by Caltrans for the Equity Index based on a review of the variables used in the methods found in our literature review and an assessment of data availability for those indicators statewide. Presumably, there is a reasonable chance that some of these indicators are already slated for inclusion in the Caltrans Equity Index for other analysis purposes, in which case it would be relatively simple to repurpose these datasets for use in evaluating displacement risk using a comparative method.

5. Key Considerations for Future Research: Selecting and Evaluating New Transit Equity Metrics

This chapter consolidates and expands on the lessons learned in Chapter 2 and the results of the research team's needs analysis presented in Chapter 3. These chapters concluded that there are theoretical (Chapter 2) and empirical (Chapter 3) needs for transit equity metrics that go beyond the limitations of the traditional transit equity metrics required by Title VI (race) and its associated regulations (income). This Chapter identifies key considerations for assessing potential alternative methods for measuring transit equity which go beyond Title VI measures of equity in a future Phase 2 research project. Specifically, it addresses the following issues:

- What do we mean by equity in transit?
- What have we learned from the literature review?
- What are some barriers to improving transit equity?
- How do we define different groups for equity?
- What aspects of transit service affect equity?
- At what decision-making level should we look at equity?
- Is there a conflict between equity and service efficiency?
- What are some potential transit equity metrics?

Implicit in these considerations is the assumption that it is difficult if not impossible to measure all aspects of transit equity. This assumption is self-evident from a literature review, which shows the myriad ways analysts have chosen to measure equity, the plethora of values and perspectives they bring to those measurement systems, and the variety of applications they are used for. Therefore, while it is sometimes tempting to take a comprehensive, all-inclusive approach gathering all possible metrics and combining them into a single index or scale, in this case, this is nearly impossible, if only due to the seemingly infinite variety of combinations and the risk that something important will be missed. Therefore, this research project sought to identify a core, key set of metrics that build on the existing metrics used in practice, that would meaningfully serve to advance our understanding and inclusiveness of transit equity measurement.

5.1 What is Meant by Equity in Transit?

We base our definition of equity in transit on the environmental justice principles set forth by the U.S. DOT:[225]

- "To avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority populations and low-income populations."
- "To ensure the full and fair participation by all potentially affected communities in the transportation decision-making process."
- "To prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations."[226]

As we discuss later, in this project we expand the third item above to include more groups, for example:

- The elderly
- The disabled
- People with limited access to cars
- Households that may be disadvantaged in other ways (e.g., single-parent households)
- Households whose geographic location falls outside existing transit service areas

5.2 What have we Learned so Far?

Chapter 2's literature review provided some key findings, leading to several conclusions for evaluating transit equity. In short, transit equity analysis should be designed for:

- Minimizing the effect of new transit decisions (operations, fares, route structure, etc.) on transportation-disadvantaged groups. As discussed below, we recommended broadening the definition of "transportation-disadvantaged groups" beyond race and income.
- Identifying current inequities in transit service and taking steps to remedy those inequities.

5.3 What are some Barriers to Improving Transit Equity?

It is worthwhile noting some of the current barriers to improving transit equity. Based on our literature review, interviews with transit equity professionals and academics, and feedback from the study's advisory committee, we have identified the following barriers:

- **Limited resources**: Funding for transit is limited by available public funds and how much transit agencies can collect in fares. These funds are limited. Hence, transit agencies are often restricted to playing a zero-sum game, i.e., improvements to transit service in one area means that service must be reduced in other areas.

- **Return to source**: There is considerable political pressure for tax revenues generated for transit to be returned to their source. This limits the extent to which the state can allocate transit funding among regions, or even to which regional agencies can allocate funding within their own regions.

- **Staff limitations**: Identifying inequities and devising ways to remedy them requires staff time and effort for analysis and planning. Smaller transit agencies are limited by the available amount of staff time they have.

- **Awareness of inequities**: Transit agencies are often unaware of inequities that exist within their service area.

5.4 What Groups Should We Consider When Looking at Equity?

FTA guidelines currently mention race (including persons with limited English-speaking ability) and income. However, based on our review of the literature and state of the practice, there are other groups that may be transportation-disadvantaged, including:

- Essential workers who do not work during the day shift

- Female single-parent households

- Zero-car households

- Households with fewer cars than workers

- Persons with limited mobility, including elderly and handicapped

The following section illustrates some of these other transportation-disadvantaged groups.

5.4.1 Time of Day of Work

Table 2 shows the average wages for urban and rural workers by type of work shift, showing that:

- Workers who do not work the daytime shift are generally in lower-paying jobs than other workers.

- Rural workers generally earn less than urban workers.

Table 4. Average Annual Worker Wages by Shift Type and Location

Work shift	**Location**		**Average**
	Urban	Rural	
Daytime	$65,300	$55,500	$64,800
Other	$47,700	$45,300	$47,600
Average	$57,500	$51,100	$57,100

Source: PUMS 2015–2019

5.4.2 Vehicle Availability

Table 5 shows the percentage of households by mode that have no cars, as well as the percentage that have fewer vehicles available per household than workers, revealing that:

- Workers who do not have any vehicles or fewer vehicles per worker in a household are highly transit-dependent.

- Vehicle availability is an important determinant of transit demand, and therefore, transit equity.

Table 5. Work Travel Mode Share and Household Vehicle Availability

Mode	Mode share	% Households by mode	
		No vehicles	With less vehicles than workers
Drive alone	74.2%	1.2%	11.0%
Shared ride	10.0%	3.1%	26.2%
Motorcycle	0.3%	6.0%	17.9%
Transit	5.0%	20.9%	33.8%
Bike/walk	3.2%	17.2%	31.2%
Work at home	5.9%	3.3%	12.5%
Other means	1.3%	12.4%	33.2%

Source: PUMS 2015–2019

5.4.3 Female-headed Households

Households with children headed by women have lower incomes than other households as seen below in Table 6.

Table 6. Median Household Income of Single Female-Headed Households

Household type	Median household income
Woman head, children present	$44,900
Other households	$78,000

Source: PUMS 2015–2019

Race and income are undoubtedly important determinants of transportation need and, therefore, of transit equity, but they are not the only ones. For example, a middle income, female single-headed household will have significant need for good transit services even though its members do not fit the demographic profile as determined by race and income alone. In sum, transit equity must consider *all* persons who are potentially transportation-disadvantaged, rather than merely focusing on race and income.

5.5 What Aspects of Transit Service Affect Equity?

Figure 15 below illustrates some connections between agency management, budgeting, and operating decisions that affect transit service equity.

