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Looking beyond the mean for equity analysis: Examining distributional impacts of transportation improvements

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ABSTRACT

Activity-based travel demand models can be useful tools for understanding the individual level equity impacts of transportation plans, because of their ability to generate disaggregate transportation measures. However, these capabilities have yet to be fully explored in public practice. In this paper we first discuss a general framework for performing transportation equity analysis using activity-based travel demand models, distributional comparisons, and incorporating equity standards. In addition, we demonstrate the advantages of distributional comparisons, relative to average measures. This demonstration uses the 2000 Bay Area Travel Survey and (activity-based) mode choice model. The findings show that distributional comparisons are capable of clearly revealing the winners and losers that result from transportation improvements, in comparison with average measures. The use of these results will likely result in different conclusions on transportation investments.

1. Introduction

Addressing inequities across all areas of society is critical for improving public policy and infrastructure. The global financial crisis of 2008 drove the subject of inequity into the forefront of public discourse, as income inequity was arguably a key factor that exacerbated this financial meltdown (Vandemoortele, 2009). In the United States, where income inequity is drastically pronounced relative to the worlds other developed nations (Tomaskovic-Devey and Lin, 2011), evidence of inequities can be found in numerous areas of society.

These equity concerns are particularly relevant in the transportation realm. Existing conditions of inequitable transportation accessibility among society have resulted from transportation planning processes which place unfair weight on the preferences of more advantaged members of society. We are left with the reality that disadvantaged members of society have experienced less-than-fair shares of transportation benefits and disproportionately higher shares of transportation externalities. These are long recognized concerns and have led to federal Environmental Justice legislation and directives (1994 Executive Order 12898, and Title VI of the Civil Rights Act of 1964) calling for government agencies (e.g. the US Department of Agriculture (USDA), the US Environmental Protection Agency (EPA), US Department of Transportation (DOT), State DOTs, and Metropolitan Transportation Organizations (MPOs)) to investigate the expected outcomes of proposed infrastructure and policy changes, and confirm that low income and minority (disadvantaged) groups will share equitably in the project benefits and not be overly adversely affected. A Comprehensive discussion on environmental justice and analysis in transportation projects is provided in Forkenbrock and Sheeley, (2004).

While there are a variety of approaches found in the literature for performing equity analysis of transportation projects, an emerging approach among metropolitan planning organizations is to assess the equity impacts of proposed metropolitan transportation plans using activity-based travel demand models (Castiglione et al., 2006; MTC, 2013). These models represent the best practices in travel demand modeling and are particularly useful for equity analysis of large-scale transportation improvements, because of their use of micro-simulation and ability to generate population and travel-related data at disaggregate levels. The disaggregate population and travel-related data from these models enable us to explore the use of distributional comparison tools and analyze the individual level impacts resulting from transportation plans. Even with the advances of activity-based travel models and the growing use of them in practice (Dong et al., 2006; Bills et al., 2012), a number of challenges remain with applying these models for transportation equity analysis.

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The critical issues addressed in this paper lie with the approaches taken to analyze equity outcomes of transportation infrastructure investments and policy changes. These approaches generally fail to paint a comprehensive picture of the resulting individual transportation impacts. In many cases the measures themselves are insensitive to the heterogeneity of transportation experiences across different communities. In this paper we present a general framework for performing equity analysis of long-range transportation plans, using activity-based travel demand models, distributional comparison measures, and incorporating equity standards. In addition, we demonstrate the advantages of distributional comparisons, relative to average measures, using the 2000 Bay Area Travel Survey and a nested mode choice model. With this demonstration, we show that distributional comparisons are capable of revealing the winners and losers that result from different transportation improvements; an analysis that is not possible using average measures. Further, distributional comparisons provide a framework for evaluating what population characteristics and conditions lead to certain distributional transportation outcomes. Ultimately, the use of these results from distributional measures will likely result in different transportation decisions, as compared to the use of average measures.

The contributions of this paper include 1) presentation of a new operational approach for performing transportation equity using activity-based travel demand models, distributional comparisons, and incorporating equity standards, and 2) demonstrating the types of information gained from performing distributional comparisons of equity indicators, relative to average measures of the indicators. The remainder of this paper is organized as follows: In section two, we discuss definitions of transportation equity, the existing practice for performing transportation equity analysis, and we discuss our proposed equity analysis approach. In section three, we present our approach for analyzing indiviual-level equity impacts of simplistic transportation scenarios. In section four we give the scenario results, and we give couclusions in section five.

