City Cycling

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6

Bicycling Infrastructure for Mass Cycling: A Transatlantic Comparison

Peter G. Furth

For the bicycle to be useful for transportation, bicyclists need adequate route infrastructure—roads and paths on which to get places. In the 1890s, when bicycling first became popular, bicyclists' chief need was better paved roads. In the present era, however, it is not poor pavement but fast and heavy motor traffic that restricts cyclists' ability to get places safely (Jacobsen, Racioppi, and Rutter 2009), as discussed in chapter 7.

European and American policies have strongly diverged on how to address this challenge. In many European countries, including the Netherlands, Germany, Denmark, and Sweden, cyclists' need for separation from fast, heavy traffic is considered a fundamental principle of road safety. This policy has led to systematic traffic calming on local streets and, along busier streets, the provision of a vast network of "cycle tracks"—bicycle paths that are physically separated from motor traffic and distinct from the sidewalk. Cycle tracks (see figures 6.1–6.3) may be at street level, separated from moving traffic by a raised median, a parking lane, or candlestick bollards; at sidewalk level, separated from the sidewalk by vertical elements (e.g., light poles), hardscape, a change in pavement or a painted line; or at an intermediate level, a curb step above the street, but also a small curb step below the sidewalk.

The success of this combination of traffic calming and cycle tracks has been well documented; for example, chapter 2 shows that the percentage of trips taken by bicycle, though less than 1 percent in the United States, exceeds 10 percent in several European countries, reaching 26 percent in the Netherlands; at the same time, their bicycling fatality rates (fatalities per million km of bicycling) are much lower than in the United States (Pucher and Dijkstra 2000; Pucher and Buehler 2010). In contrast,

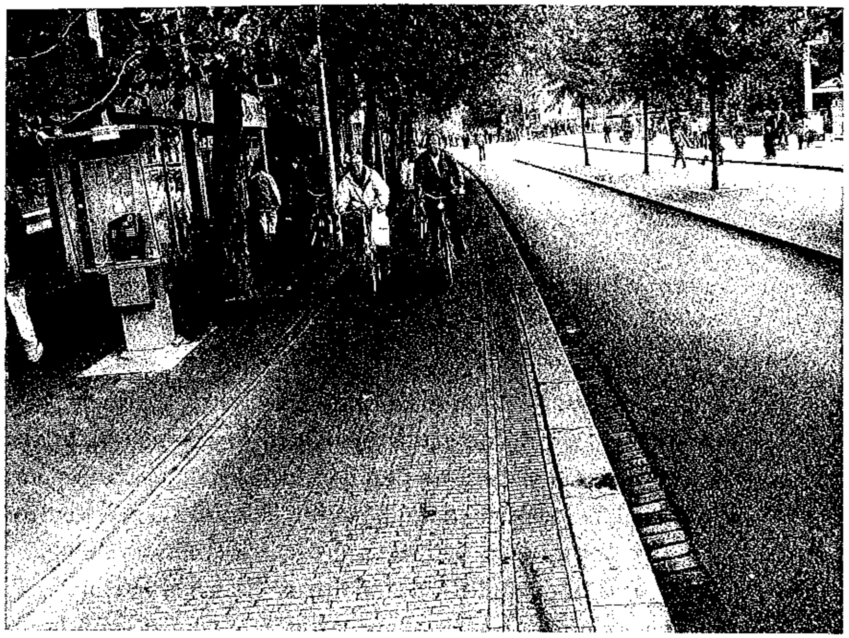

Figure 6.1
One-way cycle track in The Hague. *Credit:* Peter Furth.

Figure 6.2
Raised crossing carries a two-way cycle track across a minor street at an intersection in Delft. *Credit:* Kim Niedermaier.

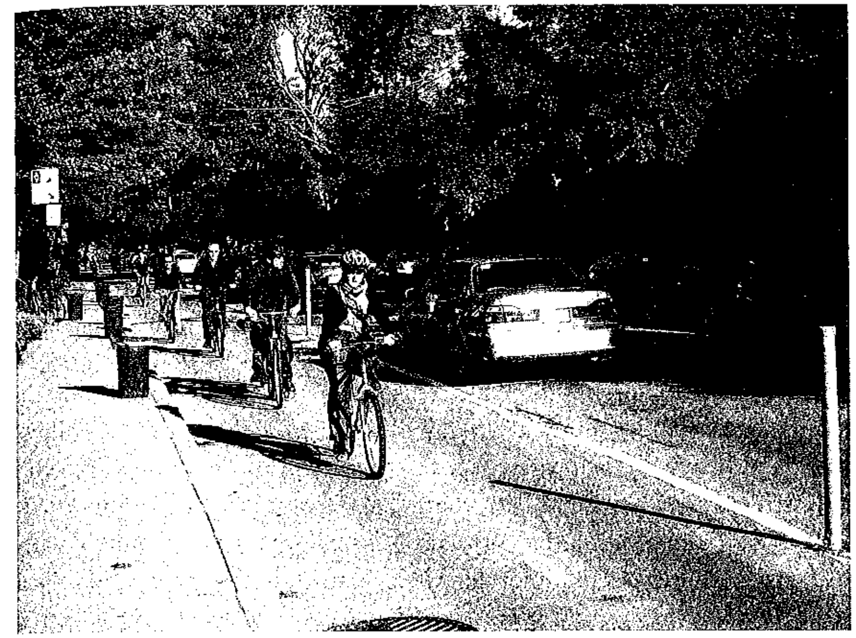

Figure 6.3
Cycle track in Montreal is separated from travel lane by bollards and a parking lane. *Credit:* Peter Furth.

the United States has mainly pursued a policy of integrating bikes with traffic, so that getting places by bike usually requires riding in streets with heavy traffic. Therefore, utilitarian bicycle use in the United States is, for the most part, limited to that fraction of the population that is "traffic-tolerant."

This first section of this chapter contrasts American and European policy regarding the provision of bicycle infrastructure. The second section analyzes different kinds of bikeways. The chapter ends with a discussion about funding for bicycle infrastructure and a conclusion.

Policy Regarding Separation from Traffic

The imperative of separating cyclists from fast and heavy motor traffic seems obvious in light of their vulnerability and their large speed and mass differential from motor traffic. Unlike motor vehicles, bicycles do not benefit from cage construction, crumple zones, or airbags (CROW 2007, 31). Separating people from danger is a fundamental principle of industrial safety. As discussed in chapter 11, this is particularly important for children, whose size, limited cognitive ability, and impulsiveness make it especially dangerous for them to integrate with traffic. As shown in chapter 3, in addition to objective risk of injury, the noise and danger of traffic imposes stress on cyclists that makes it difficult to relax and enjoy the outdoors. Many people choose bicycling because it's enjoyable; when bicycling involves constant traffic stress, that enjoyment can be lost.

The combined concerns of safety and comfort make separation from traffic stress a critical factor in attracting people to cycling. In many North American surveys, the chief reason given for not cycling more is the danger posed by motor traffic (Winters et al. 2011). Cyclists willing to ride in heavy traffic represent a small fraction of the population; the mainstream population has been characterized as traffic-intolerant (Furth 2008). At a global level, the correlation is strong; in every country with high levels of bicycle use, bicycle infrastructure that separates bicyclists from fast and heavy motor traffic is widespread (Pucher and Dijkstra 2000; Pucher and Buehler 2008), and in countries lacking routine separation, bicycle use is low. Within the United States, cities with more dedicated bicycling infrastructure tend to have more bicycle use (Dill and Carr 2003; Buehler and Pucher 2012).