Figure 15. Connections Between Service Measures and Transit Management, Budgeting, and Operating Decisions

Measures	Management, budgeting, operating decisions							
	Capital		Operating				Fares	
	Fixed guideway extensions by mode	Revenue service vehicles by mode	Area coverage	Hours / days of service	Service frequency	Network connectivity	Fare levels	Payment mechanisms
Accessibility								
Jobs	○	○	●	●	●	●	○	
Low-paying jobs	○	○	●	●	●	●	○	
Urgent care	○	○	●	●	●	●	○	
Medical	○	○	●	●	●	●	○	
Grocery shopping	○	○	●	●	●	●	○	
Other shopping & personal business	○	○	●	●	●	●	○	
Recreation	○	○	●	●	●	●	○	
Affordability							●	○
Service quality								
Walk access time / distance	●	●	●	●	●	●		
Travel time compared to auto	●	●	●	●	●	●		
Crowding	●	●	●	●	●	●		
Overall convenience	●	●	●	●	●	●		○

● = primary effect

○ = secondary effect

Access to opportunities is the primary concern for the following set of activities:

- **Mandatory (work, school)**: These are activities that most must engage in. For transportation-disadvantaged populations, access to low-paying jobs is often a concern.
- **Maintenance (shopping, banking, medical, etc.)**: These are activities that are required for personal or household maintenance.
- **Discretionary (social/recreational)**: Equity also implies providing access to social and recreational opportunities that persons could not otherwise engage in without transit service.

Access is directly related to coverage of the transit system in several respects:

- **Geographic coverage**: Geographic coverage affects walk access times and therefore feasibility of accessing transit service for households without access to a car.

- **Coverage in time**: One often ignored aspect of transit service is coverage by time of day. Small transit systems in particular are geared primarily to providing transit service on weekdays during the daytime.

5.6 At What Decision-Making Level Should We Look at Equity?

Although this study was primarily concerned with decisions at the transit agency level, these decisions are not made in isolation. Policy guidelines, funding decisions, and funding formulas, among others, are usually determined at regional, state, and federal levels and have a significant effect on the resources available for transit agencies, and, ultimately, the capability of transit agencies to address inequities in transit service.

Based on the research team's synthesis of the literature review, interviews, and professional experience, Table 7 summarizes how transit service equity is determined at several levels by a number of different actors.

Table 7. Levels of Decision-Making that Affect Transit Equity

Level	Decisions that affect equity
Transit agency	Policy on equity Implementation of equity measures within agency Vehicle stock Route structure Schedules Hours of operation Service frequency Fares
Regional/County	Policy guidelines on equity Taxation and other local revenue sources Funding allocations among transit agencies Fare and schedule coordination Fare and service standards
State	Policy guidelines on equity Taxation and other state revenue sources Empowerment of localities to assess taxes for transit (e.g., TDA) Regional funding assistance Formulas for funding allocation Funding allocation among regions and counties Performance monitoring
Federal	Policy guidelines on equity Fuel taxes Funding assistance Formulas for funding allocation

5.7 How Should We Evaluate Alternative Approaches to Assessing Transit Equity?

It is highly unlikely that a single measure would be appropriate for determining how equitable transit service is for a given agency. Therefore, several measures will be required to give a complete picture of how well transportation-disadvantaged populations are served.

An important first step in assessing potential equity metrics is to agree on a set of principles for assessment. The following is a set of preliminary criteria, developed based on the work of one of our research team's previous work,[227] used to develop final evaluation criteria for equity metrics:

- **Relevance to decision-making**: Can the equity measures directly inform decisions by management and policy makers?

- **Feasibility**: How difficult and expensive is it to acquire the necessary information for a set of equity measures?

- **Relevance to local issues**: Do the measures reflect the range of potential transit equity in California's diverse communities? Different communities will have different concerns. For example, in urban areas where transit serves choice, as opposed to transit-dependent, riders, there may be an issue of investing in less expensive modes (e.g., bus, taxi subsidy, etc.) versus more expensive modes (e.g., heavy rail, ferry). In rural areas, transit riders are more likely to be transit-dependent, so the main issues concern investment in roads versus transit, as is often the case with TDA money.

- **Compatibility with agency goals and objectives**: Are the measures compatible with, or do they conflict with, existing agency measures? For example, the issue of equity versus efficiency often comes up in discussions of equity.

- **Role in the agency**: Do the measures clearly distinguish between processes, decisions, and outcomes? It is one thing to take steps to promote equity. It is quite another to determine their outcomes.

- **Comprehensiveness**: Do the measures cover all affected groups? Income and ethnicity seem to be at the forefront of defining equity. But there are groups of concern that may fall outside of these categories, such as single-parent households or persons living far away from existing transit service.

- **Commensurability**: Decision-making entails looking at tradeoffs, for example, rail vs. bus, or how to balance existing service between geographic coverage, hours of service, days of week of service, and service frequency. The extent to which different equity measures can illuminate these tradeoffs will reflect their usefulness to decision-makers.

- **Overlap**: FTA guidelines specify race and income as two criteria for assessing transit equity. To some extent, these two criteria overlap. Other potential equity measures that address transportation-disadvantaged persons may also overlap with these. To the extent that measures for different populations overlap, these can be considered as reinforcing each other.

- **Transparency**: Are the metrics understandable to decision-makers and the public? Some academic articles on equity that we have already reviewed include some rather complex definitions of equity, e.g., a weighted index based on the gravity model to reflect transit access to jobs.

- **Manageability**: This is another aspect of the two points raised above. There is a limit to the number of things that a decision-maker can consider when making a decision. Too many equity measures can make it difficult to arrive at a conclusion.

- **Integration into agency operations**: Where do equity measures enter the decision process? Are they an essential part of the process or do they come as an afterthought once the decisions are made?

- **Implementation**: How can the measures be implemented in the agency? What are the data and analytic requirements for the measures? Does the agency have sufficient staff, data, and other resources to carry out the measures? [228]

5.8 Is there a Conflict Between Equity and Transit Service Efficiency?

Fixed-route transit service works best in environments with high residential and (especially) job density. Remedying current inequities by providing service to underserved transportation-disadvantaged populations may result in a decrease in service productivity and efficiency. Although it is not within the scope of this project to recommend alternative service configurations, by looking at different types of service provisions, transit agencies may be able to simultaneously improve both equity and service efficiency. Two examples follow:

First, taxis are an underused resource in many urban areas. In some circumstances, taxis can provide a lower-cost alternative to fixed-route transit, i.e., at a lower cost per trip. This is especially possible for nighttime and weekend service, when transit service demand is low.

Second, many transit agencies also offer some type of vanpool service. One of the barriers to vanpooling is dealing with passengers who might have to work late unexpectedly and therefore miss their vanpool. A guaranteed ride home program (either car rental or taxi voucher) has the potential to be an effective supplemental "safety net" for vanpool patrons. With appropriate safeguards on the amount of use, the cost of this type of program can be quite low.

