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Bicyclist's perceived level of comfort in dense urban environments: How do ambient traffic, engineering treatments, and bicyclist characteristics relate?

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ABSTRACT

In dense urban environments, truck loading zones introduce multimodal conflicts that could decrease the bicyclist's perceived level of comfort (PLOC), potentially reducing bicycle mode share. This study investigated the PLOC of bicyclists near urban loading zones, according to different levels of ambient traffic (low traffic volume, high traffic volume, and truck traffic), bicycle lane pavement markings (white lane markings, solid green, and dashed green), and traffic signs (no sign or warning sign). An online survey was designed and randomly distributed to 10,000 potential participants. A total of 342 participants successfully completed the survey. Repeated-measures ANOVA results indicated that when bicycling on a conventionally striped bike lane, truck traffic had the most significant effect on bicyclist PLOC, decreasing it by more than 42%. Pavement markings were more effective than traffic signs at improving bicyclist PLOC, but no difference was observed between solid and dashed green lane markings. Finally, the results of cluster analysis indicated that the effect of gender and experience on bicyclist PLOC varied with different levels of traffic and engineering treatments. Women were more affected than men by the presence of a truck in the adjacent lane but they were also more prone to a considerable increase in PLOC values due to the implementation of engineering treatments. Findings of this study could inform future policies regarding transportation infrastructure design to support safer and more comfortable bicycling in dense urban environments.

1. Introduction

There are growing concerns over the effects of motor vehicle use on the environment, neighborhood livability, safety, and health. These concerns have contributed to a paradigm shift from motorized to non-motorized modes of travel in transportation infrastructure planning, design, construction, operations, and maintenance, especially in dense urban areas. This change, in turn, has increased the popularity of bicycling. According to the U.S. Census Bureau, the number of individuals who commuted to work by bicycle in the United States grew by 50% between 2000 and 2012 (McKenzie, 2014). As a mode of active transportation, the bicycle could play a pivotal role in sustainable communities (Balsas, 2003; Rowangould & Tayarani, 2016). Traffic congestion in urban areas has led many cities to encourage bicycling as a functional alternative to driving. Bicycling is less infrastructure-intensive than public transportation and has a much longer range than walking. Many U.S. cities have plans to increase their bicycle mode share. For example, Portland, Oregon, adopted a bicycle plan that aims to achieve a 25% bicycle mode share by 2030 (PBOT, 2010).

As bicycling in urban areas grows in popularity, conflicts between bicycles and other transportation modes have become increasingly problematic. Despite the decrease in total number of motor-vehicle traffic fatalities, the proportion of all bicyclist fatalities among all fatalities increased from 1.47% in 2003 (629/42,884 bicyclist/total fatalities) to 2.33% in 2015 (818/32,166 bicyclist/total fatalities) (FARS, 2017). More specifically, bicycle conflicts with freight vehicles in dense urban areas often result in severe consequences. Large trucks are the only vehicle classification to be overrepresented in bicyclist fatalities in recent years. For example, large trucks were involved in 6.48% of bicyclist fatalities in the United States in 2015, despite comprising only 3.98% of registered vehicles (NHTSA 2017a; NHTSA 2017b).

In dense urban environments, commercial parking and loading zones are potentially high-risk areas for bicycle-truck conflicts (Conway, Thuillier, Dornhelm, & Lownes, 2013), which could decrease bicyclists' perceived level of comfort (PLOC) and negatively influence bicyclist behavior, leading to severe consequences (Duthie, Brady, Mills, & Machemehl, 2010; Teschke et al., 2012). Low PLOC while traveling near motorists is a significant factor in preventing people from bicycling (Sanders, 2013). This is a hindrance in promoting sustainable

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cities through active transportation.

Several types of engineering treatments, such as colored pavement markings and warning signs, can be applied to roadways to improve bicyclist safety in conflict areas. Colored pavement within a bicycle lane increases visibility of the facility, identifies potential conflict areas, and reinforces bicyclist priority in these areas. This treatment is commonly applied to conflict areas at intersections, driveways, and along non-standard or enhanced facilities, such as cycle tracks (NACTO, 2011). Warning signs can be used to inform road users of a potential hazard that might not be readily apparent. The *Manual on Uniform Traffic Control Devices* (FHWA, 2009) defines three types of signs for bicycle facilities: regulatory signs, warning signs, and guide signs. However, no endorsed sign directly addresses bicycle-truck interactions in urban loading zones. Furthermore, although these engineering treatments are designed and implemented to increase safety, it is unclear whether treatments in conjunction with ambient traffic conditions influence the bicyclist's perceived safety and comfort near loading zones in urban areas.

With the aim of promoting bicycling in urban areas, this study investigated the PLOC of bicyclists under different conditions of ambient traffic and engineering treatments, and considered gender and experience related differences in bicyclist PLOC. More specifically, this study evaluated whether the presence of engineering treatments, such as colored bike lanes or warning signs in conflict areas, influence bicyclist PLOC under various traffic conditions, and whether this influence is affected by the bicyclist's gender and experience.

