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Evaluating the effectiveness of on-street bicycle lane and assessing risk to bicyclists in Charlotte, North Carolina

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ABSTRACT

The objectives of this manuscript are (1) to evaluate the effectiveness of on-street bicycle lane in reducing crashes involving bicyclists on urban roads, (2) to quantify and compare risk to bicyclists on road segments with and without on-street bicycle lane, (3) to evaluate the effect of on-street bicycle lane on other road network users (all crashes), and, (4) to assess the role of on-network characteristics (speed limit, the number of lanes, the width of on-street bicycle lane, the width of the right-most travel lane, and, the numbers of driveways, unsignalized approaches and signalized intersections per unit distance) on risk to bicyclists. Data for thirty-six segments with on-street bicycle lane and twenty-six segments without on-street bicycle lane in the city of Charlotte, North Carolina were extracted to compute and compare measures such as the number of bicycle crashes per center-lane mile, the number of bicycle crashes per annual million vehicle miles traveled (MVMT), the number of all crashes per center-lane mile, and the number of all crashes per MVMT. The results obtained from analysis indicate that bicyclists are three to four times at higher risk (based on traffic conditions) on segments without on-street bicycle lane than when compared to segments with on-street bicycle lane. An analysis conducted considering all crashes showed that on-street bicycle lanes do not have a statistically significant negative effect on overall safety. An increase in annual MVMT (exposure) and the number of signalized intersections per mile increases the number of bicycle crashes, while an increase in on-street bicycle lane width or right-most travel lane width (if on-street bicycle lane cannot be provided) decreases the number of bicycle crashes. Installing wider on-street bicycle lanes, limiting driveways to less than 50 per mile and unsignalized approaches to less than 10 per mile, increasing spacing between signalized intersections, and, facilitating wider right-most travel lane if on-street bicycle lane cannot be provided reduces occurrence of bicycle crashes and lowers risk to bicyclists on roads.

1. Introduction

Reports published by the National Highway Traffic Safety Administration (NHTSA) show that over 600 bicyclists are killed and an additional 50,000 bicyclists are injured in traffic collisions annually throughout the United States (NHTSA, 2009). To enhance bicyclist safety and improve bicycling as a mode of transportation, the Federal Highway Administration (FHWA), in collaboration with local agencies, has funded several projects. These projects include constructing on-street bicycle lane, bicycle tracks, shared lane markings (also known as "sharrow", a new pavement marking that is placed in a lane shared by motorists and bicyclists), bicycle-specific pavement markings and signage, bike boulevards, and bike boxes (a special section for bikes to stop at a red light). Several researchers have focused on the effectiveness of these treatments in the past (NHTSA, 2005; Brady et al., 2011; Hunter et al., 2011; LaMondia and Duthie, 2012; Hamann and Peek-Asa 2013; Williams, 2013).

Researchers in the past have also examined the role of factors that are detrimental to perceived safety of bicyclists. Such detrimental factors include socio-economic and demographic characteristics (includes gender and age) of bicyclists, alcohol or drug consumption, non-helmet use, cycling trip lengths, years of cycling experience as well as beliefs and attitudes of bicyclists

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(Delmelle and Thill, 2008; Wood et al., 2009; Martinez-Ruiz et al., 2013; Chaurand and Delhomme, 2013; Johnson et al., 2013; Lawson et al., 2013).

A majority of bicyclists prefer to travel longer distances on a separated path rather than ride in and along with traffic (Hunter and Feaganes, 2004). Providing a clear and longitudinal solid line separation helps maintain a greater lateral distance between motorists and bicyclists and assist the bicyclists in riding out of the motorists' path and remaining stable (Chung et al., 2013). Paved shoulders and on-street bicycle lanes provide similar conditions of driving for motorists and bicyclists, and, are most effective in promoting bicyclist safety (Harkey and Stewart, 1997; Parkins and Meyers, 2010; Duthie et al., 2010).

On-street bicycle lanes that are 3 feet (~0.92 m) to 6 feet (~1.84 m) wide provide adequate space for motorists and bicyclists to interact safely. However, there is lack of enough evidence on the effectiveness of these on-street bicycle lanes in enhancing safety of bicyclists on roads. The effectiveness of on-street bicycle lane varies across locations and depends on on-network characteristics. Traffic flow (resulting in conditions not amicable for bicyclists), traffic speed (or speed limit), the number of lanes, the width of the right-most travel lane, and, the numbers of driveways, unsignalized approaches and signalized intersections per unit distance are examples of such on-network characteristics that influence safety of bicyclists. An increase in the number of bicycle crashes is associated with an increase in total center-lane miles, total length of bicycle lanes, the number of bus-stops, the number of signalized intersections, intersection density, and arterial-local intersection percentage (Wei and Lovegrove, 2013). Bicyclists are involved in crashes at a signalized intersection that are relatively more severe in nature (Zahabi et al., 2011). The presence of a raised median has the opposite effect (Strauss et al., 2013).