5.9 What are Some Potential Equity Measures?

Based on the considerations discussed above, the research team developed a preliminary list of potential alternative methods for measuring transit equity—i.e., going beyond Title VI measures of equity—according to and expanding upon the approach developed in Chapter 3. In general, transit equity metrics can be defined along a number of dimensions, including:

- Transit service characteristics:
    - Travel time
        - Within a fixed time interval (e.g., 45 minutes, 1 hour)
        - Compared to auto travel time (e.g., within 1.5 times the auto travel time)

- Access availability by time period
    - Weekday daytime
    - Weekday other times
    - Weekends
- Affordable accessibility
    - Availability of transit service with fares less than a set threshold
- Accessibility to transit services
    - Presence of or distance to nearest transit stop/station

- Population groupings by socioeconomic characteristics and geography:
    - **Economics**: Income, car availability with respect to travel needs (jobs, school, etc.), poverty status, and housing costs and affordability.
    - **Mobility/accessibility**: The ability to travel for mandatory, maintenance, and discretionary purposes.[229] In this regard, we believe that it is important not to focus just on work and school travel but travel for other purposes.
    - **Choice**: This characteristic overlaps somewhat with mobility, but it is related to the definition of equity by the need to make sure that everybody has destination choices, where they are not dependent on one location for groceries and other necessary goods but where they have a number of options to find a diversity of goods and where competition among retailers can help keep prices low. It is not enough that someone simply has access to shopping somewhere, but that they have a choice where to shop.
    - **Demographic**: Race seems to be mentioned most often, but there are other considerations such as age (e.g., seniors) and household structure (e.g., single-parent households).
    - **Disability**: Physical disabilities are clearly a barrier to accessing travel and destination services; services that transit is often uniquely qualified to provide but are often lacking.
    - **Geographic**: Location with respect to travel opportunities. Also, location with respect to transit service. This is intended to represent persons who are forced out of high-density urban areas with good transit because of high housing costs. These

persons are then faced with the choice of finding affordable housing, but in areas with little or no transit access.

5.10 What Data Sources are Available for Assessing Transit Service Equity?

Determination of transit service equity is only as good as the data available. Table 8 lists some potential data sources for measuring equity and our assessment of the advantages and disadvantages of each.

Table 8. Potential Data Sources for Assessing Equity

Data source	Uses	Advantages	Disadvantages
Public hearings	Identify any public concerns with equity. Assess the potential effects of proposed agency decisions on equity.	Provides an open discussion forum.	May not be accessible to some people, particularly groups of concern for equity. Biased sample of public in attendance. Imposed time limits are usually too short for some persons to express opinions.
On-board survey	Assess rider demographics and their concerns.	Provides detailed data on transit use and rider demographics.	Expensive. Nonresponse bias due to insufficient time on vehicle, lack of motivation for users to respond, and language difficulties.
In-person contact via door-to-door, and interviews at transit stops or other busy locations	Identify community transit service issues and concerns with equity.	Provides direct outreach to targeted populations and the opportunity for in-depth discussions.	Expensive. Potential interviewer bias. Potential nonresponse bias.
Telephone survey	Identify community transit service issues and concerns with equity.	Avoids the bias of public meetings.	Expensive. High nonresponse bias due to lack of phone service, or public fatigue with extensive telemarketing and robot calls.
Community-based organizations	Identify the needs of disadvantaged communities.	Ready-made audience for transit agency representatives to speak to. Community leaders have their fingers on the pulse of the community and can convey issues in a way that other means—such as public hearings—cannot.	Requires more effort on part of transit agency staff. May have to work with community leaders and their groups to resolve trust issues.
American Community Survey	Provides detailed demographics by Census tract.	Identifies the location and number of transit disadvantaged persons.	Potentially large error margins in data due to sample size and lack of responses.
Census Public Use Microdata Sample (PUMS)	Provides detailed crosstabulations of demographic data and journey to work data	May help identify demographic relationships that may not be readily available in existing Census tabulations.	Coarse geographic focus. Extensive input of data may bias results.

Data source	Uses	Advantages	Disadvantages
Electronic map data for critical locations.	Visual assessment of transit service in relation to critical locations such as jobs, schools, hospitals, grocery shopping, and recreational opportunities	Direct observation to identify potential deficiencies in transit service.	Not all regions have mapping data readily available. Requires trained staff to develop mapping database, which may not be available in some areas.
Regional travel model	Identify trip patterns that may be underserved by transit, estimates of transit use for different route configurations, and other service changes.	Comprehensive agency-wide assessment of underserved geographic areas, assessing the effects of potential service changes.	Potentially expensive if no off-the-shelf model is available. A travel model may not be available for the region. Many travel models in rural areas do not model transit.
Focus groups	Seek issues of concern regarding transit service.	May identify issues that may not be readily apparent to transit agency management and staff.	Expensive. Requires outreach to community groups. Expert analysis required to appropriately summarize focus group results.

As noted in our review of the literature, public hearings have been the mainstay for transit agencies to assess the equity effects of proposed changes in transit service or fare policy. Recently, some agencies such as the LADOT, San Francisco Muni, Fresno Transit, and others have engaged in further outreach efforts to assess equity, including:

- Door-to-door visitation
- Direct interviews of transit patrons
- Work with community-based organizations

In addition, advances in mapping technology have enabled visual displays of transit service in relation to affected populations that convey information in a more primary and informative way than mere numbers. The main disadvantage is that these methods require access to data that may not be available at the same level of detail in all communities. In particular, rural communities are handicapped by a lack of access to demographic and mapping data.

5.11 Conclusions

Our findings suggest several conclusions for transportation agencies. First, it is clear that no single metric, or even a small set of metrics, can fully capture all dimensions of equity. As such, moving toward a more equitable transit system is a matter of both measurement and process. Specifically, this requires the development of clear operational and planning processes that first consider a broad

definition of transit-disadvantaged persons and then the creation of strategies to best serve those groups. For this to be achieved, equity thinking must be embedded in decision-making throughout a transit agency. Developing more equitable transit operations requires an environmental justice approach that goes beyond traditional measures of race and income, as specified in Title VI-related directives, to encompass other transportation-disadvantaged groups who need transit service but may not have adequate access to it.

Second, agencies need to be mindful that traditional mechanisms for identifying inequities, mostly public hearings, are inadequate because they may not be accessible to some groups, particularly transit-disadvantaged ones.

Finally, while agencies can make financial and policy commitments to transit equity, organizations should be aware that transit equity is also affected by decisions at several levels. This applies not only to the individual transit agency but within the metropolitan region and state where the agency resides. Federal policies and budgeting formulas can also significantly affect the equity of transit service. Rural areas differ significantly from urban areas in two respects:

- Data availability is more limited.
- Transit service in rural areas is provided more as a lifeline service for the transportation-disadvantaged rather than as an alternative to the auto, as it is in urban areas.

We therefore conclude that moving toward a more equitable transit system is a matter of both measurement and process. It includes:

- Identifying underserved groups of transit-disadvantaged persons.
- Developing operational and policy strategies to better serve these groups.

6. Research Approach for Developing Alternative Transit Equity Metrics in Phase 2

6.1 Introduction

This project was designed to help Caltrans and California's transit agencies better assess transit service equity and assist with evaluating potential remedies to existing inequities. The research team conducted a literature review and interviews with selected transit agencies and advocacy groups, the results of which were presented in Chapter 2. Chapter 3 reports on the results of an evaluation of the need for new metrics by comparing the performance of five new metrics with the traditional, Title VI required metrics, race and income in Santa Cruz County, California.

This report represents the findings of the first phase of a possible two-phase project. In a second phase, the team could develop a list of promising new metrics and evaluate the feasibility of their use over a wide range of test cases from across the state. More specifically, the research team could develop a set of recommendations for how Caltrans, MTI, and other potential transit agency stakeholders could integrate these metrics and associated methods into their equity-based planning, operational, and administrative processes, including the Caltrans Equity Index.

