What are the Impacts of Adding Bicycle Infrastructure on a Low Speed Road?

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The sight of a bicyclist at a busy intersection can pose quite an inconvenience to drivers because the bicyclist adds to the already crowded visual complexity of that roadway. The drivers already have to focus on driving between the painted lines, looking for other cars, noticing speed limits, obeying traffic signals and many other things. Digioia et al. (2017) argues that a bicyclist will cause a driver to decrease the vehicle's speed. Similarly, when bicyclists are forced to share the road with vehicles in the absence of bicycle lanes, Hunter et al. (2010) purports that "motorists often neglect to safely share travel lanes with bicyclists, which can compel bicyclists to ride closer to parked motor vehicles," as well as the curb of the road. This decreases the safety of bicyclists and increases the danger of hitting a parked vehicle or an open door of a car. Bicyclists will also have to ride extremely close to the side of the road, which can be unnerving in itself. Before the addition of any bicycle infrastructure, Hunter et al. (2010) shows that the average spacing between a car and the curb was 70.5 inches after observing 400 vehicles. With the presence of bicycle sharrows, the spacing increased to an average of 77 inches (Hunter et al., 2010). A sharrow is a road marking used to indicate a shared lane environment for bicycles and automobiles (Shared Lane Markings, 2016). The increased spacing made bicyclists more comfortable on the road by not riding closer to the curb because of a vehicle. Thus, measures need to be taken to increase the safety of bicyclists by providing them with better methods of travel to decrease the likelihood of driver-induced crashes.

Water Street Corridor in Charlottesville, Virginia has high volumes of automobiles, pedestrians and bicyclists. And many crashes have been reported because of poor existing pedestrian and bicyclist infrastructure. According to the Pedestrian Safety Action Plan (Pedestrian, 2016), there have been 10 car-pedestrian crashes from 2012-2016, as well as many other bicycle related crashes. Because the existing infrastructure along Water Street Corridor lacks sufficient bicycle and pedestrian safety measures, better infrastructure needs to be put in place to increase bicycle and pedestrian safety. The technical capstone will analyze the existing infrastructure of Water Street Corridor and improvements that can be made for pedestrians and bicyclists. This sociotechnical research paper will delve into how bicycle infrastructure increases the safety of low speed roads by enhancing the protection of bicyclists and drivers alike.

Case Context

Safety and comfort are paramount for bicyclists on the road. For a road that has poor or no bicycle infrastructure, safety and comfort is put at risk. This can be seen from the aforementioned Water Street Corridor project. The existing design of the Water Street Corridor incorporates shared lane markings, or sharrows, and crosswalks for bicycle and pedestrian safety, respectively, see Figure 1.

Figure 1: Roadside view of Sharrow on Water Street Corridor (Google, n.d.)

However, as already mentioned, there have been numerous crashes and accidents from pedestrians and bicyclists alike on this corridor due to poor infrastructure (Pedestrian, 2016). Thus, an increase in safety due to better bicycle infrastructure would mitigate bicycle and pedestrian accidents, as well as create a more comfortable environment with which bicyclists and pedestrians can interact. Better bicycle infrastructure is clearly shown to improve bicycle safety and rideability, as derived from many studies. One specific study in New York shows that an increase in better bicycle infrastructure helped bicyclists ride on the streets more, and reduced the amount of crashed from previous years (Trottenberg, 2014).

Sociotechnical Topic and Case Study

The framework of coproduction will be used to describe the mutual shaping of bicyclists and drivers, as well as the influence of constitutive powers on the roadway that these users ride or drive on. Constitutive powers are the entities or systems that govern the production or maintenance of another system. Jasanoff (2004, p. 10) describes coproduction as “the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it”. Bicycles and vehicles have to adjust to the use of one another, thus shaping the ways that each system is evolved throughout time. Daly (2014) describes the negative social impact that bike riders experience while riding on the streets without bicycle infrastructure. Daly (2014) states how the presence of bicyclists on the streets and the annoyance they cause to drivers creates a negative perception and almost discourages bicyclists from riding on the streets. The bicyclists adjusted to the drivers by avoiding the streets. However, negative perceptions of infrastructure will not have a great effect on how it will be built. Constitutive powers such as the National Association of City Transport Officials (NACTO) and the Virginia Department of Transportation (VDOT) create roads in order to gain monetary value out of the use of the road. Thus, it can be assumed that some bicycle infrastructure will be built regardless of some dissenting public opinion.

