Safety, Mode Share, and Segregated Bicycle Infrastructure

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Introduction

Automobile use in cities leads to a variety of undesirable effects, including carbon dioxide emissions, noise pollution, accidents, and congestion. Cycling, which lessens or eliminates these problems, offers a viable alternative to automobile travel, especially in cities, where about half of all trips are shorter than three miles (Pucher, Komanoff, & Schimek 1999). Cities are increasingly interested in encouraging this cheaper, cleaner, quieter form of transportation.

Despite its benefits, cycle mode share in much of the developed world remains very low. Cycle trips make up only about 1% of trips in the United States (Pucher & Beuhler 2007). The reason for this low mode share may be that utilitarian cycling is not part of the prevailing cultural norms in some cities (Dill & Voros 2007; Pucher, Komanoff, & Schimek 1999), that physical factors such as the climate, topography, or infrastructure are inappropriate for cycling (Dill & Voros 2007), or that people perceive cycling as unsafe (Dill & Voros 2007; Pucher, Komanoff, & Schimek 1999). However, some European cities have managed to achieve a high cycle mode share even while their populations enjoy automobile ownership levels as high as the United States. For example, Amsterdam's bicycle mode share was 37% in 2005, and bike trips in Copenhagen in the same year encompassed 20% of all trips (Pucher & Beuhler 2007).

According to Pucher & Beuhler (2007; 2009), the cities that enjoy a high cycling mode share employ a portfolio of strategies to encourage cycling. They have dense, mixed-use development, safe and ample bicycle parking, good integration with public transit, training programs for school children, priority traffic signals at intersections, good law enforcement, and policies to restrict or inconvenience automobile use in certain areas of the city. Overall, these cities have made strong commitments to encourage and support cycling and have backed those commitments with sufficient policies and funds.

According to Pucher & Beuhler (2007; 2009), an essential piece of the portfolio to encourage cycling is for cities to provide bicycle infrastructure such as cycle paths and lanes. Separating cyclists from motor traffic makes cycling safer and easier, and it encourages more people to ride, specifically those who do not feel safe riding in traffic. However, there is some controversy surrounding this strategy. Although segregation from motor traffic is employed to some extent in all the high mode share cities examined by Pucher & Beuhler, there is disagreement in the literature about whether segregation is really appropriate. It is unclear if separate cycle infrastructure actually increases cycle mode share. Furthermore, some people claim that separate bikeways actually decrease cyclist safety (Forester 1994; 2001). These are generally the proponents of "vehicular cycling," in which cyclists ride in traffic and obey all normal rules for motorized traffic. Others, however, claim that segregation is absolutely necessary because cycling and motor traffic are simply incompatible (Godefrooij 2003).

Are separated bikeways truly more dangerous than cycling in traffic? Do bikeways encourage cycling, thereby increasing cycling mode share? This paper will examine these questions through a review of the literature.

Safety and Cycle Infrastructure

First, we will examine the issue of safety. Do separated cycle facilities increase cyclist safety as many people believe, or do they actually make cycling less safe as the vehicular cycling advocates claim?

Proponents of separated cycle facilities state that keeping cyclists and motor vehicles separate protects both parties from conflicts with one another, especially when motor traffic is heavy or traveling at high speeds. Cyclists are much more vulnerable than motorists, and heavy or quickly-moving traffic can cause stress and limit cyclists' freedom to maneuver (Godefrooij 2003). Those cycling in traffic must possess great awareness and a high level of skill to remain safe (Godefrooij 2003).

However, separated cycle facilities present problems as well. Most accidents occur at intersections, and cyclists on separated facilities still have to cross traffic at intersections. Thus, they remain unprotected where they are most vulnerable. Additionally, when cyclists are separated from traffic, it is more difficult for motorists

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and cyclists to see one another. Consequently, they may be less aware of one another, thus increasing the likelihood of conflicts (Godefrooij 2003; Haake 2009). Furthermore, requiring cyclists to stay in separated facilities on the side of the road makes it especially difficult and dangerous for them to make left turns at intersections because they have to cross all traffic lanes in order to do so. Finally, cyclists in separated facilities encounter more problems with pedestrians, especially those stepping off of buses into the bike lanes or paths (Haake 2009).

Vehicular cycling has been proposed by some, most notably John Forester and Bjorn Haake, as a solution to these problems. By placing cyclists in traffic with motorists and requiring them to follow the same set of rules, both parties benefit from good communication with other vehicles based on a standard set of principles, better visibility to one another, and better overall predictability of behavior (Haake 2009). According to Forester and Haake, separated cycle infrastructure is dangerous and should not be used. Instead, everyone should practice vehicular cycling.