This chapter builds on the findings from the previous chapters and sets the course for work that will follow in a proposed Phase 2 of this study. Based on the considerations for future research as discussed in Chapter 5, this chapter presents the proposed methods for identifying and evaluating a set of equity metrics to supplement the traditional Title VI metrics (race and income). Feasibility will be assessed by identifying promising new metrics, applying them to case study areas, and comparing the results to those generated by traditional Title VI metrics used in the transit planning and operational professions. This approach is based on our findings from Chapter 2, along with a set of principles developed by the research team for assessing the need for new metrics as seen in Chapter 5.

6.2 Selection and Evaluation of Equity Measures

Step 1. Draft and Finalize Evaluation Criteria

The goal of this project was to develop a set of equity measures that can be used by Caltrans, transit agencies, and other transit stakeholders to help improve equity in their service areas by improving on those commonly used for Title VI analysis: income and race. To that end, based on the results of the needs analysis as discussed in Chapter 3 and the considerations for future metrics research discussed in Chapter 5, the research team has developed a condensed, minimum set of criteria for assessing potential equity measures[230] in the proposed Phase 2 research:

- **Understandability**: Are the measures easily understood by transit agency management and staff, as well as the public? In particular, are they few enough in number to not confuse decision-makers and the public?[231]

- **Effectiveness**: Can the measures be linked to specific management, operational, investment, or operational decisions? How well do they measure the outcomes of these decisions?

- **Workability**: Can the measures be easily determined from available data, or is additional data collection required? Does a transit agency have the staff capability, both time and staff skills, to carry out developing the measures?

As discussed earlier, it is highly unlikely that a single measure (or group of measures combined into an index or weighted scale) would be appropriate for determining how equitable transit service is for a given agency. Therefore, several individual measures will be required to give a reasonably complete picture of how well transportation-disadvantaged populations are served by transit.

Step 2. Select Metrics for Evaluation

The research team will use a combination of the following methods to identify a pool of potential transit equity metrics (TEMs) for further evaluation:

- The findings from the detailed literature and state of the practice review in Chapter 2.

- The findings from the needs analysis described in Chapter 3.

- The research team's and panel's professional judgements.

- Commonly referenced TEMs from each major subheading of the literature/state of the practice review document.

- Select interview discussions with professionals and academics as identified in consultation with the study's advisory group.

Step 3. Determine Feasibility of New Metrics

Using the list of metrics identified in Step 2, the Phase 2 research team will perform an evaluation of the feasibility of the most promising metrics by comparing their performance with the performance of traditional Title VI metrics (race and income) in multiple counties from across California, selected to represent the geographic and demographic diversity of the state.

Based on the work described in Chapter 3 where the team evaluated the need for new transit equity metrics in Santa Cruz County, a similar set of methods will be employed in Phase 2 consisting of:

(1) visual inspection of thematic GIS maps in comparison to those generated from traditional metrics; and (2) statistical analysis (correlations) of the performance of various metrics, indicating to what degree new metrics are detecting equity conditions that are and are not captured by the Title VI metrics. Additional evaluation methods for consideration include: (3) interviews with practitioners and researchers to identify other methods and (4) follow-up review of literature to incorporate the most recent developments in the field of equity measurement.

7. Conclusions

7.1 Summary

This study has looked at equity from the viewpoint that transit should serve *all* potential users, especially those who are transportation-disadvantaged. Bearing this viewpoint in mind, we have addressed the following research questions in this study:

- Do current Title VI requirements adequately address the *needs* of persons who are transportation-disadvantaged? If not, what is missing?
- What other measures could be used to identify other transportation-disadvantaged populations? What is a rationale for determining which measures are useful?
- Is there some way of conveniently combining different measures of transportation disadvantage to come up with a unified way of determining whether transit service is equitable?

The following are our main conclusions from the study:

Current Title VI title requirements fall short in several regards in addressing the needs of transportation-disadvantaged persons. They only address how different race and income groups would be affected by proposed transit fare and service changes and do not address remedying existing inequities, nor do they consider other characteristics of transportation-disadvantaged populations such as those mentioned in the next item.

There are several other measures that could reasonably be considered as indicators of transportation-disadvantaged populations. They include low vehicle ownership, single-parent households headed by females with children, and persons who work at night where little or no transit service is running at that time.

In a test case of a single California county (Santa Cruz), we found that traditional Title VI measures do not correlate well with other potential measures of inequity, nor do they correlate well with each other. Hence, transit inequity is a multifaceted problem with a number of potential different measures, each revealing one aspect of inequity. Constructing a single index out of these different measures would entail significant value judgments of whoever constructed such an index and could well lead to overlooking significant inequity problems in the future.

In sum, the subject of equity in any provision of public services is complicated. While uniform application of a single set of standards such as those in Title VI may appear to be fair, there is considerable variation in transportation-disadvantaged populations that imply that equity measures should be tailored to the unique values of the community to whom a transit operator

provides service. This is especially true in a large state such as California, where there is a great diversity in transit service area populations.

Moreover, we see several possible use cases for applying equity measures, each with its own unique set of requirements:

- Extending service to areas that were previously underserved.
- Reallocating transit service to better serve underserved areas.
- Minimizing the effects of service cuts on transportation-disadvantaged persons.

The first of these is feasible only if additional resources become available for transit service; the second would entail reallocating service assuming the same availability of resources; the third, unfortunately, is all too likely to be overlooked given the current funding situation, where resources for transit have become increasingly threatened by budget shortfalls.

7.2 Key Findings

Our review of the literature and of transit practices first found that FTA Title VI requirements have significant shortcomings with regard to current concerns about transit equity. These are:

- They only look at race and income and not at other factors that contribute to inequity in mobility such as the unavailability of a car and working at night.
- They only address potential inequities caused by planned service changes and not the issue of remedying existing inequities.
- They do not set standards for defining and measuring equity.

The literature contains numerous examples of proposed equity measures, but many of these are not suited for current practice because of their requirements for data collection and staff skills in processing and analyzing the data. One potential equity concern is with displacement due to the construction of new transit facilities or with secondary displacement effects due to gentrification resulting from new transit facilities. However, this is of limited applicability since displacement due to gentrification has been found to be very difficult to predict.

The increased availability of mapping tools has given transit agencies, particularly those in urban areas, a way of directly displaying potential inequities in a way that is readily understandable by the public. Los Angeles Metro and San Francisco Municipal Transportation Agency (MTA), in particular, have developed mapping toolkits that readily display measures of access by transit to various opportunities (jobs, shopping, hospitals, etc.). TransitCenter has also done significant

work for a number of large urban areas around the country in developing mapping tools to examine equity in transit.

Identifying and diagnosing inequities in transit service provision are key. Traditional ways to seek public input, particularly public hearings, are typically least accessible to groups such as those with low incomes, who have the greatest concern with equity. San Francisco MTA has done extensive door-to-door survey work in disadvantaged neighborhoods to identify transit needs. Los Angeles Metro has developed guidelines for working with community-based organizations to obtain public input from disadvantaged communities. Fresno Transit has conducted interviews of transit users at transit stops to assess their views on how well transit serves them.