Bicycle infrastructure changes the perception of bicycle ownership and rideability (Habib et al. 2014). After studying bicyclist behavior in different cities around the world, Hull and O'Holleran (2014) concluded that better design of bicycle infrastructure will encourage bicycle ridership. Likewise, when cities lacked adequate or any bicycle infrastructure, bicyclists were deterred from riding on the streets (Hull and O'Holleran, 2014). Viewing the argument presented by Daly, in conjunction with arguments from Habib and Hull and O'Holleran, there is a stigma created by bicycle lanes and general bicycle infrastructure. Bicyclists are more encouraged to ride on the streets in the presence of bicycle infrastructure, and are discouraged when a road lacks bicycle infrastructure. Hull and O'Holleran (2014) go on to describe the disparity between experienced riders and inexperienced riders on certain roads with bicycle infrastructure. A lot of bicycle infrastructure in cities with complex intersections and roadways may be adequate for someone who has been riding a bicycle for many years. However, when inexperienced riders begin to traverse these complex designs, though the bicycle infrastructure is existent, there is no consideration for inexperienced riders. This idea is further expounded by Vreugdenhil and Williams (2013) who argue that the implementation of bicycle infrastructure needs to take into account the considerations of the community. A study in Tasmania, Australia was realized by Vreugdenhil and Williams that analyzed recently created bicycle infrastructure and the response of the community. They argue that this negative social response to bicycle infrastructure can deter bicyclists from wanting to bike (Vreugdenhil and Williams, 2013).

However, this is another instance of negative social responses. Social responses and perceptions are important because they create negative stereotypes of the bicyclists. And these negative responses severely reduce the attractiveness of biking and the willingness of bicyclists. Regardless of negative social responses, constitutive powers such as NACTO and VDOT will continue to create projects for monetary gain. Thus, more bicyclists will inevitably be on the road because of this increase in infrastructure. Because of this, drivers and bicyclists will have to interact with one another, regardless of the negative social response to bicycle infrastructure. NACTO and VDOT and the bicyclists and drivers will continue to mutually grow and affect one another. Drivers and bicyclists will continue to mutually affect one another with intentional interactions while the constitutive powers will affect the ways that drivers and bicyclists interact with the infrastructure.

Negative social responses to bicycle infrastructure can be further extended to a study done on the recent surge of bike share options in Shanghai. Bike share options are becoming more realized because of a conscious push towards greener transportation (Bao et al., 2017). By studying the Mobike bike share company in Shanghai, Zhang and Mi (2018) concluded that bike sharing saved nearly 8358 tons of petrol and decreased 25240 tons of CO_2 emissions in 2016. Thus, with a city as large as Shanghai, a simple change from vehicular travel to bicycle travel would cause a lot of new bicyclists to appear on the road. And with the emergence of new bicyclists, there may be a portion of riders who are either novice or casual riders. Bike share users in Shanghai tend to ride bikes during the peak hours of traffic when it is most busy (Bao et al., 2017), so the bicycle infrastructure needs to be designed to accommodate these new or inexperienced riders.

The emergence of a more environmentally conscious community is clearly evident from the data Zhang and Mi and Bao et al. presented. Mobike, as well as other bike sharing options, on its own is growing in large cities akin to Shanghai. Bike sharing is a cheap option that is convenient and available and used by many people to get to a place quickly without having to wait for the bus or a taxi or Uber. Likewise, with the growing environmental concerns and how we as humans affect the environment, there are communities that are trying to do whatever they can to reduce their carbon footprint. Thus, more people will be willing to ride bicycles instead of motorized vehicles to save energy and help the environment. With both of these areas growing at a rapid rate, there is an increased need for bicycle infrastructure to accommodate all of these new bikers on the roads.

