



Representing pedestrian activity in travel demand models: Framework and application



Kelly J. Clifton^{a,*}, Patrick A. Singleton^a, Christopher D. Muhs^a, Robert J. Schneider^b

^a Department of Civil & Environmental Engineering, Portland State University, Portland, OR, USA

^b School of Architecture & Urban Planning, University of Wisconsin-Milwaukee, Milwaukee, WI, USA

ARTICLE INFO

Article history:

Received 5 May 2015

Received in revised form 11 March 2016

Accepted 20 March 2016

Available online xxxx

Keywords:

Walking

Pedestrians

Travel demand models

Built environment

Active transportation

ABSTRACT

There have long been calls for better pedestrian planning tools within travel demand models, as they have been slow to incorporate the large body of research connecting the built environment and walking behaviors. Most regional travel demand forecasting performed in practice in the US uses four-step travel demand models, despite advances in the development and implementation of activity-based travel demand models. This paper introduces a framework that facilitates the abilities of four-step regional travel models to better represent walking activity, allowing metropolitan planning organizations (MPOs) to implement these advances with minimal changes to existing modeling systems. Specifically, the framework first changes the spatial unit from transportation analysis zones (TAZs) to a finer-grained geography better suited to modeling pedestrian trips. The MPO's existing trip generation models are applied at this spatial unit for all trips. Then, a walk mode choice model is used to identify the subset of all trips made by walking. Trips by other modes are aggregated to the TAZ level and proceed through the remaining steps in the MPO's four-step model. The walk trips are distributed to destinations using a choice modeling approach, thus identifying pedestrian trip origins and destinations. In this paper, a proof-of-concept application is included to demonstrate the framework in successful operation using data from the Portland, Oregon, region. Opportunities for future work include more research on the potential routes between origins and destinations for walk trips, application of the framework in another region, and developing ways the research could be implemented in activity-based modeling systems.

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1. Introduction

The personal and social benefits of increasing pedestrian travel are plentiful and include better public health, reduced demands on the transportation system, improved air quality, and reduced greenhouse gas emissions. Recognizing these benefits, many cities are striving to promote walking and are making strategic investments toward that end. In support of these public policies, research continues to strengthen our understanding of the links between urban form and walking (Saelens and Handy, 2008; Saelens et al., 2003); pedestrian data collection methods are becoming more widely available (AMEC, 2011; Ryus et al., 2014; Schneider et al., 2005), and land-use data are increasingly more detailed and disaggregate. In response to new policy demands, transportation planning tools are beginning to take advantage of these developments to represent walking behavior at a much finer spatial detail and with greater sensitivity to environmental and other influences (Kuzmyak et al., 2014).

Despite progress on the research, data, and scale fronts, regional travel demand forecasting models—key policy tools to evaluate project alternatives—lag in their representation of walking activity. Although about 10% of all U.S. trips are made by walking (Santos et al., 2011), many regional models in the U.S. do not forecast non-motorized travel (Singleton and Clifton, 2013). A travel modeling framework that represents walking behavior using pedestrian-scale spatial units and environmental influences could: improve model sensitivity to more walking-relevant variables (e.g., specific activity locations, fine-grained land-use mix, roadway and sidewalk conditions), yield results that are more responsive to socio-demographic changes and policy interventions (e.g., smart-growth strategies, pricing, pedestrian infrastructure investments), provide more accurate estimates of mode shifts and overall non-motorized and motorized trips, and generate more useful model outputs for pedestrian planning, safety analyses, health impact assessments, and greenhouse gas reduction evaluation. Accordingly, metropolitan planning organizations (MPOs), the primary stewards of regional travel demand models, would benefit from updating their methods of modeling pedestrian behavior.

The purpose of this paper is to introduce a comprehensive framework to represent pedestrian activity more effectively within four-step travel demand models, currently the dominant structure

* Corresponding author at: Civil & Environmental Engineering, Maseeh College of Engineering & Computer Science, PO Box 751 — CEE, Portland, OR 97201-0751, United States.
E-mail address: kclifton@pdx.edu (K.J. Clifton).

of transportation forecasting tools used by MPOs in the U.S. This framework:

- Incorporates the state of the knowledge in the use of non-motorized modes. There is now a substantial body of literature about pedestrian travel demand, and it is ready to be put into practice;
- Takes advantage of the widespread availability of disaggregate, spatially-explicit, behavioral data and fine-grained information about the built and natural environments;
- Operates at a scale relevant to pedestrians, so it is responsive to shorter trip distances and detailed environmental data previously masked by the zonal aggregation used in demand models; and
- Is scalable to fit within the traditional four-step travel demand forecasting framework, minimizing the degree of model reconfiguration required of MPOs.

The framework and methods are supported by a proof-of-concept application in the Portland, Oregon, region to demonstrate clearly their value and contributions to practice.

The following sections include a brief review of research on pedestrian behaviors and the practice of modeling pedestrians, an overview of the pedestrian modeling framework, and a proof-of-concept application of the framework. The paper concludes with a discussion of the benefits and limitations of the framework, the opportunities and challenges of applying it in other regions, and needs for future work.