Equity is also a matter of *process*, i.e., how well equity concerns are integrated into day-to-day analysis and decision-making in transit agencies. For example, Los Angeles Metro has adopted the goal of making equity a prime consideration in every agency action, including planning, budgeting, and service management.

In sum, equity goes far beyond simply comparing existing or newly planned transportation services. It entails many other transit service aspects, as discussed above and shown below in Figure 16.

Figure 16. Connections Between Service Measures and Transit Management, Budgeting, and Operating Decisions

Measures	Management, budgeting, operating decisions							
	Capital		Operating				Fares	
	Fixed guideway extensions by mode	Revenue service vehicles by mode	Area coverage	Hours / days of service	Service frequency	Network connectivity	Fare levels	Payment mechanisms
Accessibility								
Jobs	○	○	●	●	●	●	○	
Low-paying jobs	○	○	●	●	●	●	○	
Urgent care	○	○	●	●	●	●	○	
Medical	○	○	●	●	●	●	○	
Grocery shopping	○	○	●	●	●	●	○	
Other shopping & personal business	○	○	●	●	●	●	○	
Recreation	○	○	●	●	●	●	○	
Affordability							●	○
Service quality								
Walk access time / distance	●	●	●	●	●	●		
Travel time compared to auto	●	●	●	●	●	●		
Crowding	●	●	●	●	●	●		
Overall convenience	●	●	●	●	●	●		○

● = primary effect

○ = secondary effect

In addition to the race and income metrics required by Title VI, there are several other potential transportation-disadvantaged groups, including:

- Households with no vehicles available, or fewer vehicles than workers.
- Single-parent households headed by women with children.
- Workers who work at night when transit service may not be available.
- Households without internet access.

We examined how well these metrics correlate with the traditional Title VI metrics (race and income) by looking at the Santa Cruz County in particular. We observed only weak correlations between traditional Title VI measures of inequity and potential other measures such as vehicle ownership and female heads of household with children. Therefore, the research team concluded that these traditional metrics are insufficient in scope and specificity to identify the diverse range of potential transit service equity impacts and that there is a demonstrable need for additional metrics for use in California.

Our examination of the data leads us to conclude that while California is a huge state with great diversity among its population, it also has a large rural population. The significant differences between rural and urban areas indicate that equity should be viewed differently between the two. In particular:

- Transit in rural areas serves primarily transit-dependent rather than choice riders, whereas a number of transit systems in urban areas—particularly rail—serve primarily higher income, choice riders.

- Households in rural areas tend to have lower incomes, yet higher car ownership than in urban areas.

Given the diversity of areas in California and the generally weak correlations between various potential equity measures, we believe that a single index of transit equity that combines all metric components into a single number may not be useful for all potential analysis applications, because:

- It would be technically difficult to develop consistent scaling for all possible equity measures and all possible analytic uses.

- Applying any scaling measures, and especially weighting them, may introduce subjectivity. Any potential weighting scheme would have to be tested with multiple possible combinations of weights to ensure robustness.

7.3 Recommended Research

This report represents the findings of the first phase of a possible two-phase project. In a second phase, the team could develop a list of promising new metrics and evaluate the feasibility of their use over a wide range of test cases from across the state. More specifically, the research team could develop a set of recommendations for how Caltrans, MTI, and other potential transit agency stakeholders could integrate these metrics and associated methods into their equity-based planning, operational, and administrative processes, including the Caltrans Equity Index.

This project has provided an initial look at transit equity in California in relation to existing Title VI guidelines. The study findings indicate a number of possible extensions to the work so far. Among these are the following:

- A county-by-county analysis for all California counties of service provided in relation to various indicators of transportation-disadvantaged populations, similar to the example of Santa Cruz County.

- Case studies of the application of service mapping techniques currently used by Los Angeles Metro and San Francisco to several other areas in California. We recommend that a number of rural, as well as urban areas, be included in this effort.

- Development of context-sensitive equity metrics that reflect the unique conditions of each transit agency. We expect, at a minimum, that there would be significant differences between rural and urban areas in California.

- An agency-by-agency review of current transit equity practices for all major transit agencies in California. Given the large number of providers, we suggest that for such a study to be feasible, it should be limited to those agencies who are full reporters to the National Transit Database, plus a sample of smaller agencies. This would: (1) determine how many agencies do a minimum to meet Title VI requirements; and (2) identify new practices in assessing equity. Some identification of new practices was done in this study, but we know that other transit agencies in California have gone beyond simply meeting Title VI requirements.

Appendix A: Transit Equity Metrics Summary Tables

Table 9. Summary of Transit Service Equity Metrics

Metric Type	Name	Description	Source
Transit Needs Equity	Zero-Vehicle Households	Percentage of households with no vehicle available	San Diego Association of Governments (2021)
Transit Needs Equity	Poverty	Percentage of households in poverty	San Diego Association of Governments (2021)
Transit Needs Equity	Unemployment	Percentage of working age population unemployed	San Diego Association of Governments (2021)
Transit Needs Equity	Transit Access	Percentage of population within 0.5-mile of fixed-route transit stop/station	San Diego Association of Governments (2021)
Transit Needs Equity	Disability Status	Percentage of civilian non-institutionalized population with a disability	San Diego Association of Governments (2021)
Transit Needs Equity	Housing Cost Burdened	Percent of households spending > 30 percent of income on housing	San Diego Association of Governments (2021)
Transit Needs Equity	Transit Accessibility for Disadvantaged Groups	"[C]alculated using publicly available data, including the U.S. Census Bureau's Longitudinal Employer-Household Dynamics dataset and transit route and schedule information in the General Transit Feed Specification (GTFS) format."	Karner (2018)
Transit Needs Equity	Transit Equity Demand Index (TEDI)	TEDI is designed to identify locations in need of further transit investment. These "high-demand areas" are identified by measuring fifteen different indicators such as population density, vehicle availability, and the total number of households living in poverty.	LINK Houston (2020)

Metric Type	Name	Description	Source
Transit Needs Equity	% of system-wide stops with shelters and amenities	The metric can be used in conjunction with data on the percentage of demographic characteristics of the system riders served, and in doing so, "is a simple and effective method to assess stop quality and equity."	NACTO (2018)
Transit Needs Equity	Access to Transit: % of bicycle and pedestrian facility gaps within 1/2-mile of light rail, 1⁄3-mile of streetcar, and 1/4-mile of bus stops	ArcGIS is used to "calculate the linear miles and percentage of sidewalks and bikeways completed within 1/2 mile from light rail stops, 1/3 mile from streetcar stops, and 1/4 mile from bus stops; existing and planned stops region-wide within the MPA boundary and in historically marginalized communities."	Oregon Metro (2018)
Transit Needs Equity	Transit Gap Index (TGI)	The TGI relies on the General Transit Feed Specification (GTFS) and block Census data to evaluate transit service as it relates to vertical equity. GTFS enables quick and straightforward transit service analysis.	Fan & Li (2019)
Transit Needs Equity	Annual Travel Time Disparity	This metric evaluates annual travel time disparity across different population groups for car drivers, bus riders, and subway riders. Also used to emphasize the point that public transportation agencies need to do more to address inequities that persist across the transit system.	Livable Streets Alliance (2021)
Transit Needs Equity	Lorenz Curve Analysis	Lorenz curve analysis requires that "the cumulative proportion of a transit supply is mapped to the cumulative proportion of the disadvantaged	Carleton & Porter (2018)

