

From State of the Practice to State of the Art: Improving Equity Analysis in Regional Transportation Plans

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Statements and Declarations

This study compares the regional transportation plan for the San Diego Association of Governments (SANDAG) Metropolitan Planning Organization (MPO) with the regional transportation plans of 10 other MPOs in the United States. The authors of this paper received funding from the National Science Foundation (NSF) through the Smart and Connected Communities Program, in which SANDAG is the main community partner for the funded project. SANDAG did not receive any funds from NSF, aside from potentially covering travel expenses for a SANDAG employee to attend an annual NSF Principal Investigator's meeting. Moreover, the authors do not have any direct financial interest in SANDAG; however, the authors do benefit from having SANDAG's continued support as a community partner on the ongoing NSF research project.

Abstract

Metropolitan Planning Organizations (MPOs) in the United States develop long-range Regional Transportation Plans (RTPs), which are required in order for municipalities to receive federal funds for transportation projects. Title VI of the federal Civil Rights Act of 1964 requires MPOs to submit an equity analysis to demonstrate that their RTPs do not discriminate against protected groups. This paper (i) identifies and evaluates the current range of practices in transportation equity analysis in RTPs for the largest MPOs, and (ii) provides practical steps for MPOs to improve their equity analyses. To identify the range of practices, we assess how MPOs define equity goals, identify populations of concern, integrate their equity analysis into their RTP documents, use community input, and whether they meet or exceed legal standards. Additionally, we evaluate how MPOs use travel forecasting models in their equity analyses and the quality of their models; we also describe practical steps for MPOs to improve their equity analyses along this dimension. We find significant variability in how MPOs define fairness in their equity goals, define populations of concern, use community input, and use travel forecasting models in their equity analyses. For example, several MPOs conduct in-depth equity analyses using advanced travel forecasting models, synthetic populations of households, and various classifications of populations of concern. In contrast, other MPOs only display the locations of RTP projects on a map with geographies labeled as disadvantaged or non-disadvantaged. We also find that MPOs with more restrictive state requirements than federal guidelines produce higher quality equity analyses—an important finding considering the Biden Administration's review of Executive Order 12898, a potential avenue to alter guidelines to improve MPO equity analyses.

Keywords: equity, accessibility, Title VI, regional transportation plans, metropolitan planning organizations

1 Introduction

1.1 Motivation

Regional transportation plans (RTPs) involve a combination of proposed transportation infrastructure investments, transportation and land use policies, and transportation programs. The implementation of an RTP can significantly impact mobility, access to opportunities and activities, safety, employment, health, economic output, and other important societal outcomes.

The benefits and costs associated with an RTP can fall unevenly across persons or population groups within a region. Hence, in addition to evaluating the expected cumulative social benefits and costs associated with RTPs, it is also critical to evaluate an RTP's distributional impacts across persons and population groups within a region, to ensure that specific residents do not receive disproportionately fewer benefits and/or greater harms.

To some extent, the evaluation of the distributional impacts of an RTP is codified in the United States (US). Title VI of the federal Civil Rights Act of 1964 requires metropolitan planning organizations (MPOs—described in detail in Section 2.2) to demonstrate that their RTPs do not discriminate on the basis of race, ethnicity, or other protected characteristics. Some MPOs attempt to go beyond the non-discrimination requirements of Title VI, and they develop RTPs to achieve broader equity goals. To illustrate non-discrimination and ensure their RTPs achieve equity goals, MPOs conduct equity analyses. An equity analysis evaluates the distributional impacts associated with the investments, policies, and programs proposed in an RTP, and whether the distribution of impacts is consistent with the MPO's non-discrimination criteria or equity goals.

Conducting a high-quality equity analysis that can meaningfully inform long-range RTPs and ensure the RTP meets the planning agency's equity goals is a difficult challenge. Moreover, recent research argues that planning agencies have little guidance in terms of performing high-quality equity analyses of RTPs (Bills 2022; Williams and Golub 2017).

1.2 Research Questions

We aim to answer the following two research questions:

1. What is the current (range of) practice(s) associated with equity analysis at large MPOs in the US?
2. How can planning agencies improve their equity analyses conditional on their current travel forecasting model capabilities?

To answer these research questions, we perform a content analysis of the most recent RTP documentation for the ten largest, in terms of population, MPOs in the US, plus the San Diego MPO. As with prior research (e.g., Krapp et al. 2021; Martens and Golub 2021), we presume that the largest MPOs have the greatest capability to perform high-quality equity analysis, and we focus our analysis on these MPOs.

To identify the range of practices, we first assess how MPOs define fairness or equity goals/criteria and equity indicators, define populations of concern, integrate their equity analysis into their RTP documents, and incorporate community input. We also assess whether MPOs meet or exceed legal standards. Second, we evaluate how MPOs use travel forecasting models in their equity analyses and the capabilities of these models to perform high-quality equity analyses. Third, we describe practical steps for MPOs to improve their equity analyses as it relates to the use of travel forecasting models.

1.3 Preferred Attributes of RTP-based Equity Analyses

Answering the study's two research questions and critically reviewing the current practice of equity analyses requires a normative description of the preferred attributes of an RTP-based equity analysis. Following Bills and Walker (2017) and Litman (2006), we propose that RTP-based equity analyses should:

1. Define population(s) of concern.
2. Clearly define equity criteria and/or goals.
3. Identify one or more metrics associated with each equity criterion/goal.
4. Evaluate the RTP holistically, as opposed to analyzing projects and policies separately.
5. Quantify expected impacts/outcomes (in addition to inputs/investments) using forecasting models.
6. Quantify expected benefits and harms at the person-level, as opposed to the place/geographical level.
7. Evaluate whether (to what extent) an RTP meets its equity criteria (goals).

The rationale for the first three attributes is straightforward; without identifying populations of concern, defining equity criteria/goals, and identifying associated metrics, it is not possible to evaluate whether a plan is equitable. Nevertheless, many planning agencies produce equity planning documents that are ambiguous in terms of equity criteria/goals (Martens and Golub 2021). Moreover, while the seventh preferred attribute should be obvious, we state it for completeness purposes.

The rationale for assessing the equity implications of all projects and policies in an RTP holistically, instead of assessing projects and policies individually (fourth preferred attribute), is as follows. While an individual project, policy, or program in an RTP may disadvantage populations of concern, the same project, policy, or program taken together with the rest of the RTP's projects, policies, and programs could produce benefits to populations of concern otherwise not achievable. For example, a congestion pricing program that by itself negatively impacts low-income individuals would appear to produce inequitable outcomes at the individual program level. However, evaluated in conjunction with other projects and policies in the RTP that use revenues from the congestion pricing program, such as transit investments or subsidies for low-income individuals to use shared mobility modes, a congestion pricing program may produce benefits for low-income individuals that are not otherwise attainable. It is also conceivable that the collective equity benefits from the RTP are significantly less than the sum of the equity benefits from each individual project, program, and policy evaluated in isolation.

The rationales for the fifth and sixth attributes are related to each other. The location of infrastructure investments and their spatial proximity to (concentrations of) populations of concern does not provide enough information to determine whether (and at to what extent) the RTP actually benefits (i) specific geographies throughout the region, nor the (ii) populations of concern within each geography. For example, consider an RTP that includes a lane-widening project. It is conceivable that the lane-widening project produces large harms from increased pollution and vehicular crashes and small accessibility benefits to residents of geographies closest to the project, while providing large accessibility benefits and minimal pollution harms to residents of geographies farther away from the project location. Hence, evaluating investments and their spatial proximity alone is inadequate for equity analyses; it is necessary to produce estimates of the expected outcomes of an RTP, and the only manner to produce such estimates is through models that forecast those outcomes.

Relatedly, it is conceivable that the same lane-widening project provides significant net benefits to high-income commuters living in the geography closest to the lane-widening project, while providing few or negative net benefits to low-income residents who live in the same geography, particularly the low-income residents who do not own personal vehicles (Grengs 2012). Hence, when evaluating the outcomes

of an RTP, because the residents of geographies are not homogenous, it is necessary to model impacts at the person level.

While providing a normative framework for how MPOs should conduct their equity analyses, we remain mostly descriptive when analyzing the equity goals/criteria and associated indicators in RTPs. Nevertheless, we do apply several normative criteria with respect to the role of equity goals/criteria and associated indicators in terms of analyzing the equity implications of an RTP. First, consistent with our sixth preferred attribute of an RTP-based equity analysis, we deem equity goals and metrics defined at the person-level as superior to those defined at the spatial-level. Second, for a particular equity indicator, it should be clear whether a larger or smaller value for the equity indicator is preferable. Although this requirement seems obvious, some MPOs use equity metrics for which a smaller value is not obviously more (or less) equitable than a larger value. For example, Atlanta compares mode shares in census tracts with and without high concentrations of populations of concern, but they do not state whether a higher (or lower) mode share for a particular mode and population segment is preferable (ARC 2020).

