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Research Paper

Bicycle, pedestrian, and mixed-mode trail traffic: A performance assessment of demand models

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ABSTRACT

This study presents new trail demand models based on data collected between January 1, 2014 and February 16, 2016 at 32 locations in the seven major climatic regions in the continental U.S. We contribute fourfold to the literature on analysis of trail traffic demand. First, we develop a set of econometric models to predict average daily pedestrians (ADP), average daily bicyclists (ADB), and average daily mixed-mode traffic (ADM) using the 5 D's of the built environment (i.e., density, diversity, design, distance to transit, and destination accessibility), and socio-economic characteristics. Second, we test the performance of trail demand models in predicting ADB, ADP, and ADM using the leave-one-out cross-validation technique and compare the relative accuracy of the models. Third, we assess the performance of separate bicycle and pedestrian demand models in predicting mixed-mode travel demand. Fourth, we introduce a post-validation technique to advance the prediction accuracy of trail traffic demand models. The results indicate: (1) with only a few exceptions, ADP and ADB are correlated with different variables, and the magnitude of effects of variables that are the same varies significantly between the two modes; (2) The mean relative percentage error (MRPE) for bicyclist, pedestrian, and mixed-mode models equals 65.4%, 85.3%, and 45.9%; (3) Although using separate but integrated sensors to monitor bicycle and pedestrian traffic enables us to juxtapose the bicyclist demand with pedestrian demand, there is not a significant improvement in predicting total demand using these more expensive sensors; (4) A new post-validation procedure improved the demand models, reducing the MRPE of bicyclist, pedestrian, and mixed-mode models by 27.2%, 32.1%, and 14.1%. Overall, our models confirm that different variables are correlated with bicycle and pedestrian traffic volumes and that these modes need to be modeled separately. Our models can be used in practical applications such as selection of trail corridors and prioritization of investments where order-of-magnitude estimates suffice.

1. Introduction

Multiuse trails, or shared-use paths, are key links in non-motorized transportation networks in many metropolitan areas across the U.S. (Fabos, 2004; Searns, 1995). They boost accessibility to valued destinations and create recreation and utilitarian travel demand (Gobster, 1995; Ryan, Fábos, & Allan, 2006). Despite the importance of trails in urban networks, planners and advocates lack tools for estimating the demand for them. New tools are needed to plan and prioritize investments in new facilities and to inform management and maintenance of trail infrastructure. This shortcoming has been largely rooted in the absence of continuous traffic counts for non-motorized traffic (Ryus et al., 2014).

Unlike motorized traffic demand, which is fairly consistent throughout a year, non-motorized travel demand varies significantly in response to external factors such as weather and season. In addition, land use and the built environment exert different influences on decisions to drive, bike, and walk (Sun, Ermagun, & Dan, 2017). To understand differences in demand for walking and cycling, analysts need continuous pedestrian and bicyclist traffic data collected over long periods of time in different urban contexts and geographic regions. While trail traffic data are increasingly becoming available, much of previous research has been confined to particular facilities, cities, or metropolitan regions (e.g., Wang, Lindsey, Hankey, & Hoff, 2013; Lindsey, Wilson, Rubchinskaya, Yang, & Han, 2007). Consequently, efforts to transfer and apply trail demand models in different locations have met with limited success (Wang, Hankey, Wu, & Lindsey, 2016).

Counts of pedestrians and bicyclists on trails historically have been

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collected manually on a case by case basis, which has limited the duration of counts, been monotonous for field personnel, expensive, and sometimes unreliable (Ryus et al., 2014). Over the past 15–20 years, however, emerging automated technologies for counting pedestrians and bicyclists have overcome these limitations and facilitated continuous traffic counts analogous to those collected for motorized traffic (Pettebone, Newman, & Lawson, 2010). Automated monitors may count bicyclists and pedestrians separately or as mixed mode traffic (i.e., undifferentiated bicyclists and pedestrians) depending on their design and the location in which they are used. For example, passive infrared devices, which count people passing by sensing temperature differentials with background ambient conditions, do not differentiate between cyclists and pedestrians and hence yield only mixed mode counts if installed on trails or sidewalks. Inductive loops and pneumatic tubes on trails or in bike lanes count bicyclists but not pedestrians. These technologies can, however, be combined with infrared monitors to produce separate bicycle and pedestrian counts. Much of the previous research on trail traffic demand has been limited to analysis and modeling of mixed mode counts obtain through deployment of passive or active infrared sensors. The main reasons for reliance on infrared monitors have been cost, simplicity in deployment and data collection, and availability. Infrared technology is older, and portable units for measuring trail traffic that can be deployed by nonspecialists are available for a few hundred dollars. Integration of infrared devices with pneumatic tubes on trails is cumbersome and requires experienced personnel and more time. Installation of inductive loops requires specialists to cut through concrete and therefore is more expensive. However, because the needs for demand data have increased, integrated technologies that combine infrared and inductive loops for producing mode-specific measures of demand now are available at reasonable costs.