Bicycling can make important contributions to societal goals related to public health, energy independence, climate change, air quality, traffic congestion, mobility, economy, and quality of life. However, meaningful progress toward any of these goals can be achieved only with *mass cycling*. Route facilities that appeal to only the traffic-tolerant population are not enough. A goal of any bicycle infrastructure program must be to provide sufficient separation from traffic stress that it attracts the mainstream population.

Bicycling infrastructure can be classified into four levels of separation:

1. *Shared streets and shared lanes* No dedicated bicycling space.
2. *Bike lanes* Separation by roadway striping.
3. *Separated paths* Cycle tracks and shared-use paths along a road, physically separated from moving motor traffic by a barrier such as a curb or parked cars.
4. *Standalone paths* Bike paths or shared-use paths in an independent right-of-way, such as in a park or along an abandoned rail corridor.

Higher levels of separation typically involve both greater construction cost and greater amounts of space. Therefore, governments have a natural tendency to prefer lower levels of separation unless constrained by criteria aimed at meeting user needs.

Dutch and Other European Separation Guidelines

The need for clear policy concerning separation from traffic stress is well understood in European countries that have achieved a high modal share for bicycling. The most recent Dutch criteria regarding separation, developed as part of the national road safety program "Sustainable Safety" (Wegman and Aarts 2006) and the Dutch *Design Manual for Bicycle Traffic* (CROW 2007), are summarized in table 6.1. In urban areas, physical separation in the form of a cycle track is expected on any street with more than two lanes, as well as on any urban street whose speed limit exceeds 50 km/h (31 mph) and any rural road whose speed limit exceeds 60 km/h (37 mph).

For bikes to operate in mixed traffic, urban streets should meet three criteria:

Speed limit should be 30 km/h (19 mph) or less. Moreover, streets may be given this low a speed limit only if they are outfitted with traffic calming measures such as frequent sharp turns, speed humps, or very narrow roadways that make the speed limit self-enforcing.

Traffic volume should be 5,000 motor vehicles per day or less. Moreover, bike lanes are preferred when daily traffic volume exceeds 4,000 vehicles per day. Above this rate, two effects make shared streets stressful (Furth 2008). First, during peak hours, cyclists will experience the "overtaking squeeze"—when a cyclist and two motor vehicles traveling in opposite directions from one another want to pass the same point at the same time—more than once per minute. Second, motorist delay from being blocked by bikes rises to a level that tempts motorists to pass aggressively.

The road should have no car lanes marked, including no centerline. Lane striping should never channel cars toward the part of the road that bicycles normally use; therefore, marked centerlines are inconsistent with

Table 6.1
Dutch bicycle facility selection matrix

Lane configuration	Average daily traffic (vehicles/day)	Street type and speed limit: Urban local street 30 km/h (19 mph)	Urban through street 50 km/h (31 mph)	Rural local road 60 km/h (37 mph)	Fast traffic road 70+ km/h (44+ mph)
Two-way traffic with no centerline	*<2500*	Mixed traffic[a]	Bike lane[b] or cycletrack[c]	Advisory bike lane[d]	Cycle track or low-speed service road
	2000–3000			Bike lane[b] or cycle track[e]	
	3000–5000				
	>4000	Bike lane or cycle track	Bike lane or cycle track[c]		
Two lanes (1 + 1)	*any*	Bike lane or cycle track	Bike lane or cycle track[c]		
Four lanes (2 + 2) or more	*any*	(Does not exist)	Cycle track or low-speed service road		

Source: CROW 2007.
[a]For designated bike routes, a bike lane or advisory bike lane is optional.
[b]May be an advisory bike lane on road sections with no centerline.
[c]Cycle track is preferred if there is parking; cycle track is recommended for designated bike routes.
[d]Although CROW (2007) gives "mixed traffic" for this cell, the default layout for roads in this category is to mark advisory bike lanes.
[e]Cycle track is preferred for designated bike routes.

cars and bikes sharing space. Mixed traffic on multilane roads is never acceptable.

The Dutch *Design Manual* recommends bicycle lanes for a rather limited set of circumstances: roads with two lanes and no parking lanes. Where such streets have a parallel parking lane, cycle tracks are preferred; guidance recommends eliminating the bike lanes, making the road correspondingly narrower, and using the redeemed space to create sidewalk-level cycle tracks (Wegman and Aarts 2006, 162; CROW 2007, 118). Bike lanes are used less and less in the Netherlands because they are almost never part of any new road designs and on many older roads, they are being converted to cycle tracks.

On streets too narrow for exclusive bike lanes, many European countries use "advisory bike lanes" (see figure 6.4). Using dashed lines, they divide the street into a central driving zone that is too narrow for two cars and a pair of edge zones that are in effect bike lanes that cars may

Figure 6.4
Advisory bicycle lanes on a two-way street in Delft; note advisory lanes paved red and marked with dashed lines. *Credit:* William G. Gray Jr.

use when encountering opposing traffic. This treatment applies only to streets with one line of traffic per direction and no marked centerline.

King (2003) compared separation criteria used by select international and US jurisdictions. The criteria used in Denmark, Germany, and the United Kingdom are similar to the Dutch criteria in that with increasing traffic volume and speed, they recommend increased separation, moving from mixed traffic to bike lanes and then to cycle tracks. American guidelines are anomalous in that separated paths are never recommended.

Lack of Separation Criteria in the United States

The American Association of State Highway and Transportation Officials' *Guide for the Development of Bicycle Facilities* (AASHTO 1999) has no criteria regarding when cyclists should be separated from fast or heavy traffic. There is no limit to the traffic speed or number of lanes for which a road may have bike lanes or even be designated as a "shared roadway." In the United States, "Share the Road" and "Bike Route" signage are often applied to multilane arterials with heavy traffic, and bike lanes are often marked on multilane arterials with speed limits of 35, 45, and even 55 mph. For example, on San Diego's Camino del Norte, a 55 mph (90 km/h) divided highway, bike lane users are expected to weave across one lane of 55 mph traffic and then ride 900 feet (275 m) in a bike lane sandwiched between four lanes of traffic on the left and two lanes on the right.

The AASHTO *Guide* implicitly justifies its lack of criteria for separation by asserting a dichotomy between users who care more about speed and users who care more about separation from traffic. The Dutch do not see these differences as presenting a conflict; they require that bicycle facilities offer both a high level of separation from traffic stress and a direct route with as few stops as possible. The AASHTO *Guide*, in contrast, is almost doctrinal about the impossibility of meeting both needs with the same facility, stating that "no one type of bicycle facility or highway design suits every bicyclist and no designated bicycle facility can overcome a lack of bicycle operator skill" (AASHTO 1999, 6). It describes a corridor presenting two alternatives: a four-lane, 55 mph (90 km/h) highway with a 5-foot (1.5-m) shoulder and a parallel bicycle route consisting of neighborhood streets linked by short sections of shared-use

path. While recognizing that the latter route would be preferred by children and "less confident adults," it states that "most experienced and many casual adult riders will continue to use the shoulder [of the highway] for the sake of speed and convenience" (AASHTO 1999, 7). This example reflects a gross misunderstanding of user needs, as well as a false assumption that travel on neighborhood streets and paths must be slow.