To answer our second research question, related to how planning agencies can improve their equity analyses conditional on their current travel forecasting model capabilities, we focus on accessibility-oriented equity goals/criteria for several reasons. First, recent scholarly research argues that the distribution of accessibility across a population is *the* critical dimension of a transportation equity analysis (Levine et al. 2019; Manaugh et al. 2015; Martens and Golub 2021; Pereira et al. 2017). Second, most RTPs emphasize accessibility as an important dimension of equity. Nevertheless, clear equity goals/criteria and metrics related to safety (e.g., traffic violence) and health/environmental impacts (e.g., exposure to pollutants, exposure to climate change risks) are also critical components in planning an equitable transportation system. Notably, the seven preferred attributes of an RTP-based equity analysis apply directly to non-accessibility-oriented equity goals/criteria.

1.4 Related Studies

Several studies over the past decade have sought to provide guidance to MPOs concerning equity analyses, and some of these studies also review RTP documentation. Karner and Niemeier (2013) review the academic literature, regional planning documentation, federal legislation, executive orders, and federal transportation agency guidelines related to equity analysis of RTPs. They provide a critical review that emphasizes two shortcomings of RTP-based equity analysis in practice. First, they find that MPOs use spatial analysis methods primarily developed to assess environmental exposures to measure infrastructure investment benefits; they argue this method is not appropriate. Second, they find that the travel forecasting models used by MPOs for equity analyses rarely, if ever, include race as an explanatory variable. Related to this second shortcoming, and a claim by MPO modelers that forecasting demographics decades into the future is challenging, Karner and Niemeier (2013) argue for the analysis of near-future transportation system conditions and their equity implications. Manaugh et al. (2015) also review RTPs; they focus their critical review on the equity goals and objectives stated in RTPs as well as associated equity metrics used to evaluate an RTP's performance with respect to its stated goals/objectives. Williams and Golub (2017) use a similar methodology to the one in our study—they critically evaluate the equity plans and equity analysis methods in RTPs. They also provide a thorough overview of federal regulations, laws, and guidance related to RTP-based equity analyses. Finally, Krapp et al. (2021) provide a recent review of Regional Transportation Improvement Plan (RTIP) documentation, assessing the role of equity in project prioritization.

In addition to reviewing more recent RTP documentation than prior studies (Manaugh et al. 2015; Williams and Golub 2017), we provide a more comprehensive, detailed, and critical review of RTP-based equity analysis methods compared to prior research, specifically as it relates to the role of travel forecasting models in measuring the distributional impacts of an RTP. While Karner and Niemeier (2013) discuss RTP documentation, unlike the current study, they do not conduct a content analysis of this documentation. Instead, they focus their review on civil rights law, regulatory guidance for equity analysis, academic research, as well as the RTP documents, public input documents, and public meetings of only one MPO—the Metropolitan Transportation Commission (MTC) encompassing the nine-county San Francisco Bay Area. Like Manaugh et al. (2015), our study discusses and reviews the current role of equity objectives and associated metrics in RTPs; however, we focus more on the methods for forecasting the distributional impacts of RTPs. Lastly, while Krapp et al. (2021) focus on RTIP documentation, we focus on RTP documentation. The major difference is that RTIPs are short-term planning documents that focus on prioritizing individual transportation investments, whereas RTPs are long-term planning documents that focus on multiple transportation investments, policies, and programs holistically.

Although our study focuses on transportation planning and equity analysis in the US, the study is highly relevant to evaluating the equity implications of transportation plans developed by agencies in other countries. Notably, Ciommo and Shiftan (2017) argue that equity issues still do not receive serious consideration in the evaluation of transportation projects and policies in Europe. However, researchers, as opposed to planning agencies, have investigated the equity impacts of transportation policies, such as congestion pricing, in a handful of European cities (Kaddoura and Nagel 2018; Meyer de Freitas et al. 2017; Zheng et al. 2012). Additionally, in Asia, Zhou et al. (2018) analyze the distribution of access to opportunity via transit in Shenzhen over the course of a decade, as the city and its public transit system rapidly developed.

1.5 Contributions

This paper makes several contributions to the academic literature. First, as far as we are aware, this is the first academic journal article to provide an in-depth evaluation of the state and range of current practices associated with RTP-based equity analyses, with a focus on the methods used to forecast the distributional impacts of RTPs. Williams and Golub (2017) include some discussion of the various forms of equity analyses in practice in the early 2010s. However, this is not the focus of their study. Moreover, while Karner and Niemeier (2013) discuss the shortcomings of RTP-based equity analyses in the late 2000s, and they mention the potential benefits of activity-based travel forecasting models, they do not provide an in-depth discussion or analysis of the latter topic.

Our systematic analysis reveals that RTPs exhibit a wide range of equity analyses, even among the MPOs representing the ten most populated regions in the US, plus San Diego, California. Specifically, we find that the quality of an MPO's equity analysis is inherently constrained by the type of travel forecasting model that an MPO uses for its (non-equity) RTP evaluation. However, we also find that many MPOs are not taking full advantage of their travel forecasting models' capabilities to assess their RTPs' distributional impacts.

Given that equity analysis quality depends on travel forecasting model type and that MPOs are not making full use of their travel forecasting modes in terms of equity analysis, a second major contribution of this study involves providing guidance to MPOs in terms of how to improve their equity analyses. Moreover, the guidance we provide is conditional on the travel forecasting model type the MPO uses for their non-equity RTP evaluation. While some MPOs will not be able to conduct state-of-the-art equity

analyses in the short term given their modeling limitations, there are still significant areas for improvement across most MPOs.

1.6 Roadmap

The remainder of this paper is structured as follows: Section 2 provides background information on a variety of topics relevant to the study’s research question, methodology, and results. Section 3 outlines the data sources and methodology we use in our analysis. Section 4 describes the results of our analysis. Lastly, Section 5 discusses the implications of our findings and areas for future research.

2 Background

In this section, we provide background information on a variety of topics relevant to the research study. We provide definitions of key terms used in the remainder of this paper. We also provide an overview of MPOs and the US regional transportation planning process. We provide additional information on Title VI requirements for RTP-based equity analyses. We summarize and compare the two travel forecasting modeling paradigms used by large MPOs in the US. Then, we describe the use or non-use of these two modeling paradigms in performing equity analyses. Finally, we provide an overview of an equity “ladder” developed by researchers to assess how MPOs define fairness when analyzing equity.

2.1 Key Terms and Definitions

Accessibility. Following other researchers, we define accessibility as “the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)” (Geurs and van Wee 2004). Accessibility is an important dimension in evaluating equity because it is fundamental to social and economic well-being, and large disparities in accessibility between racial, income, and other groups are well documented in prior research (Martens and Golub 2021; Merlin et al. 2019).

Population of concern. MPOs, state and federal agencies, and other scholars use various terms to describe the population and/or geography segments of focus in equity analyses. Terms like “communities of concern,” “disadvantaged communities,” or “target group” are often used, sometimes with slight differences in specific meaning. For this paper, we will use the term “population of concern” as a broad description of any group or population segment that is identified and/or measured by MPOs as part of their equity analysis. When a specific population group (e.g., seniors or low-income households) or other term used to describe populations is relevant to our analysis, it will be clearly defined alongside its use.

2.2 Metropolitan Planning Organizations and the US Transportation Planning Process

In the US, MPOs are federally mandated and federally funded entities designated to implement a transportation planning process for urbanized areas with over 50,000 residents. MPOs also analyze and develop plans for economic development and environmental protection (Griffith 2021). The rationale for the creation of MPOs was to increase cooperation between local, regional, and state entities during the transportation planning process.

US Code Chapter 23 § 134(D)(2) requires MPOs in transportation management areas (i.e., MPOs with populations over 200,000) to have a policy board that consists of elected officials and public-sector transportation officials from local municipalities within the MPO’s geographical boundary, as well as state-level officials (Sanchez 2006). Hence, MPOs are inter-municipal organizations. Federal legislation permits a wide range of governing and staffing structures at MPOs (Kramer et al. 2017). Most large MPOs,

including most of the MPOs whose equity analyses we assess in this study, have technical staff consisting of planners and modelers.

