

BIKESAFE:

Bicycle Countermeasure Selection System



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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	oC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
oC	Celsius	1.8C+32	Fahrenheit	oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²
*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)				

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HOW TO USE THIS GUIDE

BIKESAFE is an expert system that allows the user to select appropriate countermeasures or treatments to address specific problems. BIKESAFE also includes a large number of case studies to illustrate treatments implemented in communities throughout the United States.

This system and the content of this guide are included on the enclosed CD and are available online at <http://safety.fhwa.dot.gov/bikesafe> and at <http://www.bicyclinginfo.org/bikesafe>. The system allows the user to refine his or her selection of treatments on the basis of site characteristics, such as geometric features and operating conditions, and the type of safety problem or desired behavioral change. The purpose of the system is to provide the most applicable information for identifying safety and mobility needs and improving conditions for bicyclists within the public right-of-way. BIKESAFE is intended primarily for engineers, planners, safety professionals, and decisionmakers, but it may also be used by citizens for identifying problems and recommending solutions for their communities.

BIKESAFE was designed to enable practitioners to select engineering, education, or enforcement treatments to help mitigate a known crash problem and/or to help achieve a specific performance objective. While the majority of the specific treatments are engineering countermeasures, many of the case studies include supplemental enforcement activities (e.g., a course that teaches police about enforcing bicycle safety) and/or educational approaches (e.g., educating people about riding on shared roadways or on roads with bicycle facilities). BIKESAFE uses known characteristics of the environment and permits the user to either view all countermeasures associated with a given objective or crash type or to view only those that are applicable to a defined set (as input by the user) of geometric and operating conditions. The objectives of the product are as follows:

- Provide information about bicycle crash types, statistics and other background resources.
- Provide user with information on what countermeasures are available to prevent specific categories of bicycle crashes or to achieve certain performance objectives.
- Outline considerations to be addressed in the selection of a countermeasure.
- Provide a decision process to eliminate countermeasures from the list of possibilities.
- Provide case studies of countermeasures introduced in communities throughout the United States.

Chapter 1 – The Big Picture gives an overview on how to create a safe bicycling environment. Chapter 2 – Bicyclist Crash Statistics describes basic bicyclist crash trends and statistics in the U.S. Chapter 3 – Selecting Improvements for Bicyclists discusses the approaches to select the most appropriate countermeasures. One approach is based on the need to resolve a known safety problem, while the other is based on the desire to change behaviors of motorists and/or bicyclists.

Chapter 4 – The Expert System describes the Web/CD application, including a description of the overall content and step-by-step instructions for use. Chapter 5 – Countermeasures contains the details of more than 50 engineering, education, and enforcement treatments for bicyclists. These improvements relate to shared roadways; on-road bike facilities; intersection treatments; maintenance; traffic calming; trails/shared-use paths; markings, signs, and signals; education and enforcement; and support facilities and programs. In Chapter 6 – Case Studies are more than 50 examples of implemented treatments in communities throughout the U.S.

Further resources are provided in Chapter 7 – Implementation and Resources, including sections on community involvement in developing priorities, devising strategies for construction, and raising funds for bicycle improvements. A list of useful Web sites, guides, handbooks, and other references is also provided.

There are also two appendices with supporting materials. Appendix A includes an assessment form that can be used in the field to collect the information needed to effectively use the expert system. Appendix B provides a detailed matrix showing the specific countermeasures that are associated with each of the case studies.

Chapter 1 – The Big Picture



Land Use and Bicycling

Assume That People Will Bicycle

Transit and Bicycling

**How Bicyclists are Affected by Motor
Vehicle Traffic Volume and Speed**

Options to Improve Bicycling

Bicycling is one of the oldest forms of human transportation, yet the modern-day cyclist faces problems related to suburban living and motor vehicle speed and traffic volume, among others. The various kinds of facilities needed to maintain bicycling as a viable transportation mode have been frequently overlooked in the building of modern transportation systems. This situation has been changing in recent years, and now people want more ways to get around their communities and elsewhere via bicycle. And they want to be able to make these bicycling trips in a safe and enjoyable manner.

The bicyclist is a vulnerable road user, and creating a safer bicycling environment involves more than striping a bike lane or re-striping motor vehicle travel lanes to accommodate a wide curb lane or even building a separated path. A truly viable bicycling network involves both the big picture and the smallest details—from how a community is built and connected, to the maps that indicate safe bicycling routes, to the surface materials on the bike path. Bicycling facilities should be accessible to various types of users, and information should be provided about the level of skill necessary on a certain route.

Because most of the work that will be done involves retrofitting existing roads, streets, and trails, improving the bicycling environment will likely start at the community level. It is not only important to identify bicycling corridors within a community and determine if improvements need to be made, but also to examine overall connectivity within the community.

LAND USE AND BICYCLING

The nature of the built environment is important not only for walking but also for bicycling. Community characteristics that foster bicycling include: having destinations close to each other; choosing sites for schools, parks, and public spaces appropriately; allowing mixed-use developments; having sufficient densities to support transit; creating commercial districts that people can access by bicycle (or foot and wheelchair); providing adequate, visible, secure parking, and so on. About 57 percent of bicycling trips are less than 3.2 km (2.0 mi).¹ When residents are segregated from sites such as parks, offices, and stores, there will be fewer bicycling trips because destinations are not close enough for bicycling. While mixed-use developments with sufficient density to support transit and neighborhood commercial businesses normally make bicycling a viable option for residents, single-use, low-density residential land-use patterns can discourage bicycling, especially if the con-



PHOTO BY DAN BURDEN

Bicycling on local streets can be an enjoyable form of transportation and recreation.

necting roads to other destinations have high speeds and traffic volumes and inadequate bicycle facilities.

The connection between land-use planning and transportation planning is critical but all too often ignored. Integrating land-use and transportation planning allows new developments to implement these strategies from the onset. Communities that support balanced transportation systems make bicycling an attractive option.

In established communities, many of these goals can be met with “in-fill development” to increase density and community viability. In addition, providing appropriate bicycling facilities between desirable destinations will result in more bicycle trips.² The facility may be as simple as a normal-width shared lane on a street with low traffic volumes and slow motor vehicle speeds. Sometimes low-volume, slow-speed streets become bicycle boulevards through neighborhoods. As motor vehicle traffic volume and speeds increase, providing space for bicyclists through bike lanes or wide curb lanes becomes more important. Sometimes providing a separated bicycle path may be nec-



The nature of the built environment is important for bicycling.

essary to provide a link between areas that have no streets suitable except for the most experienced bicyclists.

ASSUME THAT PEOPLE WILL BICYCLE

Bicycles are vehicles and are able to travel on a wide variety of roadway types. It should be assumed that bicyclists will want to ride, and plans should be made to accommodate them. The Federal Highway Administration (FHWA) has encouraged routine accommodation for bicyclists (and pedestrians) for many years, and the concept has been embraced by many state and local departments of transportation (DOTs). More detail on routine accommodation is available at <http://www.fhwa.dot.gov/environment/bikeped/guidance.htm>.

The bicycle can be used to commute to work, to run errands, to visit neighbors, to go to local stores, to transport children, to get exercise, or for recreation. Skill levels among bicyclists will vary, and novices may only feel comfortable on slow-speed, neighborhood streets or off-road paths. The experienced bicyclist will tend to feel comfortable on higher-speed, higher-volume streets if adequate *space* is provided. The space usually results from facilities such as bike lanes, paved shoulders or wide curb lanes.

Bicycling can also be encouraged by retrofitting existing streets on corridors bicyclists are known to frequent. Retrofitting could involve such things as removal of parking, narrowing of travel lanes to slow motor vehicle speeds, and using the space added from lane narrowing to accommodate bike lanes, paved shoulders or wide curb lanes.

Communities interested in promoting bicycling need to know where bicyclists ride, as well as where they want to ride. Once desired corridors are identified, inventory can be taken to identify on-street deficiencies. Deficiencies appear in many forms, including poor pavement quality, narrow streets with not enough space to share a lane with motor vehicles, inadequate space on bridges, problem intersections, etc. Deficiencies can often be improved, but sometimes right-of-way is a problem, and a separate trail or path may be needed to fill a gap.

Besides facility improvements, it is also beneficial to provide a pleasant and interesting bicycling environment. The built and natural environments are therefore important components of a pleasing bicycling environment. The environment may also be improved in part through landscape design elements, which can improve aesthetics,



PHOTO BY DAN BURDEN

Besides providing a pleasant place to ride, a separated trail can provide a desired connection.

offer a sense of visual narrowing, and perhaps slow traffic speeds. Proper use of serpentine or other traffic calming measures can accomplish the same thing.

Bicyclists also want to ride in an environment where they feel safe, not only safe from motor vehicle traffic, but also safe from crime or other concerns that can affect personal security. Lighting and other security measures should be considered in certain locations.

Traditionally, traffic safety problems have been addressed by analyzing police crash reports and improvements have been made only after they were shown to be warranted by crash numbers. However, planners, engineers and other practitioners should consider problem-identification methods such as interactive public workshops, surveying bicyclists and drivers, and talking with police to identify safety problems in an area before crashes occur. These measures may help proactively identify locations for bicycle safety improvements and will involve citizens in the process of improving safety and mobility in their own communities.

TRANSIT AND BICYCLING

Bicycling and transit are complementary. In many communities, bicycle racks are provided on buses, enabling what might be a long bicycling trip to be shortened by using transit for part of the journey. Once bicyclists get used to placing their bikes on the racks, the process tends to flow easily. Friendly and comfortable transit stops are also a plus. Some consideration needs to be given to the on-street riding conditions around transit stops frequented by bicyclists making use of bus racks. It may be relatively easy to implement minor changes that make the bicycling part of the trip to or from the transit stop much

safer and comfortable. Feeling unsafe on the bicycle for even a short distance may discourage use of a combined bike-bus trip.

It is also the case that carrying a bicycle onto a train is much more common than in the past. For example, Caltrain in the San Francisco area has become very accessible for bicyclists. Such access is yet another way to combine bicycling with another mode of transportation.

HOW BICYCLISTS ARE AFFECTED BY MOTOR VEHICLE TRAFFIC VOLUME AND SPEED

A bicycle can be ridden on almost any kind of roadway, yet certain traffic conditions create a sense of discomfort, even for the skilled bicyclist. A high volume of traffic is one of those conditions and can inhibit a bicyclist's feeling of safety and comfort. This is particularly true when no bicycle facilities exist on these roadways.

Motor vehicle traffic speed is equally critical to bikeability and safety. Though bicyclists may feel comfortable on streets that carry a significant amount of traffic at low speeds, faster speeds increase the likelihood of bicyclists being struck and seriously injured. At higher speeds, motorists are less likely to stop in time to avoid a crash. At a mere 49.9 km/h (31 mi/h), a driver will need about 61.0 m (200 ft) to stop, which may exceed available sight distance. Reducing speed limits and subsequent motor vehicle speeds should improve bicycle safety. A driver traveling at 30.6 km/h (19 mi/h) can stop in about 30.5 m (100 ft).³

Unfortunately, many of our streets are designed to accommodate higher motor vehicle traffic volumes and



If done properly, slowing speeds through traffic calming measures such as speed humps can improve safety for bicyclists, as well as pedestrians and motorists.

speeds in an attempt to better handle peak hour congestion. Most bicyclists will try to avoid these streets if possible, but a problem exists if these same streets are part of a bicycling corridor. Fortunately, there are tools that can improve the speed profile, primarily by redesigning streets through traffic calming measures. However, care must be taken to ensure that the traffic calming method is suitable for bicycling. New streets can also be configured with lower design speeds without a great sacrifice in capacity. Speed reductions can increase bicycling safety considerably. The safety benefits of reduced speeds extend to motorists and pedestrians as well. On slow speed city streets and lightly traveled roadways, bicyclists may safely operate in the normal traffic lanes. However, on heavily traveled streets, bicyclists need *space* to operate and to provide room for overtaking motorists. Space can be provided through the use of bike lanes, paved shoulders, or wide curb lanes (although wide curb lanes may not be the best choice for a high-speed and high-volume combination), and these facilities can often be created through the narrowing of traffic lanes through remarking, or what has come to be known as “road diets” (e.g., reducing traffic lanes from 3.7 m (12 ft) to 3 or 3.4 m (10 or 11 ft). More detail about traffic calming and road diets is provided in later sections.

COMPLETE STREETS

A movement called “Complete Streets” has been actively growing since about 2001. This builds on the previous concept of routine accommodation for bicyclists and pedestrians. “Complete Streets” is meant to convey a win/win for all parties who use the street. A statement of philosophy is contained on the America Bikes Web site:



High motor vehicle traffic volume can create a sense of discomfort for bicyclists when they don't have space.

Complete streets provide choices to the people who live, work and travel on them. Pedestrians and bicyclists are comfortable using complete streets. A network of complete streets improves the safety, convenience, efficiency and accessibility of the transportation system for all users. Every road project should create complete streets.

Completing the streets means routinely accommodating travel by all modes. This will expand the capacity to serve everyone who travels, be it by motor vehicle, foot, bicycle, or other means. A complete street in a rural area may look quite different from a complete street in a highly urban area. But both are designed to balance safety and convenience for everyone using the road.

The Complete Streets concept promotes changing the way designers think about the street. Instead of curb to curb, they should think more completely, such as building face to building face. Besides improving safety for bicyclists and pedestrians, completing the streets should encourage more people to bicycle and walk. States that have incorporated this type of thinking into their design policies include New Jersey and California, both of whom have new guidebooks promoting flexibility in design of main streets.^{4,5} The Thunderhead Alliance has developed a report with information about “Complete Streets” laws, policies, and plans in the United States.⁶



This street comfortably accommodates all users.

OPTIONS TO IMPROVE BICYCLING

There are many ways to improve the conditions for bicycling. The following chapters provide information on general factors related to bicyclist-motor vehicle crashes (Chapter 2), and analysis of crash types and selecting appropriate countermeasures (Chapter 3). Chapter 3 also provides information on selecting treatments for more general performance objectives. Chap-

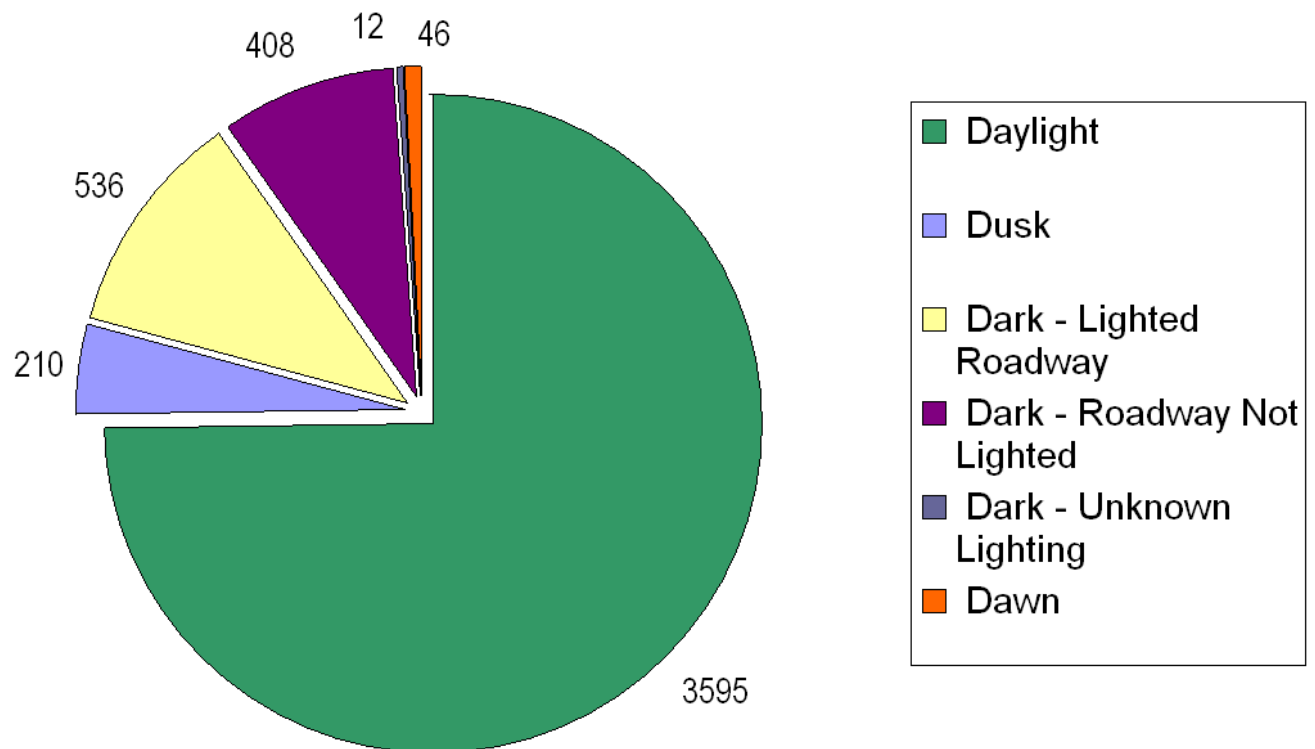
ter 4 describes the features of BIKESAFE and how to use the Web or CD-based applications. Descriptions of countermeasures, organized into general categories, are included in Chapter 5. Chapter 6 contains over 50 case studies describing implementation tips, and additional resources are documented in Chapter 7.

The Web application also allows the user to explore many countermeasure (or treatment) choices based on particular crash problems *or* performance objectives. For example, a crash problem might involve overtaking motorists striking bicyclists from the rear on a busy corridor with inadequate space. A performance objective might be to provide safe intersections for bicyclists.

These bicycling improvements represent the current best thinking of the authors and expert panel. Some of the improvements have been formally evaluated and are referenced within this document. The remainder have been implemented in a number of locations across the United States and around the world and are felt to be worthy of use. Carrying out carefully conducted evaluations and publishing the results are vital steps to improving the safety of bicycling.

Chapter 2 – Bicyclist Crash Factors

**Bicyclist-Motor Vehicle Crashes by Light Condition -
1997-2003 NC Data**



Magnitude of the Problem

Alcohol Involvement

Bicyclists Most at Risk

Special Situations Involving Bicyclists

Place and Time of Occurrence

Chapter 1 provided an overview of the need to provide a more bicycle-friendly environment on streets and highways. This chapter provides an overview of the bicycle safety problem and related factors that must be understood to select appropriate facilities and programs to improve bicycle safety and mobility. A brief description of the bicycle crash problem in the United States is discussed in the following sections and is also reported by Hunter, et al. in a related publication.¹ Similar statistics should be produced for States and municipalities to better understand the specific problems at the community level and thus select appropriate countermeasures.

MAGNITUDE OF THE PROBLEM

Bicycle/motor vehicle crashes are a serious problem throughout the world. The United States has a particular problem with bicyclist deaths and injuries.

Specifically, 622 bicyclists were reported to have been killed in motor vehicle crashes in the United States in 2003.² These deaths accounted for 1.5 percent of the 42,643 motor vehicle deaths nationwide that year. An estimated 46,000 bicyclists were injured in motor vehicle collisions, which represent 1.6 percent of the 2.9 million total persons injured in traffic crashes.²

These bicycle crashes with motor vehicles are a primary source of information on events causing injury to bicy-



PHOTO BY DAN BURDEN

Fatality and injury crash rates are lower for bicyclists age 65 and older compared with other age groups.

clists. However, these data are frequently referred to as the “tip of the iceberg,” in that these crashes are limited almost entirely to events that occur on public roadways. Thus, possible exclusions include bicycle-motor vehicle crashes that occur in non-roadway locations such as shared-use paths, parking lots, driveways, and sidewalks, as well as falls or other non-collision events that do not involve a motor vehicle, regardless of whether they occur on a roadway or in a non-roadway location. In a study using data collected at eight hospital emergency departments from three states, Stutts and Hunter found that 70 percent of the reported bicycle injury events did not involve a motor vehicle. In addition, 31 percent of the bicyclists were injured in non-roadway locations such as sidewalks, parking lots, or off-road trails.³

Bicyclist fatalities in collisions with motor vehicles decreased 23.3 percent between 1993 and 2003, and bicyclist injuries in collisions with motor vehicles decreased 35.3 percent during the same period. It does not appear that these declines are due to less bicycling. Based on the *National Personal Transportation Survey* data, the reported number of bicycling trips increased from 1.7 to 3.3 billion between 1990 and 1995. The *2001 National Household Travel Survey 10 Year Status Report* also indicated 3.3 billion reported bicycling trips.^{4,5} The *National Bicycling and Walking Study*⁵, published in 1994, had major goals of doubling the percentage of total trips made by bicycling and walking and simultaneously reducing by 10 percent the number of bicyclists killed or injured in traffic crashes. Progress is being made, and these continue to be important goals for all professions dealing with these non-motorized modes.