This lack of separation criteria combined with the tendency of government to prefer the lowest-cost solution has meant that the starting point of American policy regarding bicycle infrastructure is not a mandate to meet cyclist needs. Rather, the government's position is that its responsibility is satisfied by allowing bikes to share the road; anything beyond that is optional. If a bike lane or shared road subjects riders to more traffic stress than most people are willing to tolerate, it isn't the fault of the facility, but rather the "lack of bicycle operator skill." If a road's bike lanes vanish on an intersection approach because the road space is "needed" for a left-turn lane or for parking and cyclists are thrust into mixed traffic, that may be regrettable, but—according to American guidelines—it is acceptable.

Where user needs drive infrastructure policy, engineers are motivated to find innovative solutions, as one can find in bicycle-friendly cities across Europe. As examined in chapter 12, Davis, California, stood out for decades as a rare American city displaying this "bicycling for all" attitude. Inspired by a community leader's half-year stay in the Netherlands in the 1960s, Davis made itself a "city of bicycles" (Buehler and Handy 2008), building a bicycling network that includes 50 miles (80 km) of separated and standalone paths, including more than a dozen grade-separated crossings, as well as becoming the first American city to have bike lanes and traffic signals for bicycles. By 1980, when the national bicycle share of commute-to-work trips was less than half a percent, it was 28 percent in Davis. Unlike most American communities its size, Davis has no regular school bus service because bicycling is the usual mode for children to get to school. By 2000, as the population more than doubled and Davis's family-friendly reputation attracted many people working in distant cities such as Sacramento and Berkeley, the bike share for work trips fell to 14 percent; however, for residents working in Davis and the surrounding county, the bike share for work trips was still 25 percent (Buehler and Handy 2008; Pucher, Dill, and Handy 2010; chapter 12, this volume).

In the last decade, several US cities—spearheaded by Portland, Oregon, and New York City—have embraced the European philosophy of providing bicycle facilities targeted to mainstream, traffic-intolerant cyclists (Mapes 2009; Pucher, Buehler, and Seinen 2011). Since 1994, Portland has installed hundreds of miles of bike lanes, bike paths, and bike routes along quiet local streets using traffic-calming measures such as speed humps and diverters (see chapter 13, this volume). The result has been a six-fold increase in bicycle use and an explosion in bicycle culture, giving Portland a reputation as America's leading bicycling city (Birk 2010; Pucher, Dill, and Handy 2010; Pucher, Buehler, and Seinen 2011). New York City hired consultants from Copenhagen to help them design cycle tracks and installed 15 miles of cycle tracks between 2007 and 2010 (see chapter 14, this volume). However, adopting European design practices has not been easy (Birk 2010) because of the influence of a little-known but influential philosophy that asserts that separating cyclists from motor traffic is both dangerous and an attack on cyclists' right to ride in the road, an ideology known as "vehicular cycling."

Vehicular Cycling Theory and Opposition to Bikeways

It is impossible to understand American cycling infrastructure policy without understanding the influence of John Forester's vehicular cycling (VC) theory, which posits that "cyclists fare best when they act as, and are treated as, operators of vehicles" (Forester 1992, 2001). VC proponents argue that separating bicycles from motor traffic is inherently unsafe except along a road with no intersections (e.g., along a seawall). They assert a dichotomy between "objective safety" (crash risk) and "perceived safety," claiming that although people may feel more secure riding in their own space, such as in a bike lane or a separated path, they are in fact at greater risk of collision with motor vehicles than if they mixed with traffic as would, for example, a motorcycle. According to VC theory, when approaching any intersection, it's safer to ride where motor vehicles ride, because that's where motorists are going to look. Their reasoning contains an element of truth—intersection safety undoubtedly depends on visibility and driver expectations. However, the idea that separation *must* be dangerous ignores the massive evidence of

the European experience, and the engineering solutions developed to improve intersection safety for cyclists. It also ignores the patent dangers of riding a slow, small vehicle that lacks a protective cage in mixed traffic.

Vehicular cycling theory is preoccupied with a collision type called the "right hook," which occurs when a through-going cyclist conflicts with a right-turning motorist approaching from behind. According to VC theory, bicyclists should prevent right hooks by "controlling the travel lane," that is, occupying a lane position that blocks cars from passing. On an urban street, one should keep to the right between intersections (letting faster traffic pass) but then shift into a lane controlling position on each intersection approach. If intersections are frequent, cyclists should simply stay in the center of the travel lane. VC proponents downplay the risk of collision with same-direction traffic such as being hit from behind or sideswiped and train cyclists to ignore harassment from motorists angry with them for blocking a lane. Cycle tracks and bike lanes, which guide cyclists to stay to the right even through intersections, are therefore anathema to vehicular cycling. Forester (n.d.) teaches that they are not only inherently dangerous but are also part of the "cyclist inferiority superstition" and emphasizes cyclists' rights to operate like any other vehicle.

Forester's antibikeway philosophy has had a pervasive influence within the American bicycle advocacy community. State and local bicyclist organizations have frequently advocated against bike lanes and separated paths; Forester himself served as president of the California Association of Bicycling Organizations and of the League of American Wheelmen, now the League of American Bicyclists. In many cases, bicycle planners hired by state and local government have been VC adherents who used their influence to prevent rather than promote bikeways. Two examples are Boston and Dallas, both named the worst cycling city in America by *Bicycling* magazine (Boston in 1999 and 2006, Dallas in 2008), neither of which had any bike lanes until new bicycle coordinators were appointed in 2007 and 2009, respectively. When a citizens' group exposed Dallas's bicycle planner for remarking, "As long as I'm the Bike Coordinator for the city, Dallas will never have on-street bike lanes" (Bike Friendly Oak Cliff 2008), he defended his position by writing, "I do not worry about 'Is it popular?' or 'Is it politically correct?' or 'Is it the current style?' No. Instead I ask myself, 'Does this action endanger people more than the other alternatives?'" (Summers 2008).

Opposition to Separated Paths

Adult bicycling had a renaissance in the United States in the late 1960s with the popularization of the ten-speed bike and the earth movement. Responding to demand for bicycling facilities, California produced a bikeway planning guide whose first edition took a positive view toward European practices, recommending sidewalk-level bikeways, separated bike lanes, and regular bike lanes (UCLA Institute of Transportation and Traffic Engineering 1972, 44–47, 59–62, 70). Forester, then active in bicycle racing clubs, saw such bikeways as a threat to cyclist's right to ride in the road and a hindrance to fast bicyclists and responded by advancing his VC theory.

At the time, Forester's theory had no empirical support. The California guide cites a Danish study that found that the injury rate on an arterial with cycle tracks was 60 percent lower than on a similar arterial lacking cycle tracks (Council for Traffic Safety Research 1969). Until now, only one credible American study (Wachtel and Lewiston 1994) at first glance appears to support his theory. It compares the rate of motor vehicle–bicycle collisions for cyclists who rode in the street versus on sidewalks that had been designated as bikeways on three Palo Alto, California, streets, and found the crash risk 80 percent greater on the sidewalk bikeway. However, this study considers only crashes at intersections (including driveway junctions) and therefore gives a distorted view of overall safety. Lusk et al. (2011) showed that when between-junction crashes are accounted for along with crashes at intersections, the sidewalk bikeway's crash risk was not statistically different from the risk of riding in the street. Furthermore, because much of the risk associated with sidewalk riding was due to the relatively few cyclists who rode along the left side of the street, they found that for cyclists who used the right-side sidewalk—a discipline enforced by the one-way cycle tracks common in Europe—riding on a sidewalk bikeway carried only half the risk of riding in the street.