Research Question and Methods

The research question being analyzed in this paper is: What are the Impacts of Adding Bicycle Infrastructure on a Low Speed Road? With a rise in bicycle ownership and ridership, there needs to be a greater investigation of the infrastructure on which the bicyclists will ride on. Without such infrastructure, bicyclists are put into greater danger and greater risk of injury. In order to analyze this question, case studies such as the evaluation of bike lanes under the USDOT by Hunter et al. (2010), the investigation of infrastructure in Toronto by Habib et al. (2014) and the sociotechnical study in Tasmania by Vreugdenhil and Williams (2013) were reviewed and synthesized in order to gain a real-world knowledge of this issue. Case studies in Massachusetts, New York City, Portland and Seattle will also be analyzed to offer a broader understanding of the issue. These case studies will give insight on what types of bicycle infrastructure is beneficial and efficient and what types are not. It will also be wise to not just study the design of a bike lane but to see how bikers actually interact with different bicycle infrastructure and what their responses are. Under the framework of coproduction, the mutual interaction of bicyclists and drivers can be noted in these case studies. Likewise, the impact of state and local governments can be seen in the ways that the infrastructure is built and how it is implemented into a roadway. Constitutive powers will continue to create projects for bicycle infrastructure, and more bicyclists will continue to ride on roadways. Studying the case studies under the framework of coproduction will give greater insight into how a design is created and what is the most effective design.

Results

From the investigation of different bicycle infrastructure in cities, it was noted that bicycle infrastructure has a significant impact on the safety and wellbeing of bicyclists. The addition of bicycle infrastructure increased the width of roads, as well as the amount of space that bicyclists had to ride on roads. There was also a notable decrease in the amount of crashes or potential crash incidents due to the addition of bicycle infrastructure. Many studies showed that an increase in bicycle ridership due to bicycle infrastructure caused an increase in overall health of the bicyclists, as well as an increase in economic activity.

A study done in Cambridge, Massachusetts by Hunter et al. (2010) showed that there was a 39% decrease in avoidance maneuvers of bicycle-car interactions after the addition of a bike lane on a low speed road. An avoidance maneuver was defined as a change in speed or direction by either party to avoid the other (Hunter et al., 2010). By having less interactions between drivers and bicyclists, the potential of a crash or conflict was reduced. Similarly, before the addition of a bicycle lane, bicyclists yielded almost 17% more than drivers when riding on the road (Hunter et al., 2010). After the addition of a bicycle lane, drivers yielded 2% more than bicyclists in bicycle-driver interactions (Hunter et al., 2010). This statistic shows that with the addition of bicycle infrastructure, cars will be more cautious and aware of bicycles on the road, leading to less points of conflict.

A study done by the Seattle Department of Transportation (SDOT) concluded that bicycle infrastructure helps bicyclists feel more comfortable on roadways. The SDOT conducted telephone interviews with residents and determined that 28% of residents did not feel safe enough to ride their bicycles on the roads because of a lack of bicycle infrastructure (Seattle Department of Transportation, 2013). However, through the addition of bicycle infrastructure, there was around a 5% increase in ridership from 2014-2018, with a 12.1% increase in ridership in 2017-2018 alone, as well as a 4% decrease in bicycle collision rate from 2014-2108 (Seattle Department of Transportation, 2019). The increase in ridership can be attributed to the bolstered safety precautions of the added bicycle infrastructure. This lends to the idea that bicyclists will be more likely to ride on roads that have good bicycle infrastructure. Similarly, with the addition of bicycle lanes, ridership in New York City from 2007-2014 increased around 62%, with total bicycle related injuries decreasing 20% (Trottenberg, 2014). Creating a safer avenue for bicyclists to ride on not only encourages ridership, but also it can reduce the probability and rate of crashes, as seen from this New York City study. By being able to ride a bicycle without or with a significantly reduced risk of crashing into cars or pedestrians, bicyclists are freer to ride with ease. This is what causes the increased ridership.