Metric Type	Name	Description	Source
		population metric, thereby creating a Lorenz curve."	
Transit Needs Equity	Needs Gap Analysis	Combines metrics of transit supply and demand to give an aggregated transit need index score for populations and geographical areas.	Carleton & Porter (2018)
Transit Needs Equity	Gini Coefficient	A statistical measure of dispersion, often used to represent wealth inequalities, and sometimes used in tandem with Lorenz curves. A Gini coefficient value of zero represents perfect equality, while a value of one represents maximum inequality.	Carleton & Porter (2018)
Transit Needs Equity	Inequity Index-Gini Index	The Gini index is based on four socioeconomic factors, referred to as the Inequity Index: household income, vehicle ownership, employment density, and population density. Current and future transit performance is measured by developing "connectivity indices at stop, route, and zonal level by considering various factors such as speed, frequency, operational capacity, fare, route origins and destination, and urban form characteristics that serve the transit system."	Mishra et al. (2018)
Transit Service Change Equity	Transit Revenue Hours	Marin Transit uses this metric to determine when a service change is likely to be "major," which is when the change in transit revenue hours is greater than 30%.	Marin Transit (2020)
Transit Service	Route Path Change	Used to determine when a service change is likely to be "major," which is	Marin Transit (2020)

Metric Type	Name	Description	Source
Change Equity		when a route path is changed by more than 40% over a three-year period.	
Transit Service Change Equity	New service on streets not previously used by any route	Used to determine when a service change is likely to be "major," which is when new service is provided on streets not previously used by any route.	Marin Transit (2020)
Transit Service Change Equity	Establishment or elimination of a transit line or service	According to VTA's Title VI analysis policies, a major service change is identified and determined to be discriminatory when their impacts affect 10% more of their minority or low-income riders compared to the general population of riders, measured by the following metrics: Route-Miles, Revenue Vehicle-Hours, and Total System Revenue-Hours.	Santa Clara Valley Transportation Authority (2016)
Transit Service Change Equity	Route-Miles	Route change affecting 25% or more of a line's route-miles.	Santa Clara Valley Transportation Authority (2016)
Transit Service Change Equity	Revenue Vehicle-Hours	Span of service or frequency changes affecting 25% or more of a line's revenue vehicle-hours.	Santa Clara Valley Transportation Authority (2016)
Transit Service Change Equity	Total System Revenue-Hours	A system-wide change concurrently affecting 5% or more of the total system revenue-hours.	Santa Clara Valley Transportation Authority (2016)
Transit Service Change Equity	Addition or Removal of a Route	The Port Authority uses the addition or removal of a route to determine what will be analyzed as a major service change, and then uses those same metrics to measure the disparate and	Four Nines Technologies & Port Authority (2021)

Metric Type	Name	Description	Source
		disproportionate impacts on their ridership (or when the data is unavailable, their service area neighborhoods).	
Transit Service Change Equity	Addition or Removal of a Service Day for a Route	Uses addition or removal of a service day for a route to determine what will be analyzed as a major service change, and then uses those same metrics to measure the disparate and disproportionate impacts on their ridership (or when the data is unavailable, their service area neighborhoods).	Four Nines Technologies & Port Authority (2021)
Transit Service Change Equity	Weekly Trips	Service changes that constitute an addition or reduction of more than 30% of the weekly trips on a given route.	Four Nines Technologies & Port Authority (2021)
Transit Service Change Equity	Service-Hours	Service changes that constitute an addition or reduction of more than 30% of the service-hours on a given route.	Four Nines Technologies & Port Authority (2021)
Transit Service Change Equity	Service-Miles	Service changes that constitute an addition or reduction of more than 30% of the service-miles on a given route.	Four Nines Technologies & Port Authority (2021)
Transit Service Change Equity	Annual Hours of Service	Adding or removing more than 2,500 annual hours of service on a given route	Four Nines Technologies & Port Authority (2021)
Transit Service	Vehicle Load (load factor) for Each Mode	Vehicle load is calculated by dividing the number of passengers by the number of seats.	AC Transit (2020)

Metric Type	Name	Description	Source
Change Equity			
Transit Service Change Equity	Vehicle Headway for Each Mode	Weekday peak vehicle frequency.	AC Transit (2020)
Transit Service Change Equity	Hours of Operation for Routes	The hours of operation for routes are used as the metric for service availability.	AC Transit (2020)
Transit Service Change Equity	Weekly In-Service Miles or Hours	A change that is greater than 25% of a route's weekly in-service miles or hours.	SANDAG (2018)
Transit Service Change Equity	Weekly Span-of Service	An increase or reduction in the average weekly span-of service of more than 25%.	SANDAG (2018)
Transit Service Change Equity	Route Change	The implementation of a new route or the discontinuation of an existing route.	SANDAG (2018)
Transit Service Change Equity	Directional Route-Miles	A routing change that affects more than 25% of a route's directional route-miles and more than 25% of the route's bus stops.	SANDAG (2018)
Transit Service Change Equity	Revenue Vehicle-Hours (RVH)	Major Service Change at the Modal Level: A change in RVH per week of at least 10% by mode. Major Service Change at the Route Level: For all routes, a change in route length of at least 25% or 3 miles; or for	Massachusetts Bay Transportation Authority (2017)

Metric Type	Name	Description	Source
		routes with at least 80 RVH per week, a change in RVH per week of at least 25%.	
Transit Fare Equity	Average Fare for Minority Compared to Overall Riders	Uses a 10% change in the average fare for minority groups compared to overall riders to determine when the costs associated with changing their fare system are inequitable.	Nancy Whelan Consulting (2013)
Transit Fare Equity	Average Fare for Low-Income Compared to Overall Riders	Uses a 10% change in the average fare for low-income compared to overall riders to determine when the costs associated with changing their fare system are inequitable.	Nancy Whelan Consulting (2013)

Table 10. Summary of Underserved Populations Metrics

Metric Type	Name	Description	Source
Traditionally Underserved Populations	Community Attributed Index (CAI):	The CAI combines Census track-level data from 165 variables by using principal components analysis to statistically reduce those variables into five dimensions: economic opportunity, poverty status, educational attainment, housing and population mix, and family stability. The most critical variables (metrics) used are:	Aimen & Morris (2012)
	Economic Opportunity	• Median household income	
	Poverty Status	• % Female-headed household • Poverty rate	
	Educational Attainment	• % of 45–59-year-olds with some education • % of people with associate degree	
	Housing & Population Mix	• Total Households • Total Housing Units • Total Family Housing Units	
	Family Stability	• % of 45–59-year-olds • % married households	
Traditionally Underserved Populations	Number of Trips per Day by Sex/ Gender	The Metro (2019) study used Number of trips per day by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	Average Trip Length by Sex/Gender	The Metro (2019) study used average trip length by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	Trip Purpose by Sex/ Gender	The Metro (2019) study used trip purpose by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)