PHOTO BY DAN BURDEN

Some crashes occur when motorists turn right soon after overtaking bicyclists.

BICYCLISTS MOST AT RISK

Bicycle crashes affect all age groups, but the highest injury and fatality rates (per population) are associated with younger riders. The 10 to 15 age group has both the highest fatality rate and the highest injury rate.² This age group is more associated with ride-outs from driveways and intersections, swerving left and right, riding in the wrong direction and crossing midblock.¹ Bicyclists under age 16 accounted for 23 percent of all bicyclists killed and 37 percent of bicyclists injured in crashes with motor vehicles in 2003. There is a trend of bicyclists age 25 and older accounting for an increasing proportion of bicyclist deaths since 1993, which likely reflects more riding (exposure) by this group. The fatality and injury crash rates for bicyclists age 65 and older are generally lower than for other age groups, and this likely reflects where and when they ride—generally in safer locations and at safer times of day—and most likely that they ride less.^{1,2}

Male bicyclists are more likely to be involved in crashes than females. In 2003, 88 percent of bicyclists killed and 78 percent of bicyclists injured were males. Similarly, the fatality and injury rates per capita were higher for males.²

PLACE AND TIME OF OCCURRENCE

Once again, crash information tends to reflect exposure. Almost 70 percent of bicyclist fatalities occur in urban areas, and 71 percent occur at non-intersection locations. The hours of 5 p.m. to 9 p.m. account for 31 percent of fatalities, and the months of June, July, and August for 35 percent.²

Other locational information indicates that, for all bicycle-motor vehicle crashes¹:

- About one-third occur on local streets.
- About half are associated with intersections.
- About three-fourths occur on roads with speed limits of 35 mph or less.

ALCOHOL INVOLVEMENT

Driving under the influence of alcohol is a well-publicized issue as related to motorists in this country. It is also an issue for bicyclists. Alcohol involvement for either the bicyclist or motor vehicle driver was reported in more than one-third of the crashes that resulted in a bicyclist fatality in 2003. Some 28 percent of fatally injured bicyclists were reported to have a blood alcohol concentration (BAC) of 0.01 grams per deciliter (g/dl), and 24



PHOTO BY DAN BURDEN

Many bicycle crashes occur at intersections; a frequent factor involves the bicyclist not obeying traffic signals or stop signs.



PHOTO BY DAN BURDEN

The hours of 5 p.m. to 9 p.m. account for 31 percent of bicycle crash fatalities. Alcohol-related crashes are also more likely to occur during hours of darkness.

percent, a subset of the above group, had a BAC of 0.08 g/dl or higher.² Alcohol crashes tend to involve older bicyclists and are more frequent on weekends and during hours of darkness.¹

SPECIAL SITUATIONS INVOLVING BICYCLISTS

Within any community where bicycling occurs with any frequency, there are a number of situations that lead to problems. Efforts to improve these situations will lead to improved bicycle safety.

WRONG-WAY RIDING

Wrong-way riding, or riding facing traffic, remains a prevalent problem. This behavior puts bicyclists in a position where motorists are not expecting them to be, whether the bicyclist is in the street or on the sidewalk. An exam-



Sidewalk riding can be treacherous.

ple is a motorist making a right turn on red. The motorist is looking primarily to the left for a gap in traffic and may not recognize a bicyclist riding against traffic, either in the street or on the sidewalk.

SIDEWALK RIDING

Sidewalk riding is permitted in many, but not all, communities. Indeed, separated sidewalk bike paths, routinely used by both bicyclists and pedestrians, are sometimes used next to busy streets. If allowed on sidewalks, bicyclists need to basically travel at the speed that pedestrians walk, or about 5 to 8 km/h (3 to 5 mi/h). An inherent danger in sidewalk riding comes from the presence of driveways that cross the sidewalk. Motorists tend to drive across the sidewalk to get a better view of traffic, and this can lead to crashes with bicyclists riding on the sidewalk, especially those riding against the normal flow of traffic. The problem is similar to what is described above, where a motorist turning right from a driveway is looking primarily to the left for a gap in traffic. This same pattern is present at intersections, where bicyclists riding on the sidewalk may ride through the crosswalk, or bicyclists riding on a shared-use path or trail adjacent to the roadway may ride into the path of motor vehicles. Motorists tend to expect pedestrians to emerge from sidewalks. When bicyclists make this maneuver and travel considerably faster than pedestrians, the potential for crashes is increased.

PRESENCE OF DRIVEWAYS

Besides the potential crashes involving motorists in driveways and bicyclists on sidewalks mentioned above, considerable crashes also occur when motor vehicles pull into the street from a driveway and strike a bicyclist riding in the street. A variety of factors can be present in these crashes, including the size of the bicycle making it difficult to be seen, a bicyclist riding at night without proper lights, and poor sight distance at the driveway. Access control to limit the number of driveways on bicycling corridors can help. In addition, special signing and/or pavement marking at



Many crashes occur when motor vehicles pull into the street from a driveway and strike a bicyclist riding in the street.

the point the driveway crosses the sidewalk and enters the street can be useful remedies.

NIGHT BICYCLE RIDING

Data from the National Center for Statistics and Analysis indicate that 31 percent of bicyclist crashes occur between the hours of 5 p.m. and 9 p.m.² Not all of these crashes would result from lack of lighting associated



Lights and reflectors can make bicycling safer at night.

with the bicycle, but the problem is considerable. Analysis of recent data from North Carolina shows that almost 20 percent of bicycle-motor vehicle crashes occur under conditions of darkness (http://www.pedbikeinfo.org/pbcat/pdf/summary_bike_facts5yrs.pdf).⁶ An additional 5 percent of crashes occur at dusk. This is an educational issue for bicyclists, and local police need to be more willing to let bicyclists know if they are riding with improper equipment, whether through a warning or a citation. Besides headlights and rear reflectors, a variety of pulsing lights for the bicycle or the bicyclist now exist.

BICYCLISTS RIDING NEXT TO PARKED VEHICLES—THE “DOORING” PROBLEM

Serious injury can occur when a bicyclist strikes a door when a motorist exits a parked vehicle. In communities with bicycling corridors on streets with parked vehicles, this crash type can occur with reasonable frequency. Several on-street treatments are available. If there is a bike



PHOTO MICHAEL KING

A bicyclist passing parked vehicles can be injured if a motorist opens his or her door and strikes the bicyclist.



PHOTO BY DAN BURDEN

Bicycle-motor vehicle crashes at intersections often occur due to the bicyclist ignoring traffic signals or signs.

lane next to the parked vehicle, use of a double-striped bike lane is preferable, in that bicyclists tend to center in the middle of the bike lane, thus placing themselves further away from a door opening. Some communities are also experimenting with symbols, such as the typical bike lane logo inside a directional arrow, to see if bicyclists will track over the symbol and away from door openings. Bicyclist education emphasizing the danger of riding too close to parked vehicles would also be helpful.

BICYCLISTS NOT OBEYING TRAFFIC CONTROL AT INTERSECTIONS

About half of the bicycle-motor vehicle crashes occur at or near intersections.¹ While many of these crashes are not the fault of bicyclists, a frequent factor in these crashes is the bicyclist who ignores either traffic signals or stop signs at intersections. Bicyclist education is one remedy, but perhaps more important is law enforcement. Police often fail to respond to inappropriate maneuvers by bicyclists, and while it may be unrealistic to expect large increases in citations to bicyclists, wholesale increases in warnings could be effective.

BICYCLE CRASHES INVOLVING CHILDREN

Although bicyclists 25 years of age and older are increasingly involved in injury and fatality crashes, the number of crashes involving children under age 16 remains large. In 2003, the group under age 16 accounted for 23 percent of bicyclist fatalities and 37 percent of bicyclist injuries.² Based on North Carolina data, the under 16 group also tends to be overrepresented in crashes where the bicyclist was at fault. (http://www.pedbikeinfo.org/pbcat/pdf/summary_bike_types5yrs.pdf).⁷ Crash types where this group is overrepresented include riding out or through intersections with stop signs, riding out at non-intersection locations such as driveways, turning or merging in front of traffic, and non-roadway crashes, including those in parking lots and driveways. In essence, there are behavioral issues present that are related to lack of experience. As noted above, bicyclist education and police enforcement or warnings could help with this problem.

USE OF BICYCLE HELMETS

At present there are 21 states (counting the District of Columbia as a “state”) and at least 148 localities with some form of a mandatory bicycle helmet laws. Thirteen states have no state or local helmet laws of any kind (Bicycle Helmet Safety Institute Web site, 2006). Many serious head injuries occur at low speeds and are preventable if helmets are worn properly.

While helmets may not have an impact on the frequency of crashes, numerous studies have found that use of ap-

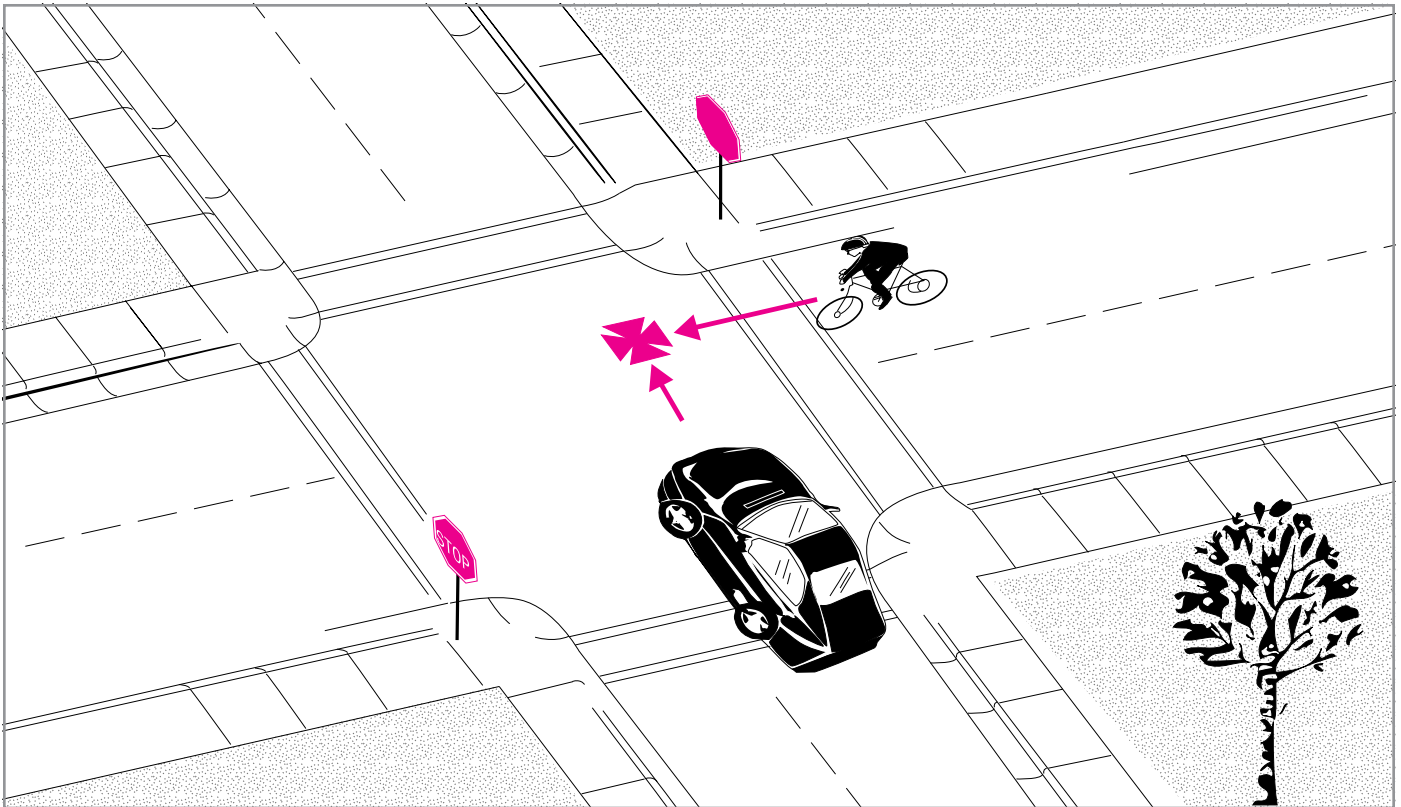


Younger bicyclists have the highest injury and fatality rates associated with bicycle crashes.

proved bicycle helmets significantly reduces the risk of fatal injury, serious head and brain injury, head injury, and middle and upper face injury among bicyclists of all ages involved in all types of crashes and crash severities. Relative risk reductions estimated in a meta-analysis of 16 peer-reviewed studies were 60 percent for head injury (OR=0.40; CI 0.29, 0.55), 58 percent for brain injury (OR=0.42; CI 0.26, 0.67), 47 percent for facial injury (OR=0.53; CI 0.39, 0.73), and 73 percent for fatal injury (OR=0.27; CI 0.10, 0.71).⁸

Rivara et al. (1999) report that helmets that do not fit properly or are misused also increase the risk of head injury. Helmets tipped backward exposing the forehead were associated with a 50 percent increase in risk of head injury when compared with helmets properly centered. Using another measure of poor helmet fit, it was also found that half of children wearing helmets 2 cm or more wider than their heads had experienced a head injury.⁹

Chapter 3 – Selecting Improvements for Bicyclists



Identification of High-Crash Locations

Bicycle Crash Typing

Definitions of Bicycle Crash Types

Crash-Related Countermeasures

Performance Objectives

Program of Improvements

Deciding on a set of treatments that will provide the greatest safety and mobility benefits for bicyclists requires transportation and land-use planners, engineers, law enforcement officials, and community leaders to engage in problem-solving. In most cases, a two-pronged approach is required. The first prong involves an examination of the bicycling crash problem through a review of historical crash data. Two specific types of crash analyses that are detailed in this chapter include:

- The identification of high-crash or hazardous locations
- The detailed examination of pre-crash maneuvers that lead to bicycle-motor vehicle collisions

However, many of the problems faced by bicyclists either do not involve crashes or the crashes are not reported. Thus, the second prong is more broad-based and focuses on performance objectives that will lead to changes in behavior that, in turn, will result in a safer and more accessible environment for bicyclists.

IDENTIFICATION OF HIGH-CRASH LOCATIONS

A first step in the problem-solving process of improving bicycle safety and mobility is to identify locations or areas where bicycle crash problems exist and where engineering, education, and enforcement measures will be most beneficial. Mapping the locations of reported bicycle crashes in a neighborhood, campus, or city is a simple method of identifying sites for potential bicycle safety improvements. One method of analyzing crash locations is through computerized Geographic Information Systems (GIS) software. This type of map can help transportation engineers and planners focus safety improvements on intersections, corridors, or neighborhoods where bicycle crashes have occurred.

Several issues should be considered when creating GIS maps of reported crash locations. First, the volumes of bicycle and motor vehicle traffic that use each location will affect reported crash density. Second, bicycle crashes may not be reported frequently enough to establish a pattern of unsafe bicycling locations. In either case, other steps may improve the identification of unsafe locations for bicycling. These include:

- Using bikeability checklists.¹
- Noting bicycle and driver behavior and examining roadway and bicycling characteristics at specific sites.
- Observing and recording the number of bicycle-motor vehicle conflicts at specific sites.²

- Mapping locations known to have a high potential for bicycle crashes in an area.
- Calculating a bicycle level of service.³

In regard to conflicts, a number of studies have been performed using bicycle-motor vehicle conflicts as a study variable in lieu of crash data.² A conflict is usually defined as a sudden change in speed or direction by either party to avoid the other. In regard to bicycle level of service, one popular tool is the Bicycle Compatibility Index, where a user inserts values for several easily obtained variables to determine the comfort level (level of service) for bicyclists on a midblock section of a street or roadway.³ An intersection level of service for the bicycle through movement has also been developed.⁴ Another intersection rating tool is under development for the Federal Highway Administration (FHWA) for both bicyclists and pedestrians. The bicyclist portion considers the through movement, right turns, and left turns.⁵

BICYCLE CRASH TYPING

The development of effective roadway design and operation, education, and enforcement measures to accommodate bicyclists and prevent crashes is hindered by insufficient detail in computerized state and local crash files. Analysis of these databases can provide information on where bicycle crashes occur (city, street, intersection, two-lane road, etc.), when they occur (time of day, day of week, etc.), and characteristics of the victims involved (age, gender, injury severity, etc.). Current crash files cannot provide a sufficient level of detail regarding the sequence of events leading to the crash.

In the 1970s, methods for typing pedestrian and bicycle crashes with motor vehicles were developed by the National Highway Traffic Safety Administration (NHTSA) to better define the sequence of events and precipitating actions leading to pedestrian- and bicycle-motor vehicle crashes.^{6,7,8} These methodologies were applied by Hunter et al. in a 1996 study to more than 8,000 pedestrian and bicycle crashes from six states.⁹ The results provided a representative summary of the distribution of crash types experienced by pedestrians and bicyclists. Some of the most frequently occurring bicycle crash types include:

- A motorist failing to yield (21.7 percent of crashes)
- A bicyclist failing to yield at an intersection (16.8 percent of crashes)
- A motorist turning or merging into the path of the bicyclist (12.1 percent of crashes)

- A bicyclist failing to yield at a midblock location (11.7 percent of crashes)
- A motorist overtaking a bicyclist (8.6 percent of crashes)
- A bicyclist turning or merging into the path of the motorist (7.3 percent of crashes)

The crash-typing methodology described above has evolved over time and has been refined as part of a software package known as the Pedestrian and Bicycle Crash Analysis Tool (PBCAT).¹⁰ The development of PBCAT was sponsored by FHWA and NHTSA. Those interested may register for the PBCAT software and user's manual from the Pedestrian and Bicycle Information Center Web site at <http://www.bicyclinginfo.org/bc/pbcats.htm>. An update of this software will soon be available on the Web site.

PBCAT is a software product intended to assist state and local pedestrian and bicycle coordinators, planners, and engineers with the problem of lack of data regarding the sequence of events leading to a crash. PBCAT accomplishes this goal through the development and analysis of a database containing details associated with crashes between motor vehicles and pedestrians or bicyclists. One of these details is the crash type, which describes the pre-crash actions of the parties involved. The more than 70 specific bicyclist crash types used in PBCAT may be collapsed into 20 crash-typing groups. Several of these groups (including rarer or unusual crash types) have been further combined into 14 BIKESAFE groups for purposes of selecting treatments. A few PBCAT types that include rarer or difficult to remedy crashes that cannot be very specifically defined are not treated in the Crash Matrix. Some of these types of crashes are discussed in group 14 in the text that follows. Examining the closely-related crash groups for countermeasures could be helpful, as well as using the Performance Objectives Matrix to identify appropriate countermeasures. (See Chapter 4 for more information on the Crash and Performance Objectives matrices.)

DEFINITIONS OF BICYCLE CRASH TYPES

Provided below are the definitions of the 14 crash groups included in the BIKESAFE application (13 are included in the interactive crash matrix). These definitions are adapted from the PBCAT software.¹⁰ For any crash group, there are multiple problems or possible causes that may have led to the crash. The following section provides examples of a few possible causes and problems for each group and some of the countermeasures within BIKESAFE that may be applicable. At the end of each potential

solution is the countermeasure number in parentheses, which can be used to quickly locate the countermeasure description in Chapter 5.

