Journal of Transport & Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

# Spatial models of active travel in small communities: Merging the goals of traffic monitoring and direct-demand modeling

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ARTICLE INFO

*Keywords:*
Non-motorized transport
Facility-demand model
Bicycle and pedestrian planning

ABSTRACT

A number of recent studies have made progress on specific components of monitoring and modeling bicycle and pedestrian traffic. However, few efforts merge the goals of collecting traffic counts and developing spatial models to meet multiple objectives, e.g., tracking performance measures and spatial modeling for use in exposure assessment. We used estimates of bicycle and pedestrian Annual Average Daily Traffic (AADT) from a comprehensive traffic monitoring campaign in a small community to develop direct-demand models of bicycle and pedestrian AADT. Our traffic monitoring campaign (101 locations) was designed specifically to capture spatial variability in traffic patterns while controlling for temporal bias. Lacking existing counts of cyclists and pedestrians, we chose count sites based on street functional class and centrality (a measure of trip potential). Our direct-demand models had reasonable goodness-of-fit (bicycle $R^2$: 0.52; pedestrian $R^2$: 0.71). We found that aspects of the transportation network (bicycle facilities, bus stops, centrality) and land use (population density) were correlated with bicycle and pedestrian AADT. Furthermore, spatial patterns of bicycle and pedestrian traffic were different, justifying separate monitoring and modeling of these modes. A strength of our analysis is that we conducted counts at a representative sample of all street and trail segments in our study area (Blacksburg, Virginia; ~5.5% of segments) – an advantage of monitoring in a small community. We demonstrated that it is possible to design traffic monitoring campaigns with multiple goals (e.g., estimating performance measures and developing spatial models). Outputs from our approach could be used to (1) assess land use patterns that are correlated with high rates of active travel and (2) provide inputs for exposure assessment (e.g., calculating crash rates or exposure to other hazards). Our work serves as a proof-of-concept on a relatively small transportation network and could potentially be extended to larger urban areas.

## 1. Introduction and literature review

Efforts to build healthy, sustainable transportation systems often include provisions for increasing rates of active travel (i.e., cycling and walking; Nieuwenhuijsen and Khreis, 2016). Integrating routine counts of cyclists and pedestrians in traffic monitoring campaigns is an ongoing effort and would allow planners and engineers to track performance measures for all modes when making decisions on investments in infrastructure. Developing methods to model spatial patterns of bicycle and pedestrian traffic flows (based on the counts collected in the traffic monitoring campaigns) could be used for multiple goals including: (1) assessing land use

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http://dx.doi.org/10.1016/j.jth.2017.08.009
Received 29 January 2017; Received in revised form 10 August 2017; Accepted 17 August 2017
2214-1405/ 

patterns that are correlated with high rates of active travel and (2) providing necessary inputs for exposure assessment (e.g., calculating crash rates or exposure to other hazards).

Tracking performance measures, for example, Annual Average Daily Traffic (AADT), is an important method for evaluating transportation systems and allocating funding for future infrastructure. Historically, efforts to collect traffic counts and model performance measures have focused on motor vehicles (FHWA, 2010); exploratory studies have introduced potential metrics to measure risk for bicycles and pedestrians (Molina et al., 2009). Emerging efforts aim to adapt traffic count procedures and modeling techniques to also collect and model information on bicycle and pedestrian traffic patterns (Lindsey et al., 2014). However, for bicycles and pedestrians, most of these efforts have not focused on designing traffic monitoring programs specifically for the purpose of spatial modeling.

Over the past decade researchers have developed best practices for implementing traffic monitoring programs for bicycles and pedestrians. Guidance has emerged on specific components of monitoring, for example, tradeoffs between short-duration count length and AADT estimation error, (Hankey et al., 2014; Nordback et al., 2013; Nosal et al., 2014) seasonality of traffic patterns (Lindsey et al., 2016; Wang et al., 2014), and developing scaling factors and factor groups for estimating AADT (Esaway et al., 2013; Miranda-Moreno et al., 2013). Most monitoring programs have focused on single components of the network, e.g., off-street trails (Lindsey et al., 2007; Wang et al., 2014) or corridors of interest (Miranda-Moreno et al., 2013); recent efforts have expanded to comprehensive monitoring of the entire network (DVRPC, 2016; Lu et al., 2017). Many of the findings from these programs have been summarized in federal guidance documents (FHWA, 2013; NCHRP, 2014a, 2014b).