Two key outputs of an MPO's transportation planning process are a long-range RTP and a shorter-term RTIP. RTPs provide long-term planning priorities for twenty years or more, while RTIPs identify projects that comply with the RTP and are funded for implementation over the next four years (Krapp et al. 2021). An RTP is required in order for MPOs and their constituent jurisdictions to acquire federal funding for transportation projects, including the projects in the RTIP. If a transportation project is not included in a region's RTP, then it cannot receive federal funding (or state funding in some cases).

During the transportation planning process, MPOs evaluate alternative policies, programs, and projects in terms of the region's goals (e.g., improved mobility and accessibility, reduced emissions, improved safety) and equity or non-discrimination criteria before settling on a final RTP. The evaluation process includes attaining stakeholder input as well as using analytical tools to assess the expected impacts of alternative combinations of policies, programs, and projects.

2.3 Title VI Requirements

MPOs create transportation plans for urbanized regions, and their planning processes must be certified by the US Department of Transportation (DOT). Under Title VI of the federal Civil Rights Act of 1964, entities receiving federal funding are prohibited from discriminating against individuals on the basis of "race, color, or national origin" (42 U.S.C. § 2000d). As a result, MPOs must include analyses proving non-discrimination in their required long-range RTPs to remain eligible to receive federal funding (Federal Transit Administration 2012).

In 2012, the Federal Transit Administration (FTA) published a circular with specific guidance on how recipients of federal funds can meet Title VI requirements (Federal Transit Administration 2012). This is the latest of several guidance documents produced across decades by US DOT modal agencies related to Title VI and Environmental Justice-related Executive Orders (Eos) — see Williams and Golub (2017) for a detailed overview of these guidance documents. According to the 2012 FTA circular, MPOs are required to submit the following:

1. Documentation of public engagement and participation.
2. A demographic profile of the region, including the region's share of ethnic/racial minority populations.
3. A description of the procedures by which the mobility needs of minority populations are identified and considered within the planning process.
4. Maps that overlay the location of transportation investments and areas where protected populations are concentrated, as well as charts that quantify how these investments are distributed.
5. An analysis of disparate impacts on the basis of race, color, or national origin. If disparate impacts are found, the MPO must determine whether there is a substantial legitimate justification for the policy that resulted in the disparate impacts, and if there are alternatives that could be employed that would have a less discriminatory impact.

While Title VI compliance is mandatory, MPOs appear, from their RTP documentation, to have considerable flexibility in how they approach their equity analyses.

As additional motivation for this study, the Biden Administration is currently moving to improve equity planning by federal agencies and other recipients of federal funds. EO 12898, issued in 1994, directs each federal agency to "make achieving environmental justice part of its mission by identifying and

addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations” (Executive Order 12898 of February 11, 1994, sec. 1-101). Although EO 12898 spurred federal agencies to consider and address problems of environmental injustice, many inequities persist. As a result, the Biden Administration is seeking to update EO 12898 to make it more effective (see Executive Order 14008 of January 27, 2021, sec. 220(b)). This study provides guidance both for MPOs seeking to promote equitable transportation planning and for federal officials seeking to provide guidance for MPOs, which receive significant federal funding.

2.4 Travel Forecasting Modeling Paradigms for Long-term Regional Planning

Given the scope of RTPs, they have the potential to substantially impact transportation systems and societal outcomes over the long term. To assist in long-range planning, MPOs rely on travel forecasting models that provide quantitative insights into the expected outcomes of combinations of proposed projects, policies, and programs two or three decades into the future. Some MPOs have even used travel forecasting models to present and discuss forecasted scenario outcomes with the public during the RTP planning process (Karner 2016; Handy 2008).

The quantitative insights that travel forecasting models can provide include measures of cumulative trips and distances, vehicle congestion or delays, modal shares, and various accessibility measures. Moreover, the outputs of travel forecasting models are often used as inputs to emissions models.

In the US, there are two main travel forecasting modeling paradigms used by MPOs—aggregate trip-based models and disaggregate activity-based models. In this section, we provide a brief overview of these two modeling paradigms. We specifically aim to distinguish between the two modeling paradigms as it relates to their capabilities for transportation equity analysis consistent with the seven preferred attributes described in Section 1.3. For more information on and distinctions between aggregate trip-based models and disaggregate activity-based models, please refer to Castiglione et al. (2014), McNally and Rindt (2007), and Boyce and Williams (2015).

Aggregate trip-based models are also known as four-step transportation planning models, with trip generation, trip distribution, mode choice, and traffic assignment as the four steps. These models are the most common travel forecasting approach used by MPOs and planning agencies around the world. However, several MPOs in the US switched to disaggregate activity-based models in the past decade, and the number of MPOs using activity-based models is growing.

The inputs to an aggregate trip-based model include information about spatial units (e.g., census tracts or travel analysis zones) and the underlying transportation network attributes connecting the spatial units. Spatial unit attributes include area, residential population, job counts by industry type, household size distribution, vehicle ownership distribution, socio-economic characteristics of the zone's residents, and land-use and built environment information. Given these inputs, the four-step modeling procedure determines (i) how many trips originate and terminate in each zone; (ii) the distribution of trips between origin-destination zonal pairs, (iii) the mode share for each origin-destination pair, and (iv) the routes of vehicle trips in the transportation network, respectively. Other model outputs include total vehicle distance traveled and congestion (i.e., delay) on each link in the network. It is also straightforward to calculate travel times between pairs of spatial units, as well as various place-based accessibility measures.

There are several shortcomings of aggregate trip-based models, stemming from (i) the aggregate nature of the model output and (ii) their focus on trips. Most importantly, aggregate models cannot provide person-

level measures for metrics like access to jobs, healthcare, shopping, etc. The lack of forecasts for person-level outcomes severely limits the types of equity analyses that are possible. Instead of analyzing the distribution of benefits and harms of the RTP across individuals or groups of individuals, aggregate outputs only permit the analysis of benefits and harms across spatial zones (Castiglione et al. 2006). While modelers can segment spatial zones by trip purpose (e.g., work vs. non-work) or socio-economic characteristics (e.g., low-income, medium-income, high-income), data storage requirements and computation run time increase exponentially as the modeler introduces each additional segmentation variable.

Additionally, trip-based models, aggregate or disaggregate, assume every trip is made independently of other trips. This assumption obscures the fact that the trips a person makes during a day depend on the other trips they make (e.g., a person can only make a work-to-restaurant trip if they first make a trip to work) and the trips other household members make (e.g., if a household has three persons and two cars, it is not possible for this household to generate three simultaneous single-occupant car trips).

The inputs to a disaggregate activity-based model include a synthetic population of all households and persons within the region as well as land-use information and transportation network attributes. Each household is characterized by its location, size, structure (i.e., number of adults and number of children), income, vehicle ownership, etc. Each person is characterized by their race, gender, age, employment status, license to drive a vehicle, etc. with explicit linkages to their household's attributes. Given these inputs, the disaggregate activity-based models used in practice include a large number of nested choice models. The nested models capture long-term household and person decisions, including work location and household vehicle ownership; medium-term decisions, such as transit pass ownership; and short-term decisions, such as trip mode, non-work activity locations, and activity start times. Disaggregate activity-based models can be integrated with static or dynamic traffic assignment models to determine route choices between activity locations. Disaggregate models can produce all of the same transportation network performance measures as aggregate models, while also providing daily activity and travel patterns for each person in the synthetic population. Disaggregate models also permit calculating person-based accessibility measures.

The major difference between these two modeling paradigms, from the perspective of equity analyses, is their respective analysis units. The unit of analysis for aggregate trip-based models are zonal trips, i.e., the number of trips between two spatial zones. The unit of analysis for disaggregate activity-based models are person-level daily activity-travel patterns, i.e., the location, time, and type of activities each person in a given analysis area (e.g., the city of Chicago) conducts over the course of a typical day, along with the mode and route each person uses to travel between their activities. Hence, disaggregate models can meet our sixth preferred attribute of an RTP-based equity analysis, whereas aggregate models cannot.

2.5 How MPOs Use (or Fail to Use) Travel Forecasting Models for Equity Analysis

This section provides an overview of how MPOs currently use (or eschew) travel forecasting models in their equity analyses. This overview is broken down into four subsections: (i) equity analysis without travel forecasting models, (ii) aggregate trip-based models, (iii) disaggregate activity-based models, and (iv) the state-of-the-art framework for equity analyses proposed in existing scholarship.

2.5.1 Equity analysis without travel forecasting

MPOs that do not use travel forecasting models for their equity analysis rely upon mapping and other spatial analyses without predicting the outcomes of their RTP. For example, a frequent practice for MPOs is to overlay the location of infrastructure investments on a map that also displays spatial units with high concentrations of populations of concern, to illustrate whether investments are distributed equitably.