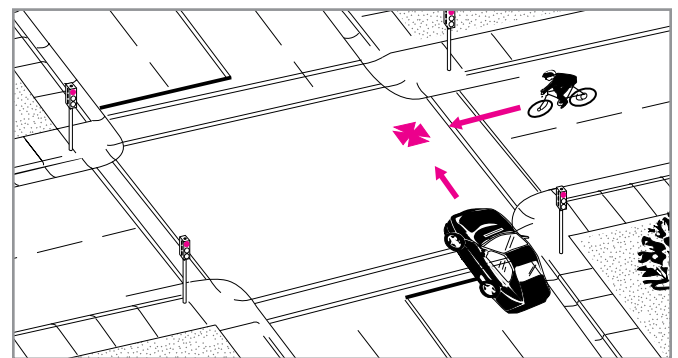
Neither the list of problems and possible causes nor the suggested countermeasures are to be considered comprehensive. Practitioners will still be required to supplement the analysis and recommendations with their own investigations and knowledge of local policies and practices. A number of potential countermeasures have, however, been identified for each group of crashes. The user is intended to think broadly initially, and develop their own narrower list of suitable options based on particular crash problems, detailed site conditions and other local circumstances. The countermeasures selection tool in the BIKESAFE software application (described in Chapter 4) is intended to aid in this process.

1. MOTORIST FAILED TO YIELD—SIGNALIZED INTERSECTION

The motorist enters an intersection and fails to stop at a traffic signal, striking a bicyclist who is traveling through the intersection on a perpendicular path. Typically, no turning movements are made by either party, except for a possible right turn on red. Many of these crashes involve bicyclists who are riding the wrong way against traffic, either in the roadway or on the sidewalk approaching the intersection.

Possible Cause/Problem #1

Motorist drives through a red signal without stopping. The motorist could be speeding and unable to stop in time, trying to get through the intersection on a yellow or amber signal indication, disregarding the signal, or failing to see the red signal.



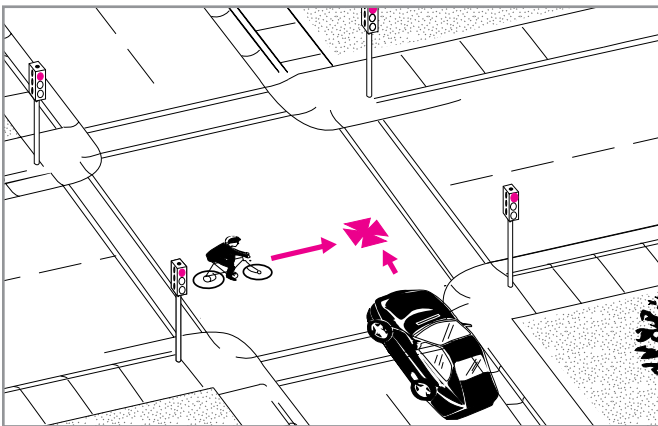
General Countermeasures

- Add/improve roadway lighting (4).
- Reduce number of lanes (9).
- Reduce lane width (10).
- Install roundabouts (17).

- e. Add/improve intersection markings (18).
- f. Improve sight distance at intersection (19).
- g. Install mini traffic circles (25).
- h. Add chicanes or other traffic calming to slow motor vehicle speeds (26, 27).
- i. Provide raised intersection (30).
- j. Provide trail intersection treatments for shared-use paths crossing the roadway at the intersection (32).
- k. Provide trail intersection warnings/advance treatments for shared-use paths crossing the roadway (33).
- l. Optimize signal timing or improve signal visibility (35).
- m. Make sign improvements (37).
- n. Improve pavement markings (38).
- o. Make school zone improvements (39).
- p. Provide law enforcement (40).
- q. Provide bicyclist education on wrong-way riding and riding on the sidewalk (41).
- r. Provide motorist education (42).

Possible Cause/Problem #2

The motorist drives out after stopping for a red signal, into the path of an oncoming bicyclist. The motorist may be making a right turn on red and fails to look to the right to see an approaching bicyclist. The bicyclist could be riding the wrong way in either the roadway or on the sidewalk.



General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Reduce curb radii to slow motor vehicle speeds (16).
- c. Install roundabouts (17).
- d. Add/improve intersection markings (18).
- e. Provide intersection sight distance improvements (19).

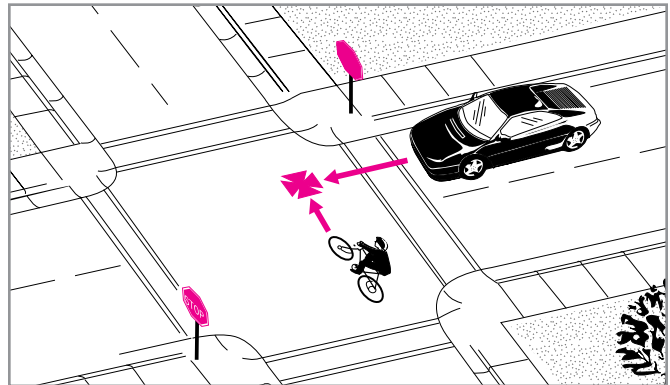
- f. Restrict right-turn-on-red (20).
- g. Provide trail-roadway intersection treatments for shared-use paths adjacent to the roadway (32).
- h. Provide trail intersection advance warning treatments for shared-use paths adjacent to the roadway (33).
- i. Make sign improvements (37).
- j. Provide bicyclist education (41).
- k. Provide motorist education (42).

2. MOTORIST FAILED TO YIELD— NON-SIGNALIZED INTERSECTION

The motorist enters an intersection without properly stopping or yielding at a stop sign, yield sign, or uncontrolled location, striking a bicyclist who is traveling through the intersection on an initial perpendicular path. Many of these crashes also involve bicyclists who are riding the wrong way against traffic, either in the roadway or on the sidewalk approaching the intersection.

Possible Cause/Problem #1

Motorist fails to stop at a stop sign or yield at a yield sign or uncontrolled intersection. The motorist could be speeding or otherwise fail to observe correct right-of-way, including flagrantly violating sign control.



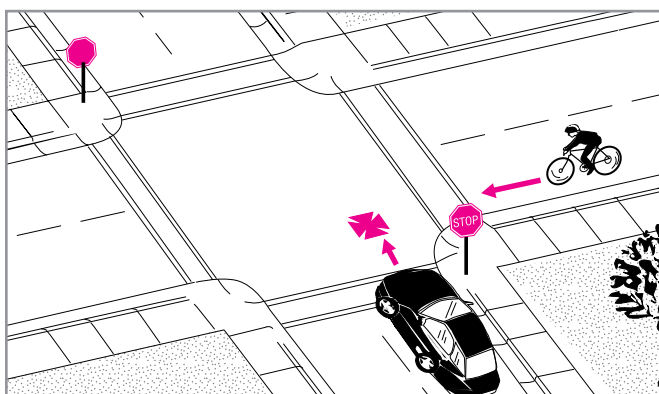
General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Reduce number of lanes (9).
- c. Reduce lane width (10).
- d. Reduce curb radii to slow motor vehicle turning speeds (16).
- e. Install roundabout (17).
- f. Add/improve intersection markings (18).
- g. Improve intersection sight distance (19).

- h. Redesign merge area (21).
- i. Install mini traffic circle at intersection (25).
- j. Add chicanes or other traffic calming to reduce vehicle speeds (26, 27).
- k. Provide raised intersection and other traffic calming treatments (30).
- l. Provide path intersection treatments for shared-use paths crossing the roadway (32).
- m. Provide path intersection warnings/advance treatments for shared-use paths crossing the roadway (33).
- n. Install traffic signal (35). If signal is installed, add bike detection/activation (36).
- o. Make sign improvements (37).
- p. Improve pavement markings (38).
- q. Make school zone improvements (39).
- r. Provide law enforcement (40).
- s. Provide bicyclist education on wrong-way riding and riding on the sidewalk (41).
- t. Provide motorist education (42).

Possible Cause/Problem #2

The motorist pulls out into the path of a bicyclist traveling through the intersection after first stopping (or slowing). The bicyclist could be riding the wrong way or on the sidewalk or both and ride into the intersection in the pedestrian crosswalk area. The motorist may pull out and fail to check or notice the bicyclist approaching (particularly from the right). The motorist may be turning right.



General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Reduce curb radii to slow turning speeds (16).
- c. Install roundabout (17).
- d. Add/improve intersection markings (18).

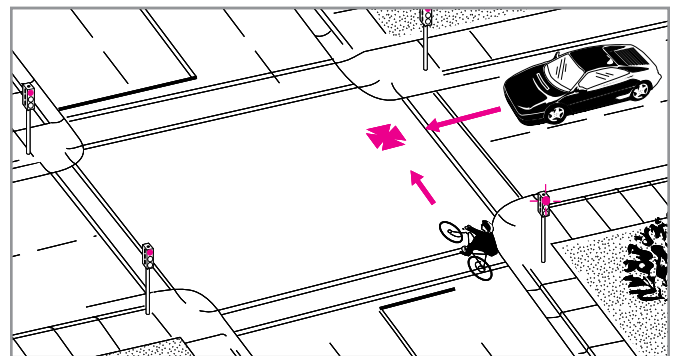
- e. Improve sight distance (19).
- f. Install mini traffic circle (25).
- g. Provide raised intersection (30).
- h. Provide path intersection treatments for shared-use paths crossing the roadway (32).
- i. Provide trail intersection warnings/advance treatments for shared-use paths adjacent to the roadway (33).
- j. Make school zone improvements (39).
- k. Provide bicyclist education (41).
- l. Provide motorist education (42).

3. BICYCLIST FAILED TO YIELD—SIGNALIZED INTERSECTION

The bicyclist enters an intersection on a red signal or is caught in the intersection by a signal change, colliding with a motorist who is traveling through the intersection. This group of crashes could involve a lack of understanding of the signal or inexperience for a young bicyclist or flagrant disregard for the signal by an older bicyclist. In many of these crashes, the bicyclist is likely to be riding on the sidewalk or riding the wrong way, against traffic, and fail to notice the signal indication.

Possible Cause/Problem #1

The bicyclist rides into the intersection through a red signal without stopping. The bicyclist may be trying to rush through on an amber signal indication, fail to see the red signal, or choose to disregard the signal. The bicyclist may not want to interrupt momentum or stop for a signal with an excessively long delay or that does not detect bicyclists' presence. Inexperience could also contribute to this type of crash. The signal may be more difficult to observe if the bicyclist is traveling wrong-way or riding on the sidewalk.



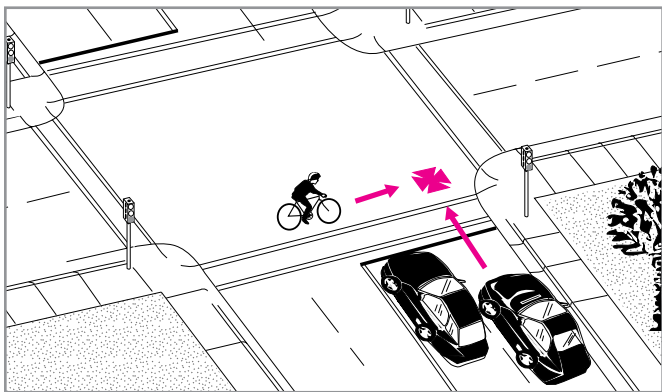
General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Install roundabout (17).

- c. Add/improve intersection markings (18).
- d. Improve sight distance (19).
- e. Provide path intersection treatments for shared-use paths crossing the roadway (32).
- f. Provide path intersection advance warning treatments for shared-use paths crossing the roadway (33).
- g. Install/optimize signal timing (35).
- h. Install bike-activated signals (36).
- i. Make sign improvements (37).
- j. Improve pavement markings (38).
- k. Make school zone improvements (39).
- l. Provide law enforcement (40).
- m. Provide bicyclist education (41).

Possible Cause/Problem #2

The bicyclist enters the intersection on a green or amber traffic signal indication but fails to clear the intersection when the traffic signal changes to green for the cross-street traffic. A multiple threat crash can also occur when the signal changes to green for the cross-street traffic and the bicyclist is struck by a motor vehicle whose view was obstructed by standing or stopped traffic in an adjacent lane.



General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Reduce the number of traffic lanes (9).
- c. Reduce the width of traffic lanes (10).
- d. Install roundabout (17).
- e. Add/improve intersection markings (18).
- f. Improve sight distance at the intersection (19).
- g. Add traffic calming treatments to slow motor vehicle speed (25, 26, 27, and 30).
- h. Provide path intersection treatments for shared-use paths crossing the roadway (32).

- i. Provide path intersection warnings/advance treatments for shared-use paths crossing the roadway (33).
- j. Optimize signal timing (35).
- k. Install bike-activated signal (36).
- l. Make school zone improvements (39).
- m. Provide bicyclist education (41).
- n. Provide motorist education about multiple threat (42).

Possible Cause/Problem #3

The bicyclist rides into the intersection after stopping for a red signal and into the path of a motorist. The bicyclist may ride out after waiting for a green indication if there is no provision for bicycle detection or the delay is excessive.

General Countermeasures

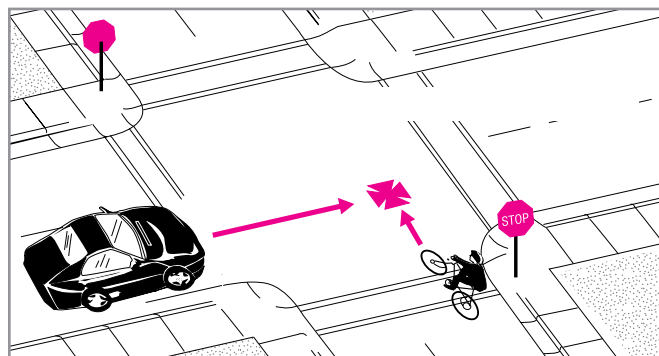
- a. Install a modern roundabout (17) or mini traffic circle (25) (depending on street function and volumes).
- b. Improve signal timing (35).
- c. Add bike-activation to the traffic signal (36).
- d. Enforce traffic laws (40).
- e. Provide bicyclist education (41).

4. BICYCLIST FAILED TO YIELD—NON-SIGNALIZED INTERSECTION

The bicyclist enters an intersection and fails to stop or yield at a non-signalized intersection (typically controlled by a stop sign), colliding with a motorist who is traveling through the intersection. This group of crashes could involve a lack of understanding of the sign control or inexperience for a young bicyclist, or flagrant disregard for the sign by an older bicyclist.

Possible Cause/Problem #1

Bicyclist fails to yield at a stop sign, yield sign or uncontrolled intersection. Sidewalk or wrong-way riding may exacerbate



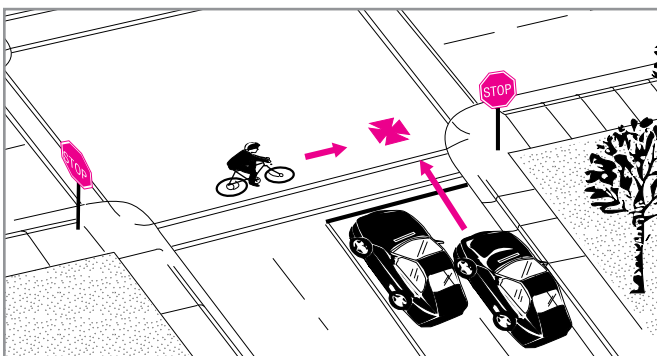
the problem by increasing the chances the bicyclist will not notice and obey sign control. Younger bicyclists tend to be disproportionately involved in this crash type.

General Countermeasures

- a. Add/improve lighting (4).
- b. Install roundabouts (17).
- c. Improve sight distance at intersection (19).
- d. Install mini traffic circle (25).
- e. Provide path intersection treatments (32).
- f. Provide path intersection warnings/advance treatments (33).
- g. Install traffic signal (35) and bike-activated signal (36).
- h. Make sign improvements (37).
- i. Improve pavement markings (38).
- j. Make school zone improvements (39).
- k. Provide law enforcement (40).
- l. Provide bicyclist education (41).

Possible Cause/Problem #2

The bicyclist rides out after stopping (or slowing). At a yield or two-way stop, the motorist could be speeding, the bicyclist may underestimate the time needed to start-up and get through the intersection, or the bicyclist may not detect an approaching motorist. At a four-way stop, the bicyclist may not understand right-of-way rules. A multiple threat situation can also occur at a non-signalized location.



General Countermeasures

- a. Add/improve lighting (4).
- b. Reduce the number of traffic lanes (9).
- c. Reduce the width of traffic areas (10).
- d. Install roundabout (17).
- e. Implement special intersection markings (18).

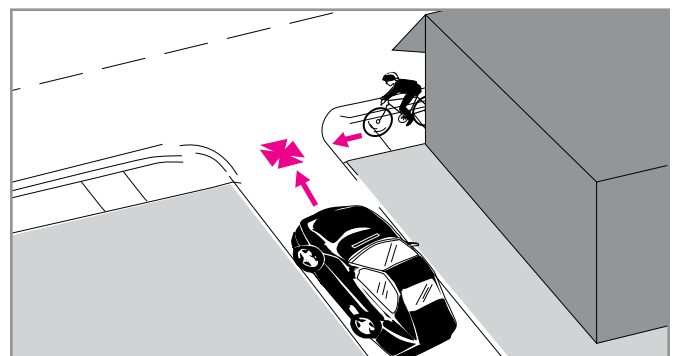
- f. Improve sight distance at the intersection (19).
- g. Redesign merge area (21).
- h. Install mini traffic circle (25).
- i. Install chicanes or other traffic calming measures to slow motorist speeds (26, 27, 30).
- j. Install speed tables, humps, or cushions (27).
- k. Install raised intersection (30).
- l. Install traffic signal (35) and bike-activated signal (36).
- m. Provide bicyclist education (41).
- n. Provide motorists education about multiple threat and child bicyclists (42).

5. MOTORIST DROVE OUT—MIDBLOCK

The motorist typically pulls out of a driveway or alleyway and fails to yield to a bicyclist riding along the roadway or on a parallel path or sidewalk. Two-thirds of these types of crashes typically involve a bicyclist who is riding the wrong way against traffic, either on the sidewalk or on the roadway.

Possible Cause/Problem

The motorist pulls out of a residential or commercial driveway or alleyway and fails to yield to a bicyclist riding along the roadway, on the sidewalk, or on a parallel shared-use path. Visibility may be obscured by buildings, parked cars, trees and shrubs, signal control boxes, sign posts and a host of other things that can be found along the sidewalk or edge of the roadway. The motorist may also fail to look right before pulling out or fail to detect higher-speed bicyclists or those traveling wrong-way on the roadway or sidewalk.



General Countermeasures

- a. Make parking improvements to increase sight distance (5).
- b. Make driveway improvements (7).

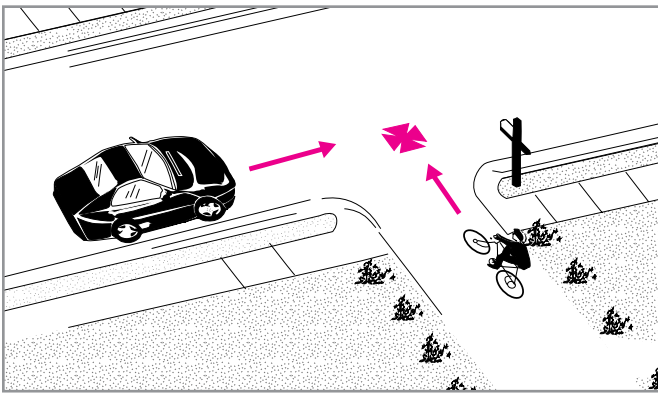
- c. Improve access management (8).
- d. Provide path intersection treatments for shared-use paths adjacent to the roadway (32).
- e. Provide path intersection warning treatments for shared-use paths adjacent to the roadway.
- f. Optimize signal timing to create gaps mid-block (35).
- g. Make sign improvements (37).
- h. Improve pavement markings (38).
- i. Provide law enforcement (40).
- j. Provide bicyclist education (41).
- k. Provide motorist education (42).