2. Background

2.1. State of the research on environmental influences of pedestrian travel

Early efforts to model pedestrian travel were hampered by a lack of pedestrian data and commensurate information about the built environment at appropriate scales to assess walking behavior. However, the availability of data has vastly improved and thus pedestrian research has advanced over the last two decades, particularly in the literature linking travel behavior to the built environment (e.g., Ewing and Cervero, 2010; Saelens and Handy, 2008; Saelens et al., 2003). This research has identified many factors that influence how frequently people walk (rate of trip generation), whether people walk (mode choice), and activity locations where people walk (destination choice).

While the magnitudes of the effects vary across studies, research has identified a common set of built environment features that affect walking. Walk trip frequency and walk mode choice have been positively related to higher residential and employment densities, greater land-use mix or diversity, and more connected street networks or higher intersection densities (Ewing and Cervero, 2010; Saelens and Handy, 2008; Saelens et al., 2003). Some results also point to positive associations with accessibility to transit (Schneider et al., 2009) and street-level factors like sidewalks (Ewing and Cervero, 2010; Rodríguez and Joo, 2004). All of these built environmental influences appear to affect walking even when controlling for self-selection (Cao et al., 2009). Work now focuses on the appropriate spatial scale at which to operationalize these measures (Gehrke and Clifton, 2014). In general, smaller scale and individual-focused accessibility measures may be more strongly associated with walking behavior than regional accessibility measures (Greenwald and Boarnet, 2001; Saelens and Handy, 2008), emphasizing the need to use small geographic scales in pedestrian travel behavior research.

Very few studies have looked solely at environmental correlates of pedestrian destination choice (Clifton et al., 2016). Results of more general studies of walking suggest that distance to destinations is a motivating factor (Saelens and Handy, 2008). Borgers and Timmermans (1986) studied retail shopping trips made on foot in the city center of

Maastricht, the Netherlands, and found that distance and retail floor area had significant impacts. Eash (1999) used a pedestrian environment factor (PEF) in destination choice models for non-motorized trips in Chicago, Illinois, but PEF was a relatively crude measure of conditions for pedestrians and had limited policy relevance.

2.2. State of the practice on modeling pedestrian travel demand

Transportation planning practice has not kept pace with progress on pedestrian research (Kuzmyak et al., 2014). Few regional travel-demand models estimate pedestrian travel demand (Liu et al., 2012; TRB, 2007), and those that do lack sophistication relative to the models for motorized modes. A recent review of the practice investigated the treatment of walking within MPO travel-demand models (Singleton and Clifton, 2013). Many models either excluded pedestrian travel or combined walking and bicycling together as a “non-motorized” mode. Only two-thirds of the largest MPOs modeled non-motorized travel, and less than half of those models distinguished walking from bicycling. Most MPO models with non-motorized modes included them as alternatives in a mode-choice model, while others created mode-split models before or after trip distribution or used a separate non-motorized trip generation process. Furthermore, the environmental influences on walking behavior represented in MPO models inadequately reflect the state of the knowledge. While most models included measures of residential and/or employment density, few used diversity or design variables or information on walking facilities to predict pedestrian demand. Finally, the majority of large MPO models operationalized basic environmental, demographic, and socioeconomic correlates of walking at a coarse spatial scale (Singleton and Clifton, 2013).

This notable gap between pedestrian travel demand research and practice exists for several reasons. First, accurate, detailed, and widespread information on walking behaviors across an urban area historically has been difficult to obtain. The rich data collected for the studies identified above tended to have smaller sample sizes and narrower geographic scopes; regional travel model applications require larger samples collected across entire metropolitan areas. Until the 1990s, many regional household travel surveys omitted walking trips altogether or only asked respondents to record walking trips of certain types or those over a minimum distance or duration threshold (Clifton and Muhs, 2012).

Second, relevant measures of the built environment were not always available. Metrics of density, diversity, and design have been challenging to calculate for the entire spatial extent of the modeled region because of the difficulties obtaining consistent land use and transportation system data, particularly information about the existence and completeness of sidewalk networks (Peiravian et al., 2014). Third, many model applications have relied (and continue to rely) on large-scale transportation analysis zones (TAZs) and high functional class street networks. This coarse scale fits nicely with census geographies and eases computational modeling burdens by dealing with smaller matrices (TRB, 2007), but it is a relic of an era when travel models were designed to forecast demand for automobile and transit modes, exclusively. Large zones can muddle the determinants of walking, as TAZ averages of spatial and environmental measures can obscure finer-grained variations that matter at the pedestrian scale. In addition, walking trips can be hidden as intra-zonal travel; walking activity often occurs within neighborhoods and along lower-volume roadways and off-street paths. As a result, TAZ-based models can yield poor estimates of pedestrian travel demand and walking distances-traveled. Given these considerations, many practicing transportation modelers perceive travel survey and built environment data limitations to be key barriers inhibiting a more realistic and policy-sensitive representation of walking in applied models (Singleton and Clifton, 2013).

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