Because the populations of concern are identified based on predetermined thresholds within geographical units, and the approach only considers investments (i.e., inputs and not outputs), we describe this approach as a location- and threshold-based investments-only approach.

The location- and threshold-based investments-only approach precludes an equity analysis that meets our fifth and sixth preferred attributes for a high-quality RTP-based equity analysis. It quantifies only inputs/investments instead of outputs/impacts (preferred attribute 5). It also provides measures at a place/geographical level, instead of a person level (preferred attribute 6). Moreover, the approach does not appear to meet the fifth requirement of the 2012 FTA circular, because it does not measure impacts.

Section 1.3 describes the main shortcomings of an investments-only approach and a location-based approach through the lane-widening example. Herein, we expound on those shortcomings, identify additional shortcomings of an investments-only approach, and discuss issues with a threshold-based approach.

First, because the investments-only approach only considers monetary inputs, it does not provide information on non-monetary land use and transportation policies. This is problematic because policies, in addition to infrastructure investments, are critically important in the context of understanding and advancing transportation equity. Since past policies have codified and reinforced many present-day inequities, forecasting and evaluating the impacts of proposed policies alongside infrastructure projects is essential.

Second, MPOs typically identify disadvantaged communities as geographies where a population of concern exceeds a specified threshold (e.g., the geography has a higher concentration of Black residents compared to the region-wide share of Black residents). This location- and threshold-based approach to defining communities of concern can lead to differing outcomes depending on the threshold chosen and the level of spatial aggregation, such that the conclusions of an equity analysis (even one where outcomes are analyzed instead of just investments) are somewhat arbitrary. To address this issue, planning agencies can use multiple thresholds and different spatial aggregations to evaluate the robustness of their equity conclusions. However, we find this practice is uncommon.

Third, when using a location- and threshold-based approach, MPOs only evaluate impacts on populations of concern located in the geographies identified as disadvantaged. Unfortunately, populations of concern in geographies not designated as “disadvantaged” are effectively ignored since their residential zone does not exceed the chosen threshold. Additionally, even within geographies designated as “disadvantaged,” there is no information to identify how populations of concern are impacted in particular. This might be problematic, for example, in historically low-income areas that are beginning to gentrify, where populations of concern may not benefit from certain investments (e.g., a new intersection design that improves vehicular traffic flow but increases walking delays) to the same extent as more affluent residents.

The major limitations of the location- and threshold-based investments-only approach reflect implicit assumptions that transportation investments in one area primarily benefit (i) the geography itself and nearby geographies and (ii) all residents of those geographies. These assumptions may not be true, depending on the project and the residents of the nearby geographies, as the lane-widening example in Section 1.3. highlights.

To go beyond an evaluation that only considers inputs (investments) towards a fuller assessment of true impacts, a forecasting model is necessary. However, to partially address the shortcoming of the threshold-based approach, a forecasting model is not necessary. One option to address the threshold

shortcoming is a location-based population-weighted approach that does not use thresholds for designating communities of concern. Rather, such an approach weighs the benefit or harm to each geography by the percentage of persons in the geography that are designated as members of populations of concern (Rowangould et al. 2016; Twaddell and Zgoda 2020). Thus, this approach avoids the threshold issue that otherwise hampers location-based equity analysis. Nevertheless, the location-based population-weighted approach still involves the aggregation of impacts at a given geography, ignoring how travel constraints and preferences vary between different groups and persons within the geography. The following subsections detail the importance of forecasting and analyzing the outcomes of proposed policies and projects in the RTP, as well as the shortcomings of using spatial zones as the unit of analysis when evaluating the impacts of RTPs on equity.

2.5.2 Equity analysis with aggregate trip-based travel forecasting models

Aggregate trip-based travel forecasting models yield benefits for all analyses (including equity analyses), compared to an investments-only approach, because forecasting models permit estimation of future system outcomes (e.g., location-based accessibility measures) based on the policies and projects proposed in RTPs. Instead of showing where investments are located relative to geographies of interest, travel forecasting models estimate the impacts of the proposed RTP, thereby permitting a distributional analysis of outcomes instead of resource allocation alone.

However, aggregate trip-based models, as described in Section 2.4, are unable to meet our sixth preferred attribute of an RTP-based equity analysis—they can only provide measures at the level of spatial units rather than at the person level. Moreover, unfortunately, many MPOs also use a threshold-based approach to designate spatial units as disadvantaged or non-disadvantaged. Once again, using a population-weighted approach for equity analysis with the aggregate trip-based model can address the threshold issue, as described in the prior subsection.

Prior research affirms that measuring equity at geographic levels can obfuscate systematic differences in travel behavior across and within specific populations (Karner 2016; Golub and Martens 2014; Manaugh et al. 2015; Rowangould et al. 2016). Moreover, recent research finds that performing zonal-level equity analysis can produce directionally incorrect inferences if applied to the individual level, in the case of the employment accessibility benefits from robo-taxis across income levels (Hyland and Ahmed 2022).

2.5.3 Equity analysis with disaggregate activity-based travel forecasting model

Disaggregate activity-based travel forecasting models overcome the shortcomings of aggregate trip-based models for the purposes of equity analyses. Because disaggregate activity-based models use the synthetic person and household as the unit of analysis, these models can measure the benefits and costs of an RTP at the person level. Given the person-level outputs, it is relatively straightforward for analysts to evaluate the distribution of benefits and harms across (and within) population segments. Hence, disaggregate activity-based models can clearly indicate whether low-income, and/or racial/ethnic minority populations received fewer benefits and greater harms than other income groups and/or racial/ethnic groups. Thus, disaggregate activity-based models can support equity analyses that meet all of our preferred attributes for high-quality RTP-based equity analyses in Section 1.3.

2.5.4 State-of-the-art framework for equity analyses

Bills and Walker (2017) propose a framework for analyzing equity in transportation plans that we believe represents the state-of-the-art. This four-step process outlines how MPOs can use activity-based travel forecasting models to improve their equity analyses. The four steps include:

- (1) Identifying which populations are of interest and what indicators are being measured;
- (2) Calculating indicators using travel model data;
- (3) Comparing distributions rather than means of results; and
- (4) Evaluating multiple scenarios based on selected equity criteria.

Steps one and two are fairly common for MPOs who have travel forecasting models, but steps three and four are far less common. Step three involves analyzing the complete distribution of outcomes across individuals within a population of concern instead of the population of concern's mean result (Bills et al. 2012). This is particularly important as one set of policies and projects may provide large benefits to a population of concern (e.g., low-income households) on average, but with significant variance, so that a small (but significant) subset of the population of concern may receive few benefits and face significant harms. Researchers have affirmed the importance of evaluating outcomes in this manner in recent case studies that measure distributional impacts to accessibility in London, England (Dixit and Sivakumar 2020) and pollution exposure in Tampa, Florida (Gurram et al. 2019). Notably, disaggregate activity-based travel demand models produce person-level outputs and thereby permit the analysis in step three. Step four involves evaluating and comparing multiple scenarios based on the equity criteria chosen. This is in line with recent efforts to integrate scenario planning into long-range transportation planning (Lempert et al. 2022).

A recent addition to this framework involves choosing an equity standard by which to evaluate scenarios, as the standard used can change how outcomes are interpreted (Bills 2022). For example, recent research argues for a focus on insufficiencies in accessibility for all persons, rather than discrepancies in accessibility across population segments, when evaluating the equity/inequity in a transportation system. (Martens et al. 2022; Pereira et al. 2017). Section 2.6 also delineates various equity standards that an MPO might employ when crafting equity goals.

Martens et al. (2022) argue that planners should determine sufficiency criteria for access to opportunity and make planning decisions such that everyone in a region obtains accessibility levels above the given threshold. They suggest this approach is preferable to simply trying to decrease the gaps in accessibility between population segments. While our study is an analysis of existing RTPs, and those RTPs almost exclusively discuss equity in terms of disparity, travel forecasting models are (in many ways) agnostic with respect to sufficiency versus disparity. The models provide (estimated) measures of accessibility based on the implementation of the proposed RTP. A planner can use those accessibility measures to assess disparity or sufficiency.

2.6 The Equity Ladder

Prior research documents variations in the equity analyses submitted by MPOs. An analysis of the 10 largest MPOs in the U.S. found that all MPOs satisfy the non-discrimination standard of Title VI (Martens and Golub 2021). They also provide a taxonomy to assess how MPOs define fairness. This "ladder of equity" (shown below) provides a useful framework for understanding where on the spectrum of equity a given MPO's equity goals lie—from mere legal compliance (i.e., meeting Title VI requirements) to restorative equalization, which aims to proactively remedy past inequities.