Along with the safety of the roads, adding bicycle infrastructure was shown to improve physical health and fuel business growth. Based on Figure 2, different cities across the nation and in Canada saw a significant increase in bicycle ridership. The increase in ridership causes more people to be outside and active, which can lead to better overall health of the individuals. Likewise, it should be noted that the bike lanes described in Figure 2 are all either protected or buffered bike lanes. This is important because these types of bike lanes add extra protection for the bicyclists. A protected bike lane is one that is protected from the street with some sort of medium (cones, poles, parked cars, etc.). A buffered bike lane is one that has a painted striped buffer between the street and the bike lane, thus adding an extra layer of protection for the bicyclists. These two types of bike lanes add extra protection and create an even safer atmosphere than would a regular bike lane next to a road. And with an increase in protection and safety, there will be an increase in ridership. Thus, the extra protection is very effective, as can be seen by the substantial percent increases in ridership.

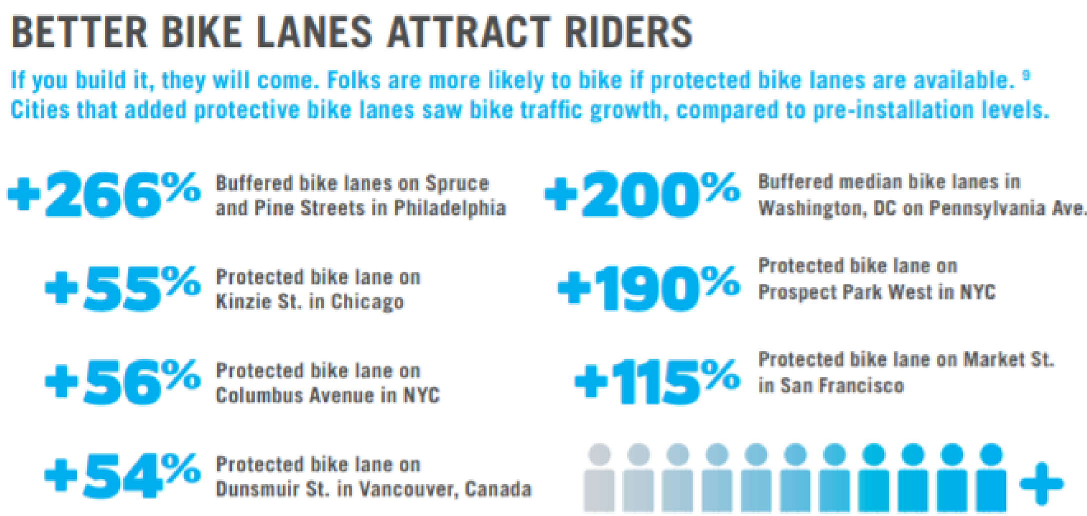

Figure 2: Increased ridership after the addition of bike lanes (Puncher et al., 2013)

Similarly, because of efforts to add bicycle infrastructure to the streets of Portland, Oregon, residents avoided gaining around 17 million pounds each year by their bicycle ridership (Beil, 2011). Bicycling doubles as a quick mode of transportation and a good cardio exercise to lose weight. Bicycling at a 12-13.9 miles per hour pace for 30 minutes is shown to burn, on average, 298 calories for a 155-pound person, and increases calories burned with increased weight (355 calories burned for a 185-pound person) (Harvard Health Publishing, 2018). Thus, by adding increased protection and better means for bicyclists to ride on roads, ridership will increase, time spent riding will increase, and more pounds will be shed.

In addition, with increased bicycle traffic, 8th and 9th Avenues in Manhattan saw a 49% increase in retail sales (New York City Department of Transportation, 2012). In Figure 3, it was found that people traveling on bike spent less on average per trip to retail stores, but spent more on average per month. In Portland, Oregon, with similar trends in Toronto and cities New Zealand, bicyclists would spend around 24% more per month when shopping compared to people who drove (Anderson and Hall, n.d.). Thus, with increased ridership, businesses largely benefit in profit and usage.