Similar to traffic monitoring, spatial modeling of bicycle and pedestrian traffic patterns has become a useful tool in bicycle and pedestrian planning. Resource requirements for integrating bicycles and pedestrians in travel demand models are large; however, progress is being made to develop these inputs (Hood et al., 2011; Iacono et al., 2010; Krizek et al., 2009; NCHRP, 2014a, 2014b). Direct-demand modeling is a statistical-empirical approach that has emerged as an alternative to travel demand modeling. Multiple studies have used existing traffic count databases to develop city-specific direct-demand models (Fagnant and Kockelman 2016; Hankey and Lindsey, 2016; Jones et al., 2010; Miranda-Moreno and Fernandes, 2011; Pulugurtha and Repaka, 2008; Schneider et al., 2009a, 2009b, 2012; Wang et al., 2016). Typically, traffic monitoring programs are not designed specifically for the purpose of spatial modeling and models often reflect spatial and temporal biases associated with the choice of count locations and time period of data collection.

A key need to better assess patterns of bicycle and pedestrian traffic is to integrate spatial modeling as a design criteria in traffic monitoring programs. In this paper, we present direct-demand models of bicycle and pedestrian traffic from a small, rural college town: Blacksburg, Virginia. Our models were developed using counts from a traffic monitoring program that was developed: (1) to estimate performance measures for use in Town planning (a common use of traffic counts) and (2) for building spatial models (as an additional output of traffic monitoring). The traffic monitoring program was developed specifically to estimate AADT as the input for model building and thus better control for temporal variation in traffic. Our work contributes to the literature by illustrating how traffic monitoring programs can be tailored specifically for the purpose of developing spatial models. The outputs of these models can then be used to assess the impact of land use patterns on rates of active travel and as an input to exposure assessment for traffic safety or air quality (Hankey et al., 2017; Jacobsen, 2003; Khreis et al., 2016). Our study area is a small rural college town which allows for (1) exploration of trends in bicycle and pedestrian traffic in a small community (most studies are in large urban areas) and (2) development of a proof-of-concept study for merging traffic monitoring and spatial modeling where it is possible to sample a relatively large portion of the transportation network (i.e., we sampled 5.5% of street and trail segments in Blacksburg) as compared to previous studies (primarily conducted in large urban areas).

## 2. Data and methods

We used the results of a traffic monitoring campaign in Blacksburg, VA to develop direct-demand models of bicycle and pedestrian AADT. The traffic monitoring campaign resulted in 101 locations with separate estimates of bicycle and pedestrian traffic. Our overarching goal is to demonstrate how traffic monitoring campaigns can be designed for multiple purposes, such as tracking performance measures over time and developing spatial models.

### *2.1. Study location*

Our study area is the small, rural college town of Blacksburg, VA (full-year population: ~12,000; student population: ~30,000). Blacksburg is part of the Blacksburg-Christiansburg-Radford statistical area (population: ~160,000) in the Appalachian Mountains in southwest Virginia. The area is heavily influenced both economically and demographically by Virginia Tech University.

### *2.2. Site selection and data collection*

We collected traffic counts using three types of automated counters: (1) pneumatic tubes for bicycles on streets (MetroCount MC 5600 Vehicle Classifier System), passive infrared for pedestrians on sidewalks (Eco-Counter Pyro), and radiobeam for bicycles and pedestrians on trails (Chambers RadioBeam Bicycle-People Counter). We collected continuous counts for year-2015 at four reference sites to capture temporal trends. We also collected 1-week counts at 97 short-duration count locations for spatial coverage. Using the counts from the four reference sites we developed day-of-year scaling factors (Hankey et al., 2014; Nordback et al., 2013; Nosal et al., 2014) to estimate AADT at the 97 short-duration count sites. Further details on the traffic count campaign and method for estimating