- *Non-discrimination*: no group is explicitly discriminated against; legally required by Title VI
- *Pareto*: no community is harmed while some group(s) receive benefits
- *Pareto-plus*: no community is harmed, and all groups receive significant benefits

- *Proportional equity*: all groups receive an equal share of benefits
- *Restorative equalization*: historically marginalized groups receive a greater share of benefits

3 Data and Methods

To assess the quality of equity analyses performed by the 11 MPOs in our sample, we analyze the contents of RTPs and their supporting documents. Section 3.1 first details our data sources (e.g., the specific RTPs and documents analyzed) and then Section 3.2 describes the measures we use to evaluate the equity analyses contained in those planning documents.

3.1 Data Sources

For our analysis, we evaluate a sample of 11 large MPOs, including MPOs representing the largest metropolitan areas in the US. For these 11 MPOs, we evaluate their most recently published RTP as of 2021 and other publicly available supplementary documentation relevant to equity metrics or analysis. Supplementary documentation may include an Environmental Justice appendix or a separate equity report or appendix. Memos or other documentation were reviewed if they were referenced within the RTP and appeared to be relevant to the MPO's equity analysis. For example, the San Diego Association of Governments (SANDAG) shares its board of directors' meeting agendas, and documentation from one such meeting provides details on how they approached the equity analysis in their 2021 RTP. The table below lists the MPOs in our sample, the date the RTP reviewed was adopted, and a list of documents reviewed.

540 **Table 1: Summary information for sampled MPOs**

MPO Name and RTP Reference	City/ Region	Date RTP Adopted	Document(s) Reviewed, in addition to RTP
San Diego Association of Governments (SANDAG 2021a)	San Diego, CA	December 2021	Appendix B - Implementation Actions Appendix E - Performance Monitoring Appendix H - Social Equity Appendix P - Benefit-Cost Analysis Public Involvement Plan Memo - Social Equity Analysis
Southern California Association of Governments (SCAG 2020)	Los Angeles, CA	September 2020	Environmental Justice Technical Report Memo – Racial Equity Early Action Plan
Metropolitan Transportation Commission (MTC 2021a)	San Francisco, CA	October 2021	Performance Report Equity Analysis Report
Chicago Metropolitan Agency for Planning (CMAP 2018a)	Chicago, IL	October 2018	Regionally Significant Projects Benefits Report Indicators Appendix Online - Indicators Dashboard and GitHub Repository
North Central Texas Council of Governments (NCTCOG 2018a)	Dallas, TX	June 2018	Appendix B - Social Considerations Public Participation Plan TIP Project Selection
Houston-Galveston Area Council (HGAC 2019)	Houston, TX	May 2019	Appendix I - Environmental Justice Appendix P - Performance Measures
Atlanta Regional Commission (ARC 2020)	Atlanta, GA	February 2020	RTP Project List The Regional Plan's Policy Framework TIP Project Evaluation Online - Dashboard that tracks trends and plan performance
Transportation Planning Board (TPB 2018a)	Washington, D.C.	October 2018	Appendix B - Summary of Projects Memo - Methodology for Equity Emphasis Areas Resolution - Racial Equity as a Fundamental Value Environmental Justice and Title VI Analysis Technical Report Online - Interactive map of Equity Emphasis Areas
New York Metropolitan Transportation Council (NYMTC 2021)	New York City, NY	September 2021	Appendix D - Environmental Justice & Title VI Assessment
North Jersey Transportation Planning Authority (NJTPA 2021)	Northern New Jersey	September 2021	Title VI Implementation Plan Fair Housing and Equity Assessment Report
Delaware Valley Regional Planning Commission (DVRPC 2021)	Philadelphia, PA	September 2021	Policy Manual Online - Indicators Dashboard

541 3.2 Measures

542 In the first part of our analysis, we assess the current state-of-the-practice of equity analysis carried
543 out by MPOs by identifying:

- 544 1. Where equity goals and metric targets lie on the equity ladder defined by Martens and Golub (2021).
545 Below is our coding scheme with corresponding examples of language from MPOs in our sample:

- a. *Non-discrimination* is language that focuses on proving that vulnerable communities are not
546 disproportionately negatively affected by the RTP.
547

- 548 Example: "To date, DVRPC has undertaken program or system level analysis tests to identify
549 potential disparities with poor bridge and pavement conditions and crashes to determine if they
550 are disproportionately concentrated in census tracts with above average or well-above average
551 low income, racial minority, and ethnic minority communities." (DVRPC 2021, p. C-3)
- 552 b. *Pareto* is language indicating the RTP or a project would provide some benefits, even if those
553 benefits are not distributed to all groups, without causing significant harm.
- 554 Example: "Connect SoCal will reduce roadway noise impacts at the regional level but does not
555 specifically improve impacts for disadvantaged communities." (SCAG 2020, p. 147)
- 556 c. *Pareto-plus* is language indicating that no community is disproportionately harmed, and all
557 groups receive meaningful benefits.
- 558 Example: The Dallas MPO aims to "go above and beyond basic requirements to create a
559 transportation system that is beneficial to all residents of the region" (NCTCOG 2018a, p. 26)
- 560 d. *Proportional equity* is language indicating that all groups receive equal benefits.
- 561 Example: "An examination of individual performance measures finds [Equity Emphasis Areas]
562 and the Rest of the Region experience similar benefits or burdens across all measures" (TPB
563 2018b, p. 17)
- 564 e. *Restorative equalization* is where historically marginalized groups receive the largest share of
565 benefits in order to remedy past inequities.
- 566 Example: The San Francisco MPO has an equity score that "calculates the ratio of the
567 monetized accessibility benefit from the project experienced by a person with low income" and
568 identifies ratios of 60% or greater as their target to advance equity (MTC 2021b, p. 16)
- 569 2. How MPOs define populations of concern. Following the method used by Krapp et al. (2021) to
570 evaluate how RTIP analyses identify populations of concern for measurement purposes, we examine
571 whether MPOs use:
- 572
- 573 a. *Geographies* (e.g., census tracts with high concentrations of a particular population like low-
574 income residents);
- 575 b. *Users* (e.g., a specific group like low-income residents across the entire region); or
- 576 c. Both geographies and users.
- 577
- 578 3. The source documents describing the equity analyses in order to assess the extent to which equity
579 analyses are integrated into RTPs. Relevant source documents include:
- 580
- 581 a. RTPs
- 582 b. Appendices
- 583 c. Memos
- 584 d. Technical reports
- 585 e. Meeting agendas

- 586
- 587 4. The role of community engagement in developing metrics. We examine whether MPOs engage with
- 588 other governmental actors, community-based groups, advisory committees, and/or other groups to
- 589 choose equity-related metrics.
- 590 5. Whether the equity analysis goes beyond what is legally required of MPOs, by comparing equity
- 591 analyses to Title VI and, where applicable, state requirements. Hence, we determine whether an MPO's
- 592 equity analysis:
- 593 a. Simply meets legal requirements, or
- 594 b. Exceeds legal requirements

595 Through this content analysis RTP documentation, we are able to identify both the range of the state-of-

596 the-practice of equity planning for the MPOs in our sample as well as the approaches most commonly used.

597 The second part of our analysis focuses on how MPOs use models, particularly travel forecasting

598 models, in equity analyses. All MPOs are required to employ models to evaluate their plans, although they

599 are not currently required to use models in their equity analyses. As a result, every MPO already has a

600 modeling tool that can assist in equity analyses. However, the types and quality of equity analyses possible

601 depend on the type of model an MPO uses, as described in Section 2.5. We therefore assess the capabilities

602 of the model each sampled MPO currently uses.

603 Existing models used by MPOs can be classified as either aggregate trip-based or disaggregate activity-

604 based models. While only the latter type of model permits state-of-the-art equity analyses, other approaches

605 can still produce valuable spatial equity analyses. We categorize MPOs both in terms of (1) the models they

606 use and (2) the quality of their equity analyses conditional on the travel forecasting model type they use for

607 general transportation planning analysis. This approach allows us to tailor guidance to MPOs' existing

608 technical capacity rather than identifying a state-of-the-art technique that may not be viable for MPOs with

609 relatively limited modeling capabilities and resources.

610 **4 Results**

611 In this section, we present and discuss the results of our analyses. The first half of this section describes

612 the range of the state-of-the-practice for equity analyses in RTPs, from the lowest level to cutting-edge

613 practices. The second half describes how existing equity analyses compare to the state-of-the-art framework

614 and how MPOs can progress towards the state-of-the-art based on their current modeling capabilities. For

615 a detailed overview of the results of our analysis, see Table 2.