Detractors of separated paths frequently cite Moritz (1997), who found that sidewalk riding carries five times the accident risk of bicycling in the street. Apart from the fact that separated paths are different from

sidewalks, this finding is not scientifically valid even for sidewalks, both because of a faulty study design and an inadequate sample. This study used a survey in which respondents reported their mileage and crash frequency on different types of facilities (standalone paths, bike lanes, streets without bike lanes, and "other"). Because the study had been designed for other purposes, the questionnaire never mentioned "sidewalk"; results reported for sidewalks are based on responses for facility type "other." Moreover, facility type "other" accounted for only twelve reported crashes.

Montreal presents a unique North American test bed for the safety of separated paths. Inspired by a city official's visit to Amsterdam, it constructed 15 miles of separated two-way paths in the 1980s. Lusk et al. (2011) examined nine years of injury data on six representative cycle tracks and parallel alternative routes and found that injury risk on cycle tracks was 28 percent less than cycling in the street. They also found that the cycle tracks carried 2.5 times more cyclists than the alternative routes.

Residents of European countries with extensive cycle track networks find it astonishing that a theory could persist that separated paths are dangerous. How to overcome the evidence of the massive European experiment, in which, for decades, millions of cyclists have ridden daily on cycle tracks, with crash rates far lower than in the United States and a far greater appeal to vulnerable populations such as children and seniors (Pucher and Dijkstra 2000; Pucher and Buehler 2008, 2010)? Forester, who has never visited the Netherlands as an adult, attempts an explanation: "The Dutch produced a very dangerous bikeway system, compared to cycling on the road, but they have overcompensated for those dangers by installing protective measures that make it extremely inconvenient, again compared to cycling on the road" (Truewheelers 2000). What Forester does not explain is why, if the measures used to make Dutch bikeways safe are so inconvenient, *why* do so many people use them?

American Policy against Separated Paths

Perhaps the most far-reaching impact of Forester's philosophy was getting an effective ban on separated paths written into the AASHTO *Guide for the Development of Bicycling Facilities*. As mentioned earlier, California's first guide had recommended, among other treatments, separated bike paths at both the street and sidewalk level. Along with bike lanes, such separated paths were considered "Class II bikeways," defined as designated cycling space within the road right-of-way. ("Class I bikeways" are standalone paths, and "Class III bikeways" are shared streets.) However, in spite of a complete lack of empirical evidence against separated paths, California's guide was changed to denounce those separated path treatments; "Class II bikeways" came to mean bike lanes and nothing more. The AASTHO *Guide* then followed the revised California guide, stating that bike lanes should never be placed behind parking lanes and that sidewalk-level bikeways should be used only where there are virtually no intersections, such as along a seawall or while crossing a long bridge (AASHTO 1999, 20, 33–35, 58). Forester credits his movement for keeping European-style separation out of the United States:

> When bicycle traffic increased in the 1960s, motorists worried that "their roads" would be plugged up by bicycles. The motor-minded California legislature attempted (1970–2) to bring in the Dutch-style sidepath system to get cyclists off the roads. The motoring establishment thought that they would have great public support, because they believed, as if it were one of the laws of nature that everybody knew was true, that the prime safety requirement for cyclists was staying out of the way of same-direction motor traffic. However, at this time there were cycling spokesmen able to make scientific challenges to their designs, to demonstrate how dangerous these designs are and how much safer vehicular cycling is. This was the start of the American bikeway debate. Cyclists managed to convince the government that it would be held liable for accidents caused by the most obviously dangerous designs, which were then withdrawn. However, the designs which were not so obviously dangerous [bike lanes] were retained as the basis of the governmental bicycle transportation policy. (Forester, n.d.)

Having essentially dismissed separated paths, the AASHTO *Guide* offers designers a meager toolbox for bike facilities: bike lanes or nothing, unless there happens to be an available off-road corridor for a standalone path. And because the design community has by and large felt obligated to follow the *Guide*'s recommendations, the ban on separated paths has been self-perpetuating because committees that control national guidelines tend to accept evidence from US safety studies only, and without American examples whose safety performance could be studied, Forester's assertions that separated paths are dangerous have stood unrefuted.

Undoubtedly, a reason for AASHTO's embrace of VC principles is that they don't call for any money or roadway space being devoted to bicycling. VC demands are music to their ears: "You don't have to build us any bikeways; in fact, doing so would actually harm cyclists. All bicyclists want is wide roads, smooth pavement, and modified drain covers so that our bicycle wheels won't get caught."

Recently, however, a few American municipalities have begun to embrace separated paths for cyclists. Cambridge, Massachusetts, whose bicycle planner studied in Copenhagen, installed a pair of one-way sidewalk-level cycle tracks in 2003. New York City captured the imagination of the country in 2007 when they installed the first of several European-inspired "protected lanes," street-level cycle tracks between the curb and a parking lane (see chapter 14, this volume). Officials report that it has seen a 57 percent increase in number of cyclists and a 50 percent decline in total crashes. Other US cities that have built cycle tracks since 2007 include Indianapolis, Portland, Washington, and Minneapolis.

At this writing, the AASHTO *Guide* is under revision. A review draft suggests that the next edition will mute its criticisms of separated paths; however, it still won't recommend them or offer design guidance for them. Frustrated by AASHTO and aware of engineers' need for guidance as more cities embrace European practices, the National Association of City Transportation Officials (NACTO), led by member cities Portland and New York, developed its own *Urban Bikeway Design Manual* (NACTO 2011), with guidance on several different forms of cycle tracks as well as several other European-style treatments. Its publication may be a major turning point for American bicycling.

Bicycle Route Facility Types

This section describes the principal types of bicycle route facility, with a focus on how they can be applied to create low-stress bike routes that will serve the mainstream population.

Standalone Paths

Standalone paths are usually built in green settings in parks, along rivers and canals, and along abandoned rail rights-of-way. In the United States, they are typically shared with pedestrians and other nonmotorized users, though dual path systems (one path for pedestrians, one for bikes) are standard in Europe and are sometimes used in the United States as well. By providing a largely intersection-free route, standalone paths appeal to the dual user needs of separation from traffic stress and minimizing delay. Standalone paths enjoy strong political support because few Americans can picture themselves as bicycle commuters, but most can see themselves as recreational path users, whether on a bicycle or on foot. Nevertheless, in urban areas, standalone paths are often heavily used for commuting and other utilitarian transportation.

Standalone paths are by nature limited to where a right-of-way exists. Nevertheless, the potential network of standalone paths in North American cities is large. Most American cities developed along river and rail corridors, making paths in such corridors ideal for commuting; examples can be found in many cities. Large parks can also be ideal path settings; Minneapolis and the National Capital region are examples of urban areas with historically strong parks programs that feature many miles of greenway paths.