2. Background

2.1. Defining transportation equity

To date, there seems to be no consensus among scholars on how transportation equity should be defined (Thomopoulos, 2009; Levinson, 2010). In effort to organize the various definitions found in the literature and provide a clearer understanding of what is meant by *transportation equity* in this paper, we have structured the definitions in terms of a general equity concept, equity dimensions, and equity standards. Note that we generally take a very technical definition of equity, given that our objective is to operationalize equity in the evaluation of transportation projects.

Concept: Transportation Equity refers to the fair or just distribution of transportation costs and benefits, among current (and future) members of society (Litman, 2002). (Note that there are a number of different rules for whether a distribution is considered *fair* and these rules will be referred to as *equity standards*, as discussed below.) In this case, transportation costs may include direct transportation user costs as well as environmental costs that result from transportation-related construction, maintenance, operations, and policy changes. These environmental costs may include the direct emissions from automobile use, traffic congestion, noise pollution, etc. Transportation benefits range from improvements in accessibility, mobility, and economic vitality on the general scale, to reductions in travel time and travel user costs.

Dimensions: Transportation equity can be defined along two primary dimensions: Horizontal and Vertical equity (Musgrave and Musgrave, 1989; Litman, 2002). Horizontal equity, which may include spatial and generational equity, refers to the distribution of impacts (costs and benefits) across groups that are considered to be equal in ability and need. Note that in some cases spatial and generational equity are seen as separate dimensions, but for simplification purposes we group them with the Horizontal equity dimension. Vertical equity refers to the distribution of transportation impacts among sub-populations that differ in ability and need, such as different social and income classes, age groups, and disabled or special needs groups.

Standards: We refer to competing principles of equity as equity standards. A number of different standards have been discussed in the academic literature. These standards represent alternative ideas of what distribution (regarding rights, opportunities, resources, wealth, primary goods, welfare, utility, etc.) is accepted as *fair* or most desired. These standards include pareto, egalitarianism, utilitarianism, restorative justice, etc. (Rawls, 1972; Hensher, 1977; Frohlich and Oppenheimer, 1992; Khisty, 1996; Forkenbrock and Sheeley, 2004). A sample of these are presented in the Table 4.

2.2. The existing practice for transportation equity analysis

In public practice, the literature points to two high-level approaches to transportation equity analysis. The first approach, which we refer to as the *modeling approach*, analyses equity impacts using regional travel demand models, and the second approach, which we refer to as the *non-modeling approach* does not apply travel demand models to evaluate equity outcomes.

The *non-modeling approach*, which is more prevalent among planning organizations (Amekudzi et al., 2012), is characterized by the use of spatial analysis tools to map the residential locations of low income and minority communities in relation to the location of the proposed transportation projects. This is done to discern the level of benefits to these communities based on spatial proximity. In some cases, these analyses include determining whether the communities are being overly exposed to transportation externalities (air or noise pollution, traffic congestion, etc.) (MTC, 2001; Rodier et al., 2009).

Our focus in this paper is on the *modeling approach* to equity analyses, where transportation (and land-use) scenarios are modeled using a regional travel demand model. This is to measure the expected impacts of transportation (and land-use) improvements on defined population segments and to compare these impacts (costs and/or benefits) across the segments in order to judge whether the distributions of impacts is equitable. This existing approach is summarized in the following three steps:

1. Select equity indicators (such as travel times, transit mode share, accessibility to jobs, etc.) and segment the population into two categories: target group(s) and comparison group(s).
2. Calculate indicators for the target and non-target groups.
3. Compare the changes in these measured indicators across the groups, and across scenarios (which simulate the expected changes after some transportation improvement has been made).

2.3. Critiquing the existing equity analysis process

There are two critical issues with the existing modeling approach for transportation equity analysis. These issues are regarding the unit of analysis used for segmenting the population and the method of comparing equity indicators.

Regarding the unit of population segmentation, MPOs often define the target group as “communities of concern” or Environmental Justice communities (Forkenbrock and Sheeley, 2004; MTC, 2009; MTC, 2013; SANDAG, 2011). While the segmentation variables (e.g. income, ethnicity, etc.) can vary, these are generally selected to capture locations with high concentrations low income and minority households. Further, the units of segmentation used are aggregate spatial units, such as travel analysis zones (TAZs) or census tracts. For

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