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How bicycle level of traffic stress correlate with reported cyclist accidents injury severities: A geospatial and mixed logit analysis

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ABSTRACT

Transportation agencies need efficient methods to determine how to reduce bicycle accidents while promoting cycling activities and prioritizing safety improvement investments. Many studies have used standalone methods, such as level of traffic stress (LTS) and bicycle level of service (BLOS), to better understand bicycle mode share and network connectivity for a region. However, in most cases, other studies rely on crash severity models to explain what variables contribute to the severity of bicycle related crashes. This research uniquely correlates bicycle LTS with reported bicycle crash locations for four cities in New Hampshire through geospatial mapping. LTS measurements and crash locations are compared visually using a GIS framework. Next, a bicycle injury severity model, that incorporates LTS measurements, is created through a mixed logit modeling framework. Results of the visual analysis show some geospatial correlation between higher LTS roads and “Injury” type bicycle crashes. It was determined, statistically, that LTS has an effect on the severity level of bicycle crashes and high LTS can have varying effects on severity outcome. However, it is recommended that further analyses be conducted to better understand the statistical significance and effect of LTS on injury severity. As such, this research will validate the use of LTS as a proxy for safety risk regardless of the recorded bicycle crash history. This research will help identify the clustering patterns of bicycle crashes on high-risk corridors and, therefore, assist with bicycle route planning and policy making. This paper also suggests low-cost countermeasures or treatments that can be implemented to address high-risk areas. Specifically, with the goal of providing safer routes for cyclists, such countermeasures or treatments have the potential to substantially reduce the number of fatalities and severe injuries.

1. Introduction

1.1. Background

As awareness of the health, economic, and environmental benefits of riding a bicycle continues to increase (Simmons et al., 2015), individuals have been increasingly selecting bicycle as their mode of transportation. As a result, bicycle trips have grown from 1.7 billion in 2001 to 4 billion in 2009 (Milne and Melin, 2014; The League of American Bicyclists, 2015). Unfortunately, this increase in bicycle trips is accompanied by an increase in bicycle fatalities (NHTSA, 2014; Wang et al., 2016). Bicyclists, however, suffer a higher risk of severe injuries compared to motor-vehicles (Beck et al., 2007; National Center for Statistics and Analysis, 2017). Therefore, both national and local bicycle fatality trends motivate state departments of transportation (DOT), transportation planning agencies (e.g., MPOs), local governments, city planners, and engineers to identify bicycle crashes as a primary focus area for investing in safety and infrastructure funding (Wang et al., 2016). However, engineers and planners are facing three interrelated challenges when conducting safety or planning analysis for bicyclists: (1) insufficient data regarding bicycle crashes (i.e., due to under-reporting and the low overall frequency of bicycle crashes at any given point on the system), (2) lack of bicycle volume data on a network scale, and (3) the lack of tools to analyze safety improvement and bicycle planning applications (Lowry et al., 2012). Accordingly, transportation agencies need efficient tools that can improve bicycle safety under constraints of limited budgets. One such method includes the level of traffic stress (LTS) criteria proposed by Mekuria et al. (2012), which is primarily used to predict how various facility improvements will impact connectivity. Although this method has become more

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commonly used by transportation agencies, it has not been adopted exclusively for safety purposes.

In an attempt to fill the three gaps discussed above, by including LTS and other factors, this study utilizes 10 years of bicycle crash data from four cities in New Hampshire (NH). More specifically, this work seeks to analyze bicycle crashes with the goal of providing a safe and accessible transportation network for pedestrians and bicyclists (Coates, 2014). The crash data used in the current study was created by the NH Department of Transportation (NHDOT) Bike & Pedestrian Team and provided by the New Hampshire Bike-Walk Alliance (NHBWA), in which all reported bicycle and pedestrian crashes between 2002 and 2013 are included. The LTS data was obtained from a pilot project done by NHDOT for a proof of concept, although it has not been endorsed by NHDOT or the NH Bicycle & Pedestrian Advisory Committee (NH BPTAC). Now, The Southern New Hampshire Planning Commission (SNHPC) cooperates with NHDOT on classifying road segments by "Level of Traffic Stress" for roads in the City of Manchester (Bike Manchester, 2017).

Although cycling is on the rise, transportation agencies find it difficult to justify bicycle planning and investment due to the lack of sufficient non-motorized data. However, thanks to the dramatic increase of using GPS devices in smart-phones, the popularity of using apps such as STRAVA provides a valuable database for analyzing cyclist behavior and route choice. STRAVA is a smart-phone based application that records athletic activities, including time, route choice, and demographic information of the cyclist or runner (STRAVA, 2017). The Oregon Department of Transportation (ODOT), as the first organization to purchase and use STRAVA Metro data to inform policy and project decision, stated that this easily accessed data illustrates the future of crowdsourcing data (Jonathan Maus, 2014). NHDOT, collaborating with Plymouth State University, invested $55,000 in a new project to enhance active transportation by using STRAVA data and LTS criteria (New Hamphshire Department of Transportation, 2016). STRAVA Metro data has been used in researches and projects, although it has its own bias: (1) only representing a small proportion of total bike users (1–2.5%), (2) heavily representing recreational cyclists rather than commuters, and (3) GIS skill is needed for analysis and solving the double count issue (Monsere et al., 2017; Jonathan Maus, 2014; Jestico et al., 2016). Therefore, it is also urgent to analyze the correlation between STRAVA data and LTS to identify future potentials in regards to STRAVA data.