Figure 3: Bicycle rider spending trends (Anderson and Hall, n.d.)

Further Discussion

Bicycle infrastructure can be extended further than safety and wellbeing. There is a social factor to biking that can be ameliorated through bicycle infrastructure. A certain negative stereotype can build up from inadequate bicycle infrastructure or poor bicycle-car interactions, as described in the case in Australia by Vreugdenhil and Williams (Vreugdenhil and Williams, 2013). But good bicycle infrastructure can help with this negative stereotype, and create a better bicycle-car relationship.

Bicycle infrastructure is very influential in the way that it can deter or encourage bicyclists to ride on the road. Likewise, because bicyclists can affect drivers on the road, as seen by the case study mentioned above, bicycle infrastructure shapes and is shaped by drivers and bicyclists alike. Thus, the framework of coproduction describes the relationship between bicyclists, drivers and bicycle infrastructure: the ways in which bicycle infrastructure is evolving and developed is inseparable from the use of it by bicyclists and drivers. There is a mutual shaping between bicycle infrastructure and bicyclists and drivers.

One limitation that arose during this process was the scalability of the research. Because of the focus on low speed roads, there was a limitation on how bicycle infrastructure could be extended to or analyzed on larger roads. This would be very pertinent data because focusing on intra-city or intra-neighborhood travel is not enough to see how bicycle travel could be further developed to an inter-city or inter-state mode of transportation.

If I were to continue this research, I would focus more on the scalability of bicycle infrastructure. With a push towards greener infrastructure and transportation, bicycling is an attractive mode of transportation. So, to be able to make bicycles and infrastructure to travel further would allow for a greener, healthier mode of transportation. Likewise, on a smaller scale, bicycle infrastructure has a lot of potential to make bicycling a primary mode of transportation within a city. So, there is a lot of worth in focusing on creating bicycle infrastructure for cities and roads on a smaller scale in order to increase the usage of bicycles. This will result in the rise of the aforementioned benefits of healthier living, a greener environment, and boosted productivity. As a civil engineer, I will be working on roadway and highway design in the future. However, bicycle infrastructure is not something that I plan to work on or specialize in in the future. Thus, I do not think that this or bicycle infrastructure will be used to advance my engineering practice.

Conclusion

Bicycle infrastructure increases the safety of low speed roads by enhancing the protection of bicyclists and drivers alike. But bicycle infrastructure contributes much more than only safety. This infrastructure is an avenue for better change. Better infrastructure contributes to healthier living, economic growth, a greener environment, and much more. Viewing bike lanes and sharrows only as a safer way to travel is simply scratching the surface of what bicycle infrastructure can be used for. Better bicycle infrastructure can be the impetus for a healthier life and a better functioning city. By pushing deeper into the health-related benefits of better bicycle infrastructure, governing bodies or the general public may see a greater need for bicycle infrastructure. A city that is healthier and more productive for businesses and citizens alike is much more attractive and likely to bring in newer and better opportunities. Bicycle infrastructure has the capability to create a healthier, more productive way of living. Thus, cities and individuals need to make a greater push to be educated on bicycle infrastructure and reap the benefits that are associated with it.

References

Anderson, M. & Hall, M. L. (n.d.). Protected bike lanes mean business. *How 21st Century Transportation Networks Help New Urban Economies Boom*. Retrieved from https://www.seattle.gov/Documents/Departments/SDOT/BikeProgram/Protected_Bike_Lanes_Mean_Business.pdf

Bao, J., He, T., Ruan, S., Li, Y., & Zheng, Y. (2017). Planning Bike Lanes based on Sharing-Bikes Trajectories. *Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining - KDD 17*. doi: 10.1145/3097983.3098056

Beil, K. (2011). *Physical Activity and the Intertwine: A Public Health Method of Reducing Obesity and Healthcare Costs*. Retrieved from https://bikeportland.org/wp-content/uploads/2011/02/IntertwinePAObesityAssessment.pdf

Daly, E. (2014). *The Social Implications of Bicycle Infrastructure: What it Means to Bike in America 's Best Cycling Cities* (Unpublished master's thesis). Macalester College, Minnesota.