6. BICYCLIST RODE OUT—MIDBLOCK

The bicyclist rides out from a residential driveway, commercial driveway, sidewalk, or other midblock location into the road and is struck by or collides with a motorist.

Possible Cause/Problem

The bicyclist rides out from a residential driveway, commercial driveway, sidewalk, or other midblock location into the road without stopping or yielding and is struck by a motorist. This crash type is a common one for young children who fail to stop and scan for vehicles before crossing the road or pulling out into traffic. Motorists speeding through neighborhood streets increase the risk of being unable to avoid this type of crash, so traffic calming measures may be appropriate.



General Countermeasures

- a. Make parking improvements to increase visibility (5).
- b. Install medians or crossing islands (6).
- c. Make driveway improvements (7).
- d. Improve access management (8).

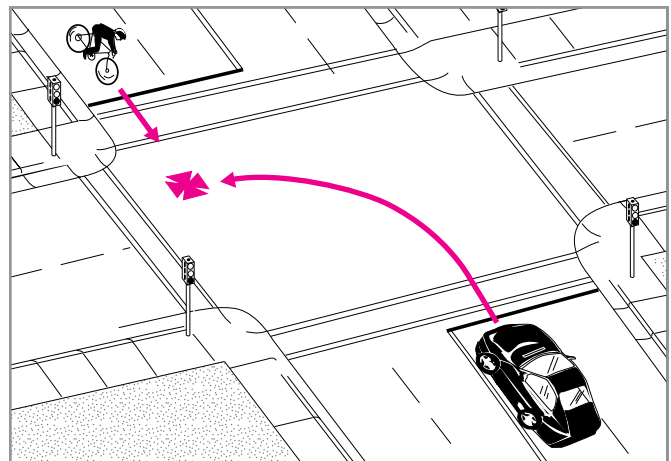
- e. Reduce number of lanes (9).
- f. Reduce lane width (10).
- g. Install traffic calming measures (26, 27, 28, 29).
- h. Provide path intersection treatments for midblock roadway crossings (32).
- i. Provide path intersection advance warnings treatments (33).
- j. Optimize signal timing to create gaps mid-block (35).
- k. If midblock signal is installed, add bike detection or activated signal (36).
- l. Provide school zone improvements (39).
- m. Provide law enforcement (40).
- n. Provide bicyclist education (41).

7. MOTORIST TURNED OR MERGED LEFT INTO PATH OF BICYCLIST

The motorist turns left into the path of an oncoming bicyclist or turns or merges left across the path of a bicyclist who is traveling straight in the same direction as the motorist. This crash can also involve motorists or bus or delivery vehicles pulling out of parking spaces or stops.

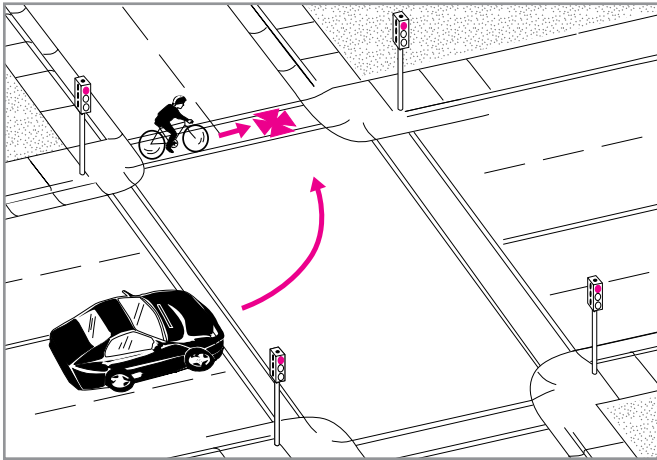
Possible Cause/Problem #1

The motorist turns left into the path of an oncoming bicyclist. The problem frequently occurs at signalized intersections on roads with four or more lanes, but may occur at driveways and other non-signalized junctions. The left-turning motorist is waiting for a gap in oncoming traffic and fails to look for, see, or yield to the oncoming bicyclist.



Possible Cause/Problem #2

A motorist turns or merges left across the path of a bicyclist who is traveling straight ahead in the same direction as the motorist. Many times this crash occurs at an intersection or driveway where the bicyclist is riding the wrong way against traffic or is riding the wrong way against traffic on the sidewalk. Reducing wrong-way riding would be a goal of bicyclist education and other countermeasures. Most general countermeasures are the same for these first two types of crashes.



General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Install medians or crossing islands (6).
- c. Make driveway improvements (7).
- d. Improve access management (8).
- e. Provide bike lanes (11).
- f. Provide paved shoulders (13).
- g. Reduce curb radii or redesign skewed intersections (16).
- h. Install roundabout (17).
- i. Enhance intersection markings (18).
- j. Make sight distance improvements at intersection (19).
- k. Restrict left turns (20).
- l. Implement mini traffic circle (25).
- m. Install traffic diversion (29).
- n. Install raised intersection (30).
- o. Provide path intersection treatments for shared-use paths adjacent to the roadway (32).
- p. Provide path intersection warnings/advance treatments for shared-use paths adjacent to the roadway (33).
- q. Install or optimize signal timing (dedicated left turn) (35).

- r. Add sign improvements (37).
- s. Provide bicyclist education (41).
- t. Provide motorist education (42).

Possible Cause/Problem #3

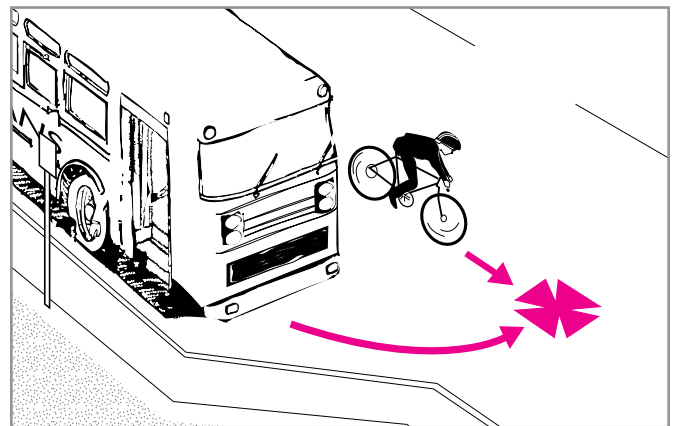
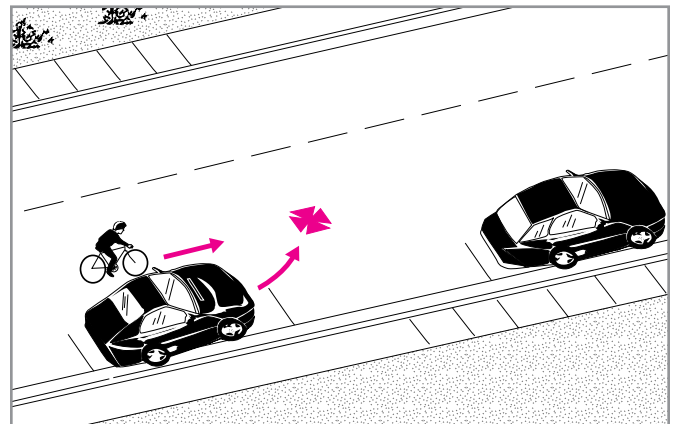
A motorist merges left across the path of a bicyclist traveling straight ahead at an on/off ramp or other merge or weave area.

General Countermeasures

- a. Improve roadway lighting (4).
- b. Enhance intersection markings (18) or make pavement marking improvements (38).
- c. Add sign improvements (37).
- d. Redesign merge area (21).

Possible Cause/Problem #4

A motorist, bus, or delivery vehicle strikes a bicyclist when pulling out of a parking space or stop.



General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Provide parking treatments (5).

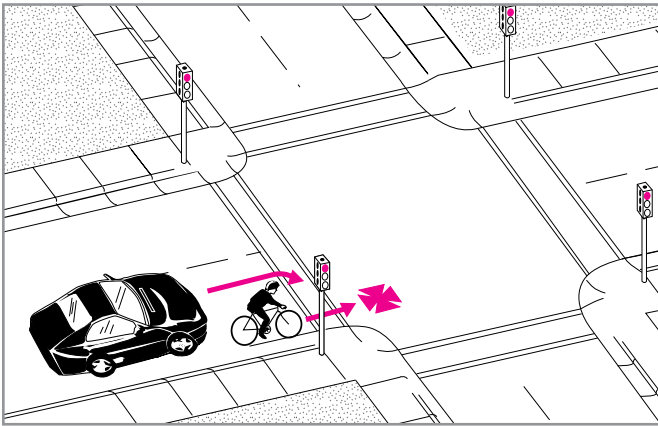
- c. Provide transit stop treatments (covered under bike lanes) (11).
- d. Provide combination lanes (14).
- e. Provide bicyclist education (41).
- f. Provide motorist education (42).

8. MOTORIST TURNED OR MERGED RIGHT INTO PATH OF BICYCLIST

The motorist turns right into the path of a bicyclist traveling in the same direction or a motorist turning right strikes an oncoming bicyclist who is riding against traffic. This crash can also involve motorists pulling into parking spaces, bus or delivery vehicle pull-overs, or motorists making right turns on red.

Possible Cause/Problem #1

At an intersection, merge area, or driveway, the motorist turns or merges right across the path of a bicyclist who is traveling straight ahead in the same direction. The motorist may misjudge the speed of the bicyclist or believe (mistakenly) that the bicyclist should wait for them.



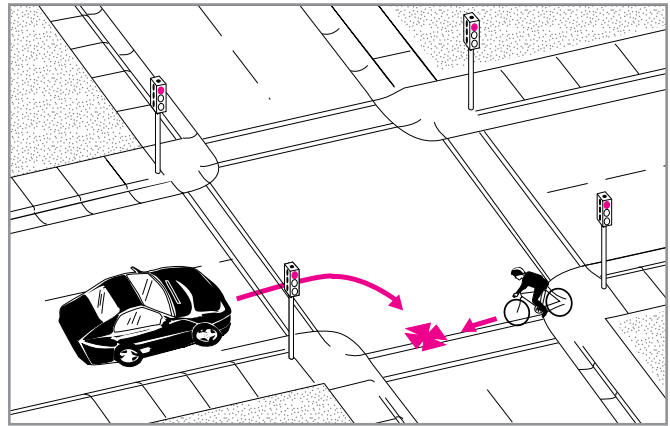
General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Provide parking treatments (5).
- c. Make driveway improvements (7).
- d. Improve access management (8).
- e. Reduce number of travel lanes to slow motor vehicle speeds (9).
- f. Reduce lane width to encourage bicyclists to take the lane (in low-speed areas) (10).
- g. Provide bike lanes (11).
- h. Provide paved shoulders (13).

- i. Reduce curb radii (16).
- j. Improve intersection markings (18).
- k. Implement turning restrictions (20).
- l. Redesign merge areas (21).
- m. Install traffic diversion (29).
- n. Add raised intersection (30).
- o. Provide path intersection treatments for shared-use paths adjacent to the roadway (32).
- p. Provide path intersection warnings/advance treatments for shared-use paths adjacent to the roadway (33).
- q. Make sign improvements (37).
- r. Improve pavement markings (38).
- s. Provide law enforcement (40).
- t. Provide bicyclist education (41).
- u. Provide motorist education (42).

Possible Cause/Problem #2

A motorist turns right, striking a bicyclist approaching from the opposite direction. The bicyclist is most likely riding the wrong way, against traffic, but could be legally riding on the sidewalk or an adjacent shared-use path. This crash may involve a right-turn-on-red, with the bicyclist possibly violating a red signal since the crash type involves traveling on a parallel path to the motorist.



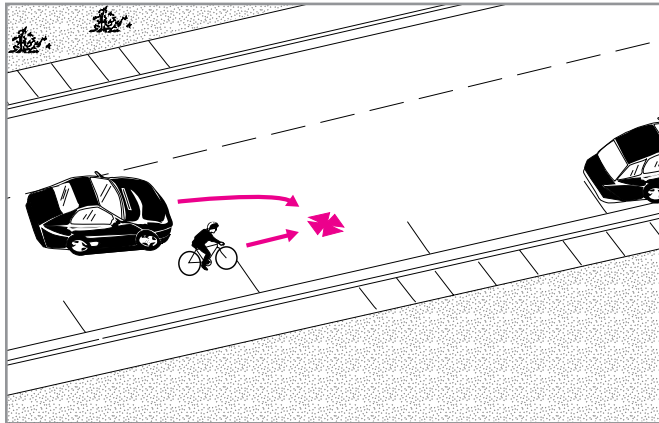
General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Make driveway improvements (7).
- c. Implement turning restrictions (20).
- d. Install traffic diversion (29).
- e. Provide path intersection treatments for shared-use paths adjacent to the roadway (32).

- f. Provide path advance of intersection warning treatments for shared-use paths adjacent to the roadway (33).
- g. Make sign improvements (37).
- h. Provide bicyclist education (41).
- i. Provide motorist education (42).

Possible Cause/Problem #3

A motorist, bus, or delivery vehicle strikes a bicyclist when pulling into a parking space or stop.



General Countermeasures

- a. Add/improve roadway lighting (4).
- b. Provide parking treatments (5).
- c. Provide transit stop treatments (covered under bike lanes) (11).
- d. Provide combination lanes (14).
- e. Provide bicyclist education (41).
- f. Provide motorist education (42).

Possible Cause/Problem #4

A motorist merges right across the path of a bicyclist traveling straight ahead at an on/off ramp or other merge/weave area..

General Countermeasures

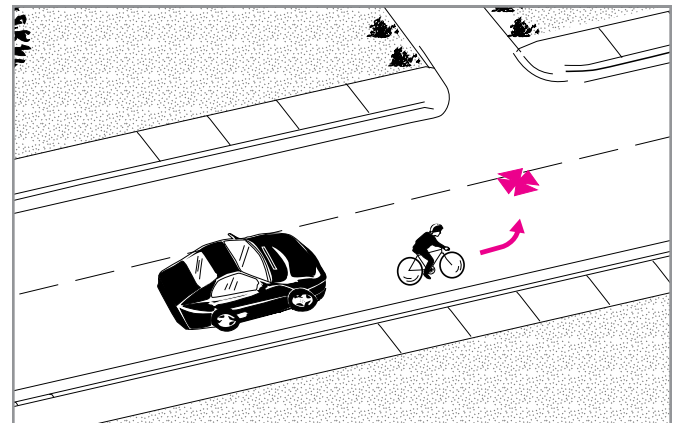
- a. Improve roadway lighting (4).
- b. Enhance intersection markings (18) or make pavement marking improvements (38).
- c. Add sign improvements (37).
- d. Redesign merge area (21).

9. BICYCLIST TURNED OR MERGED LEFT INTO PATH OF MOTORIST

The bicyclist turns or merges left into the path of an overtaking motorist who is traveling straight ahead in the same direction as the bicyclist, or a bicyclist turning left strikes an oncoming motorist. This crash can also involve a bicyclist riding out from a sidewalk or path beside the road. The bicycle and the motor vehicle are initially on parallel paths.

Possible Cause/Problem #1

The bicyclist turns or merges left from the right side of the roadway. The rider fails to see or yield to a motorist coming from behind and is hit by the overtaking motorist. The crash also could involve a bicyclist riding out from a sidewalk or path beside the road. Speed of overtaking vehicles may be a factor in this group of crashes. The motorist also may not see the bicyclist, or may not suspect that the bicyclist will turn in front in time to react.



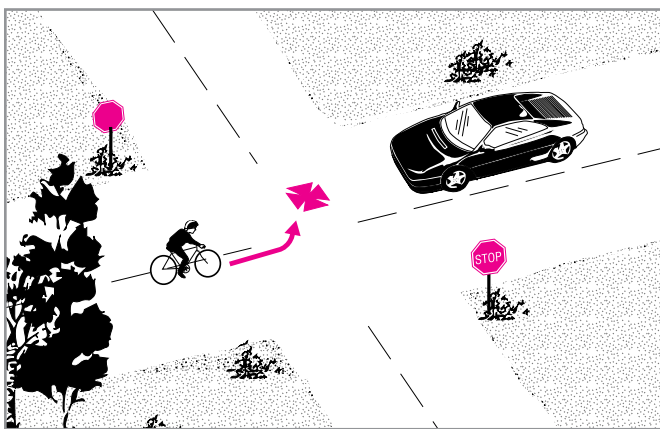
General Countermeasures

- a. Make roadway surface hazard improvements (1).
- b. Add/improve roadway lighting (4).
- c. Provide parking improvements (5).
- d. Reduce number of lanes/road diet (9).
- e. Reduce lane width in low-speed areas to encourage shared-lane use (10).
- f. Install roundabout (17).
- g. Improve intersection markings (18).
- h. Perform repetitive and short-term maintenance to reduce surface hazards (22).
- i. Perform major maintenance (23).
- j. Institute a hazard identification program (24).
- k. Install mini traffic circle (25).
- l. Provide traffic calming treatments (26, 27, 28) to slow motor vehicle speeds.

- m. Divert traffic (29).
- n. Install raised intersection (30).
- o. Provide path intersection treatments (parallel paths adjacent to the roadway) (32).
- p. Provide path intersection warnings/advance treatments (33).
- q. Make pavement marking improvements (38).
- r. Provide bicyclist education (41).

Possible Cause/Problem #2

The bicyclist attempts to make a left turn and rides into the path of an oncoming motorist. The crash could occur at an intersection, a midblock driveway, or a shared-use path.



General Countermeasures

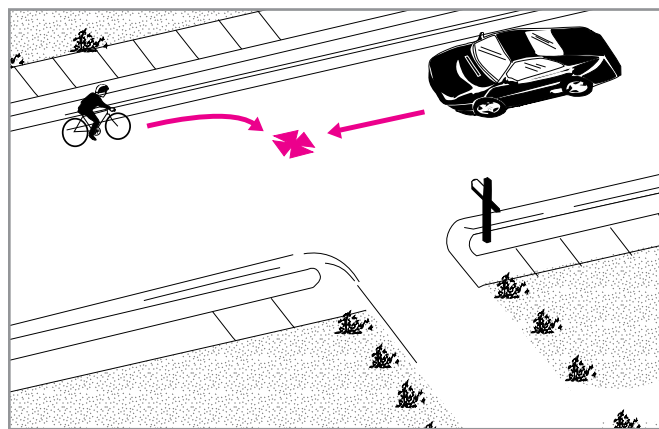
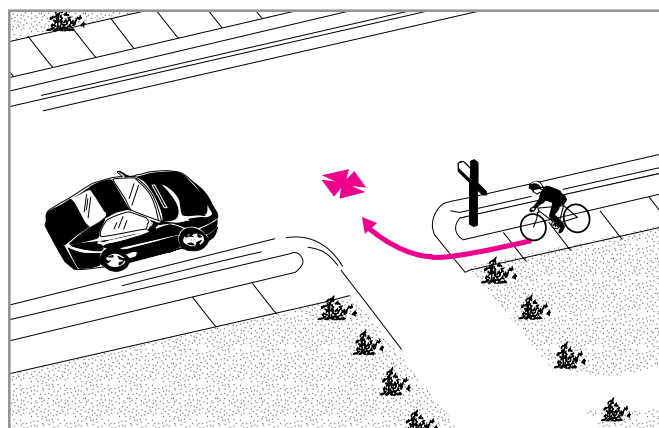
- a. Install medians or crossing islands (6).
- b. Improve driveways (7).
- c. Improve access management (8).
- d. Reduce number of lanes/road diet (9).
- e. Reduce lane width (10).
- f. Install roundabout (17).
- g. Improve intersection markings (18).
- h. Improve sight distance (19).
- i. Install mini traffic circle (25).
- j. Provide trail intersection treatments (32).
- k. Provide trail intersection warnings/advance treatments (33).
- l. Install/optimize signal timing (35).
- m. Add bike activated signals (36).
- n. Make pavement marking improvements (38).
- o. Provide bicyclist education (41).