616 **Table 2: Summary table of the results of our analysis**

MPO	RTP travel model	Model use in equity analysis	Segment Type	Segmentation categories	Equity indicators/metrics	Process of metric development	Target distributional standard
San Diego	Activity-Based	Forecasts cost/benefit by population segment	Population	- Low-income - Ethnic/racial minorities - Seniors	- People within 0.5 miles of transit (by transit tier) - Access to employment centers - Access to higher education - Benefit-cost ratio - Transportation system use costs - Access to retail - Access to parks - Access to medical/healthcare - Average particulate matter (PM2.5) - People within 0.25 miles of bicycle facilities	Developed alongside community-based organization partners and stakeholders	Proportional Equity
Los Angeles	Trip-Based	Forecasts outcomes by zones with high concentrations of population segments and the overall region	Population and Geography	- Low-income - Ethnic/racial minorities - Seniors - Disabled	- Share of employment and shopping destinations within 30 minutes by automobile or 45 minutes by transit - Share of park acreage within 30 minutes by automobile or 45 minutes by transit - Roadway noise impacts - Emissions impact analysis - Impacts along freeways and highly traveled corridors - Travel time and travel distance savings - Rail-related impacts - Share of transportation system usage - Connect SoCal revenue sources in terms of tax burdens - Connect SoCal investments by mode - Geographic distribution of Connect SoCal transportation investments - Mileage-Based User Fee impacts	SCAG chose the metrics, but regional EJ stakeholders influenced the analysis and categorization of the metrics	Proportional Equity (with some Pareto and Restorative Equalization)
San Francisco	Activity-Based	Forecasts allocation of benefits by population segment	Population and Geography	- Low-income - Ethnic/racial minorities	- Share of income spent on transportation-housing - Per Trip Average Transit Fare - Auto Out-of-Pocket Expense - Parking Costs and Tolls - Share of Households Located Near High-Frequency Transit (0.5mi) - Number of Jobs That Are Accessible by Transit/Auto/Bike/Walk - Share of Households in High-Resource Areas That Are Households with Low Incomes - Share of Neighborhoods That Experience Loss of Low-Income Households - Urban Park Acres per 1,000 Residents - PM2.5 Emissions Density (Daily Tons of Emissions per 10 Square Miles) - Annual Fatalities per 100,000 People (from Non-Freeway Incidents) - Share of Risk-Prone Households That Are Protected from Risk of Sea Level Rise, Earthquake and Wildfire - Job Growth by Industry Type - Average Commute Distance (miles)	The Regional Equity Working Group and the Policy Advisory Council's Equity and Access Subcommittee were advisory to the equity analysis process.	Restorative Equalization
Chicago	Trip-Based	Not used in equity analysis	Population and Geography	- Low-income - Ethnic/racial minorities	- % of income spent on housing/transportation by moderate- and low-income groups - Real median household income - Gini coefficient - Average journey to work time - Preventable hospitalizations - Access to parks in economically disconnected areas - Share of New Infill Development Occurring in Economically	Various committees helped shape the indicators, including the citizens advisory committee, but no committees were dedicated to equity	n/a

					- Disconnected Areas - Educational Attainment - Workforce Participation - Unemployment - Change in Mean Household Income by Quintile - Change in Non-Residential Market Value		
Dallas	Trip-Based	Forecasts outcomes by zones with high concentrations of population segments	Geography	- Protected populations (ethnic/racial minorities and low-income households)	- Number of jobs accessible within 30 minutes by automobile & 60 minutes by transit - Population within 30 minutes of a university - Population within 30 minutes of a regional shopping center - Population within 15 minutes of a hospital - Average level of congestion - Average travel time	Metrics were chosen alongside other governmental/regional transportation organizations	Pareto Plus
Houston	Trip-Based	Forecasts outcomes by zones with high concentrations of population segments	Geography	- EJ Areas (low-income & ethnic/racial minorities) - EJ High Disadvantage (limited English proficiency, seniors, limited educational attainment, carless households, and female head of households)	- Commute time (HBW Trips mobility analysis) - Jobs accessible by car/transit - Average vehicle trip time (car and transit) - Average vehicle trip distance (car and transit) - Average vehicle speed (car and transit) - Compare investments in EJ vs. non-EJ zones - Accessibility to pedestrian/cyclist infrastructure - Accessibility to libraries - Accessibility to hospitals - Accessibility to trauma centers - Accessibility to higher education facilities - Accessibility to fixed-route transit	Unknown	Unclear; mixture of language, from Pareto to Proportional Equity, is used
Atlanta	Activity-Based	Forecasts mode choice in zones with high concentrations of "environmental justice populations"	Geography	- EJ communities (low-income & ethnic/racial minorities)	- Mode Choice in Census Tracts with High Concentrations of Environmental Justice Populations (<i>SOV, HOV, transit, and walking/cycling</i>)	The Transportation Equity Advisory Group, which included planners and advocates, guided the equity analysis.	Unclear; some indication of Pareto Plus, but only one metric is identified
Washington, D.C.	Trip-Based	Forecasts outcomes by zones with high concentrations of population segments	Geography	- Equity Emphasis Areas (low-income & ethnic/racial minorities)	- Average number of jobs accessible by auto - Average number of jobs accessible by transit - Average number of jobs accessible by High Capacity Transit - Average number of jobs accessible by bus - Population with walkable access to High Capacity Transit - Population with walkable access to bus service - Average commute time by auto - Average commute time by transit - Average travel time to closest hospital by auto - Average travel time to closest hospital by transit	Two advisory committees and other governmental organizations influenced equity analysis	Proportional Equity
New York City	Trip-Based	Not used in equity analysis	Geography	- Low-income - Ethnic/racial minorities		n/a	n/a
Northern New Jersey	Trip-Based	Not used in equity analysis	Geography	- Ethnic/racial minorities		n/a	n/a
Philadelphia	Trip-Based	Used to measure Air Quality, but is otherwise not used in equity analysis	Geography	- Primary - Low-income - Ethnic/racial minorities - Secondary: - Sex (female) - Age (elderly) - Limited English proficiency - Foreign-born - Persons with disabilities.		n/a	n/a

4.1 *Range of the State-of-the-Practice*

In our evaluation of the characteristics of equity analyses, we find the range of the state-of-the-practice varies considerably. Within the wide range, there seem to be three distinct clusters of approaches to equity analyses:

1. A focus on meeting legal requirements without using model forecasts thereby not measuring RTP expected outcomes (i.e., impacts) on populations of concern;
2. Proving non-discrimination by using common accessibility metrics like access to jobs or other resources, as well as showing how investments proposed within the RTP are allocated across different geographies; and
3. Cutting-edge approaches focused on evaluating the impacts of the proposed plan on populations of concern.

The following three subsections describe these approaches in more detail and provide specific examples.

4.1.1 *Equity analyses that meet legal requirements*

Of the 11 MPOs, three limit their analyses to mapping census tracts where low-income and minority populations are concentrated throughout their respective regions. Two of these three—the New York City and Northern New Jersey MPOs—only identify ethno-racial minorities and low-income households as populations of concern, as is required by Title VI. The Philadelphia MPO identifies six other groups—elderly, disabled, youth, limited English proficiency, women, and foreign-born—as populations of concern. Lastly, all of these MPOs use the threshold- and location-based investments-only approach to assess equity for the populations of concern.

In terms of the equity ladder, these three MPOs use a mixture of language from non-discrimination to restorative equalization within their equity analyses. However, the only clear metrics or goals they describe relate to achieving proportional investments between identified geographies with concentrated populations of concern versus the remaining region. All three of the most recent RTPs by these MPOs do not tie their equity analyses to broader RTP goals or describe any avenues by which community engagement has influenced equity analyses or the development of equity metrics. In general, the strategy these MPOs seem to employ involves showing that planned investments are equitably distributed across different geographies in order to meet the Title VI requirement of proving non-discrimination.

4.1.2 *Equity analyses that use a conventional approach with accessibility metrics*

Five MPOs in our sample exceed basic legal requirements but fall short of achieving the cutting-edge state-of-the-practice. These MPOs include Atlanta, Chicago, Dallas, Houston, and Washington, DC. All five of these MPOs identify specific equity metrics, many of which are similar in nature.

The Chicago, Dallas, Houston, and Washington, DC MPOs measure commute times and access to resources like jobs and parks by car and transit. All of these MPOs use geographies for metric measurement, evaluating census tracts with high concentrations of low-income and minority populations. As described in the background section above, the aggregate trip-based modeling approach may not accurately identify who receives benefits within a spatial zone.