Metric Type	Name	Description	Source
Traditionally Underserved Populations	Car Availability by Sex/ Gender	The Metro (2019) study used car availability by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	Average Number of Trip Chains by Sex/ Gender	The Metro (2019) study used average number of trip chains by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	Average Trip Chain Length by Sex/Gender (All Modes)	The Metro (2019) study used average number trip length by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	Peak Period (Time-of-Day) for Traveling by Sex/Gender (All Modes)	The Metro (2019) study used peak period (time-of-day) for traveling by sex/gender (all modes) to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	% of Riders Riding Transit 3 Days per Week or More on Average by Sex/Gender	The Metro (2019) study used % of riders riding transit three days per week or more on average by sex/gender to understand these unique needs.	Los Angeles Metro (2019)
Traditionally Underserved Populations	% of Women Riders who Bring Children on Transit	The Metro (2019) study used % of women riders who bring children on transit to understand these unique needs.	Los Angeles Metro (2019)

Table 11. Summary of Transit Accessibility Equity Metrics

Metric Type	Name	Description	Source
Isochronic (Cumulative Opportunity)	Accessibility for Disadvantaged Groups	Equity refinements to the isochronic metric: (1) measured complete travel time between origins and destinations; and (2) assessed six different destinations and nearly one dozen population cohorts.	Ermagun & Tilahun (2020)
Isochronic (Cumulative Opportunity)	Cumulative Opportunity Measure	Measures transit accessibility by examining financial access to transit as well as transit accessibility to jobs. The inclusion of fares into a transit accessibility model has historically been overlooked.	Deboosere et al. (2016)
Isochronic (Cumulative Opportunity)	Cumulative Opportunity	Refinements to the isochronic metric by comparing accessibility to low-income jobs for vulnerable. This approach allows planners to distinguish between finance and manufacturing jobs while calculating the average commute time for both vulnerable and non-vulnerable groups by mode.	Deboosere et al. (2018)
Isochronic (Cumulative Opportunity)	Access to Transit for Disadvantaged Groups	This isochronic measure uses data from the EPA's Access to Jobs and Workers via Transit database. The data included in this database uses a 45-minute travel limit to determine accessibility.	Griffin & Sener (2016)
Gravity-Based	Transit and Automobile Accessibility	A gravity-based metric to measure changes in transit and auto accessibility over time to jobs for low-income groups as an indicator for equity progress in U.S. urban areas from 2002 to 2014.	Stokes & Seto (2018)
Gravity-Based	Transit Accessibility to Low-Income Jobs	This metric formula can be applied to a variety of destinations to help planners evaluate access to jobs, as well as things like fresh food or hospitals. Can also be used during land use analysis to "consider the levels of access and mobility experienced by transit-dependent populations in	Ferguson et al. (2012)

Metric Type	Name	Description	Source
		multiple land use scenarios under a fixed transit budget."	
Gravity-Based	Gravity-Based Accessibility	Most gravity-based accessibility metrics rely on travel demand models for critical data inputs that are difficult to develop and maintain. In response to this shortcoming, Kaplan et al. (2014) developed an accessibility metric that was simple to calculate using easily obtained public datasets.	Kaplan et al. (2014)
Other	Transit Opportunity Index (TOI)	The Transit Opportunity Index (TOI) developed by Mamun et al. (2013) expands on these existing metrics by including trip coverage into its accessibility model.	Mamun et al. (2013)
Other	Transit Opportunity Index (TOI)	While Mamun et al. (2013) originally developed the Transit Opportunity Index (TOI) and calculated it by hand for the relatively small city of New Haven (CT), Bertolaccini et al. (2018) automated its calculation and applied it to larger metropolitan areas, including Boston, MA, Atlanta, GA, Hartford, CT, Minneapolis-St. Paul, MN, Denver, CO, and Seattle, WA. Compared to other transit accessibility metrics that calculate the total number of land use destinations that can be reached from an origin zone, the TOI measures the geographic and temporal coverage of transit networks themselves by combining three major components: spatial coverage, temporal coverage, and trip coverage	Bertolaccini et al. (2018)

Table 12. Transit Procedural Equity Metrics

Metric Type	Name	Description	Source
Finance and Project Programming	Projected Use	"Base equity assessments on modeled utilization of a project instead of simply on a project location (Metropolitan Transportation Commission)."	Caltrans (2021)
Finance and Project Programming	Proximity to DAC	The Sacramento Area Council of Governments (SACOG) leverages CUBE Access (a travel demand model) software to determine "accessibility at a user-specified geography (e.g., accessibility to jobs from each block group, census tract or TAZ)." SACOG claims that "Project Performance Assessment obtains the project average accessibility (the average accessibility for an entire project based on the accessibility of the census blocks in the project)."	Caltrans (2021)
Finance and Project Programming	Concentration of Affordable Housing	"Projects are awarded points for making multimodal improvements within 0.5 mile of higher concentrations of affordable housing options (relative to regional concentrations)."	Caltrans (2021)
Finance and Project Programming	Cost Recovery	"Cost recovery analysis assumes that people should receive public resources in proportion to how much they pay in fees and taxes."	Litman (2021)
Finance and Project Programming	Average subsidy per passenger	The primary problem of the Transportation Development Act (TDA) is that it allocates funds on a per capita ridership basis, which varies significantly between urban and suburban communities. Recommendation is to distribute TDA funds based on fare revenues and not per capita.	Taylor (1991)

Metric Type	Name	Description	Source
Finance and Project Programming	Average Subsidy per Passenger	"Disparities were reflected in subsidies to passengers, too. Public subsidies to the Blue Line were estimated at $128 million per year, enough to subsidize 17 of the MTA's 22 busiest bus lines."	Grengs (2002)
Finance and Project Programming	Profile of Major Transportation Challenges	The main point of this report is to remind planners in rural counties to be mindful of disadvantaged individuals and the challenges they face. Special considerations might be needed to ensure that all community members, especially the transportation-disadvantaged, can participate in the planning process.	Redwood Community Action Agency (2006)
Public Participation	Proportion of Stakeholders	This metric "[c]alculate[s] the proportion of stakeholders that are involved in the process. This can be done by calculating the percentage of stakeholder groups that are represented in the process from an assessment or inventory of all potentially affected stakeholder groups (including those who may not reside adjacent to the project)."	Transportation Research Board (1999)
Public Participation	Meeting Convenience	"A major component of a successful process is clearly identifying all of the stakeholders affected by/interested in a project and then getting representatives of those groups to participate."	Transportation Research Board (1999)
Public Participation	Shared Decision-making	"The degree to which decision-making is shared by all stakeholders (from the public participants to the managers and decision-makers) drastically influences a project's chance for approval."	Transportation Research Board (1999)