10. BICYCLIST TURNED OR MERGED RIGHT INTO PATH OF MOTORIST

The bicyclist turns or merges right into the path of an oncoming motorist, or a bicyclist turns right across the path of a motorist traveling in the same direction as the bicyclist. This crash can also involve a bicyclist riding out from a sidewalk or shared-use path beside the road. The bicycle and the motor vehicle are initially on parallel paths.

Possible Cause/Problem #1

The bicyclist turns or merges right into the path of an oncoming motorist. The crash could occur at an intersection or mid-block. The bicyclist may be riding out from an adjacent sidewalk or shared-use path or attempting to make a right turn from the wrong side of the roadway.



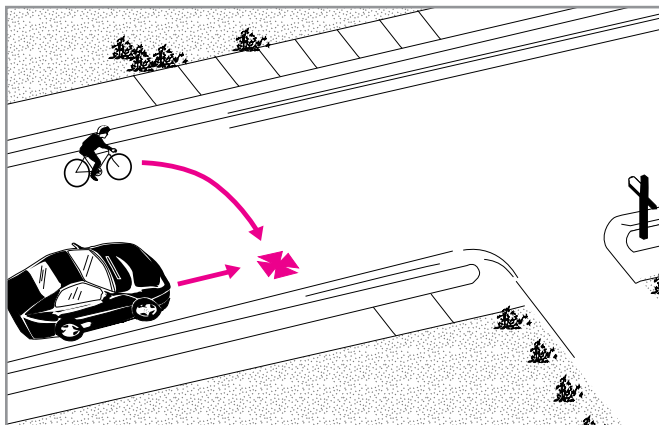
General Countermeasures

- a. Reduce number of lanes/road diet to gain space for bike lanes (9).
- b. Reduce lane width (10).
- c. Install bike lanes on both sides of the street (11).
- d. Provide/improve intersection markings (18).
- e. Perform repetitive and short-term maintenance (22).

- f. Perform major maintenance (23).
- g. Institute a hazard identification program (24).
- h. Add traffic calming treatments to slow motorist speeds (25, 26, 27, 28, 29, 30).
- i. Provide path intersection treatments for shared-use paths adjacent to the roadway (32).
- j. Provide path intersection warnings/advance treatments for shared-use paths adjacent to the roadway (33).
- k. Make pavement marking improvements (38).
- l. Provide bicyclist education on wrong-way riding (41).

Possible Cause/Problem #2

The bicyclist turns or merges right into the path of a motorist who is traveling straight ahead in the same original direction as the bicyclist. The bicyclist may be attempting to change lanes to make a right turn. This crash can also involve a bicyclist riding out from a sidewalk or shared-use path beside the road or changing from traveling facing traffic (wrong side of the street) to the correct side of the street.



General Countermeasures

- a. Reduce number of lanes/road diet to gain space for bike lanes (9).
- b. Reduce lane width to slow motor vehicle speeds (10).
- c. Install bike lanes on both sides of the street (11).
- d. Provide or improve intersection markings (18).
- e. Institute good maintenance practices to reduce surface and other hazards (22, 23, 24).
- f. Add traffic calming treatments (25, 26, 27, 28, 29, 30).
- g. Provide trail intersection treatments for shared-use paths adjacent to the roadway (32).
- h. Provide trail intersection warnings/advance treatments for shared-use paths adjacent to the roadway (33).

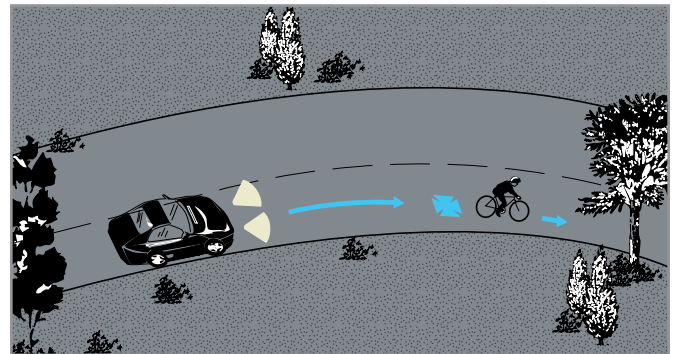
- i. Make pavement marking improvements (38).
- j. Provide bicyclist education on wrong-way riding and scanning behind (41).

11. MOTORIST OVERTAKING BICYCLIST

The motorist is overtaking a bicyclist and strikes the bicyclist from behind. These crashes tend to occur because the motorist fails to detect the bicyclist, the bicyclist swerves to the left to avoid an object or surface irregularity, or the motorist misjudges the space necessary to pass the bicyclist.

Possible Cause/Problem #1

The motorist is overtaking and fails to detect a bicyclist, striking the bicyclist from behind. These crashes often occur at night, and one or both parties may have been drinking. The bicyclist may have inadequate lights or reflectors, or may not be using lights.

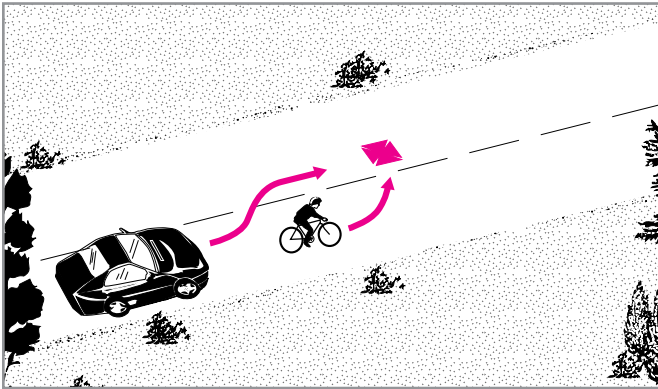


General Countermeasures

- a. Provide space on bridges/overpasses (2).
- b. Provide space and other measures in tunnels/underpasses (3).
- c. Add/improve roadway lighting (4).
- e. Provide space on roadway for bicyclists with bike lanes (11), wide curb lanes (12), paved shoulders (13), or combination lanes (14).
- f. Provide chicanes or serpentine for low-speed, shared-lane situations (26).
- g. Provide other traffic calming measures (27, 28, 29).
- h. Provide a separate path or trail (31).
- i. Make sign improvements (37).
- j. Improve pavement markings (38).
- k. Provide bicyclist education about conspicuity and riding at night (41).
- l. Provide motorist education (42).

Possible Cause/Problem #2

The overtaking motorist strikes a bicyclist suddenly swerving to the left, possibly to avoid an object or surface irregularity, extended door of a parked car, or other obstacle.



General Countermeasures

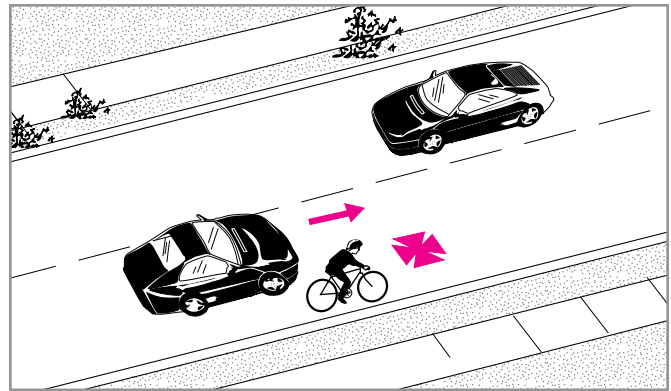
- Make roadway surface hazard improvements (1).
- Add/improve roadway lighting (4).
- Provide parking improvements (5).
- Make driveway improvements (7).
- Provide bike lanes (11).
- Provide wide curb lanes (12).
- Provide paved shoulders (13).
- Perform repetitive and short-term maintenance (22), major maintenance (23), and institute a hazard identification program (24).
- Provide chicanes or serpentine design or other traffic calming measures (26, 27, 28, 29).
- Provide a separate path or trail (31).
- Make sign improvements (37).
- Improve pavement markings (38).
- Provide bicyclist education about avoiding objects and correct spacing from parked motor vehicles (41).
- Provide motorist education (42).

Possible Cause/Problem #3

The overtaking motorist detects the bicyclist ahead but fails to allow enough space to safely pass the bicyclist.

General Countermeasures

- Make roadway surface hazard improvements (1).
- Provide space on bridges and overpasses (2).
- Provide space and other measures in tunnels and underpasses (3).



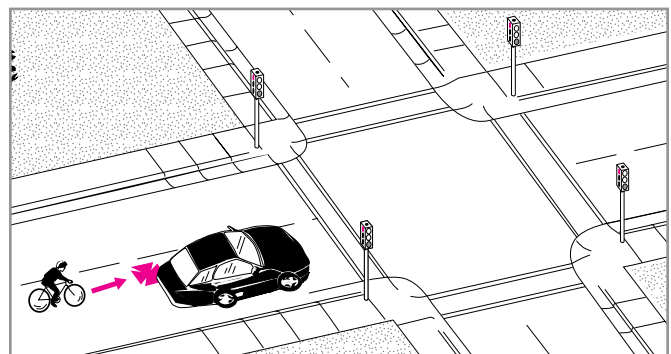
- Add/improve roadway lighting (4).
- Reduce lane width (on low speed roads) to encourage bicyclist to “take the lane” (10).
- Provide space for bicyclists on high speed roadways with bike lanes (11), wide curb lanes (12), or paved shoulders (13).
- Identify maintenance needs and perform routine and major maintenance (22, 23, 24).
- Provide chicanes or chicane-like parking (26).
- Provide a separate shared-use path (31).
- Make sign improvements (37).
- Improve pavement markings (38).
- Provide bicyclist education (41).
- Provide motorist education (42).

12. BICYCLIST OVERTAKING MOTORIST

The bicyclist is overtaking and strikes the motor vehicle from behind. These crashes tend to occur because the bicyclist tries to pass on the right or left, the bicyclist strikes a parked vehicle while passing, or the bicyclist strikes an extended door on a parked vehicle while passing.

Possible Cause/Problem #1

The overtaking bicyclist strikes a motor vehicle while attempting to pass on either the right or the left.

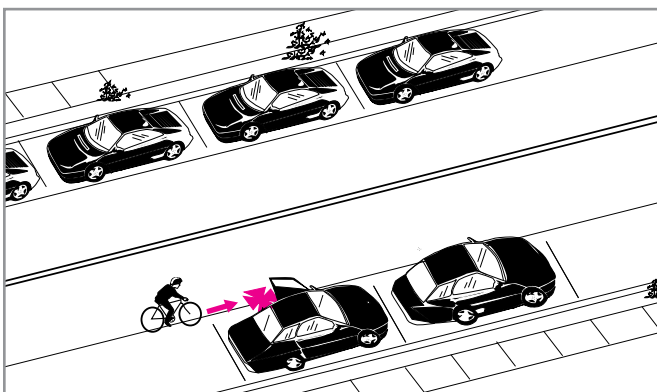
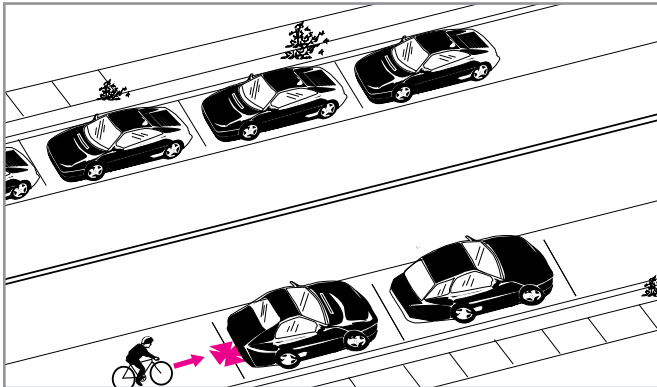


General Countermeasures

- a. Provide space for bicyclists with bike lanes (11), wide curb lanes (12), paved shoulders (13), or combination lanes (14).
- b. Perform repetitive and short-term maintenance (22).
- c. Perform major maintenance (23).
- d. Institute a hazard identification program (24).
- e. Provide a separate shared-use path (31).
- f. Improve pavement markings (38).
- g. Provide bicyclist education (41).

Possible Cause/Problem #2

The overtaking bicyclist strikes a parked motor vehicle or extended door of a parked motor vehicle while attempting to pass on either the right or the left.



General Countermeasures

- a. Implement parking treatments (5).
- b. Provide bike lanes (11).
- c. Provide wide outside lanes (12).
- d. Provide paved shoulders (13).

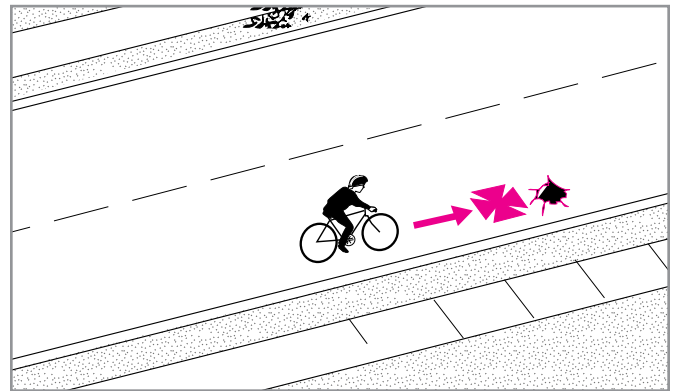
- e. Provide a separate shared-use path (31).
- f. Improve pavement markings (38).
- g. Provide bicyclist education (41).
- h. Provide motorist education (42).

13. NON-MOTOR VEHICLE CRASHES

These crashes do not involve a motor vehicle and can occur in a variety of ways, including falls from a bike, a collision between two bicycles, a collision between a bike and a pedestrian, or a bicyclist striking an object.

Possible Cause/Problem #1

The bicyclist loses control due to a pavement surface irregularity, debris, or other hazard.

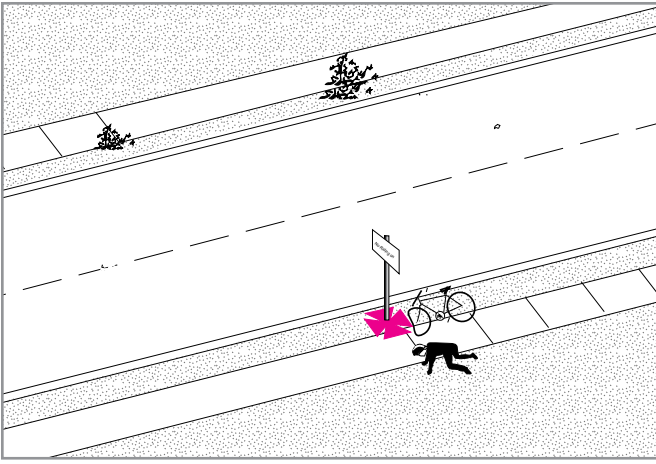


General Countermeasures

- a. Make roadway surface hazard improvements (1).
- b. Improve bridge access and surfaces (2).
- c. Improve tunnel access and surfaces (3).
- d. Add/improve roadway lighting (4).
- e. Make driveway improvements (5).
- f. Perform repetitive and short-term maintenance (22).
- g. Perform major maintenance (23).
- h. Institute a hazard identification program (24).
- i. Implement “share the path” measures (34).
- j. Improve pavement markings (38).
- k. Provide bicyclist education (41).

Possible Cause/Problem #2

The bicyclist strikes a pedestrian, object or other bicyclist on a shared-use path, sidewalk, or roadway.



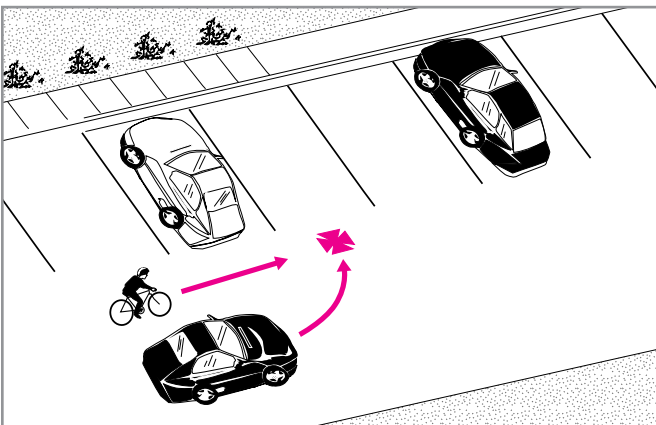
General Countermeasures

- Make roadway surface hazard improvements (1).
- Add/improve lighting (4).
- Make parking improvements (5).
- Implement maintenance countermeasures (22, 23, 24).
- Provide path intersection treatments (32).
- Provide path intersection advance warning treatments (33).
- Implement “share the path” measures (34).
- Improve pavement markings (38).
- Provide school zone improvements (39).
- Provide bicyclist education (41).

14. NON-ROADWAY AND OTHER CRASHES

Possible Cause/Problem #1 (Non-Roadway)

A motorist and bicyclist collide in a parking lot or driveway. The motor vehicle may be backing at the time of the crash.

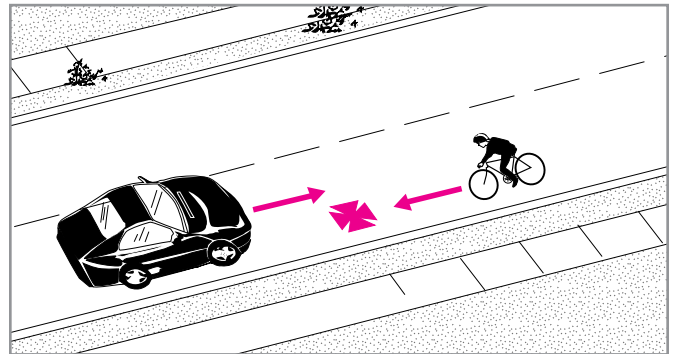


General Countermeasures

- Add/improve lighting (4).
- Redesign parking (5).
- Make driveway improvements (7).
- Perform repetitive and short-term maintenance (22).
- Perform major maintenance (23).
- Institute a hazard identification program (24).
- Provide speed tables, humps, or cushions (27).
- Make sign improvements (37).
- Improve pavement markings (38).
- Provide bicyclist education (41).
- Provide motorist education (42).

Possible Cause/Problem #2 (Other)

Either the bicyclist or the motorist was traveling in the wrong lane or direction and collided head-on with the other. The bicyclist could have been riding on the wrong side of the roadway or the motorist could have been passing another vehicle when the crash occurred.

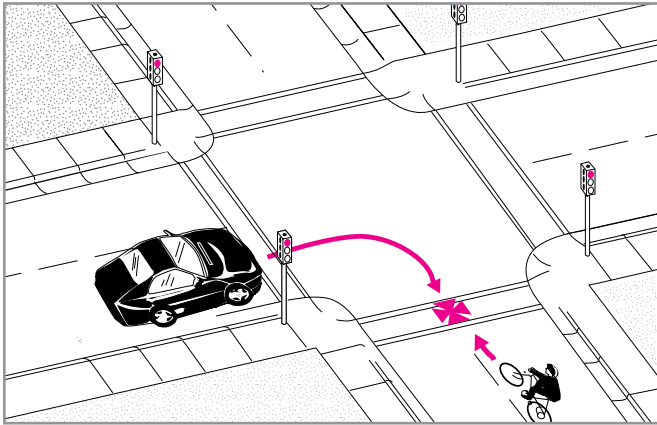
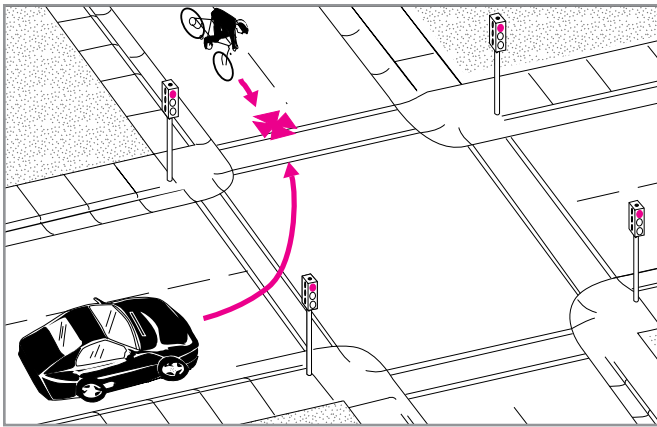


General Countermeasures

- Add or improve roadway lighting (4).
- Provide bike lanes (11).
- Provide paved shoulders (13).
- Complete repetitive and short-term maintenance (general sight distance maintenance) (22, 24).
- Provide law enforcement (40).
- Provide bicyclist education about wrong-way riding and conspicuity and using lights at night (41).
- Provide motorist education on safe passing (42).