1.2. Objective of paper

The objective of this paper is to determine the geospatial and statistical relationship between bicycle LTS and bicycle injury severity. As a result, this work seeks to show how LTS models can serve as an alternative method for bicycle safety and planning analysis. There are three specific goals for this work: (1) determine the correlation between high stress levels and high injury severity, (2) determine the correlation between high stress levels and high crash frequencies, (3) determine if stress levels contribute to the severity of crashes, and (4) identify a correlation between crowdsourcing data (STRAVA) and LTS. By using a stress level analysis to aid in predicting where crashes may occur, communities can allocate funds more effectively for infrastructure safety improvements.

1.3. Organization of paper

This paper is organized as follows: Section 2 reviews the literature on LTS and risk factors identified through previous injury severity studies; Section 3 presents a brief summary of the crash data, the limitations, and the four study sites in New Hampshire included in the geospatial and modeling analysis; Section 4 details the geospatial and mixed logit methodologies used to conduct the analysis; GIS-based visual results and modeling results are provided in Section 5; Section 6 discusses the results of the mixed logit analysis, as well as the STRAVA analysis; and, Section 7 concludes the paper with remarks regarding future work.

2. Literature review

2.1. Pros and cons for LTS

Mekuria et al. (2012) developed a criteria that provides consistent and effective measurement on the transportation network: LTS. This criteria, LTS, can be used by city planners and engineers to make more informed decisions. However, the original idea was created by the Geelong Bike Plan Team in 1978 (Harkey et al., 1998; Wang et al., 2016). Traditional observation and survey data are the main approaches used to measure the effectiveness of LTS, where four different classifications of urban bicyclists (from children with low cycling skill to cyclists who can cycle under any condition) are utilized (Wang et al., 2016). In doing so, the LTS system is defined based on resident cycling comfort level rather than skill level. The four levels of LTS, level 1 to level 4, represent comfort level from high to low. LTS 1 is suitable for children, LTS 2 represents the traffic stress that most adults can tolerate, and LTS 3 and LTS 4 represent greater levels of stress.[1]

Variables used to define LTS include posted speed limit, number of lanes, cycling infrastructure improvements, on-street parking, and lane width (Mekuria et al., 2012). Collecting the necessary data, defining LTS based on the collected data, then utilizing LTS is affordable for small jurisdictions; therefore, small jurisdictions can develop maps for bicycle safety and policy evaluation (Wang et al., 2016). Of the variables used for defining LTS, posted speed limit and the number of lanes are crucial in determining subjects' perceptions of service levels (Kirner Providelo and da Penha Sanches, 2011; Kang and Lee, 2012). Traffic condition is significant, as cyclists prefer cycling along residential streets rather than riding on major streets with higher speeds and higher volumes of traffic (Caulfield et al., 2012; Habib et al., 2014). Bicycle infrastructure improvements, such as buffered bike lanes, correlate with higher cycling rates at the household, neighborhood, and municipal level (Dill and McNeil, 2013; Kirner Providelo and da Penha Sanches, 2011; Wang et al., 2016). Since individuals are more willing to take a route with a lower stress level, infrastructure improvements can also determine route choice (Tilahun et al., 2007; Hood et al., 2011; Arentze and Molin, 2013).

While many studies promote the benefits of LTS, some literature doubts the effectiveness of LTS, specifically the variables used to estimate the bicycle mode share and bicycle trips. Using GPS data, some of the latest research on route choice found that traffic volumes are critically important to better understand route choice (Broach et al., 2012).[2] Traffic volume data can be costly for small jurisdictions; however, it can directly represent the route choice of riders (Winters et al., 2011; Li et al., 2012). Traveler awareness of connectivity is just as important as the availability of bicycle connectivity of a network itself (Lundberg and Weber, 2014). Several studies have also included other factors that may have significant influence on bicycle route choice, such as wayfinding (Wierda and Brookhuis, 1991; Campbell and Lyons, 2008), trip difficulty measures (Milakis and Athanasopoulos, 2014), signalization (Kirner Providelo and da Penha Sanches, 2011; Broach et al., 2012; Titze et al., 2008; Sener et al., 2009), built and natural environment variables (Cervero and Duncan, 2003), and accessibility to a variety of activities and transit stations (Wang et al., 2016). Furthermore, being that prioritization of investments is critical to local transportation agencies, Larsen et al. (2013) used GIS for a spatial comparison. This established a bicycle infrastructure investment

[1] For more detail on LTS, the reader is referred to Mekuria et al. (2012), and Dill and McNeil (2013).

[2] When measuring LTS, traffic volumes are generally not included to mitigate the data intensiveness.