Metric Type	Name	Description	Source
Public Participation	Reprioritization	"Having a Reprioritization of processes and goals at regular intervals serves to reaffirm to participants that their input has been heard and acted on. Not only does this help improve the efficiency of the process but it reaffirms that participant's views are worthwhile."	Transportation Research Board (1999)
Public Participation	Timing and Focus of Involvement	"The effectiveness of public involvement is frequently tied to how well public consultation is focused on the real issues an agency is considering early and throughout plan or project development. If the public sees that input is sought and heeded on real issues from the start, it is assumed that participation will continue."	Transportation Research Board (1999)
Public Participation	Racial Equity Analysis and Decision-Support Tool	"[I]nclude[s] training and support for staff to successfully use the tool, a questionnaire to guide equity's incorporation into the agency's activities, and community engagement to ensure that the people most affected by the agency's activities have the opportunity to shape those activities"	Portland Metro (2016)
Public Participation	Votes for Municipality per Person	MPO boards are more likely to reflect the region's municipalities/jurisdictions, and not their demographics. This metric helps to identify the number of residents each board member represents.	Marcantonio et al. (2017)
Public Participation	Influence on Decisions/Process	"Allowing the participants to adjust the process increases the degree of influence and gives the participants a feeling of sponsor accountability and flexibility."	Transportation Research Board (1999)
Public Participation	Access to information and participation	"This indicator addresses the desire of the Florida Department of Transportation to ensure that persons with disabilities have	Kramer et al. (2008)

Metric Type	Name	Description	Source
	opportunities by persons with disabilities	an opportunity to participate fully in the transportation decision-making process."	
Public Participation	Convenience of meetings and events to public transportation, where available	"This indicator tracks whether persons who rely on public transportation or paratransit have access to public meetings and transportation events. It is also an indicator as to whether the general public could use public transportation to attend public involvement events."	Kramer et al. (2008)
Public Participation	Geographic dispersion of involvement opportunities	"This indicator tracks whether public involvement opportunities have been reasonably distributed across the affected area. For example, are meetings always held in a central location or is the location alternated to capture higher rates of localized neighborhood participation?"	Kramer et al. (2008)
Public Participation	Convenience of meeting or event time	"This indicator tracks whether those participating or invited but not participating feel that the public involvement opportunities of the agency were offered at a convenient time."	Kramer et al. (2008)
Public Participation	Convenience of meeting or event location	"This indicator tracks whether stakeholders feel that public involvement opportunities have been held at a convenient location."	Kramer et al. (2008)
Public Participation	Diversity of participants in public events	"Percent of participants by age, racial/ethnic, income, gender and employment characteristics reflects demographics of affected population."	Kramer et al. (2008)
Public Participation	Diversity of project committee representation	"Percent of participants in project committees by age, racial/ethnic, income, gender and employment characteristics	Kramer et al. (2008)

Metric Type	Name	Description	Source
		reflects demographics of affected population."	
Public Participation	Availability of information in languages other than English	"Information is provided in languages other than English where the affected population comprises a high proportion of non-English speakers. Translators are available at public meetings in areas where a high proportion of the affected population comprises non-English speakers."	Kramer et al. (2008)

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Dr. Ferrell began his career in 1995 as a planner for the Metropolitan Transportation Commission (MTC). He completed his doctoral studies in City and Regional Planning at the University of California at Berkeley in 2005 and worked as a consultant with Dowling Associates, Inc. for 10 years before leaving to help form CFA Consultants in 2010. He is currently a principal, board member, and the executive director of Transportation Choices for Sustainable Communities Research and Policy Institute, a 501(c)(3) non-profit. He has been the principal investigator for eight research projects for the Mineta Transportation Institute, where he has been a Research Associate since 2005. His research focuses on the relationships between transportation and land use, livability, travel behavior, transportation policy, and planning-related institutional structures. His research experience includes the study of multimodal transit and freeway corridors, the best practices for building successful transit-oriented development, the effects of transit-oriented development on surrounding property values, the effects of neighborhood crimes on transportation mode choice, and a set of methods, metrics, and strategies for evaluating transit corridor livability. As a practitioner, he has planned mixed-use, infill, and transit-oriented development projects; analyzed the impacts of specific and general plans; planned and implemented intelligent transportation systems; and developed bicycle and pedestrian plans. He has taught several quantitative methods classes in San Jose State University's Urban Planning Department and a course in transportation and land use in the City and Regional Planning Department at the University of California at Berkeley.

David Reinke, MS, MRP

Mr. David Reinke is a transportation engineer/economist with over 40 years of experience in travel demand modeling, transportation economics, survey design and management, database management, and software engineering. He has worked on a number of leading-edge projects in travel demand and economics, including development of activity-based travel demand models, development of discrete-choice travel forecasting models, the development of microsimulation-based models for analysis of congestion pricing alternatives, and applications of economic methods to transportation policy analysis. His areas of expertise include policy analysis, advanced statistical methods, machine learning methods, economic analysis, survey design and management, and applications of advanced computational techniques to transportation. He is currently a Research Associate with the Mineta Transportation Institute where he has worked on studies of transit equity and transportation economics. David currently co-chairs the Education and Outreach Subcommittee for the Committee on Artificial Intelligence and Advanced Computing Applications (AED50) at the Transportation Research Board (TRB) and is a past member of TRB committees on Statistics, Economics, and Travel Behavior and Values. He is also a member of the IEEE Intelligent Transportation Systems Society.

John M. Eells, MCP

John Eells is a transportation planner with 44 years of experience preparing comprehensive transportation plans and developing sustainable transportation projects at the local and regional level. John's experience includes two years in the Legislative Analyst Office in the California State Legislature, five years with the California Department of Transportation (Caltrans), seven years as the Transportation Planning Coordinator for Marin County, and thirty years as a consultant.

He holds a bachelor's degree in Architecture and a Master's degree in City Planning from the University of California at Berkeley. John has assisted in the preparation of Regional Transportation Plans for Sacramento and Lake Tahoe and reviewed Regional Transportation Plans throughout California for conformance with State greenhouse gas reduction requirements for the California Attorney General's Office. He participated in a joint effort by Caltrans and the California Council on Science and Technology to develop a proposal for a new California Center for Transportation Innovation to coordinate transportation research activities in California. John has also managed major multi-modal transportation studies, evaluated the feasibility of proposal ferry services, and worked on the implementation of several rail transit projects including the Sacramento Light Rail project, the ACE Commuter Rail Service from Stockton to San Jose, the SMART Commuter Rail Service from Cloverdale to Larkspur, proposed AMTRAK service from Oakland to Reno, and the proposed high speed Maglev Service from Los Angeles to Las Vegas.

Matthew Schroeder, MUP

After earning a degree in environmental policy from Seattle University, he returned to Santa Clara County, accepting a position at the City of Cupertino within its Safe Routes to School Program. This role ignited his passion for transportation as he witnessed its profound effect on daily life. Understanding the interconnected nature of planning and its impact on transportation, Matthew decided to pursue a Master of Urban Planning degree in 2021. During his studies, he served as a research assistant at the Mineta Transportation Institute, studying transit equity measurement for Caltrans. Concurrently, Matthew worked as a graduate intern at the City of San Jose, where he partnered with local business owners to install bike racks and lockers on private property. Recently, Matthew accepted a role at the Santa Cruz County Regional Transportation Commission and is responsible for legislative affairs and GIS analysis.

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