Unfortunately, although these two authors are very vocal in expressing their opinions, the evidence they present is largely anecdotal and unscientific. As an example, consider Forester's condemnation of sidepaths based on a single test in which he used himself as a subject (2001). He spent an afternoon riding on a new sidepath in Palo Alto, CA. He claims to have encountered more dangerous situations in one day riding the sidepath than he had in many years riding in traffic on that same stretch of road. He condemns all separated cycle facilities based on this single test, or at least presents this test as evidence of his conviction instead of conducting or presenting any convincing scientific studies. He neglects to consider that his particular sidepath may have been poorly designed in the first place or that the drivers in the area may not have been overly accustomed to cyclists (Forester 2001). Other claims by Forester (1994; 2001) and Haake (2009) are similarly lacking in rigor. Thus, in order to assess the relationship between cycle facilities and safety, we must look elsewhere.

Pucher & Beuhler (2007) claim that separated cycle facilities increase cyclist safety. The countries with the lowest accident rates have the highest cycling mode share, and all of those countries make extensive use of separated cycle facilities. Thus, separated cycle facilities increase safety, and, furthermore, a higher mode share or larger number of cyclists also increases safety (Pucher & Beuhler 2007). A comparison of accident statistics shows that cyclist fatalities are over five times more likely in the United States than in the Netherlands, even though American cyclists are much more likely to wear helmets (Pucher & Beuhler 2007). Unfortunately, the causal relationships in their arguments are questionable, and we learn little more from their claim than we do from Forester and Haake.

There have been many studies assessing cyclist safety and cycle infrastructure. A meta-analysis of these studies found that the number of accidents increased after separated cycle facilities were installed on roads (Elvik, Høye, Vaa, & Sørensen 2009). However, the authors of this analysis point out a flaw in many of the studies they review. Most did not take into account the number of cyclists but simply reported an increase in the total number of accidents. Thus, the increase in accidents could reflect an increase in the total number of cyclists rather than an increase in the number of accidents per cyclist.

A study commissioned by the Municipality of Copenhagen (Jensen, Rosenkilde, & Jensen 2007; Jensen 2008) did account for an increase in the number of cyclists. The study found an overall 10% increase in crashes and injuries after cycle facilities (cycle tracks and lanes, colored crossings at intersections, and raised exits) were installed (Jensen, Rosenkilde, & Jensen 2007). Accidents at intersections increased by 18% (Jensen 2008). In addition to conflicts with turning vehicles, there were more instances of bicycles hitting one another from behind and bicyclists hitting pedestrians.

The authors attributed some of the increase in crashes to a motor vehicle parking problem. After cycle infrastructure was installed on the main roads, cars could no longer park there and instead had to turn onto side roads in order to park. This lead to a huge increase in turning vehicles that crossed the cycle tracks, resulting in increased conflicts between cyclists and motor vehicles (Jensen 2008). This suggests that perhaps these cycle facilities are not inherently flawed but simply suffer from unforeseen circumstances that could be fixed or avoided in the future.

The authors also found that accident rates varied for different types of intersections and cycle facilities, suggesting that some designs are safer than others

Berkeley, California. Photo: Joel Batterman, 2010

(Jensen, Rosenkilde, & Jensen 2007). Some facility types or configurations might be inherently better than others, and the appropriateness of each facility type undoubtedly depends upon the road and traffic conditions. Cyclists can ride in visually segregated on-street lanes or in physically segregated cycle tracks or paths (Godefrooij 2003). On-street lanes without physical barriers are cheap and easy to build, but parked cars and delivery vehicles can create obstructions (Pucher & Beuhler 2009). Physically segregated paths include sidewalk paths, bike-only paths, and shared recreational paths (Pucher & Beuhler 2009). Other examples of bicycle infrastructure include streets on which only bicycles are allowed and traffic-calmed streets in which cyclists ride in traffic, but traffic is reduced to low speeds by means of obstructive infrastructure (Pucher & Beuhler 2009). Intersections vary in types of markings, signals, and cyclist waiting areas.

The type of infrastructure that is appropriate for a particular road depends on budget constraints, available space, and roadway traffic conditions (Pucher & Beuhler 2009). Planners must balance the needs of both sets of roadway users in order to allocate the available road space in the safest and most effective way possible (Godefrooij 2003). According to the Dutch design manual for bicycle-friendly infrastructure, integrating cyclists with traffic is only appropriate on road stretches with low speeds and traffic volumes. In these areas, overtaking maneuvers will be infrequent, and cyclists will not significantly slow down traffic (Godefrooij 2003). A greater degree of separation is needed with higher motor traffic volumes and speeds. Godefrooij (2003) attempts to quantify this relationship, although he notes that existing research of cyclist safety on roads of varying speed and traffic volume is very limited. His criteria are largely based on "practical experience and common sense" (Godefrooij 2003, p. 495).