Possible Cause/Problem #3 (Other)

Either the bicyclist or motorist made a turning error (swung too wide on a right turn or cut the corner on a left turn) and turned into the opposing lane or path of the other.

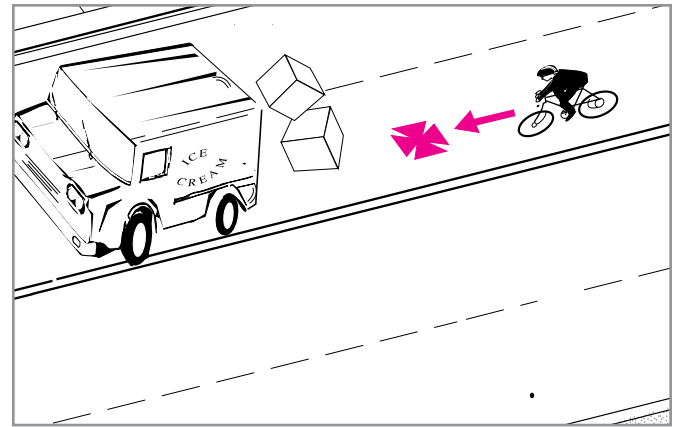


General Countermeasures

- a. Install median divider (6).
- b. Make driveway improvements (7).
- c. Revise curb radii or re-align skewed intersections (16).
- d. Install roundabout (17) or mini traffic circle (25) at intersection.
- e. Add or improve intersection markings (18).
- f. Impose turning restrictions (20).
- g. Install raised intersection (30).

Possible Cause/Problem #4 (Other)

The bicyclist or motorist intentionally caused the crash, one or the other lost control due to impairment, mechanical problems, or other causes, or there were other unusual circumstances such as the bicyclist being struck by falling cargo. Few specific countermeasures can be identified for unusual or non-specific types of crashes other than educational and enforcement measures. To view general performance objectives and corresponding countermeasures to reduce crashes and encourage safer bicycling, go to the Performance Objectives section.



CRASH-RELATED COUNTERMEASURES

A total of 50 different bicyclist countermeasures are presented in Chapter 5 of this guide. To assist engineers and planners who may want further guidance on which measures are appropriate to address certain types of bicycle crashes, a matrix is provided on pages 32–33. The applicable treatments within the nine categories of countermeasures are shown for each of the 13 crash type groups.

To illustrate how to use the table, consider the sixth crash type group in the table (“Bicyclist Ride Out—Mid-block”). This is a crash involving a bicyclist riding out into the roadway from a location in the middle of the block, such as a residential driveway. This tends to be a right-angle crash and often involves younger bicyclists.

The chart shows that there are 17 potential countermeasures that may reduce the probability of this type of crash, depending on the site conditions. These countermeasures include shared roadway improvements, such as removal of parking to increase sight distance, traffic calming measures such as speed humps that could slow motor vehicle speeds and decrease the braking distance, and other possible countermeasures.

In Chapter 5, details are provided on each of the countermeasures listed. The quick reference index at the start of Chapter 5 can be used to easily locate the page containing the detailed description. The Web/CD-ROM application allows the list of countermeasures to be refined on the basis of site characteristics (see Chapter 4).

These charts are intended to give general information on candidate solutions that should be considered when trying to reduce a pattern of bicycle crashes at a specific location or roadway section. Many bicyclist crashes are the direct result of careless or illegal motorist behavior or unsafe bicyclist behavior. Many of these crashes can-

not necessarily be prevented by roadway improvements alone. In such cases, bicyclist and motorist education and enforcement activities may be helpful.

PERFORMANCE OBJECTIVES

Bicyclists face a variety of challenges when they ride along and across streets with motor vehicles. Communities are asking for help to “slow traffic down,” and “make the street more inviting to bicyclists.”

The following is a list of requests (objectives) that transportation professionals are likely to face when working to provide bicycle safety and mobility:

- Provide safe on-street facilities/space for bicyclists.
- Provide off-road paths or trails for bicyclists.
- Provide and maintain quality surfaces for bicyclists.
- Provide safe intersections for bicyclists.
- Improve motorist behavior/compliance with traffic laws.
- Improve bicyclist behavior/compliance with traffic laws.
- Encourage and promote bicycling.

Each of these objectives can be accomplished through a variety of the individual treatments presented in this chapter. Yet, most treatments will work best when used at multiple locations and in combination with other treatments.

In addition, many of the treatments will accomplish two or more objectives. The key is to make sure that the right treatments are chosen to accomplish the desired effect.

The matrix located on pages 34–35 shows which countermeasures are appropriate to consider for the seven performance objectives. In using the chart, it is important to remember that it is simply a guide. In all cases, good engineering judgment should be applied when making decisions about what treatment will be best for a specific location.

PROGRAM OF IMPROVEMENTS

While some bicycle crashes are associated with deficient roadway designs, bicyclists and motorists often contribute to crashes through a disregard or lack of understanding of laws and safe driving or riding behavior.⁹ Because most crashes are a result of human error, crashes will not be completely eliminated as long as bicyclists and motor vehicles share the same space. The consequences of these crashes are exacerbated by speeding, failing to yield, or failing to check both directions for traffic, so new education, enforcement, and engineering tools are needed to

manage the conflicts between bicyclists and drivers.

A complete program of bicyclist safety improvements includes:

- Shared roadway accommodations, such as provision of roadway surface improvements or lighting where needed.
- Provision of bicyclist facilities, such as bike lanes, wide curb lanes and separate trails.
- Provision of intersection treatments, such as curb radii revisions and sight distance improvements.
- Maintenance of roadways and trails.
- Use of traffic calming treatments, such as mini circles and speed control measures.
- Adequate signs, signals, and markings, particularly as pertains to intersections and share-the-road philosophies.
- Programs to enforce existing traffic laws and ordinances for motorists (e.g., obeying speed limits, yielding to approaching bicyclists when turning, traffic signal compliance, obeying drunk-driving laws) and bicyclists (e.g., riding in the same direction with traffic, obeying traffic signals and signs).
- Encouraging bicyclists to use reflective clothing and appropriate lighting when riding at night.
- Encouraging and educating bicyclists in proper helmet use.
- Education programs provided to motorists and bicyclists.
- Providing support facilities, such as bicycle parking and events, such as ride-to-work days or fundraisers to support bicycling.

Roadway improvements can often reduce the likelihood of a bicycle-motor vehicle crash. Physical improvements are most effective when tailored to an individual location and traffic problem. Factors to consider when choosing an improvement include: location characteristics, bicycle and motor vehicle volume and types, motor vehicle speed, design of a given location, city laws and ordinances, and financial constraints. Many of these factors are included for consideration in the BIKESAFE Selection Tool (see Chapter 4).

It is important to remember that overuse or unjustified use of any traffic control measure is not recommended, since this may breed disrespect for such devices. While facilities and shared roadway accommodations for bicyclists can, in many cases, reduce the risk of collisions, crash reduction is not the only reason for providing such accommodations. Other benefits include improved access to destinations by riding, better air quality due to less dependence on driving, and improved personal health. Traffic and transportation engineers have the responsibility

for providing facilities for all modes of travel, including bicycling (and walking).

COUNTERMEASURES ASSOCIATED WITH SPECIFIC CRASH GROUPS

Crash Type	Shared Roadway	On-Road Bike Facilities	Intersection Treatments	Maintenance
1) Motorist failed to yield – signalized intersection	<ul style="list-style-type: none"> · Lighting Improvements · Reduce Lane Number · Reduce Lane Width 		<ul style="list-style-type: none"> · Curb Radii Revisions · Roundabouts · Intersection Markings · Sight Distance Improvements · Turning Restrictions 	·
2) Motorist failed to yield – non-signalized intersection	<ul style="list-style-type: none"> · Lighting Improvements · Reduce Lane Number · Reduce Lane Width 		<ul style="list-style-type: none"> · Curb Radii Revisions · Roundabouts · Intersection Markings · Sight Distance Improvements · Merge and Weave Area Redesign 	
3) Bicyclist failed to yield – signalized intersection	<ul style="list-style-type: none"> · Lighting Improvements · Median/Crossing Island · Reduce Lane Number · Reduce Lane Width 		<ul style="list-style-type: none"> · Roundabouts · Intersection Markings · Sight Distance Improvements 	
4) Bicyclist failed to yield – non-signalized intersection	<ul style="list-style-type: none"> · Lighting Improvements · Reduce Lane Number · Reduce Lane Width 		<ul style="list-style-type: none"> · Roundabouts · Intersection Markings · Sight Distance Improvements · Merge and Weave Area Redesign 	
5) Motorist drive out – midblock	<ul style="list-style-type: none"> · Parking Treatments · Driveway Improvements · Access Management 			
6) Bicyclist ride out – midblock	<ul style="list-style-type: none"> · Parking Treatments · Median/Crossing Island · Driveway Improvements · Access Management · Reduce Lane Number · Reduce Lane Width 			
7) Motorist turned or merged left into path of bicyclist	<ul style="list-style-type: none"> · Lighting Improvements · Parking Treatments · Median/Crossing Island · Driveway Improvements · Access Management · Reduce Lane Number 	<ul style="list-style-type: none"> · Bike Lanes · Paved Shoulders · Combination Lanes 	<ul style="list-style-type: none"> · Curb Radii Revisions · Roundabouts · Intersection Markings · Sight Distance Improvements · Turning Restrictions · Merge and Weave Area Redesign 	
8) Motorist turned or merged right into path of bicyclist	<ul style="list-style-type: none"> · Lighting Improvements · Parking Treatments · Driveway Improvements · Access Management · Reduce Lane Number · Reduce Lane Width 	<ul style="list-style-type: none"> · Bike Lanes · Paved Shoulders · Combination Lanes 	<ul style="list-style-type: none"> · Curb Radii Revisions · Intersection Markings · Turning Restrictions · Merge and Weave Area Redesign 	
9) Bicyclist turned or merged left into path of motorist	<ul style="list-style-type: none"> · Roadway Surface Improvements · Lighting Improvements · Parking Treatments · Median/Crossing Island · Driveway Improvements · Access Management · Reduce Lane Number · Reduce Lane Width 		<ul style="list-style-type: none"> · Roundabouts · Intersection Markings · Sight Distance Improvements 	<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
10) Bicyclist turned or merged right into path of motorist	<ul style="list-style-type: none"> · Reduce Lane Number · Reduce Lane Width 	<ul style="list-style-type: none"> · Bike Lanes 	<ul style="list-style-type: none"> · Intersection Markings 	<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
11) Motorist overtaking bicyclist	<ul style="list-style-type: none"> · Roadway Surface Improvements · Bridge and Overpass Access · Tunnel and Underpass Access · Lighting Improvements · Parking Treatments · Reduce Lane Width 	<ul style="list-style-type: none"> · Bike Lanes · Wide Curb Lanes · Paved Shoulders · Combination Lanes 		<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
12) Bicyclist overtaking motorist	<ul style="list-style-type: none"> · Parking Treatments 	<ul style="list-style-type: none"> · Bike Lanes · Wide Curb Lanes · Paved Shoulders · Combination Lanes 		<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
13) Non-motor vehicle crashes	<ul style="list-style-type: none"> · Roadway Surface Improvements · Bridge and Overpass Access · Tunnel and Underpass Access · Lighting Improvements · Parking Treatments · Driveway Improvements 			<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program

Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement
<ul style="list-style-type: none"> Mini Traffic Circles Chicanes Speed Tables/Humps/Cushions Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Sign Improvements Pavement Marking Improvements School Zone Improvements 	<ul style="list-style-type: none"> Law Enforcement Bicyclist Education Motorist Education
<ul style="list-style-type: none"> Mini Traffic Circles Chicanes Visual Narrowing Speed Tables/Humps/Cushions Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Sign Improvements Pavement Marking Improvements School Zone Improvements 	<ul style="list-style-type: none"> Law Enforcement Bicyclist Education Motorist Education
<ul style="list-style-type: none"> Mini Traffic Circles 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Bike-Activated Signal Sign Improvements Pavement Marking Improvements School Zone Improvements 	<ul style="list-style-type: none"> Law Enforcement Bicyclist Education Motorist Education
<ul style="list-style-type: none"> Mini Traffic Circles Chicanes Speed Tables/Humps/Cushions Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Bike-Activated Signal Sign Improvements Pavement Marking Improvements School Zone Improvements 	<ul style="list-style-type: none"> Law Enforcement Bicyclist Education Motorist Education
	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Sign Improvements Pavement Marking Improvements 	<ul style="list-style-type: none"> Law Enforcement Bicyclist Education Motorist Education
<ul style="list-style-type: none"> Chicanes Speed Tables/Humps/Cushions Visual Narrowing Traffic Diversion 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Bike-Activated Signal School Zone Improvements 	<ul style="list-style-type: none"> Law Enforcement Bicyclist Education
<ul style="list-style-type: none"> Mini Traffic Circles Traffic Diversion Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Sign Improvements Pavement Marking Improvements 	<ul style="list-style-type: none"> Bicyclist Education Motorist Education
<ul style="list-style-type: none"> Traffic Diversion Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Sign Improvements Pavement Marking Improvements 	<ul style="list-style-type: none"> Bicyclist Education Motorist Education
<ul style="list-style-type: none"> Mini Traffic Circles Chicanes Speed Tables/Humps/Cushions Visual Narrowing Traffic Diversion Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Install Signal/Optimize Timing Bike-Activated Signal Pavement Marking Improvements 	<ul style="list-style-type: none"> Bicyclist Education
<ul style="list-style-type: none"> Mini Traffic Circles Chicanes Speed Tables/Humps/Cushions Visual Narrowing Traffic Diversion Raised Intersection 	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments 	<ul style="list-style-type: none"> Pavement Marking Improvements 	<ul style="list-style-type: none"> Bicyclist Education
<ul style="list-style-type: none"> Chicanes Speed Tables/Humps/Cushions Visual Narrowing Traffic Diversion 	<ul style="list-style-type: none"> Separate Shared-Use Path 	<ul style="list-style-type: none"> Sign Improvements Pavement Marking Improvements 	<ul style="list-style-type: none"> Bicyclist Education Motorist Education
	<ul style="list-style-type: none"> Separate Shared-Use Path 	<ul style="list-style-type: none"> Pavement Marking Improvements 	<ul style="list-style-type: none"> Bicyclist Education Motorist Education
	<ul style="list-style-type: none"> Path Intersection Treatments Intersection Warning Treatments Share the Path Treatments 	<ul style="list-style-type: none"> Pavement Marking Improvements School Zone Improvements 	<ul style="list-style-type: none"> Bicyclist Education

COUNTERMEASURES ASSOCIATED WITH SPECIFIC OBJECTIVES

Objectives	Shared Roadway	On-Road Bike Facilities	Intersection Treatments	Maintenance
1) Provide safe on-street facilities/space for bicyclists.	<ul style="list-style-type: none"> · Roadway Surface Improvements · Bridge and Overpass Access · Tunnel and Underpass Access · Lighting Improvements · Parking Treatments · Median/Crossing Island · Driveway Improvements · Access Management · Reduce Lane Number · Reduce Lane Width 	<ul style="list-style-type: none"> · Bike Lanes · Wide Curb Lanes · Paved Shoulders · Combination Lanes · Contraflow Bike Lanes 		<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
2) Provide off-road paths or trails for bicyclists.				<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
3) Provide and maintain quality surfaces for bicyclists.	<ul style="list-style-type: none"> · Roadway Surface Improvements · Bridge and Overpass Access · Tunnel and Underpass Access 			<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
4) Provide safe intersections for bicyclists.	<ul style="list-style-type: none"> · Lighting Improvements · Parking Treatments · Reduce Lane Number · Reduce Lane Width 		<ul style="list-style-type: none"> · Curb Radii Revisions · Roundabouts · Intersection Markings · Sight Distance Improvements · Turning Restrictions · Merge and Weave Area Redesign 	
5) Improve motorist behavior/compliance with traffic laws.	<ul style="list-style-type: none"> · Lighting Improvements · Parking Treatments · Driveway Improvements · Reduce Lane Width 		<ul style="list-style-type: none"> · Curb Radii Revisions · Roundabouts · Intersection Markings · Sight Distance Improvements · Merge and Weave Area Redesign 	<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
6) Improve bicyclist behavior/compliance with traffic laws.	<ul style="list-style-type: none"> · Roadway Surface Improvements · Bridge and Overpass Access · Tunnel and Underpass Access · Parking Treatments 	<ul style="list-style-type: none"> · Bike Lanes 	<ul style="list-style-type: none"> · Intersection Markings · Sight Distance Improvements · Merge and Weave Area Redesign 	<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program
7) Encourage and promote bicycling.	<ul style="list-style-type: none"> · Roadway Surface Improvements · Bridge and Overpass Access · Tunnel and Underpass Access · Lighting Improvements · Median/Crossing Island 	<ul style="list-style-type: none"> · Bike Lanes · Paved Shoulders 		<ul style="list-style-type: none"> · Repetitive/Short-Term Maintenance · Major Maintenance · Hazard Identification Program

Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement	Support Facilities and Programs
-----------------	-------------------------	--------------------------	---------------------------	---------------------------------

- Mini Traffic Circles
- Chicanes
- Speed Tables/Humps/Cushions
- Visual Narrowing
- Traffic Diversion
- Raised Intersection

- Sign Improvements
- Pavement Marking Improvements
- School Zone Improvements

- Practitioner Education

- Wayfinding
- Aesthetics/Landscaping

- Separate Shared-Use Path
- Path Intersection Treatments
- Intersection Warning Treatments
- Share the Path Treatments

- Sign Improvements
- Pavement Marking Improvements

- Bicyclist Education
- Practitioner Education

- Wayfinding
- Aesthetics/Landscaping

- Pavement Marking Improvements

- Practitioner Education

- Mini Traffic Circles
- Chicanes
- Speed Tables/Humps/Cushions
- Raised Intersection

- Path Intersection Treatments
- Intersection Warning Treatments

- Install Signal/Optimize Timing
- Bike-Activated Signal
- Sign Improvements
- Pavement Marking Improvements
- School Zone Improvements

- Practitioner Education

- Mini Traffic Circles
- Chicanes
- Speed Tables/Humps/Cushions
- Visual Narrowing
- Traffic Diversion
- Raised Intersection

- Install Signal/Optimize Timing
- Sign Improvements
- Pavement Marking Improvements
- School Zone Improvements

- Law Enforcement
- Motorist Education

- Bike Maps
- Events/Activities

- Mini Traffic Circles

- Path Intersection Treatments
- Intersection Warning Treatments
- Share the Path Treatments

- Install Signal/Optimize Timing
- Bike-Activated Signal
- Sign Improvements
- Pavement Marking Improvements
- School Zone Improvements

- Law Enforcement
- Bicyclist Education

- Bike Maps
- Events/Activities

- Separate Shared-Use Path

- Bike-Activated Signal
- School Zone Improvements

- Bicyclist Education
- Motorist Education
- Practitioner Education

- Bike Parking
- Transit Access
- Bicyclist Personal Facilities
- Bike Maps
- Wayfinding
- Events/Activities
- Aesthetics/Landscaping

Chapter 4 – The Expert System

BIKESAFE: Background - Mozilla Firefox

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http://www.bicyclinginfo.org/bikesafe/background.cfm

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BIKESAFE Bicycle Countermeasure Selection System


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Background

Bicycling is one of the oldest forms of human transportation, yet the modern-day cyclist faces problems related to suburban living and motor vehicle speed and traffic volume, among others. The various kinds of facilities needed to maintain bicycling as a viable transportation mode have been frequently overlooked in the building of modern transportation systems. This situation has been changing in recent years, and now people want more ways to get around their communities and elsewhere via bicycle. And they want to be able to make these bicycling trips in a safe and enjoyable manner.