Building new paths can be expensive, with estimates ranging from $300,000 to $1.5 million per mile ($200,000 to $1,000,000 per km) or more if bridges are involved. However, some cities have found ways to stretch their path dollars. As noted in chapter 12, Boulder, Colorado, has a network of more than a hundred miles of bike paths, largely along its creeks, including seventy-four underpasses (Pucher, Dill, and Handy 2010). This development took advantage of regulations for flood control that paid for expanding the bridges over the creeks; including paths with these undercrossings involved little incremental cost. Some cities have found that they can develop standalone paths at almost no direct cost by requiring that developers complete any part of the city's path network plan that lies within their development. For example, Davis, California, on seeing the popularity of a "greenbelt" path voluntarily built by one housing developer, began to require that successive developers add to the greenbelt network as the city expanded (Buehler and Handy 2008). Scottsdale, Arizona, and Eagle, Idaho, suburbs of Phoenix and Boise, have each adopted an extensive plan of shared use paths, mostly following existing irrigation canals; developers are required to build path sections lying in their development area.

Narrower Travel Lanes

Where no off-road corridor exists, cyclists must be accommodated in road rights-of-way. Gaining acceptance for 10-foot-wide travel lanes has

been a key to several US cities' ability to find space for bikeways. Many city and state highway departments consider anything below 12 feet (3.65 m), the standard lane width for freeways, to be substandard, even though the AASHTO highway design guide (AASHTO 2004, 311–312) allows considerable flexibility regarding lane widths and several US cities routinely use 10-foot-wide lanes on arterials with heavy bus traffic. Potts, Harwood, and Richard (2007), in an extensive study sponsored by the Federal Highway Administration (FHWA), found that on urban and suburban arterials, 9- and 10-foot (2.7- and 3.0-m) travel lanes had the same safety performance as 11- and 12-foot travel lanes, except on undivided multilane arterials.

Cycle Tracks

Cycle tracks form the greater part of the cycling network in cities in the Netherlands and Denmark. The few examples in North America include two-way "sidepaths" in Boulder, one-way "raised bike lanes" in Eugene and Bend, Oregon, "protected bike lanes" in New York between the curb and a parking lane (some one-way, some two-way), and several two-way "bike paths" in Montreal that are at street level and separated from travel lanes by parking lanes, raised medians, and bollards.

Riding on a cycle track involves paying attention to traffic for a few moments when crossing an intersection, then relaxing until the next one. Most people find the quality of this experience far superior to riding in an environment in which one has to pay constant attention to traffic. Having only discrete points that demand attention to traffic conflicts makes cycle tracks better suited to children's cognitive abilities. Cycle tracks also offer cyclists an environment with less traffic noise and cleaner air compared to riding in the road (Kendrick et al. 2011).

A challenge of cycle track design is ensuring safety at intersecting streets and driveways. Motorists' expectation of conflicting bicycle traffic can be enhanced by marking bicycle crossings through intersections, just as crosswalks mark the pedestrian path (NACTO 2011). At minor street intersections, a preferred treatment in Sweden, Denmark, and the Netherlands is to keep the cycle track and sidewalk elevated at sidewalk level through the crossing (see figure 6.2). Elevated crossings clearly signal cyclists' priority over cross traffic and act as a speed hump, reducing both the likelihood and severity of crashes with motor vehicles (Garder, Leden, and Pulkkinen 1998). Where intersecting cycle tracks meet at signalized intersections, making the cycle tracks continuous around each corner gives cyclists a protected place to queue far in advance of motorists (Markenlei 2011).

Intersection risk along main arterials can be reduced by limiting the number of minor intersections. Access management—limiting driveways and minor intersections on streets whose main function is to carry through traffic—is a well-recognized safety practice in both Europe and the United States, though the American legal framework makes it more difficult to apply. In the Netherlands, most arterials built after World War II have infrequent intersections and no driveways, with the result that cycle tracks along these arterials have long, conflict-free sections between intersections. For older urban arterials with frequent intersections, it used to be questioned whether a bike lane might be preferable to a cycle track (CROW 1994, 81); since 1997, however, the cycle track option has been declared superior (CROW 2007, 119). This change in policy occurred partly because of the success of elevated crossings and partly because research found that a disproportionate share of cycle track crashes involved mopeds, which since a legislative change in 1997 ride in the roadway, not the cycle track, in urban areas. Since 2000, the trend in Dutch cities has been to replace arterial bike lanes with cycle tracks where space permits; Markenlei (2010) provides an excellent visual example.

At signalized intersections, bike signals (green, yellow, and red bicycles)—common in Europe, and also used in Montreal, Portland, and New York—can control the cycle track when the time that it's safe for bikes to cross differs from the time that the parallel traffic phase is green. Dutch arterials frequently have right-turn lanes controlled by a green arrow so that cyclists and right-turning motorists can have separate green phases. Cycle tracks along one-way avenues in New York's cycle tracks, located on the left in order to avoid conflicts with bus stops, use a mirror image scheme to resolve the conflict with left-turning traffic.

Cycle tracks should be wide enough to permit passing or side-by-side cycling. However, space constraints can make this goal difficult to achieve on some streets. Narrow, one-way cycle tracks are better suited to placement at sidewalk level (a common configuration in Germany) so that cyclists can pass one another using the sidewalk when it is clear of pedestrians. Intersections also provide passing opportunities.

Two-way cycle tracks achieve some economy of space because they offer passing opportunities without a passing lane; also, their wider layout makes snow removal easier. For these reasons, Montreal's cycle tracks are almost all two-way. However, two-way cycle tracks bring more complications to intersections and are therefore not permitted in Copenhagen, even though they are ubiquitous a few kilometers away in Malmo, Sweden's number one cycling city. The Dutch *Design Manual* (CROW 2007, 120) favors one-way cycle tracks but recognizes that two-way cycle tracks may be preferred in order to facilitate a safer alignment in general (e.g., if one side of a street has few intersections because it borders a river or railroad), eliminate the need for cyclists to cross a wide street twice, or where there isn't enough space for a pair of one-way cycle tracks. Also, where wrong-way riding on a one-way cycle track is prevalent, it is common Dutch practice to formally convert it to two-way, because with the conversion comes signs and markings that heighten motorists' expectations of two-way cycling. Dutch cities continue to build two-way cycle tracks; recently, some have made it a policy to convert all of their cycle tracks to two-way.

Bike Lanes

This section presents both a defense and a criticism of bike lanes. On one hand, bike lanes are an inexpensive and space-efficient means of accommodating bikes. Lane lines are an effective means of channeling traffic, and because bike lanes are usually so narrow that motorists have no incentive to drive in them, they can provide bicyclists a reserved zone for riding despite the lack of a barrier from motor traffic. On the other hand, the close proximity to moving traffic makes bike lanes more stressful to ride in than a cycle track, especially where traffic is fast or turbulent. Bike lanes offer no protection against illegal parking, often expose cyclists to "dooring" (when a parked car's door suddenly opens, colliding with a passing bike), and present complications at intersections with heavy right-turning traffic.

The Magic of Lines

Vehicular cycling proponents have opposed bike lanes because they guide cyclists to stay to the right, when they would prefer that cyclists be educated to shift frequently between a position on the right (allowing faster traffic to pass) to a lane-controlling position (to block cars and thus prevent a right hook collision). They have argued that the bike lane function could be met by providing a wide outside lane (14–15 feet or 4.3–4.6 m wide)—wide enough for a bike and car to ride side by side, but also narrow enough for a bicyclist to control the lane by riding in the middle. Through their influence, wide outside lanes became a recognized bicycle facility in the United States in the 1990s. Bike lane supporters have countered that wide lanes don't give cyclists the same sense of security as a bike lane and make roads more dangerous by encouraging higher speeds.