"Integration and segregation might each be appropriate in certain circumstances because of safety and practicality, but each comes with tradeoffs."

Integration and segregation might each be appropriate in certain circumstances because of safety and practicality, but each comes with tradeoffs. Separating cyclists from traffic might reduce conflicts, but it can also restrict the free movement of cyclists (Godefrooij 2003) and give the message that cyclists are somehow inferior to motor vehicles (Forester 1994). Furthermore, segregation can be seen as a sort of "banishment" from the roadway designed to keep cyclists from restricting the free flow of motor traffic rather than to really provide them with good infrastructure suited to their own needs (Godefrooij 2003). Forester (2001) claims that the US Bikeway Standards are designed with precisely this goal in mind. On the other hand, good cycle infrastructure could be a sign that cyclists are respected (Pucher, Komanoff, & Schimek 1999) and a demonstration of a municipality's commitment to supporting cycling as a viable mode of transportation.

Perceived safety

People's decisions to cycle do not necessarily correspond to objective measures of safety but instead reflect their perception of safety (Dill & Voros 2007). Thus, regardless of whether or not separated cycle infrastructure actually creates safer conditions, if people believe that cycling on separated facilities is safer than cycling in traffic, they are more likely to feel safe and comfortable. If they feel safe and comfortable, they are more likely to cycle. Many studies show that this is, indeed, the case. People feel safer riding separate from traffic (Elvik et al. 2009; Heinen, Van Wee, & Maat 2010; Jensen, Rosenkilde, & Jensen 2007; Pucher, Komanoff, & Schimek 1999).

Vehicular cycling requires a high level of awareness and skill (Godefrooij 2003). Not all cyclists possess these qualities, or even if they do, they may prefer the less stressful and more relaxed cycling experience that separated facilities allow. In other words, all but the most serious of cyclists may be discouraged from cycling if separated facilities are not provided. The elderly and children, especially, may not be well-suited to vehicular cycling because they tend to be slower, less skilled, and less aware (Pucher & Beuhler 2009).

Mandating vehicular cycling, according to Pucher & Beuhler (2009), precludes many classes of people from cycling, thus creating a situation of social injustice. Cycling should be for everyone, they argue, and not everyone is comfortable with or capable of vehicular cycling. Forester (2001), however, counters this argument by claiming that nearly everyone can be trained to cycle properly in traffic. Vehicular cycling rules are the same as the rules for motorists, and the special cycling techniques are not difficult. Even children can learn to ride safely in traffic. Haake (2009) further points out that it is cheaper to train cyclists to ride in traffic than to build and maintain cycle facilities. Those who are trained feel much more comfortable riding in traffic. Pucher & Beuhler (2009) hold to their argument, however, even though bicycle education programs are a standard part of school curricula in the high-mode-share European cities they survey. It should also be noted that both Forester and Haake are professional cyclist trainers. They undoubtedly understand the nuances of their profession, but they may be biased by their professional interests. Regardless of whether cyclists ride in the road or on separate paths, it seems reasonable to

Amesterdam, The Netherlands
Photo: Andrew Morang, 2004

assert that more and better cyclist (and motorist) education will increase safety and comfort levels.

Our discussion of perceived safety and cyclist skill level suggests one possible explanation for the increase in accidents after the installation of cycle facilities. If cycle facilities truly encourage cyclists who are less experienced and less comfortable, then those people are probably more likely to have accidents anyway. Thus, we would expect to see an increase in accidents when those people join the regular fleet of cyclists.

Cycle Infrastructure and Mode Share

Do separated cycle facilities truly encourage more people to cycle, either because of an increase in perceived safety or for some other reason?

