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A high resolution agent-based model to support walk-bicycle infrastructure investment decisions: A case study with New York City☆,☆☆

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ABSTRACT

Active transportation modes–walk and bicycle–are central for low carbon transport, healthy living, and *complete streets* initiative. Building a community with amenable walk and bicycle facilities asks for smart planning and investments. It is critical to investigate the impact of infrastructure building or expansion on the overall walk and bicycle mode usage prior to making investment choices utilizing public tax money. This research developed a high performance agent-based model to support investment decisions that allows to assess the impact of changes in walk-bike infrastructures at a fine spatial resolution (*e.g.*, block group level). We built the agent-based model (ABM) in Repast-HPC platform and calibrated the model using Simultaneous Perturbation Stochastic Simulation (SPSA) technique. The ABM utilizes data from a synthetic population simulator that generates agents with corresponding socio-demographic characteristics, and integrates facility attributes regarding walking and bicycling such as sidewalk width and total length bike lane into the mode choice decision making process. Moreover, the ABM accounts for the effect of social interactions among agents who share identical home and work geographic locations. Finally, GIS-based maps are developed at block group resolution that allows examining the effect of walk-bike infrastructure related investments. The results from New York City case study indicate that infrastructure investments such as widening sidewalk and increasing bike lane network can positively influence the active transportation mode choices. Also, the impact varies with geographic locations–different boroughs of New York City will have different impacts. Our ABM simulation results also indicate that social promotions foucsing on active transportation can positively reinforce the impacts of infrastructure changes.

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1. Motivation and related works

Active transportation–walking and bicycling–plays a pivotal role in many contexts including sustainable transportation, low-carbon living, walkable communities, and public health. Researchers and practitioners from transportation planning and policy community highly advocate for the proliferation of active transportation modes (*e.g.*, walk and bike) that can help to alleviate congestion, reduce greenhouse gas emissions, and contribute to fighting obesity. Vehicle Miles Traveled (VMT) is an important metric to consider regarding reducing greenhouse gas emissions from the road networks which is a major contributor to climate change. Switching people to non-motorized modes of transportation is one of the effective approaches. This is important because active transportation modes are able to meet the travel needs of the people at zero greenhouse gas consumptions. The goal is to decrease motorized VMT and balance the travel needs by means of increasing non-motorized (walking and bicycling) VMT.

Among several approaches, one potent direction asks for the development and/or expansion of walk-bike infrastructure in cities to attract users towards walk and bike mode of transportation when feasible.[1] Investing in building and/or expanding walk-bike facilities requires significant portion from the state and federal funds. Accordingly, we need to assess beforehand the impact of infrastructure expansion in terms of number of people using the newly developed or expanded walk-bike facilities. This necessitates active transportation modeling accounting for socio-demographic characteristics, trip attributes, walk-bike network features, social interactions, perception of traffic safety, and so on. This research offers a high resolution agent-based model (ABM) that will assist in investment decision making by assessing the impact of changes in transportation infrastructure, level of traffic safety, and socio-demographic attributes.

Historically walk-bike (non-motorized) trips are often discarded in the planning process with the emphasis on motorized trips only. However, recent demand modeling approaches are enhanced to account for walk-bike modes (NCHRP, 2013) in the planning process. Tour-based and activity-based travel demand models are capable to include walk and bike trips (Singleton and Clifton, 2013). Generally, discrete choice models are estimated using a small representative sample controlling for socio-demographic attributes and trip characteristics (Clifton and Dill, 2005; Ferdous et al., 2011; Handy and Xing, 2011; Khan et al., 2014). These models provide aggregate level mode shares for the planning region (*e.g.*, Best Practice Model for the New York City Metropolitan Region). Although the aggregate level output tells us the change in mode share for the entire city, it cannot identify which block groups in the city will have the most impact from expanding active transportation infrastructure such as bike lanes. Although the sample used by discrete choice model is representative to the entire region, the results cannot be transferred to a finer scale such as block group level with statistical validity. In addition, the change in behavior at individual level is challenging to capture. For instance, it is possible to have users showing different attitude towards walk and bike modes while socio-demographic attributes are identical. Recent developments in econometric approaches (Greene, 2008) integrates heterogeneity by means of mixing distributions in the parameter estimates. However, the effects are at sample level and only aggregate level inferences can be made. In this research we aim to address these challenges by using synthetic population instead of small sample with an agent-based modeling framework.

Agent-based modeling has been used in many transportation science problems such as commodity transport (Liedtke, 2009), policy framing and optimization (Taeihagh et al., 2014; Ma et al., 2016), destination choice problems (Horni et al., 2011), activity travel scheduling Ma et al. (2012), Zou et al. (2016), and Chen and Rakha (2016), traffic signal control (Aziz and Ukkusuri, 2016), integrated traffic simulation and air pollution estimation (Hülsmann et al., 2014), parking studies (Chou et al., 2008; Benenson et al., 2008; Levy et al., 2013) and hurricane evacuation (Ukkusuri et al., 2016). Few agent-based approaches to model walk and bicycling include modeling school trips of children (Yang et al., 2014), daily walking (Yang et al., 2011), and assessing walkability (Yin, 2013). These efforts to model active transportation have limited spatial scope and are not suitable to accommodate agents in scales of millions. Further, bicycle modes are not considered in most cases. Further, majority of active transportation choice models (both econometric and agent-based) do not integrate walk-bike infrastructure data into the framework. Most approaches use data from a single source (e.g., regional travel survey) and specific attributes of active transportation networks such as bike lane features are not accounted for in a direct manner. As a result, these models cannot provide estimate the effects of walk-bike infrastructure changes in a significant manner.

Further, traffic safety for pedestrians and bicyclists is now a corner stone within the *complete streets* initiative. The *Vision Zero* (Elvik, 1999; Johansson, 2009) scheme[2] emphasizes on the safety of pedestrians and bicyclists. The perception of safety affects the choice of to walk and bike in cities (Winters et al., 2010; Handy et al., 2006). Most existing works do not consider the traffic safety aspect into the transportation mode choice process. Our proposed agent-based modeling framework integrates both walk-bike infrastructure and traffic safety data (number of pedestrian and bike crashes) into the decision making process of an agent.

Finally, our developed ABM accounts for the agent-to-agent interactions that influence the transportation mode choices (Abou-Zeid et al., 2013; Maness et al., 2015). Traditional econometric and approximate proportional models cannot accommodate agent-level interaction inherently. On the contrary, ABMs can capture the dynamic attributes such as learning from experience and spatial evolution in the system (Oakes, 2006; Yang et al., 2011). Our developed ABM incorporates the interactions among the agents sharing identical home and work geographic locations in the active transportation network.

[1] Not all trips can be made by walking or bicycling due to distance constraints.

[2] *Vision Zero* aims to reduce traffic-related injuries and fatalities with the principle that only acceptable number of traffic deaths and serious injuries is zero. Vision Zero was initiated in Sweden in 1997 and now adopted by many countries across the globe. US cities including New York, Chicago, Boston, San Francisco, Seattle, Portland, San Diego, have recently adopted Vision Zero policies.