2. Literature review

Previous research considered the PLOC of bicyclists on various roadway facilities. Traffic volume has been demonstrated to have a significant influence on bicyclist PLOC. A survey of 1402 current and potential bicyclists in Vancouver, Canada, indicated that one of the greatest motivators of an individual's decision to bicycle was whether a route was separated from traffic. Most respondents were more likely to ride on facilities that had low traffic volumes or separated bicyclists from vehicular traffic (Winters, Davidson, Kao, & Teschke, 2011). Other research considered specific types of treatments that help improve perceived levels of comfort and safety. A recent study investigated the comfort level of bicyclists in various types of buffered bike lanes, using generic diagrams of facilities. Respondents rated protected bicycle facilities with physical buffers as offering greater PLOC than standard bike lanes (McNeil, Monsere, & Dill, 2015). Monsere et al. (2014), found similar results, noting that physical barriers provided more comfort for bicyclists than painted buffers.

The perception of safety influences the decision to bicycle and the frequency of bicycling. One comprehensive study conducted in the Bay Area demonstrated that the perceived risk greatly influences the attractiveness of a facility, particularly for infrequent and potential bicyclists (Sanders, 2013). Improving the perceived safety of a bicycling infrastructure is an important condition for increasing levels of bicycling (Dill & Mcneil, 2013). In a survey of 1707 cyclists in Montreal, Canada, the perception of safety was one of the most influential factors in determining the frequency of cycling, even for experienced cyclists (Damant–Sirois & El–Geneidy, 2015).

Two decades ago, transportation planning goals were heavily mobility-based, but there has been substantial advancement since the early 2000 s in acknowledging social equity issues as being of critical importance as well (Manaugh, Badami, & El-Geneidy, 2015). Bicycling has long been promoted as a form of social equity which also contributes to sustainability in urban environments. Social equity in transportation necessitates that people with diverse backgrounds, different demographics, and various capabilities to be considered in the planning and design process. The data shows that today in the United States, for every 3 male bicyclists, there is only 1 female bicyclist who commutes to work (McKenzie, 2014). This problem is closely tied to the gender-related perception of safety and comfort regarding bicycling in dense urban environments. The role of gender in bicycling behavior has been widely studied in recent literature (e.g., McNeil et al., 2015; Monsere, Dill, McNeil, & Clifton, 2014). Women's perceptions of safety and comfort are critical elements in their tendency to bicycle (Tilahun, Levinson, & Krizek, 2007). One study analyzed three different surveys in Minnesota with a focus on safety and cycling infrastructure preferences. Women were more likely to report a lack of bicycle paths as a reason for not feeling "very safe" when bicycling. Women were more likely to prefer safer forms of bicycling infrastructure and were willing to accept longer travel times than men to access a preferred facility (Krizek, Johnson, & Tilahun, 2005). Another survey of six small cities in the western United States evaluated factors influencing the decision to bicycle. Using multivariate analysis, the study found that comfort level was one of the most important factors for women choosing to bicycle. Women were generally comfortable on off-street paths and were more concerned than men about safety (Emond, Tang, & Handy, 2009).

With regards to the interaction of bicycles and trucks in urban loading zones, very little previous research exists. Conway et al. (2013) collected observations at loading zones in Manhattan, New York City, and found that about 14% of commercial vehicles conflicted with a bicycle in dense urban areas. Additionally, they found a correlation between bicycle lane configurations and conflict frequency. In another study, the same research group found that more than half of bicycle collisions in New York City occurred on truck routes, which make up only 19% of the on-street bicycle network. Commercial vehicle involvement in bicycle collisions was highly related to land use type and freight demand (Conway et al., 2016).

Moreover, whereas numerous studies have evaluated bicyclist PLOC on roadway facilities, comparatively little research has looked specifically at PLOC near urban loading zones. Sanders (2013) reported that bicyclists preferred route alternatives that did not include bicycle lanes next to on-street parking, presumably because of conflicts with vehicles (e.g., attempting to enter/exit the parking lane, opening the door into the bicycle lane, etc.). Among surveyed bicyclists across eight facilities in the United States, 25% stated that delivery vehicles loading or unloading are often encountered in a protected bike lane. Moreover, 36% of surveyed bicyclists stated that vehicle loading/unloading is a major problem (McNeil et al., 2015). This negative perception of the interaction between delivery vehicles and bicyclists in an urban environment has yet to be considered through the lens of PLOC. Therefore, this research attempted to quantify the factors that influence bicyclist PLOC near urban loading zones.

3. Method

3.1. Study design and survey

Scenarios with different levels of ambient traffic and engineering treatments were created to represent bicycling near a loading zone in a dense urban environment. Three levels of ambient traffic were considered: 1) low traffic volumes, 2) high traffic volumes, and 3) truck traffic in the adjacent lane. For pavement marking levels, recommendations from the National Association of City Transportation Officials *Urban Bikeway Design Guide* (NACTO, 2011) were considered. Three levels of bike lane pavement markings were used: 1) white lane markings with no supplemental pavement color (called white lane markings hereafter), 2) white lane markings with solid green pavement applied on conflict area (called solid green hereafter), and 3) white lane markings with dashed green pavement applied on conflict area (called dashed green hereafter). Finally, two levels of traffic signs were considered: 1) no sign and 2) sign warning bicyclists of a potential truck conflict on the road. These independent variables (factors) and levels resulted in a study with a $3 \times 3 \times 2$factorial design. Google Sketchup 2017 software was used to create three-dimensionally rendered images illustrating the factorial design. The roadway cross-section included