This debate led to several "wide lane conversion" studies observing motorist and cyclist behavior when wide outside lanes were divided into a travel lane and a bike lane. Hunter and Feaganes (2005) and Duthie et al. (2010), studying road sections without parking, found that with a bike lane, cyclists rode further from the curb—evidence of less fear of cars approaching from behind. They also found that motorists passing a bike encroached less on the adjacent travel lane, revealing less stress on their part. For motorists, a line marking the boundary between bicycling and driving zones makes it easier from a distance to gauge a cyclist's lateral position and predict their path.

With cyclists and motorists thus adjusting their position, the average separation between a cyclist and passing motorist becomes smaller. Parkin and Meyers (2010) similarly found a smaller average separation on road sections with bike lanes versus without, a counterintuitive result that was widely picked up by the press ("bike lanes worsen safety!"). However, safety is not a matter of average separation distance, but of the likelihood of zero or scant separation. Although none of these studies reports on the distribution of separation distance, the first two show a strong decline in the variability of motorist position, its main component, which can decrease the probability of near-zero separation even if mean separation decreases. Moreover, the clear shift in position by cyclists, whose accumulated experience is bound to include low-probability events such as vehicles passing with scant clearance, suggests that marking bike lanes improves objective as well as perceived safety.

The second argument that vehicular cyclists have advanced against bike lanes is that where they lie along parking lanes, they increase cyclists' risk of dooring by "guiding them" to keep to the right rather than control the lane. To eliminate the dooring hazard, a bike lane should

reach 14.5 feet (4.4 m) from the curb (NACTO 2011); however, many bike lanes reach only 12 or 13 feet from the curb, and a cyclist riding in the middle of such a lane is at risk of dooring. Van Houten and Seiderman (2005) tested the effect of marking bike lanes on motorist, cyclist, and parked car position on a 44-foot-wide street with parallel parking. In the first stage, the only marked line was a double yellow centerline; in the final stage, bike lane lines divided each half of the road into a 7-foot-wide parking lane, a 5-foot-wide bike lane (thus the "reach" was 12 feet), and a 10-foot-wide travel lane. Marking the bike lane shifted bicyclists an average of 2.4 inches (6 cm) further from parked cars and decreased the fraction of cyclists riding in the most vulnerable position, less than 9.0 feet (2.7 m) from the curb, by 12 percent. The likely mechanism for this shift is that the added lines serve to confine and push motor traffic toward the centerline, giving cyclists more confidence about riding further to the left. Thus, when user behavior is accounted for, bike lanes are more effective in reducing the dooring hazard than having an undivided shared lane.

Landis, Vattikuti, and Brannick (1997) and Harkey, Reinfurt, and Knuiman (1998) developed models of cyclists' comfort based on ratings given by cyclists. Both found that marking bike lanes had a strong positive effect on cyclists' perceived safety beyond the effect that could be attributed to available roadway space. With either model, subdividing a wide outside lane into a travel lane and a bike lane improves level of service by 90 percent of a grade change on a scale of A (best) to F. Based on these studies, several state highway departments, including Florida and Massachusetts, no longer recommend wide outside lanes as a form of bicycle accommodation.

Bike Lane Criteria for Low-Stress Cycling

In some traffic environments and with adequate width, lines alone can be sufficient to create a low-stress bicycling environment. Zwolle, the Netherlands (Ligtermoet 2010), and Davis, California, are cities in the population range of 50,000 to 120,000 that have achieved high levels of bicycle use relying mainly on a combination of wide bike lanes (2 m) and standalone paths with grade separated crossings. Marked buffers make bike lanes effectively wider (figure 6.5), providing a degree of separation that begins to approach that of a cycle track. Portland has recently

Figure 6.5
Bike lane in Delft is wide, paved red, and has marked buffers on both sides. *Credit:* Peter Furth.

installed a pair of 6-foot bike lanes with 2-foot buffers marked on either side in an attempt to provide a low-stress, yet low-cost, bicycling facility.

However, in many traffic environments, bike lanes can subject users to far more traffic stress than the mainstream population will accept. This is why Dutch criteria shown earlier in table 6.1 recommend bike lanes for only a limited combination of traffic speeds, volumes, and number of travel lanes. In addition, low-stress bike lanes should satisfy criteria related to right-turn conflicts and clearance from parked cars.

Because of the variability in parking lane width (widths of 7–12 feet are common in the United States), the key dimension for a bike lane next to a parking lane is not its width but its reach from the curb. Because of the dooring hazard, 14.5 feet is the desirable reach for a bike lane next to a parking lane. Before any smaller reach is considered, other road dimensions (e.g., travel lanes, median offset) should be reduced to their minimum, because a smaller reach represents a safety compromise.

Unfortunately, the AASHTO Guide (1999, 22) calls a configuration with a 13-foot reach (8 feet of parking, 5 feet of bike lane) "desirable" for a bike lane next to a high-turnover parking lane. Designers unfamiliar with cyclists' needs have often followed these dimensions even where space for a greater reach was available.

The most recent Dutch guidelines are blunt: "Cycle lanes are not recommended in combination with parking bays" (CROW 2007, 118). If there must be a parking lane next to a bike lane, Dutch guidelines recommend marking a buffer between the parking lane and the bike lane. They also suggest that a superior solution is to narrow the road by eliminating the bike lane and using that space to make a cycle track at sidewalk level.

Where there is heavy right-turning traffic, a common solution is to use a "pocket bike lane" positioned between a through lane and a right-turn lane. With this configuration, the conflict between cyclists and right-turning cars is resolved at a weaving point upstream of the intersection. For a pocket bike lane to qualify as low-stress, the right-turn lane must begin abruptly to the right of the bike lane, with the bike lane continuing straight and uninterrupted, so that cyclists' priority at the weave point is unambiguous. Additionally, the right-turn lane should be short so that cars driving in it can't go fast. Unfortunately, many pocket bike lanes in the United States do not have these properties. On many arterials, the right travel lane becomes a right-turn lane, forcing cyclists to weave across a lane of full-speed traffic to get from their curbside bike lane to a pocket bike lane.

An alternative to pocket bike lanes, frequently used in the Netherlands and Germany, is a "refuge cycle track," a short section of elevated cycle track on an intersection approach (figure 6.6). Refuge cycle tracks give cyclists a more secure place to queue and, by using separate signal phases, allow them to pass through the intersection without any conflict with right-turning cars.

Contraflow on One-Way Streets

Contraflow bicycling, in which streets are designated as two-way for bicycle travel even though they are one-way for motor traffic, improves safety and mobility for cyclists in many ways. Contrary to often-heard objections, contraflow is consistent with the "rules of the road": traffic