The bicyclist is a vulnerable road user, and creating a safer bicycling environment involves more than striping a bike lane or re-striping motor vehicle travel lanes to accommodate a wide curb lane or even building a separated path. A truly viable bicycling network involves both the big picture and the smallest details – from how a community is built and connected, to the maps that indicate safe bicycling routes, to the surface materials on the bike path. Bicycling facilities should be accessible to various types of users, and information should be provided about the level of skill necessary on a

Page Contents:

- [Land Use and Bicycling](#)
- [Assume That People Will Bicycle](#)
- [Transit and Bicycling](#)
- [How Bicyclists are Affected by Motor Vehicle Traffic Volume and Speed](#)
- [Options to Improve Bicycling](#)

How to Use BIKESAFE

Countermeasures

Selection Tool

Case Studies

Interactive Matrices

The BIKESAFE expert system is provided on the enclosed CD-ROM and is available online at <http://safety.fhwa.dot.gov/bikesafe> and at <http://www.bicyclinginfo.org/bikesafe>. This chapter provides an overview of the application and specific instructions on how to access and use the tools available. The application is designed to:


- Provide information on the countermeasures available to prevent bicycle crashes and improve motorist and bicyclist behavior.
- Highlight the purpose, considerations and cost estimates associated with each countermeasure.
- Provide a decision process to select the most applicable

countermeasures for a specific location.

- Provide links to case studies showing the various treatments and programs implemented in communities around the U.S.
- Provide easy access to resources such as statistics, implementation guidance, and reference materials.

The expert system combines the resources provided in this document with online tools (see home page below) to enable practitioners to effectively select engineering, education, or enforcement treatments to mitigate a known crash problem or achieve a specific performance objective.

[skip to main content](#) | [site map](#)



Bicycle Countermeasure Selection System

RESOURCES | [background](#) | [crash factors](#) | [crash analysis](#) | [objectives](#) | [implementation](#)

[more info](#) | [downloads](#) | search:

TOOLS | [selection tool](#)

[interactive matrices](#)

[countermeasures](#)

[case studies](#)

What is BIKESAFE?

The Bicycle Countermeasure Selection System (BIKESAFE) is intended to provide practitioners with the latest information available for improving the safety and mobility of those who bicycle. The information on the site falls into two categories, Resources and Tools, explained below. [Learn more about BIKESAFE's contents and purpose](#), or go directly to any of the links above.


Resources

The resources are informational pages providing an overview of bicycling in today's transportation system, information about bicycle crash factors and analysis, and selecting and implementing bicycling improvements. [Learn more about the resources sections](#) or choose any link from the navigation bar above to get started.

Tools

The tools allow the user to select appropriate countermeasures or treatments to address specific bicycling objectives or crash problems. [Start with one of these tools](#) if you're already familiar with the issues involved in bicycle safety and mobility and want to start learning how you can make improvements in your own community.

Project sponsored by:



U.S. Department of Transportation
Federal Highway Administration

Site created January 2006.

This site is best viewed in [Firefox 1.5+](#), [Netscape 8+](#), or [Internet Explorer 6.0+](#) browsers.

The home page of the BIKESAFE Web application introduces the site and highlights the Resources and Tools sections.

The resource materials included in the Web/CD-ROM application are related to this document as follows:

WEB/CD-ROM	PRINT DOCUMENT*
Background	Chapter 1: The Big Picture
Crash Factors	Chapter 2: Bicyclist Crash Factors
Crash Analysis Objectives	Chapter 3: Selecting Improvements for Bicyclists
Implementation Publications	Chapter 7: Implementation and Resources

*Chapters 5 and 6 include the countermeasures and case studies, which are available as Tools on the Web/CD-ROM application.

HOW TO USE BIKESAFE

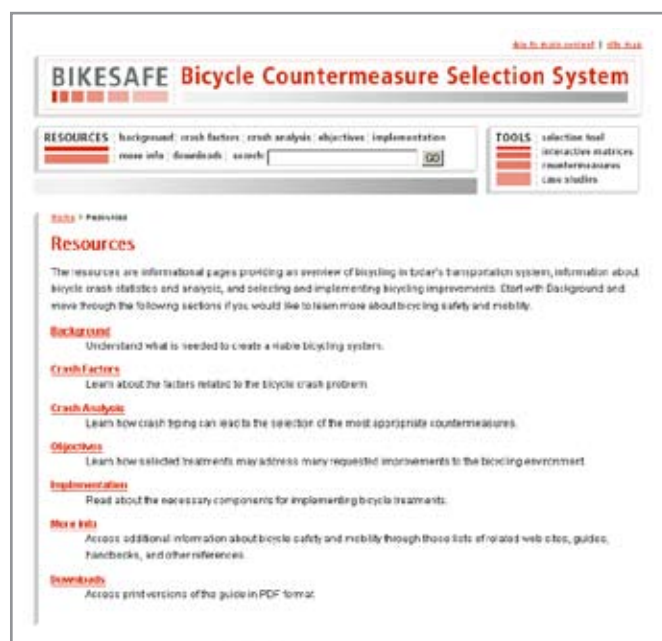
The opening page gives a brief explanation of BIKE-SAFE and then highlights the “Resources” and “Tools” sections. The “Resources” section provides an overview of bicycling in today’s transportation system, information about bicycle crash statistics and analysis, and selecting and implementing bicycling improvements. “Tools” allows the user to select appropriate countermeasures or treatments to address specific objectives, such as the need to make intersections safer for bicyclists, or crash problems, such as overtaking motorists striking bicyclists from the rear on a busy corridor with inadequate space. This section also includes a large number of case studies to illustrate

treatments implemented in communities throughout the United States.

The rest of this chapter focuses on the four tools available on the Web/CD-ROM application. Each can be used to enter the system, as described below:

- **Selection Tool** – This interactive tool allows the user to develop a list of possible countermeasures on the basis of site characteristics, such as geometric features and operating conditions, and the type of safety problem or desired behavioral change. The decision logic used to determine when specific treatments are and are not applicable is based on input from an expert panel of practitioners.
- **Interactive Matrices** – This tool shows the relationship between the countermeasures and the performance objectives or crash types and can be used to display applicable countermeasures.
- **Countermeasures** – Details of 50 engineering, education, enforcement, and other treatments or programs for improving bicycle safety and mobility are provided in the categories of shared roadway treatments; on-road bicycle facilities; intersection treatments; traffic calming applications; trails/shared-use paths; markings, signs, and signals; education and enforcement; and support facilities and programs.
- **Case Studies** – More than 50 real-world examples illustrate various treatments or programs as implemented in a state or municipality.

BIKESAFE is designed to allow the tools and information to be accessed from multiple points of entry. Links are provided to allow users to easily navigate between the tools and to quickly access the resource materials. Provided below are four examples of how a user may choose to enter the system and access the tools.



Resources page.



Tools page.

1) Selection Tool – The user may have information available about geometrics and operating conditions of a particular location and either has a specific type of crash problem or desires to change motorist/bicyclist behavior at the site. Known location information may be entered by answering a series of questions. The system will then display the countermeasure options to be considered.

2) Interactive Matrices – The user has a specific type of crash problem or desires to change motorist/bicyclist behavior but does not have specific information about the characteristics of the site. The matrices can be used to view and access the types of countermeasures available for further consideration.

3) Countermeasures – The user is interested in acquiring information about a particular treatment or program. The countermeasures page can be directly accessed and displays the nine categories of treatments included. Detailed descriptions of the 50 countermeasures can be accessed from this point. Links to relevant case studies can then be accessed from the description pages.

4) Case Studies – The user wishes to see specific examples of treatments that have been installed. The case studies page provides a list of all case studies assembled, as well as the option of selecting a specific implementation example by type of treatment or by location (state and municipality). From there, the user can access the countermeasure description pages that are relevant to a particular example.

Each of these tools is described in more detail in the remainder of the chapter.

SELECTION TOOL

The interactive selection tool allows the user to refine their selection of countermeasures on the basis of specific site characteristics and/or the type of safety problem or desired behavioral change. One begins by choosing selection tool from the Tools menu. A screen will appear with specific instructions on how to use the tool (see next page), and then allows the user to click on “Start the Selection Tool.” This leads to a simple three-step process:

Step 1: Choose the Location—A text box is provided for the user to describe the location of interest (e.g., “Route 1 between Spring Ave. and Summer Ave.” for a roadway segment, or “Intersection of Route 1 and Spring Ave.” for an intersection). This is entirely for the benefit of the user and allows other descriptive information to be entered

as well. This information will be stored and displayed as typed with the results so the project can be identified. In the figure on the next page, a specific intersection location—Main Street and Broadway Avenue—has been entered.

Step 2: Select the Goal of the Treatment—The user must then choose a particular type of crash problem to be mitigated or a performance objective to be achieved. As shown in the figure on page 42, there are seven performance objectives and 13 crash groups. Only one can be selected. As the user proceeds through the steps, the previous input is shown on the right side of the screen (in this example, the roadway location from Step 1).

Step 3: Describe the Site—Finally, the user is asked to provide input about the characteristics of the site. As shown in the figure on page 43, there are nine questions that are asked in reference to the general location, geometric features, and operating conditions. The default value is “Not Applicable/Unknown” for each question. The answers to these questions are used to narrow the list of appropriate countermeasures for a specific goal or crash type. For example, if the location of interest was a roadway segment (midblock location), then the treatments associated with intersection improvements would not be applicable and would not be included in the results as applicable countermeasures.

The field investigation form included in Appendix A can be used for site visits to obtain the information asked for in this last step. For any question where the information is not known, an entry of “Not Applicable/Unknown” will simply retain all countermeasures relevant to the question, and the choice of treatments will not be reduced.

After completing these three steps, the user clicks Get Results. The information entered is used to develop a list of applicable countermeasures, which are presented as shown on page 44. The user can then read more about a specific countermeasure by selecting it, which takes the user to the countermeasure description page. The user is advised to carefully read the countermeasure description page, especially if some of the suggested treatments seem “inappropriate.” The description of the countermeasure, along with the “Considerations” section, hopefully will clear up questions. As an example, “Reduce Lane Width” is displayed for the crash type of motorist overtaking bicyclist on a shared roadway. While this may seem counterintuitive, reducing lane width is one way to reduce motor vehicle speed. If speed is reduced, then some overtaking crashes may be averted (e.g., on curves with poor sight distance).

Selection Tool

How the Tool Works

The selection tool is designed to receive input on several variables from the user in three steps.

1

Choose the Location

First, enter the location of the site in question. This allows the user to create reports for several different sites and keep the results separated by location. It is used for reporting purposes only and is not stored permanently by the operators of this web site.

2

Select the Goal of the Treatment

Second, one must decide on the goal of the treatment. It may either be to achieve a specific performance objective, such as reduce traffic volumes, or to mitigate a specific type of bicyclist-motor vehicle collision.

3

Describe the Site

Once a specific goal has been selected, the third step is to provide answers to a series of questions related to the geometric and operational characteristics of the site in question. The answers to these questions are used to narrow the list of appropriate countermeasures for a specific goal. For example, if the location of interest were a segment of roadway, or midblock location, then the treatments associated with intersection improvements would not be applicable and thus, would not be included in the results as possible countermeasures.

For any question where the information is not known, an entry of "unknown" will simply retain the countermeasures relevant to the question, and the range of treatments will not be reduced.

[Start the Selection Tool](#)

The Selection Tool includes three simple steps that are described on its opening page.

Selection Tool

Step One: Choose the Location

For the roadway location being addressed, please enter a description.

Location:

Main Street and Broadway Avenue

Proceed to Step 2

The user may enter any combination of text and numbers to describe the location of interest.

Selection Tool

Step Two: Select the Goal of the Treatment

For the roadway location being addressed, the goal of the bicycling treatment is intended to improve bicyclist safety and access by either achieving one of the following performance objectives OR mitigating one of the following crash types.

Therefore, you must choose one of the following to begin:

Performance Objectives

- ☒ Provide safe on-street facilities/space for bicyclists
- ☐ Provide off-road paths or trails for bicyclists
- ☐ Provide and maintain quality surfaces for bicyclists
- ☐ Provide safe intersections for bicyclists
- ☐ Improve motorist behavior/compliance with traffic laws
- ☐ Improve bicyclist behavior/compliance with traffic laws
- ☐ Encourage and promote bicycling

Crash Types

- ☐ Motorist failed to yield - signalized intersection
- ☐ Motorist failed to yield - non-signalized intersection
- ☐ Bicyclist failed to yield - signalized intersection
- ☐ Bicyclist failed to yield - non-signalized intersection
- ☐ Motorist drove out - midblock
- ☐ Bicyclist rode out - midblock
- ☐ Motorist turned or merged left into path of bicyclist
- ☐ Motorist turned or merged right into path of bicyclist
- ☐ Bicyclist turned or merged left into path of motorist
- ☐ Bicyclist turned or merged right into path of motorist
- ☐ Motorist overtaking bicyclist
- ☐ Bicyclist overtaking motorist
- ☐ Non-motor vehicle crashes

Your Input:

Roadway Location:

test

Next Steps:

[Proceed to Step 3](#)

A specific performance objective or crash type to be mitigated must be selected in step two.

Selection Tool

Step Three: Describe the Site

Please answer the following questions.

1. Is the problem location on an off-road multi-use path (not at an intersection with a roadway) or on a roadway (or roadway/path intersection)?

- ☒ Roadway
- ☐ Path
- ☐ Not Applicable/Unknown

2. In what type of area is the roadway located?

- ☐ Urban CBD
- ☐ Urban - Other
- ☒ Suburban
- ☐ Rural
- ☐ Not Applicable/Unknown

3. What is the functional class of the roadway?

- ☐ Local
- ☐ Collector & Minor Arterial
- ☐ Principal Arterial
- ☒ Not Applicable/Unknown

4. Is the problem location at an intersection or midblock?

- ☐ Intersection
- ☒ Midblock
- ☐ Not Applicable/Unknown

5. Is vehicle volume low, medium, or high?

- ☐ Low (<10,000 ADT)
- ☒ Medium (10 - 25,000 ADT)
- ☐ High (>25,000 ADT)
- ☐ Not Applicable/Unknown

6. Is vehicle prevailing speed low, medium, or high?

- ☐ Low (<= 30 mph)
- ☒ Med (31 - 44 mph)
- ☐ High (>45mph)
- ☐ Not Applicable/Unknown

7. What is the number of through lanes?

- ☐ <=2
- ☒ 3 or 4
- ☐ 5 or more
- ☐ Not Applicable/Unknown

8. Is a traffic signal present, being considered, or not an option?

- ☐ Present (removal not an option)
- ☐ Present (removal could be an option)
- ☐ Not present (installation is not an option)
- ☐ Not present (installation possible)
- ☒ Not Applicable/Unknown

9. What are the existing on-road bicycle facilities?

- ☐ Bike Lane
- ☐ Wide Curb Lane
- ☐ Paved Shoulder
- ☒ None or Other
- ☐ Not Applicable/Unknown

Your Input:

Roadway Location:

Main Street and Broadway Avenue

Your Performance Objective:

**Provide safe on-street facilities/
space for bicyclists.**

Next Steps:

Edit:

[Change Your Performance
Objective](#)

[Start Over](#)

[Get Results](#)

The characteristics of the location are provided in step three by answering nine questions.

In addition to the applicable countermeasures, the results page also provides the user with a list of the inputs made in the three steps. Options are provided for changing these inputs for the location of interest, exporting the results to Microsoft Excel, or starting over with a new location.

[Home](#) > [Selection Tool](#) > [Step One: Choose the Location](#) > [Step Two: Select the Goal of the Treatment](#) > [Step Three: Describe the Site](#) > [Applicable Countermeasures](#)

Applicable Countermeasures

Based upon your input, the following countermeasures were found:

- Shared Roadway
 - [Roadway Surface Improvements](#)
 - [Bridge and Overpass Access](#)
 - [Tunnel and Underpass Access](#)
 - [Lighting Improvements](#)
 - [Parking Treatments](#)
 - [Median/Crossing Island](#)
 - [Driveway Improvements](#)
 - [Access Management](#)
 - [Reduce Lane Number](#)
 - [Reduce Lane Width](#)
- On-Road Bike Facilities
 - [Bike Lanes](#)
 - [Wide Curb Lanes](#)
 - [Paved Shoulders](#)
 - [Combination Lanes](#)
 - [Contraflow Bike Lanes](#)
- Maintenance
 - [Repetitive/Short-Term Maintenance](#)
 - [Major Maintenance](#)
 - [Hazard Identification Program](#)
- Traffic Calming
 - [Speed Tables/Humps/Cushions](#)
 - [Visual Narrowing](#)
- Markings, Signs, Signals
 - [Sign Improvements](#)
 - [Pavement Marking Improvements](#)
 - [School Zone Improvements](#)
- Education and Enforcement
 - [Practitioner Education](#)
- Support Facilities and Programs
 - [Wayfinding](#)
 - [Aesthetics/Landscaping](#)

Your Input:

Roadway Location:

Main Street and Broadway Avenue

Your Performance Objective:

**Provide safe on-street facilities/
space for bicyclists.**

Your answers to the previous
questions:

Roadway or Path: Roadway

Location: Suburban

Functional Class: Not Applicable

Intersection or Midblock:

Midblock

**Volume: Medium (10 - 25,000
ADT)**

Speed: Med (31 - 44 mph)

Lanes: 3 or 4

Signal: Not Applicable

Bike Facilities: None or Other

Next Steps:

Edit:

[Change Your Performance
Objective](#)

[Change Your Answers to Site
Description](#)

Save:

[Output Results to Microsoft Excel](#)

[Start Over](#)

The results produced from the Selection Tool provide a list of applicable countermeasures and present the user with options to edit the responses, save the results, or start over..

INTERACTIVE MATRICES

Also included in the Web/CD-ROM application are two matrices that may be accessed by selecting “interactive matrices” from the Tools menu. The objectives matrix (shown below) provides the user with a quick view of the relationship between the seven performance objectives and the nine countermeasure groups. The crash analysis matrix (shown on the following page) allows the user to see the relationship between the 13 crash type groups and the nine countermeasure groups. In either matrix, a filled cell indicates that there is a specific countermeasure within the countermeasure group (shown in the columns) that is applicable to the crash group or performance objective listed in each row. The user can click on the bullet in any filled cell to obtain a drop-down list of the specific applicable countermeasures. From there, the user can select a countermeasure and be linked to the countermeasure description page or select another cell within the matrix.

[Home](#) > [Interactive Matrices](#) > Objectives Matrix

Objectives Matrix

Select an Objective and Countermeasure Group from the matrix below by clicking on one of the dots, or [view the text-only version](#).

Objective	Countermeasure Group								
	Shared Roadway	On-Road Bike Facilities	Intersection Treatments	Maintenance	Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement	Support Facilities and Programs
1. Provide safe on-street facilities/space for bicyclists.	•	•		•	•		•	•	•
2. Provide off-road paths or trails for bicyclists.				•		•	•	•	•
3. Provide and maintain quality surfaces for bicyclists.	•			•			•	•	
4. Provide safe intersections for bicyclists.	•		•		•	•	•	•	
5. Improve motorist behavior/compliance with traffic laws.	•		•	•	•		•	•	•
6. Improve bicyclist behavior/compliance with traffic laws.	•	•	•	•	•	•	•	•	•
7. Encourage and promote bicycling.	•	•		•		•	•	•	•

Cells with a bullet indicate there are one or more countermeasures within a countermeasure group that are applicable to a specific performance objective.

Crash Matrix

Select a Crash Group and Countermeasure Group from the matrix below by clicking on one of the dots, or [view the text-only version](#).