The Atlanta MPO only identifies mode choice by race/ethnicity as an equity metric. Moreover, the Atlanta RTP does not provide any specific criteria or goals related to this equity metric. In fact, it is unclear whether a higher transit mode share for populations of concern vs. the other residents of the region is preferable for the purposes of the Atlanta RTP.

The Chicago MPO uses metrics that are tied to specific populations of concern instead of geographies. However, its equity analysis neither forecasts outcomes based on the RTP nor identifies targets for these metrics. This leaves the impacts of the Chicago MPO's RTP on equity ambiguous and also makes it difficult to identify what the Chicago MPO's RTP would define as an equitable outcome.

In terms of the equity ladder, these MPOs have a mixture of equity standards. Both the Chicago and Atlanta MPOs have equity measures that do not seem to have specific targets or aims, making their equity standard hard to discern. Some of their language implies a proportional equity standard, maybe even restorative equalization, but without clarity on targets or goals, it is unclear. For example, when describing their average commute times by race and ethnicity metric in their Indicators Appendix, the Chicago MPO says that *"Local and regional planning should emphasize improving commute times and options for residents facing long commutes"* (CMAP 2018b, p.78). Since Black residents have the longest commute times, this seems to imply a restorative equalization standard despite no specific goal being specified.

The Houston and Dallas MPOs both seem to employ lower standards compared to the other MPOs. Much of the language in their equity analyses focuses on proving non-discrimination, primarily via measures that show existing inequities in accessibility that actually favor geographies with high concentrations of populations of concern. While the Houston MPO employs a proportional equity standard for much of its equity analysis, it also uses the lower Pareto standard to justify a highway project that would provide almost no benefit to populations of concern.

The Washington DC MPO primarily employs a proportional equity standard, evaluating whether benefits received by communities of concern and non-communities of concern are approximately equal.

Apart from the Atlanta and Houston MPOs, all these MPOs discuss equity metrics in multiple RTP documents. The Atlanta and Houston MPOs address equity more broadly in other portions of their RTP documents, but their metrics related to equity are only identified in a single location. All these MPOs also have identified committees and/or advisory groups that helped develop their equity analyses and metrics. The only exception is the Houston MPO, which describes its public outreach efforts, but did not explain how its equity analysis or metrics were influenced via public engagement. Overall, all these MPOs go beyond the legal bare minimum requirements described in the previous subsection, but do not represent the cutting-edge state-of-the-practice.

4.1.3 Equity analyses with cutting edge practices

The remaining three MPOs in our sample—the Los Angeles, San Diego, and San Francisco MPOs—have equity analyses in their most recent RTPs that exemplify the cutting-edge state-of-the-practice. These MPOs use common accessibility metrics employed by other MPOs, such as access to jobs, parks, shopping, and other resources. They also use metrics not common across our sample, including changes in particulate matter, transportation and housing costs, and benefit to cost ratio (BCR). BCR compares the costs of planned projects to the benefits they generate based on outputs from activity-based models and the assumed monetary value of those benefits. Additionally, San Diego and San Francisco distinguish themselves by evaluating forecasted impacts of their plans on populations of concern rather than geographies where those populations of concern are concentrated. For example, the San Diego MPO forecasts and compares the impacts of build and no-build scenarios on minority, non-minority, low-income, and non-low-income populations. On the other hand, the Los Angeles MPO forecasts and compares accessibility of the base year, with accessibility metrics in future build and future no-build scenarios for various geographies with high concentrations of populations of concern. Given that LA only uses an aggregate trip-based travel forecasting model, their equity approach represents the cutting edge under this model limitation.

In terms of the equity ladder, these three MPOs use varying standards. The San Diego MPO mostly uses a proportional equity standard in its equity analysis, evaluating whether "the percentage point difference between the groups is substantial enough to potentially qualify for further evaluation as a disparate impact or disproportionate effect." The Los Angeles MPO uses mixed language, ranging from Pareto (e.g., justifying roadway noise reduction that primarily benefits white and affluent residents but has no negative impact on other groups), to restorative equalization (e.g., specifically identifying the need to close disparities in bicycle and pedestrian risks between populations of concern and the rest of the population). The San Francisco MPO employs a restorative equalization standard, specifically identifying whether individual projects advance, maintain, or reduce equity compared to its 2015 plan.

All three MPOs have categorized their equity metrics under broader plan goals, reference their equity analyses in their RTPs, and provide detailed appendices on their equity analyses. Additionally, the San Francisco and Los Angeles MPOs both convened working groups focused on equity or environmental justice advising their equity analyses and metric selection. The San Diego MPO collaborated with community-based organizations and stakeholders to choose equity metrics as part of their analysis.

Notably, these three MPOs are all located in California where state law provides stricter guidelines for equity analyses than the federal government's Title VI requirements. This may be the impetus or at least a contributing factor for the more advanced state-of-the-practice in California specifically.

4.2 Moving Towards the State-of-the-Art

As described above, the state-of-the-art equity analysis proposed by Bills and Walker (2017) involves the use of a disaggregate activity-based model to measure specific performance indicators on populations of concern in order to compare distributions of results and prioritize plans based on the chosen equity criteria. In order to understand where MPOs currently stand in comparison to the state-of-the-art, this section identifies how our sample of MPOs currently use travel models in their plan broadly and in equity analysis specifically. It then describes how they can advance towards the state-of-the-art regardless of their current capabilities.

In our analysis, we identified three strategies currently employed by the eleven MPOs we evaluated: (i) analysis does not use a travel forecasting model, (ii) analysis uses an aggregate trip-based travel demand model, and (iii) analysis uses a disaggregate activity-based travel demand model. In the subsections below, we describe how MPOs in each of these tiers use models and how they can improve their respective equity analyses.

4.2.1 Analyses without travel forecasting models

While each MPO in our sample used a travel forecasting model for its RTP, many did not use this model to forecast and measure the impacts of their plans on populations of concern. Specifically, the Chicago, New York, New Jersey, and Philadelphia MPOs all have travel forecasting models but did not use them in their equity analyses. Instead, they rely upon Census and American Community Survey (ACS) data to prove non-discrimination in terms of the locations of planned investments. The Chicago MPO identifies numerous equity metrics, but primarily uses ACS data to measure current conditions and does not forecast the future impacts of the RTP.

These MPOs can improve their equity analyses along two dimensions. First, they can and should use their travel forecasting models to evaluate the impacts of their RTPs on populations of concern. Second, they should identify metrics, such as accessibility, which are important for their equity analysis.

The Los Angeles MPO provides a cutting-edge use of a trip-based travel forecasting model by evaluating impacts across numerous populations of concern, although it still classifies these populations using a location- and threshold-based approach. We discuss the Los Angeles MPO approach in more detail below. Chicago, New York, New Jersey, and Philadelphia MPOs should look to replicate the Los Angeles MPO's approach to equity analysis, which is both superior to their current practices and technically feasible given their travel modeling capabilities.

4.2.2 Analyses using trip-based travel forecasting models

The Dallas, Houston, Los Angeles and Washington, DC MPOs all use trip-based travel forecasting models to evaluate equity outcomes in their RTPs. The Houston and Washington, DC MPOs use their travel forecasting models to compare how current, build, and no build scenarios differ across geographies with and without concentrations of low-income and minority populations. Specifically, they look at accessibility metrics like number of jobs accessible by car and transit and the amount of investment allocated to low-income and minority geographies versus the rest of the region. While this approach improves on equity analyses that only use current ACS data and do not make forecasts, the Dallas and Los Angeles MPOs leverage their trip-based models more thoroughly than the Houston and Washington, DC MPOs.

The Dallas MPO evaluates similar metrics (e.g., access to jobs and amount of investment) as the Washington, DC and Houston MPOs. However, Dallas evaluates outcomes for two different types of geography classifications—geographies with high concentrations of ethno-racial minorities and geographies with concentrations of low-income populations. This approach enables the MPO to evaluate how the RTP will impact distinct populations of concern, as opposed to other analyses that combine such populations. For example, the Dallas MPO's analysis forecasts that its African American population will have access to 7.7% more jobs within 30 minutes by transit (NCTCOG 2018b, p. 38) whereas its low-income population will see a forecasted increase of 16.6% (NCTCOG 2018b, p. 36). If these two groups were combined in the analysis, the distribution of benefits between them would be unclear. The Los Angeles MPO goes further than the Dallas, Houston, and Washington DC MPOs in two ways. First, it includes population segments for all five of the region's income quintiles and one for households below the federal poverty line, which is a subset of households in the lowest income quintile. Second, it evaluates outcomes for these segments across the entire region, using traffic analysis zones (TAZs) with concentrations of low-income and minority populations, and census tracts with disproportionate exposure to pollution.