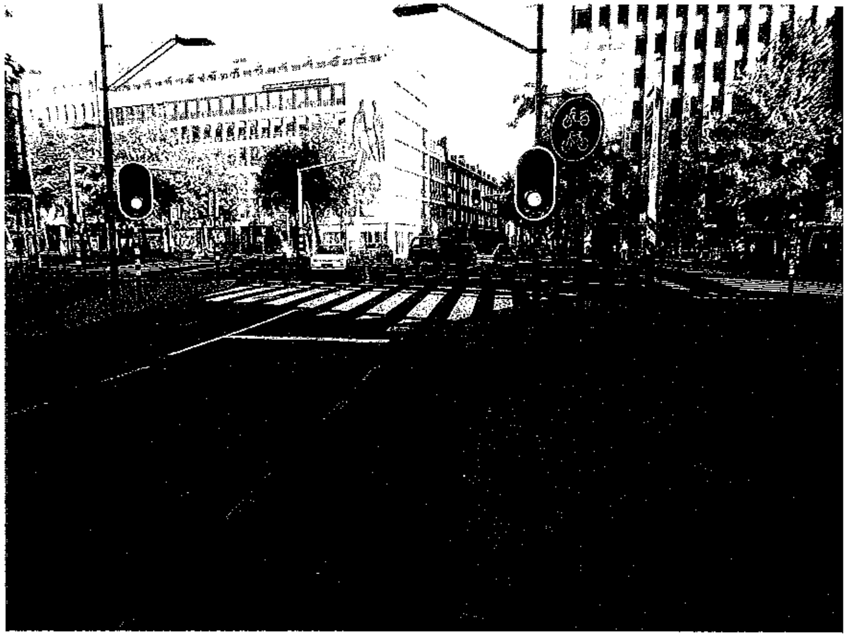

Figure 6.6
Refuge cycle track in Rotterdam gives cyclists a protected place to queue far in advance of the cars' stopline and bundles motor vehicle conflicts with pedestrians and bicycles at a single point. *Photo:* Kevin Levesque.

in either direction keeps to its right, and the street functions like any other two-way street, except that motor vehicles aren't permitted in one direction. Contraflow allows cyclists, who—like pedestrians—operate under their own power, to avoid around-the-block detours. On many one-way streets, cyclists already ride contraflow in considerable numbers, often using the sidewalk; legalizing contraflow helps reduce sidewalk cycling, and the signs and markings that come with formalization improve safety at intersections by raising driver expectations.

In many cities, one-way restrictions keep through traffic from using neighborhood streets, making those neighborhood streets a far safer bicycling environment than riding on the arterials. Brussels's designated bicycle network relies heavily on contraflow for creating bike routes along low-traffic streets. For the same reason, the bicycle network plan for Brookline, Massachusetts, calls for contraflow on fourteen streets, of which two have been implemented as of early 2012.

Germany, France, Belgium, and the Netherlands have all followed the progression of first forbidding bicycle contraflow, then allowing it by exception, and ultimately making contraflow the default treatment for one-way streets in residential areas and in historic downtowns (Covelier 2008). Blanket application of contraflow is seen as a remedy to the injury done to cycling by one-way schemes introduced in the 1970s to facilitate traffic and parking. German research a few years after contraflow was legalized in several communities in 1997 found that most sites had no bicycle collisions and that where they occurred, their frequency and severity was no worse for contraflow cyclists than for with-flow cyclists (Alrutz et al. 2002). Recognizing the successful continental European experience with contraflow, recent British guidance is: "Where one-way systems are introduced, consideration should always be given to maintaining two-way working for cycles through contraflow, if it can be safely accommodated" (Department for Transport 2008, 37).

Contraflow can be implemented with three levels of separation from opposite direction traffic. One extreme is to use a barrier, making the contraflow lane a cycle track, as on University Avenue in Madison, Wisconsin. A second is to mark a contraflow lane using a continuous lane line that acts as a centerline, separating opposite direction travel. The most common treatment in Europe does not mark any lane line or centerline, consistent with the standard treatment used on two-way local streets; it uses only signs and sometimes intermittent markings to alert road users to two-way bicycle traffic. This treatment, recently applied in Washington, D.C., allows contraflow on streets too narrow to have an exclusive bike lane.

European experience has shown no problem with bicycle contraflow next to a parking lane. The risk of injury from dooring to a contraflow cyclist is much smaller than when riding with the flow because (1) the cyclist rides next to the passenger side doors, which are used far less often; (2) the car occupant faces the cyclist; and (3) if a contraflow cyclist hits an opening door, the impact tends to close the door rather than open it further.

In the United States, although the *Manual on Uniform Traffic Control Devices* (FHWA 2009a) recognizes contraflow bicycling, the AASHTO *Guide* discourages it, and only a handful of applications exist. Views persist that contraflow promotes lawlessness and that it will lead to head-on collisions, even though the opposite-direction encounters that contraflow legitimizes are no different than those that occur countless times per day on millions of local two-way streets. For example, Boulder, Colorado, officials insisted that a one-block contraflow lane on 13th Street be separated by a raised median, even though the block has only one lane for motor traffic and is so short (600 feet or 180 m between stop signs) that traffic speed is low.

Road-Sharing and Lane-Sharing Treatments: Advisory Lanes and Sharrows

On streets too narrow to mark exclusive bike lanes, both Europeans and Americans have developed treatments to make road sharing safe and less stressful. In Europe, the common treatment is advisory bike lanes, described earlier (figure 6.4). They give cyclists almost the same low-stress environment as an exclusive bike lane, because the markings make it plain that the edge zones are for cyclists and that motorists may enter them only where there is a gap in cyclist traffic. Minneapolis introduced the first US application of advisory lanes in 2011.

The principal American road-sharing treatment is sharrows ("shared lane arrows"), a bicycle silhouette topped by a double chevron, usually marked every 200 feet (65 m) in the middle or right third of a travel lane in order to encourage cyclists to ride at a safe distance from parked cars. Sharrows are used on both two-lane and multilane roads. A San Francisco study (Alta Planning + Design 2004) showed limited effectiveness; when influenced by an overtaking car, sharrows shifted the average cyclist position to the left by only 4 inches (10 cm), indicating that sharrows do little to increase cyclists' willingness to control the lane. Surveys also showed that few cyclists or motorists understood their meaning. Alhough some cyclists feel that sharrows give them legitimacy when controlling the lane, there is a danger that sharrows will become a cop-out, a way for a city to claim that it's created bike routes without really doing anything to improve bicycling conditions.

Advisory lanes in Europe have proven acceptable to mainstream cyclists, including children and seniors, but there is no such evidence for sharrows. A subtle but fundamental difference is that advisory lanes are a *shared road* treatment, but sharrows—which almost always leave the centerline and (on multilane roads) lane lines intact—are a *shared lane*

treatment. The European approach delineates the bicyclists' space and allows motor vehicles to share it, as guests, when they need to. The American approach delineates motor vehicle lanes and then asks cyclists to ride in the middle of them.

Bike Routes Using Quiet Streets

Local streets, which typically have low traffic speeds and volumes, are vital for people to have access to the bicycle network. In addition, local streets can be used to form main bicycle routes. The concept is more complex than it may first appear, because the very factors that keep through traffic from using local streets—for example, being discontinuous or labyrinthine—also make them unsuitable for through bicycling.

Creating a bike route along quiet streets can be approached from two directions. One is to take an existing long, continuous street and apply measures to divert and slow traffic while allowing bikes to pass through. The West Coast cities of Berkeley, Palo Alto, and Portland have taken advantage of their grid street network to make selected streets "bicycle boulevards" using partial street closures and median barriers to divert through motor traffic, along with traffic circles and speed humps to slow traffic (Walker, Tressider, and Birk 2009; Pucher, Dill, and Handy 2010; Pucher, Buehler, and Seinen 2011). Another diversion treatment is applying reversing one-way restrictions in conjunction with bicycle contraflow (Department for Transport 2008, 38).

The second approach is to connect discontinuous local streets using bicycle-pedestrian links such as short sections of path to connect cul-de-sacs or provide a shortcut through parks or bridges and underpasses to overcome barriers such as highways and streams. Many new European suburbs make extensive use of this strategy, making local streets that are discontinuous for cars but continuous for bikes and pedestrians.