Because of their availability and the integration of new capabilities such as wireless data transmission, public agencies throughout the world increasingly are deploying integrated infrared and inductive loop systems. Examples of agencies and nonprofit organizations in the U.S. now using these technologies to monitor trail traffic include the North Carolina and Minnesota Departments of Transportation, the Delaware Valley Regional Plan Commission, and the cities of Portland and Seattle. In 2014, to support its efforts to increase accessibility to urban trails across the United States, the nonprofit Rails to Trails Conservancy (RTC) launched a new initiative, the Trail Modeling and Assessment Platform (T-MAP) that included deployment of integrated infrared and inductive loop monitors in 13 urban areas across the U.S. An objective of T-MAP is to produce trail demand models to support development of new trails (Rails to Trails., 2016).

This paper presents new trail demand models based on new data from the T-MAP traffic monitors. These data are distinctive in three respects. First, the data cover a relatively long period of record: from January 1, 2014 through February 16, 2016. Second, the data are more comprehensive as they are encompass 32 locations from the seven major climatic regions in the continental U.S. Third, and most importantly, because the counts were taken using integrated sensors, we have separate counts for bicyclists and pedestrians at each location. We therefore report mode-specific measures of annual daily traffic (ADT) and annual average daily traffic (AADT). These measures are:

- Average Daily Bicyclists (ADB)
- Average Daily Pedestrians (ADP)
- Average Daily Mixed-mode Traffic (ADM)
- Annual Average Daily Bicyclists (AADB)
- Annual Average Daily Pedestrians (AADP)
- Annual Average Daily Mixed-mode Traffic (AADM).

To model the effects of land use, transportation facilities, and sociodemographics on trail demand, we augmented the counts with data representing the 5 D's of the built environment: Density, Diversity, Design, Distance to Transit, and Destination Accessibility, extracted from the USEPA's 2014 Smart Location Database (Ramsey & Bell, 2014). We chose to construct our models using this database because the same measures have been calculated for every Census Block Group in the U.S. and the availability of data will facilitate application of the models in practical contexts.

These data enable us to contribute fourfold to the practical literature on trail traffic demand analysis. First, we develop a set of econometric models to predict ADP, ADB, and ADM using 5 D's of the built environment and socio-economic characteristics. Second, we test the performance of trail demand models in predicting ADB, ADP, and ADM using the leave-one-out cross-validation technique, and we compare the accuracy of the models against one another. Third, we assess the performance of separate bicycle and pedestrian demand models in predicting mixed-mode travel demand. This assessment allows us to understand whether and to what extent we gain in the accuracy of nonmotorized total demand prediction when we invest in integrated sensors that produce separate bicycle and pedestrian counts rather than mixed-mode sensors. Fourth, we introduce a post-validation technique to advance the prediction accuracy of trail traffic demand models. In particular, we aim to answer the following questions:

(1) How much do built-environment and socio-economic characteristics describe bicyclist and pedestrian trail traffic demand, and do these correlates vary between modes?
(2) How accurately can trail traffic models predict demand?
(3) Can we predict total (i.e., mixed-mode) travel demand more accurately when we use multimodal devices that generate separate estimates of bicycle and pedestrian traffic?
(4) How and to what extent can we improve the accuracy of trail traffic models using post-validation techniques?

The remainder of this research is structured as follows. First, we synthesize the growing literature on trail traffic and demand analysis. Second, we present a descriptive analysis of the data used in this study, especially, the variation in ADP, ADB, and ADM over the study locations. Third, we develop a set of econometric models to regress the trail demand against the 5 D's of the built-environment and socioeconomic characteristics. Specifically, we develop and compare bicycle-only, pedestrian-only, and mixed-mode demand models. Fourth, we discuss the results and introduce a post-validation technique to advance the prediction accuracy. We then conclude by summarizing the key findings and discussing the implications for both future modeling efforts and practice.

2. Recent progress in nonmotorized demand modeling

Researchers have made considerable progress in modeling demand for non-motorized transportation over the past 20–25 years, moving from models based on two hour manual counts of bicyclists and pedestrians on roads, sidewalks, and trails to models using continuous counts recorded with automated devices of different types. In general, as researchers have gained access to longer, longitudinal datasets, their use of more sophisticated modeling techniques has increased. Because of the importance of trails in non-motorized networks, the absence of motorized traffic on trails, and a geometry that lends itself to monitoring, better datasets are available for trail traffic than for bicycles on streets and pedestrians on sidewalks. The increased availability of trail datasets is reflected in the modeling literature.

Demand models based on bicycle, pedestrian, or trail counts have been built both to explore theoretical relationships and for practical purposes such as prediction. These models have shown that weather and the built environment exert powerful influences on demand for both cycling and walking. For example, researchers have developed count-based, facility demand models of hourly or daily traffic to explore the effects of weather on bicycling (Corcoran, Li, Rohde, Charles-