Motorists tend to move from the curb lane to inside lane after recognizing that there is a bicyclist downstream. They reduce speeds when passing bicyclists to ensure safe passing maneuver and then accelerate after passing bicyclists (Sando et al., 2011). The lateral space between the bicyclist and the motorist (which depends on on-street bicycle lane width and/or right-most travel lane width) affects violations, close passes, comfort and safety of road network users (Kroll and Ramey, 1977; Hunter and Feaganes, 2004), in particular, on streets with available travel space less than 15 feet (~4.57 m). If the space is inadequate, motorists tend to encroach or drive closer to the lane to their left so as to maintain a gap with bicyclists to their right. The attention or extra caution of motorists towards bicyclists along with the encroachment or shift in motor vehicle paths could increase the risk of colliding with other vehicles to their left on the roads in the United States. These may be more non-fatal (sideswipe) crashes on multilane roads and fatal (head-on) crashes on two-lane roads (one lane in each direction). The percentage of such encroachments by the motorist into the adjacent lane to their left is low on roadway with on-street bicycle lane (McHenry and Wallace, 1985).

Landis (1994) developed Intersection Hazard Score (IHS) to assess bicyclists' level of hazard likelihood based on the traffic volume, speed limit, right-most travel lane width, pavement condition, and, the number of driveways. However, literature documents no research on risk of bicycling on segments without on-street bicycle lane when compared to bicycling on segments with on-street bicycle lane. Further, there is lack of evidence on the effect of on-street bicycle lane on safety of other road network users (positive or negative consequence). No documentation on the effect of number of driveways, unsignalized approaches, and signalized intersections per unit distance on risk to bicyclists was also found in the literature. This manuscript, therefore, focuses on evaluating the direct and indirect effect of on-street bicycle lane, assessing the role of selected factors on risk to bicyclists, and modeling risk to bicyclists.

Four objectives were identified to research and contribute to the current body of knowledge pertaining to bicyclist safety area. They are: (1) to evaluate the effectiveness of on-street bicycle lane in reducing crashes involving bicyclists on urban roads, (2) to quantify and compare risk to bicyclists on road segments with and without on-street bicycle lane, (3) to evaluate the effect of on-street bicycle lane on other road network users (all crashes), and, (4) to assess the role of on-network characteristics (speed limit, the number of lanes, the width of on-street bicycle lane, the width of the right-most travel lane, and the numbers of driveways, unsignalized approaches and signalized intersections per unit distance) on risk to bicyclists.

2. Study area and selection of study segments

The city of Charlotte in the State of North Carolina, United States was selected as the study area for this research. According to 2010 Profile of General Population and Housing Characteristics published by the United States Census Bureau, the total population of the city of Charlotte is 731,424. Geographically as well as financially, the city forms a core and integral part of the Metrolina region urban area. As per 2012 Metrolina Regional Household Travel Survey, the mode of travel for 0.2% of all household trips is bicycle (Etc Institute, 2012). The city of Charlotte has over 72 center-lane miles of bicycle lanes when compared to 1 center-lane mile in 2003 (Moore, 2013).

Study segments (bi-directional) in the study area were identified such that the number of lanes, speed limit, presence of sidewalks, crosswalks at signalized intersections and median are same along the segment (example, the number of lanes cannot be 2 for one portion of the segment and 3 for the remaining portion of the same segment). Of these segments, thirty-six segments have on-street bicycle lane (Class II facility with a portion of a roadway designated by striping, signing and pavement markings for bicyclists) that existed from year 2008 to 2010 in the study area.

In addition, twenty-six geographically distributed segments without on-street bicycle lane (and no other changes from year 2008 to 2010) were also identified and used in this research. The characteristics of these twenty-six segments without on-street bicycle lane were ensured to be similar to the thirty-six segments with on-street bicycle lane. None of the selected study segments used in this research have designated on-street parking spaces or shared lane markings. As three selected segments with on-street bicycle lane had shoulder, a proportional number of segments (two) without on-street bicycle lane that had shoulder were selected. Wherever feasible, a segment without on-street bicycle lane was selected along the same corridor that had a segment with on-street bicycle lane. Overall, the total center-lane length of segments with on-street bicycle lane is 37.00 miles (~59.20 km), while the total center-lane length of segments without on-street bicycle lane is 34.80 miles (~55.68 km).

3. Data gathering and preparation

Bicycle crash data and all crash data collected by Police in the study area and entered into a database by the staff of the city of Charlotte Department of Transportation (CDoT) for a three-year period (2008–2010) was obtained along with average daily traffic (ADT) during the same period from the local agency. The number of crashes and ADT were identified for each segment (total for both directions) with and without on-street bicycle lane. Bicycle counts (or volume), an important variable indicating bicycle activity and exposure along a segment, are not available and, hence, were not considered in this research.