Several studies show that places with high cycle mode share employ separated cycle infrastructure. Several European cities of various sizes with very high mode share have included separated bicycle infrastructure as integral parts of their plans (Pucher & Beuhler 2007). A regression study based on census data showed that a higher cycle mode share is correlated with more cycle infrastructure in 43 of the largest US cities (Dill & Carr 2003). A study in Portland, OR, in which 166 frequent cyclists were given GPS units to record their routes for a period of time, revealed that 50% of the miles traveled were on streets with cycle infrastructure even though only 8% of Portland streets are equipped with such infrastructure (Dill, 2009). This would seem to indicate that cyclists prefer to use this infrastructure. However, none of these studies shows the causal relationship between cycle infrastructure and mode share. It is conceivable that cycle infrastructure was not the cause of the high mode share but was instead built in order to support an already large number of cyclists. In the case of the Portland study, the city could have placed the infrastructure on the routes that most cyclists chose to take in the first place. Forester (2001), in his relentless quest to devalue cycle infrastructure, points to this causal difficulty as a fundamental flaw in the arguments of cycle infrastructure proponents.

Some studies, however, have attempted to overcome this causal fallacy. A longitudinal study of Minneapolis and St. Paul, MN, showed that new cycle facilities significantly increased the amount of cycling, especially when cyclists were provided facilities for crossing bridges (Barnes, Thompson, & Krizek 2005). Similarly, a before-and-after study of cycle-facility-equipped roads in Denmark showed that cycle and moped traffic increased 20% while motor traffic decreased 10% (Jensen 2008). It is unclear in either of these studies if the changes truly reflect a change in mode choice. They could simply indicate route choice changes by both cyclists and motorists. Or, the increase in cyclists could be induced demand, new trips that would not have occurred otherwise. It should also be noted that these facilities were built in areas that already had relatively high cycle mode share.

The Overall Benefits of Cycling

Cities wish to increase cycle mode share because of the external benefits of substituting automobile trips with cycle trips. Cycling produces far less noise and pollution (Jensen 2008), reduces congestion (Heinen, Van Wee, & Maat 2010), and improves public health by increasing physical activity (Heinen, Van Wee, & Maat 2010; Jensen 2008). If installing separated cycle infrastructure significantly increases cycle mode share, it is possible that the external benefits of this increase could outweigh the cost of an increase in accident rates.

Salensminde (2004) conducted a cost-benefit analysis of implementing cycle and walking tracks in three Norwegian cities. He considered reduced traffic congestion, increased feelings of security, reductions in school bus transport, better health, reduced pollution, reduced infrastructure costs, and reduced parking costs as benefits. Although he purposefully used low estimates for the benefits and high estimates for costs of installation, the analyses still resulted in net benefits. Unfortunately, because many of these benefits are uncertain and difficult to quantify, it is hard to know how much to trust the results.

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Furthermore, the author did not consider any changes in accident rates in his study, so the study is of limited use in our current investigation. However, it provides a reasonable model for further studies to follow assuming that changes in accident rates can be estimated with any reasonable level of accuracy. If his assumptions are reasonable, and if accurate estimates of accident increases could be obtained, we could determine if the external benefits outweigh the costs.

Conclusion

Are separated cycle facilities safer than vehicular cycling, or do they actually decrease safety? Do they encourage cycling and increase cycle mode share? Our review of the literature has revealed no conclusive answers to any of these questions. Evidence supporting all sides of these issues is weak, uncertain, or non-existent.

As Pucher & Beuhler (2007) point out, cycle infrastructure is only one part of the portfolio of strategies employed to encourage cycling and increase cycle mode share. The lack of conclusiveness of the mode share studies we examined likely reflects the fact that cycle infrastructure alone does not encourage cycling. A comprehensive strategy demonstrating a strong local commitment and cultural willingness is needed for a high mode share.

Similarly, it is likely that the presence or lack of cycle infrastructure is not the sole factor determining safety. Other factors may play equal or larger roles. It seems reasonable to conclude that the design of cycle infrastructure plays an important role in cyclist safety. Good designs will undoubtedly be safer than bad designs. Furthermore, although his attempt at quantifying the relationship might be dubious, Godefrooij's assertion (2003) that different types of infrastructure are appropriate in different types of road conditions seems far more reasonable than arguments asserting that cycle infrastructure is always good or always bad. Examining these relationships would be a good topic for further empirical research. It is also reasonable to conclude that good education for both cyclists and motorists will increase safety, whether cyclists ride in traffic or separate from it. Each group must be trained to understand and respect the other and to safely utilize whatever facilities are provided.

In conclusion, the questions of whether or not separate cycle infrastructure leads to greater cyclist safety and whether or not providing it increases cyclist mode share are not conclusively answered in the reviewed literature. Because there is great variation in cycle infrastructure and the context in which it is placed, this lack of conclusiveness is not entirely surprising. It would be unwise to advocate for either separated cycle facilities or vehicular cycling without specifying particular conditions or context, and those seeking to increase cycling levels should keep in mind that infrastructure is only one part of the more comprehensive strategy that is needed.

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