Digioia, J., Watkins, K. E., Xu, Y., Rodgers, M., & Guensler, R. (2017). Safety impacts of bicycle infrastructure: A critical review. *Journal of Safety Research, 61*, 105–119. doi: 10.1016/j.jsr.2017.02.015

Google. (n.d.). [Google Maps roadside view of Water Street]. Retrieved from https://www.google.com/maps/@38.0302536,78.4826218,3a,75y,111.62h,67.68t/data=!3m6!1e1!3m4!1sforERXOlQ7zti3SuzHY_mg!2e0!7i13312!8i6656

Habib, K. N., Mann, J., Mahmoud, M., & Weiss, A. (2014). Synopsis of bicycle demand in the City of Toronto: Investigating the effects of perception, consciousness and comfortability on the purpose of biking and bike ownership. *Transportation Research Part A: Policy and Practice*, *70*, 67–80. doi: 10.1016/j.tra.2014.09.012

Harvard Health Publishing. (2018). Calories burned in 30 minutes for people of three different weights. Retrieved from https://www.health.harvard.edu/diet-and-weight-loss/calories-burned-in-30-minutes-of-leisure-and-routine-activities

Hull, A., & O'Holleran, C. (2014). Bicycle infrastructure: can good design encourage cycling? *Urban, Planning and Transport Research, 2*(1), 369–406. doi: 10.1080/21650020.2014.955210

Hunter, W. W., Thomas, L., Srinivasan, R., Martell, C. A., & Do, A. (2010). *Evaluation of shared lane markings*. McLean, VA: United States Department of Transportation, Federal Highway Administration.

Jasanoff, Sheila. (2004). *States of Knowledge: The Co-Production of Science and Social Order*. London: Routledge.

New York City Department of Transportation. (2012). *Measuring the Street: New Metrics for 21st Century Streets*. Retrieved from http://www.nyc.gov/html/dot/downloads/pdf/2012-10-measuring-the-street.pdf

Pedestrian Safety Action Plan. (2016). [Pedestrian Safety Action Plan (PSAP) Information]. Retrieved October 28, 2019, from https://uvalibrary.maps.arcgis.com/home/webmap/viewer.html?webmap=953f54350b084601bc63843b29487b07

Puncher, J., Dill, J., Handy, S., & Buehler, R. (2013). *How to Increase Cycling for Daily Travel: Lessons from Cities across the Globe*. Retrieved from https://bloustein.rutgers.edu/wp-content/uploads/2014/10/ITE_Webinar_14August2013_05August2013.pdf

Seattle Department of Transportation. (2013). *Seattle Department of Transportation Telephone Survey of Seattle Residents*. Retrieved from https://www.seattle.gov/Documents/Departments/SDOT/BikeProgram/135004bicycleivrreport.pdf

Seattle Department of Transportation. (2019). *Seattle Bicycle Master Plan*. Retrieved https://www.seattle.gov/Documents/Departments/SDOT/About/DocumentLibrary/BicycleMasterPlan/190613_BMP_Imp_Plan_FINAL.pdf

Shared Lane Markings. (2016). [Urban Bikeway Design Guide]. Retrieved from https://nacto.org/publication/urban-bikeway-design-guide/bikeway-signing-marking/shared-lane-markings/

Trottenberg, P. (2014). *Protected Bike Lanes in NYC*. Retrieved from http://www.nyc.gov/html/dot/downloads/pdf/2014-09-03-bicycle-path-data-analysis.pdf

Vreugdenhil, R., & Williams, S. (2013). White line fever: a sociotechnical perspective on the contested implementation of an urban bike lane network. *Area*, *45*(3), 283–291. doi: 10.1111/area.12029

Zhang, Y., & Mi, Z. (2018). Environmental benefits of bike sharing: A big data-based analysis. *Applied Energy*, *220*, 296–301. doi: 10.1016/j.apenergy.2018.03.101