Bike routes that follow quiet streets often need safety treatments where they cross main roads such as median refuges or signalization. Where they meet main streets at T junctions, a short section of cycle track may be needed on the main street until the path can resume on the next local street. If bikes have to ride in the road along the main street, intersection safety is better if the route involves a left turn onto the main street.

Routes that follow local streets can be difficult to follow, necessitating wayfinding signs or markings. The Netherlands has a well-developed system of wayfinding signage that American cities, led by Portland, have begun to emulate.

Traffic Calming in City Centers and Beyond

The historic road network's focus on city centers makes them strategic for bicycling. If the city center is dominated by cars, it can effectively cut one side of the city off from the other. Several European cities employ traffic diversion schemes to prevent through traffic through the historic center, forcing cars to leave the center at the same access point where they entered. Where these diversions are permeable to bikes, it can make the entire central area open to low-stress bicycling (Pucher and Buehler 2008; Pucher, Dill, and Handy 2010) without a need for bike-specific treatments such as bike lanes or cycle tracks.

Houten, a "new town" suburb of Utrecht in the Netherlands, has extended this model to encompass the entire town of 45,000 people. Two ring roads surround the town, meeting to form a figure eight. Within the rings, through traffic by car is not possible; to get from one side of town to another, cars must use the ring road. The ring roads have many access points, preventing any large concentration of traffic on the interior streets. The interior streets have turns every 75 m or less, making the 30 km/h speed limit self-enforcing. Without bike lanes or cycle tracks apart from standalone paths through parks, the town is a paradise of low-stress bicycling, with 40 percent of trips made by bike, earning it the title "Bicycle City" by the national Bicyclists Union in 2008.

Network Density

So far, this section has described treatments that can be used to create low-stress bicycle routes. To be effective, these routes must form a network connecting neighborhoods with destinations such as employment sites, schools, shopping areas, recreation areas, and train stations.

In built-up areas, the network must inevitably take the form of a fine mesh. The Dutch *Design Manual* recommends a mesh of 250 m (about one-sixth of a mile) (CROW 2007, 65); however, the mesh at this level is mostly for local access. More important is the spacing for *through* bicycle routes, which can be measured at linear barriers such as rivers and wide roads. For example, in Delft, the average spacing of bike routes across barriers is 400 m (0.25 miles) at the provincial highway and at the extended Zuidwal, and 750 m (0.45 miles) at the railroad, main canal, and freeway. With this dense a mesh, access to all neighborhoods and meaningful destinations is virtually assured.

Funding Bicycling Infrastructure

The development of bicycling infrastructure in the United States has been hindered by three principal barriers, as illustrated poignantly in Birk's (2010) story of Portland's birth as a bicycle-friendly city. One is lack of popular interest, something that has clearly turned around in many American cities. Second is national engineering guidance biased in favor of vehicular cycling, which may also have reached a turning point with the publication of the NACTO bikeway design guide (NACTO 2011). The remaining hindrance is the political question of funding for bikeway improvements.

Although developing a high-quality bicycle network is inexpensive compared to a highway or rail network, it still requires considerable investment. Interviews with officials from three Danish cities revealed annual per capita expenditures on bicycle route infrastructure of between $11 to $27; Dutch officials quote a national average of €37 ($50), plus an equal amount spent on bicycle parking and noninfrastructure programs—and these are countries that already have an excellent existing network. In the United States, Portland has estimated that a citywide network of low-stress bike routes would require an investment of $773 million to put all residents within 0.25 miles (400 m) of a low-stress bikeway, or $329 million to reach 80 percent of the population (Gotschi 2011); Austin estimates that its bikeway network will cost $250 million. Spread over twenty years, these investments would involve spending between $20 and $66 per capita per year.

What mechanisms might be invoked to secure this level of funding? The first is bicycle accommodation laws and policies, which require providing bicycling infrastructure on road construction projects. In the United States, bicycle and pedestrian needs must be "considered" on federally funded road projects; as of early 2012, Congress is considering legislation that would mandate their accommodation. Because bicycling by nature occurs mostly on nonregional streets, accommodation or "complete street" policies are especially important at the local level. A small but growing number of states and local jurisdictions have adopted "complete street" policies (ABW 2012).

Second, engineering guidelines should stop discouraging separated bike paths and should include criteria for separation from traffic that responds to the needs of traffic-intolerant users. Without those changes, accommodation or "complete street" requirements have little actual impact. For example, because Massachusetts until recently recognized "wide outside lanes" as a form of bicycle accommodation, the state's accommodation law was satisfied on several projects by simply making the outer travel lanes a bit wider.

Third, planning regulations can require that land development projects include bicycling infrastructure. We have already cited examples of cities requiring developers to build regional paths within their developments; traffic mitigation requirements can also ensure that appropriate route sections and crossings be provided as part of private development projects.

A fourth mechanism is piggybacking on infrastructure projects. In addition to the earlier example of Boulder taking advantage of flood control projects to build underpasses for bike trails, Portland is using $20 million from a large stormwater project to turn several local streets into "neighborhood greenways" with low-stress bike routes. Marking bike lanes when streets are repaved is the most popular piggybacking scheme.

In many cities, one can see scattered sections of bike lane here and there as repaving and mitigation opportunities have been exploited. Clearly, reactive mechanisms alone are insufficient; deliberate funding is also needed in order to supply vital links that cannot be realized opportunistically. Some examples in the United States include Washington, D.C., where approved projects in 2010 amounted to $8 per capita per year, and Oregon, which since 1971 has required that 1 percent of state highway funds be devoted to bicycles and pedestrians—a factor that has helped make Portland, Eugene, and Corvallis among the most bicycle-friendly cities in the United States.

In most communities, the federal government has been the main source of funding for bicycling infrastructure through programs such as Transportation Enhancements, Recreational Trails, and Congestion Mitigation and Air Quality. Yet over the period 2000–2008, annual federal expenditure for bicycle and pedestrian projects combined rose from $1 to a paltry $1.50 per capita (FWHA 2009b). That level of funding would enable a city of 500,000 people to develop less than one mile of path per year; a single bridge could consume twenty years' funding. Clearly, another funding model is needed. In 2005, the Non-Motorized Transportation Pilot Program provided one-time funding of $25 million to four different communities in order to demonstrate the ability of better infrastructure to encourage more walking and bicycling. That amounted to $170 per capita for Columbia, Missouri, but only about $8 per capita for Minneapolis. The Rails-to-Trails Conservancy and other advocates are currently trying to garner support for an expanded program providing $25 to $75 million to each of forty communities.

Conclusion

For bicycling to contribute meaningfully to societal goals in the areas of public health, livability, traffic congestion, and energy use, it has to appeal to the mainstream, traffic-intolerant population. Bicycling infrastructure in many parts of Europe has been successful in achieving mass cycling because it respects the fundamental human need to be separated from traffic stress. This chapter has shown how the antiseparation vehicular cycling ideology has stymied America's development of bicycling infrastructure and how that influence is waning as American communities begin to embrace the European attitude and infrastructure designs. A huge challenge still remains for how the needed infrastructure will be funded. A promising model is to build as much as possible with whatever funds can be found and to trust that the resulting growth in bicycle ridership will create the public pressure and political climate that makes additional funding possible. It is this writer's opinion that the turning point will be when children begin again riding bikes to school in large numbers. When bicycle infrastructure and children's safety become intertwined, funding for bicycle infrastructure will be secure.

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