The Los Angeles MPO provides a cutting-edge framework for the use of trip-based travel forecasting models in equity analysis. However, without a disaggregate activity-based model, it is impossible to compare disaggregate outcome data and evaluate the impact on individual agents. Without this capability, these equity analyses are limited to evaluating spatially aggregated data that obscure impacts on populations of concern and inhibit comparing distributions of outcomes, a key component of the state-of-the-art framework. Notably, the Los Angeles MPO has already developed an activity-based model while both the Houston and Washington DC MPOs are in the process of developing activity-based models.

4.2.3 Analyses using activity-based travel forecasting models

The Atlanta, San Diego, and San Francisco MPOs all use activity-based travel demand models in their equity analyses. The Atlanta MPO under-utilizes its activity-based model in its equity analysis while the San Diego and San Francisco MPOs exemplify cutting edge use of their models. However, the cutting-edge state-of-the-practice still has room to advance towards the state-of-the-art.

The Atlanta MPO only measures one equity metric with its activity-based model, namely, mode choice, on census tracts with high concentrations of populations of concern. This metric does not leverage

the activity-based model's ability to evaluate individual agents since it aggregates data by geography instead of populations of concern. It is also unclear from the Atlanta documentation what constitutes an equitable or more equitable outcome for mode choice in census tracts with high concentrations of populations of concern.

The San Diego MPO uses its activity-based model to evaluate accessibility metrics across low-income, minority, and senior populations. The activity-based model forecasts individual travel behavior and evaluates how those groups are impacted by the RTP across the region. The San Diego MPO also assigns monetary value to travel benefits and estimates that low-income, minority, and disabled residents collectively receive over 80 percent of the benefits while only making up 68 percent of the region's population.

The San Francisco MPO uses its activity-based model similarly, though it does not evaluate minority populations throughout the region, instead opting to focus on geographies with high concentrations of low-income and minority populations. However, the San Francisco MPO uses its model to evaluate how various accessibility and cost metrics change for low-income populations as well as job growth by wage level. Its activity-based model also measures displacement and access to high-resource neighborhoods, making San Francisco the only MPO in our sample that measured this salient issue. Importantly, it uses its model to assess individual projects and flag projects if populations of concern do not receive their fair share of benefits.

While the San Diego and San Francisco MPOs exemplify cutting edge equity analysis practices, even these MPOs could do more to move towards a state-of-the-art equity analysis framework. In particular, neither of these MPOs compare distributions of outcomes across populations of concern nor do they analyze the distribution of outcomes within populations of concern, the third component of the Bills and Walker (2017) framework. Instead MPOs continue to compare averages that are prone to masking valuable information about the distribution of benefits and harms of long-term plans within populations of concern. A key benefit of activity-based models is the ability to obtain disaggregated data that allows analysts, planners, and community members to obtain and visualize distributions of outcomes across a given population of concern. MPOs with activity-based models can compare how their RTP benefits not just low-income residents on average, but how those benefits are distributed within that population of concern to compare outcomes more thoughtfully. For example, the San Diego MPO shows that the percentage of low-income residents with access to rail and rapid transit increases from 11.8% in the base year to 41.1% in 2050 as a result of the RTP, but it is unclear how those benefits are allocated within that population segment (SANDAG 2021b, H-39).

5 Discussion

Our analysis reveals a spectrum of the state-of-the-practice for RTP equity analyses by large MPOs. While some of the sampled MPOs are simply meeting Title VI requirements by mapping areas with concentrations of populations of concern and planned investments, most are using travel forecasting models to measure outcomes to evaluate equity. Many of the sampled MPOs used similar accessibility and mobility metrics, like average commute time, accessibility to jobs, etc. While use of the same metrics might generally make sense, certain contexts may necessitate the use of different metrics. For example, the Houston MPO uses metrics that show that the region's populations of concern, which are concentrated in the urban core, have greater access to jobs by car and transit compared to non- populations of concern. Without accounting for potential discrepancies in car ownership rates as well as how many jobs are truly accessible based on

differing characteristics between those populations, it is difficult to make conclusions about the RTP's impact on equity (Grengs 2012).

Additionally, the use of modeling techniques varies across our sample. While every MPO in our sample has a travel forecasting model available, three did not use their models at all in their equity analyses. Five MPOs used aggregate trip-based models and the remaining three used their disaggregate activity-based models to perform their equity analysis. Despite differences in resources and approaches, we were able to identify ways in which MPOs, regardless of current practices, can advance their equity analyses towards the state-of-the-art equity analysis framework.

The San Francisco and San Diego MPOs are practicing many of the components of the state-of-the-art equity analysis framework, including evaluating equity results across different scenarios. However, neither MPO compares the distributions of benefits and harms within populations of concern. Rather they only calculate and analyze the means of the RTP outcomes across populations of concern. For example, the San Francisco MPO forecasts housing and transportation costs will decrease by 49% for households with low-income. However, how these cost savings are distributed across low-income households is not presented, making it unclear what proportion of low-income households will benefit or be negatively affected. In this way, they are under-utilizing their activity-based models in their equity analyses. By analyzing the distributions, they could evaluate not just how low-income households are affected compared to other households, but also how benefits are distributed across that population of concern. While none of the MPOs in our sample generated a state-of-the-art equity analysis, they all have clear ways to edge closer towards doing so.

We agree with Martens and Golub that MPOs need to clearly state their RTP goals as they relate to equity. To support this, MPOs ought to define a fairness standard to inform how they interpret the results of their analysis (Bills 2022). Moreover, our study highlights the analysis techniques required by MPOs to clearly evaluate whether an MPO's plan meets its clearly defined equity goals, regardless of their software capabilities.

Importantly, legal requirements and guidelines seem to influence equity analyses. The California MPOs in our sample are subject to stricter state guidelines than the other MPOs. As such, it is unsurprising that their analyses went above Title VI requirements. The fact that these three MPOs also represented the cutting edge within our sample indicates that stricter guidelines can influence the quality of equity analyses carried out by MPOs. This may be an especially important finding as the Biden administration reviews Executive Order 12898, a potential avenue to alter guidelines to improve equity analyses by MPOs.

We recommend that federal transportation agencies modify or clarify the guidance in the 2012 FTA circular that currently requires MPOs to submit an analysis of the disparate impacts of their RTP on the basis of race, color, or national origin (Federal Transit Administration 2012). Specifically, we recommend a modification that requires each MPO to use a travel forecasting model to analyze the potential disparate impacts of their RTP on the basis of race, color, or national origin. Moreover, we recommend analyzing the following RTP outcomes with the travel forecasting model: accessibility to jobs and other opportunities/activities (e.g., healthcare and groceries). Given that MPOs already use travel forecasting models to assess their RTPs, adding an additional requirement that MPOs use the same travel forecasting model to perform an equity analysis should not represent a significant burden.

This paper has several limitations. First, our analysis primarily evaluates accessibility metrics and is less focused on safety and health/emissions metrics. While this reflects the current focus of MPOs' equity analyses and travel forecasting models, clear goals and metrics regarding exposure to criteria pollutants,

risks from climate change, and traffic violence are critical components of an equitable transportation system plan. Based on our preliminary analysis, we believe MPOs should put more effort into measuring the equity implications of an RTP's impacts on exposure to criteria pollutants. Regarding exposure to traffic violence and risks from climate change, while these are not our areas of expertise, it seems that more research is needed to connect long-term planning decisions with outcomes related to traffic violence and climate change impacts. One recent study, Guo et al. (2020), provides an integrated framework that considers accessibility, emissions, and safety in an integrated equity analysis.

Second, as we have noted throughout this paper, any equity analysis has built-in assumptions that will impact the results and the fairness standard deployed will inform how those results are interpreted. This is particularly important as the outputs from travel forecasting models are influenced by their inputs, which often have various assumptions built into them.

Third, our sample is limited to 11 MPOs in large metropolitan areas in the US. This limits the generalizability of our analysis to smaller MPOs and regions as well as inhibits our ability to identify important equity considerations in rural and less urban areas. While our analysis is limited to geographies within the US, researchers have evaluated the potential use of activity-based models to assess the impacts of various policy and project proposals in Europe, South America, and Asia (Martinez et al. 2015; Niu and Li 2019; Tomasiello et al. 2020) while governments in The Netherlands and Belgium have developed their own activity-based models (Arentze et al. 2000; Bellemans et al. 2010; Tajaddini et al. 2020). Understanding differences and relative strengths in how equity is analyzed via activity-based models in geographies outside the US is not addressed in our analysis but is a relevant line of inquiry for future research.

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