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# A behavioral modeling approach to bicycle level of service

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ABSTRACT

Bicycle level of service (LOS) measures are essential tools for transportation agencies to monitor and prioritize improvements to infrastructure for cyclists. While it is apparent that different types of cyclists have varying preferences for the facilities on which they ride, in current research and practice, measures are used that are either insufficiently quantitative and empirical or lack cyclist segmentation. In this study, we conducted a detailed survey on cyclist habits, preferences, and user experience, capturing responses to videos of a bicycle traveling on road segments in the San Francisco Bay Area. The survey provided rich behavioral data, which invited both quantitative and qualitative exploration. We compared facility preferences from the survey to scores from two common measures, NCHRP bicycle level of service (NCHRP BLOS), and level of traffic stress (LTS); and we examined the responses to open-ended questions to gain insights about heterogeneity of preferences among cyclists. Finally, we applied behavioral analysis tools as a proof of concept for a new bicycle level of service measure that accounts for the segmentation of cyclist types via a latent class choice model. Combining statistics and behavioral analysis, we can improve the quality of bicycle level of service measures to make decisions driven by empirically measured cyclist preferences.

## 1. Introduction

Bicycle level of service (LOS) measures are essential tools for transportation agencies to monitor the performance of their roadway infrastructure as it relates to bicycling. They attempt to relate objective measures of the roadway environment to subjective measures of cyclist user experience—whether safety, comfort, or performance—using statistical models, point systems, or weakest link approaches. Such measures are also crucial in prioritizing infrastructure improvements, since they provide a method to evaluate how different designs would affect the performance. To evaluate the performance of their roads, agencies need to collect, analyze, and report information regarding various elements of the infrastructure. This effort can be costly, and while agencies may prefer to apply measures that are simpler and have fewer data requirements, measures that are empirically based and use statistical models will produce better results.

A number of these measures are designed to complement automobile LOS, using the name bicycle level of service, or BLOS, and the same A through F scale, where the score represents an average for all cyclists (Dixon, 1996; Landis et al., 1997; Jensen, 2007;

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Dowling et al., 2008; HCM, 2010). A commonly used measure, NCHRP BLOS (Dowling et al., 2008)—along with several other measures (Landis et al., 1997; Harkey et al., 1998; Jensen, 2007; Dowling et al., 2008; HCM, 2010)—uses empirically based quantitative models with dependent variables based on user responses to riding on or viewing videos of roadway segments. This statistical approach helps to avoid the biases inherent in measures based on expert opinion or design standards. However, by averaging the responses across the cyclist population, it fails to acknowledge that different types of cyclists may have varying preferences for the facilities on which they ride.

The idea that cyclist heterogeneity needs to be considered when planning for roadway infrastructure is not new. A number of cyclist typologies based on attributes such as bicycling frequency, skill, and comfort level have been proposed (Wilkinson et al., 1994; Sorton and Walsh, 1994; Geller, 2006; Winters et al., 2011). Studies have shown that some socio-demographic characteristics can also have an impact on bicycle use, including age (Rietveld and Daniel, 2004; Sener et al., 2009), income (Pucher and Beuhler, 2008), gender (Pucher and Beuhler, 2008; Krizek et al., 2005), ethnic origin (Moudon et al., 2005; Pucher and Beuhler, 2008), car ownership and use (Dill and Voros, 2007; Pucher et al., 2010), and bicycle ownership (Pinjari et al., 2008; Rietveld, 2000). Although these studies looked at how various characteristics of cyclists individually related to bicycle use, it is also important to examine how the combined information of these personal attributes gives us insight into cyclist facility preferences.

Another vein in bicycle performance research recognizes the need to incorporate cyclist heterogeneity, while eschewing statistical models. These studies focus on the stress of riding different facilities for riders with different comfort levels (Sorton and Walsh, 1994; Mekuria et al., 2012). Level of traffic stress (LTS) (Mekuria et al., 2012), in particular has gained popularity among local agencies, for its ease of application and interpretation. This measure's rating system coarsely maps onto the Portland typology of cyclists developed by Geller (2006), which includes four ordinal types: "strong and fearless" (LTS4), "enthused and confident" (LTS3), "interested but concerned" (LTS2), and "no way no how." LTS1, instead of corresponding to Geller's "no way no how" type, is intended for very cautious riders, including those riding with children. An LTS score corresponds to the minimum comfort/experience level willing to ride on a facility. This labelling approach provides a more meaningful rating than the opaque A through F scores of BLOS. It acknowledges the different behavior and preferences of different cyclists, but assumes that all cyclist types fall upon an ordinal scale of skill and comfort, which may not be the best factors to determine preferences. Additionally, rather than using an empirically developed model, LTS ratings are based on the Dutch bicycle facility design guidelines and use a weakest link approach, which simplifies application but restricts the combinations of attributes that can accomplish a good rating.

Establishing how different types of cyclists experience the varying elements of the built environment is vital to designing and providing adequate bicycle infrastructure. While current approaches are either statistical or behavioral, we argue that an approach that is both statistical and behavioral is best. To this end, we conducted a detailed survey on bicycling habits, preferences, and user experience, capturing responses to videos of a bicycle traveling on road segments in the San Francisco Bay Area. The survey provided rich behavioral data, which invited both quantitative and qualitative exploration. We compared facility preferences from the survey to NCHRP BLOS and LTS scores, and examined the responses to open-ended questions to gain insights about heterogeneity of preferences among cyclists. Finally, we applied behavioral analysis tools as a proof of concept for a new bicycle LOS measure that accounts for the segmentation of cyclist types.

In the following section, we describe the survey methodology and infrastructure data collection. Subsequently, we compare the preference ratings from the survey to the NCHRP BLOS and LTS scores on the study roadway segments (Section 3) and discuss evidence of the heterogeneity of cyclists from the survey (Section 4). This is followed in Section 5 by a description of the proposed behavioral modeling approach, pilot model results, and options for applying results as a bicycle LOS measure.

## 2. Data

Data collection for this study included two major tasks, development and implementation of a bicycle user experience survey, and collection of infrastructure variables on the facilities recorded for the survey. The diagram in Fig. 1 provides an overview of the data collection.

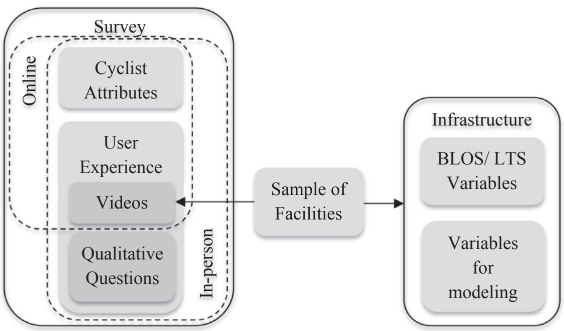


**Fig. 1.** Overview of data collection.