Crash Group	Countermeasure Group							
	Shared Roadway	On-Road Bike Facilities	Intersection Facilities	Maintenance	Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement
1. Motorist failed to yield – signalized intersection	•		•		•	•	•	•
2. Motorist failed to yield – non-signalized intersection	•		•		•	•	•	•
3. Bicyclist failed to yield – signalized intersection	•		•		•	•	•	•
4. Bicyclist failed to yield – non-signalized intersection	•		•		•	•	•	•
5. Motorist drove out – midblock	•					•	•	•
6. Bicyclist rode out – midblock	•				•	•	•	•
7. Motorist turned or merged left into path of bicyclist	•	•	•		•	•	•	•
8. Motorist turned or merged right into path of bicyclist	•	•	•		•	•	•	•
9. Bicyclist turned or merged left into path of motorist	•		•	•	•	•	•	•
10. Bicyclist turned or merged right into path of motorist	•	•	•	•	•	•	•	•
11. Motorist overtaking bicyclist	•	•		•	•	•	•	•
12. Bicyclist overtaking motorist	•	•		•		•	•	•
13. Non-motor vehicle crashes	•			•		•	•	•

Cells with a bullet indicate there are one or more countermeasures within a countermeasure group that are applicable to a specific crash group.

COUNTERMEASURES

Each of the 50 engineering, education, and enforcement countermeasures described in Chapter 5 are included in the Web/CD-ROM application. After selecting “countermeasures” within the Tools menu, the user may select one of the following nine categories of treatments:

- Shared Roadway
- On-Road Bike Facilities
- Intersection Treatments
- Maintenance
- Traffic Calming
- Trails/Shared-Use Paths
- Markings, Signs, Signals
- Education and Enforcement
- Support Facilities and Programs

A specific countermeasure may then be selected from those listed for each category. Each countermeasure includes a description of the treatment or program, purpose(s), considerations of which one should be aware, and cost estimates. Finally, there are links to specific case studies (if available) where the particular countermeasure has been implemented. An example countermeasure description page is shown on the following page for Bike Lanes.

[Home](#) > Countermeasures

Countermeasures

A total of 50 engineering, education, and enforcement countermeasures are discussed in this section. The treatments and programs selected for inclusion in this application are those that have been in place for an extended period of time and/or have been proven effective at the time the material for this product was being compiled. Since that time, new countermeasures continue to be developed, implemented, and evaluated. Thus, practitioners should not necessarily limit their choices to those included here; this material is a starting point. More information on the latest treatments and programs can be found through many of the Web sites and resources included in this section and the [More Info](#) section.



Shared Roadway:

The goal of an appropriately designed roadway should be to safely and efficiently accommodate all modes of travel, from bicyclists to pedestrians to motorists.



On-Road Bike Facilities:

Various kinds of on-road facilities, such as bike lanes, paved shoulders, and wide curb lanes, make bicyclists more comfortable.



Intersection Treatments:

Nearly half of all bicycle-motor vehicle crashes occur at intersections or other junctions.



Maintenance:

Maintenance of all kinds of bicycle facilities must be planned for and done routinely.



Traffic Calming:

Traffic calming is a way to design streets, using physical measures, to encourage people to drive more slowly.



Trails/Shared-Use Paths:

Bike paths or shared-use trails are complementary to the road network and serve recreational, child, and even commuter bicyclists.



Markings, Signs, Signals:

Traffic engineers have an arsenal of pavement markings, signs, and signals that can be used to inform, regulate, and warn both motorists and bicyclists.



Education and Enforcement:

Education and enforcement are key strategies in increasing bicyclist and motorist awareness and behavior.



Support Facilities and Programs:

The simple promotion of bicycling is a way to increase the amount of riding in a community.

The 50 countermeasures are divided among the nine categories of improvements shown here.

CASE STUDIES

The case studies described in Chapter 6 are included in the Web/CD-ROM application. The user can access the implementation examples by selecting “case studies” within the Tools menu. As shown on the following page, the user then has the option of selecting a case study on the basis of location or type of countermeasure. The figure on the following page provides an example of selection by countermeasure. The selection of the On-Road Bike Facilities countermeasure group produces a list of the five treatments included in the application. The selection of Bike Lanes produces a list of 16 case studies in which a bike lane was a component of the treatments implemented. Accessing each of these case studies provides information about the specific problem that was addressed, the solution implemented and the results achieved.

Home > Countermeasures > On-Road Bike Facilities > Bike Lanes

Bike Lanes:

View Other On-Road Bike Facilities Treatments

Bike lanes indicate a preferential or exclusive space for bicycle travel along a street. Bike lanes are typically 4.2 to 5.8 m (14 to 19 ft) in width and are designated by striping and/or signs. Colored pavement (for example, blue or red bike lanes) or a different paving material has also been used in certain situations to distinguish bike lanes from the motor vehicle lanes. Use of colored bike lanes is being reconsidered but is not yet an accepted MUTCD standard.² Bike lanes are usually marked along the right side of the roadway and should be designated in the left turning or right-turn lanes. Sometimes bike lanes are marked on the left side of a one-way street.

Adaptations to bike lanes have been used to solve local problems. An innovative bike lane transit stop treatment in Portland, OR, is used to reduce conflicts between bicycles and electric transit stop users adjacent to a bike lane (see [case study #19](#)). Adaptation for this treatment should be possible for a shared roadway situation. Some communities also employ combination bike and bus lanes, a single lane in which the curb that is shared by the two modes. This is generally workable unless there is incompatible bike and bus traffic.

Bike lanes have been found to provide more consistent separation between bicycles and passing motorists than shared travel lanes. The presence of the bike lane stripe has also been shown from research to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both motorists and bicyclists.⁷ The extra space created for bicyclists to also a benefit on congested roadways where motorists may be able to pass motor vehicles on the right.

Purpose

- Create on-street, separated travel facilities for bicycles.
- Provide separate operational space for safe motorist overtaking of bicyclists.
- Reduce or prevent the problems associated with bicyclists overtaking motor vehicles in narrow, congested areas.
- Narrow the roadway or roadway motor vehicle traffic lanes to encourage lower motor vehicle speeds.

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Considerations

- Where bike lanes are to be considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide adequate bike lane width.
- Provide a smoothly paved surface and keep the bike lane free of debris.
- Provide adequate space between the bike lane and parked cars so that open doors do not create a hazard for bicyclists.
- Avoid termination of bike lanes where bicyclists are left in a vulnerable situation.
- Determine if special signs or markings are necessary for situations such as a high-volume of bike left turns on a busy roadway.

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Estimated Cost

The cost of installing a bike lane is approximately \$3,100 to \$11,800 per kilometer (\$5,000 to \$18,900 per mile), depending on the condition of the pavement, the need to remove and repave the lane then, the need to adjust signalization, and other factors. It is most cost-efficient to create bike lanes during street reconstruction, street resurfacing, or at the time of original construction.

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Case Studies

- #1 - A Tale of Portland Bridges - Portland, OR
- #2 - Valencia Street Road Diet - Creating Space for Cyclists - San Francisco, CA
- #3 - Shoreline Park Expansion Project - Provision of Route and Pedestrian Encouragements - Santa Barbara, CA
- #4 - Bike Lane Safety Evaluation - Phoenix, AZ
- #5 - Establishing Bike Lanes - Chicago Streets for Cyclists Plan - Chicago, IL
- #6 - How Hampshire Street Pavement Markings Influence Bicycle and Motor Vehicle Performance - Cambridge, MA
- #7 - Bicyclist Safety Lanes and Other Traffic Calming Treatments on Jones Road - Eugene, OR
- #8 - Crossing Bike Lanes in Conjunction with Parallel Parking - San Francisco, CA
- #9 - Incorporating a Bike Lane through a Streetcar Platform - Portland, OR
- #10 - Preferential Transit Bicycle Right Turn Lanes on Broadway Boulevard - Tucson, AZ
- #11 - Fanning the Urban Aerial - Madison, WI
- #12 - Converting Bicycle Lanes on Utah Streets - Cambridge, MA
- #13 - Left Side Bike Lanes on One-Way Streets - Minneapolis, MN
- #14 - Converting Bicycle Lane/Right-Turn Lanes - Portland, OR
- #15 - Blue Bike Lanes at Intersection - Peachtree Forest, Portland, OR
- #16 - Converting an Adjacent Roadway to a Shared Right-Turn Lane - Bicycle Right-Turn Lane - Portland, OR
- #17 - Greenway Bike Route and Corridor Improvements - Schenck Plaza, VA

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Each countermeasure includes a description, purpose, considerations, estimated cost, and links to case studies where the treatment or program has been implemented.

Choose a Case Study

The 50 engineering, education, enforcement and promotional countermeasures are described in the [Countermeasures](#) section. Included in this section are case studies that illustrate these treatments or programs as implemented in a state or municipality. Examples are included from many States.

Each case study includes a description of the problem that was addressed, relevant background information, a description of the implemented solution, and any quantitative results from evaluation studies or qualitative assessments.

Many communities find it difficult to conduct formal evaluations of projects due to staff and budget limitations, but assessing whether a treatment has helped toward the intended objectives and not caused unexpected adverse impacts is critical to long-term improvement. We tend to think that some evaluation is better than none but occasionally may be misled by short-term or single-event types of assessments. In these cases, the judgment of experienced practitioners may help to fill in the gaps in knowledge or interpret results that seem "too good to be true." By far, longer-term evaluations (bicyclist/traffic counts, speed studies, etc.) are preferable to short-term project assessments. Multiple short-term studies of the same types of facilities do, however, build on each other and help to provide a more complete picture of the effectiveness of bicycling countermeasures. These cautions should be borne in mind when reviewing the case studies that follow.

Included for each study is a point of contact in the event that further information is desired. Please note that in some cases the specific individual listed may have left the position or agency. There should still be someone at the municipal or state agency who is familiar with the project and can provide any supplemental information.

Not all traffic control devices (TCDs) in the case studies comply with the *Manual on Uniform Traffic Control Devices* (MUTCD). The Federal Highway Administration (FHWA) does not endorse the use of non-compliant TCDs except under experimentation, which must be approved by the FHWA Office of Transportation Operations.

All Case Studies

- [#1 – Minimizing Roadway Surface Hazards for Bikes, Seattle, Washington](#)
- [#2 – A Tale of Portland Bridges, Portland, Oregon](#)
- [#3 – Lighting and Advance Warning of Bicyclists in the Knappa Hill Tunnel, State of Washington](#)
- [#4 – Back-in Diagonal Parking with Bike Lanes, Vancouver, Washington](#)
- [#5 – Valencia Street Road Diet — Creating Space for Cyclists,](#)

By Location

- ▣ [Inside the United States](#)
- ▣ [Outside the United States](#)

By Countermeasure Group

- ▣ [Shared Roadway](#)
- ▣ [On-Road Bike Facilities](#)
- ▣ [Intersection Treatments](#)
- ▣ [Maintenance](#)

By Countermeasure Group

- ▣ [Shared Roadway](#)
- ▣ [On-Road Bike Facilities](#)
 - ▣ [Bike Lanes](#)
 - ▣ [Wide Curb Lanes](#)
 - ▣ [Paved Shoulders](#)
 - ▣ [Combination Lanes](#)
 - ▣ [Contraflow Bike Lanes](#)
- ▣ [Intersection Treatments](#)
- ▣ [Maintenance](#)
- ▣ [Traffic Calming](#)
- ▣ [Trails/Shared-Use Paths](#)
- ▣ [Markings, Signs, Signals](#)
- ▣ [Education and Enforcement](#)
- ▣ [Support Facilities and Programs](#)

Bike Lanes

- ▣ [#10 – How Hampshire Street Pavement Markings Influence Bicycle and Motor Vehicle](#)
- ▣ [#11 – Raised Bicycle Lanes and Other Traffic Calming Treatments on Ayres Road](#)
- ▣ [#12 – Floating Bike Lanes in Conjunction with Part-time Parking](#)
- ▣ [#13 – Incorporating a Bicycle Lane through a Streetcar Platform](#)
- ▣ [#16 – Preferential Transit-Bicycle-Right Turn Lanes on Broadway Boulevard](#)
- ▣ [#17 – Taming the Urban Arterial](#)
- ▣ [#18 – Contraflow Bicycle Lanes on Urban Streets](#)
- ▣ [#19 – Left Side Bike Lanes on One-Way Streets](#)
- ▣ [#2 – A Tale of Portland Bridges](#)
- ▣ [#21 – Combined Bicycle Lane/Right-Turn Lane](#)
- ▣ [#22 – Blue Bike Lanes at Intersection Weaving Areas](#)
- ▣ [#23 – Crossing an Arterial through an Offset Intersection: Bicycle-Only Center-Turn](#)
- ▣ [#25 – Grandview Drive Roundabout and Corridor Improvements](#)
- ▣ [#5 – Valencia Street Road Diet — Creating Space for Cyclists](#)
- ▣ [#6 – Shoreline Park Expansion Project — Provision of Bicycle and Pedestrian Facilities](#)
- ▣ [#8 – Bike Lane Safety Evaluation](#)
- ▣ [#9 – Establishing Bike Lanes — Chicago's Streets for Cycling Plan](#)

The case studies may be selected by location or countermeasure. Opening a countermeasure group folder reveals the list of countermeasures included. Selecting a specific countermeasure reveals the case studies in which that treatment/program was a component.

Chapter 5 – Countermeasures



Shared Roadway

On-Road Bike Facilities

Intersection Treatments

Maintenance

Traffic Calming

Trails/Shared-Use Paths

Markings, Signs, Signals

Education and Enforcement

Support Facilities and Programs

A total of 50 engineering, education, and enforcement countermeasures are discussed in this chapter. The treatments and programs selected for inclusion in this document are those that have been in place for an extended period of time or have been proven effective at the time the material for this product was being compiled. Since that time, new countermeasures have continued to be developed, implemented, and evaluated. Thus, practitioners should not necessarily limit their choices to those included here; this material is a starting point. More information on the latest treatments and programs can be found through many of the Web sites and resources included in this chapter and Chapter 7. The categories of improvements include:

- Shared Roadway
- On-Road Bike Facilities
- Intersection Treatments
- Maintenance
- Traffic Calming
- Trails/Shared-Use Paths
- Markings, Signs, Signals
- Education and Enforcement
- Support Facilities and Programs

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SHARED ROADWAY

Although “shared roadway” is a term used by MUTCD to mean “a roadway that is officially designated and marked as a bicycle route, but which is open to motor vehicle travel and upon which no bicycle lane is designated,” the general concepts covered by this category of countermeasures are geared toward providing safe, smooth surfaces, good visibility, and appropriate, safe and easy access for bicyclists on all roadways that bicyclists are allowed to use. The countermeasures described in this category are among perhaps the most important factors in providing a safe and accessible street and path network for bicyclists since the vast majority of travel-ways used by most bicyclists will be roadways shared with motorists. Appropriate use of this group of tools helps to manage traffic and vehicle speeds suitable to the roadway type and area the roadway serves, outcomes that benefit bicyclists and other road users.

The countermeasures discussed under Shared Roadway will remain applicable in most riding circumstances, even for specialized bicyclist facilities such as bike lanes. Lighting, attention to surfaces and other countermeasures are also important with respect to shared-use pathways. Attention to all of these measures will help to ensure that bicyclists have safe places to ride.

Shared Roadway tools are most effectively incorporated at the planning and design stage for streets being constructed or re-constructed, with consideration to all road users. Good design can prevent problems later on and reduce maintenance issues and costs. Some improvements can be made, such as lighting, parking redesign, or maintenance upgrades that improve surface conditions to existing roadways, but are typically more difficult to implement as retrofit measures. Providing safe access to and space on bridges and overpasses and through tunnels and underpasses may be particularly challenging to implement as retrofit measures.

The countermeasures under Shared Roadway are as follows:

- Roadway Surface Improvements
- Bridge and Overpass Access
- Tunnel and Underpass Access
- Lighting Improvements
- Parking Treatments
- Median/Crossing Island
- Driveway Improvements
- Access Management
- Reduce Lane Number
- Reduce Lane Width



PHOTO BY DAN NABORS

Slow speed downtown streets can be safely shared by bicyclists and motorists. (Santa Barbara, CA)



PHOTO BY DAN BURDEN

A raised median helps reduce cut-through traffic and reduce conflicts with turning vehicles.



PHOTO BY DAN BURDEN

Lighting, street trees, on-street parking, bicycle parking, and buildings close to the roadway signal that this is an urban, low-speed, shared-use street. (Santa Cruz, CA)

1. ROADWAY SURFACE IMPROVEMENTS

Bicyclists are particularly vulnerable to sudden changes in the roadway (or path) surface, such as potholes or sudden drop-offs. Slippery surfaces, presence of water or debris, broken pavement, and gaps in pavement parallel to the roadway that can trap bicycle tires can also be hazardous. In addition to causing bicyclist falls, surface irregularities may contribute to a sudden weaving movement that may place the cyclist in the path of a motorist. Poor riding surfaces may also increase bicyclist discomfort and potentially discourage riding. Therefore, providing smooth but non-slippery pavement surfaces is a key to maintaining a good level of service for bicyclists. Good initial design can help reduce future repair and maintenance costs.

Several overarching issues warrant particular attention.

- Initial design and materials selection help to prevent problems such as poor drainage, slippery surfaces, gaps in pavement and others. Once design standards are determined, inspectors and project contractors should ensure that standards are met.
- Having a plan for regular sweeping and identifying and making spot repairs is key to keeping surfaces in good condition.
- Bicyclist considerations should also be incorporated into long-term maintenance and upgrades.
- Good design, hazard identification and maintenance practices should be institutionalized. Identification of bicyclist priorities and a system for regular inclusion of best bicyclist facilities practices within a regular maintenance framework can help to improve conditions for bicyclists without substantially increasing costs.

To provide smooth, level surfaces, the following are some potential hazards that may be minimized by instituting good design and maintenance practices. Drain grates should be maintained level with the surrounding pavement, which may require raising the grates following re-paving, and a bicycle-friendly design should be used so that tires will not be trapped by slots parallel to the roadway (see images). Particularly with new or reconstruction, curb inlets could be installed. Designs should also ensure that utility covers and other potential hazards are placed out of the predominant bicycling pathways, are level with the surrounding pavement, and have non-skid surfaces. Pavement should be kept in good condition, particularly near the edges where bicyclists tend to ride most often.

Additionally, when designing bike facilities, pavement seams should be placed where they minimally conflict with the bicycle right-of-way. Excessively wide gutter

Purpose

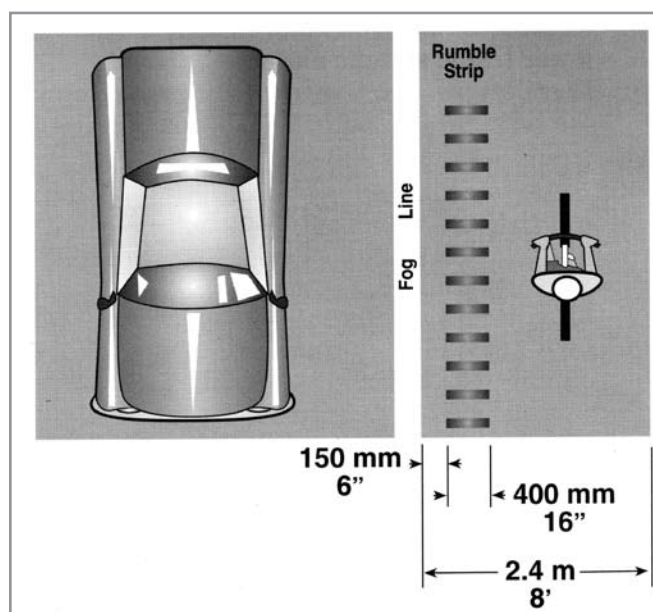
- Provide smooth, safe surfaces for bicyclists.

Considerations

- Institutionalizing good design, street sweeping, and maintenance practices with respect to bicyclists can help to reduce liability.
- Hazard identification programs can facilitate identification and repair of potential surface hazards.

Estimated Cost

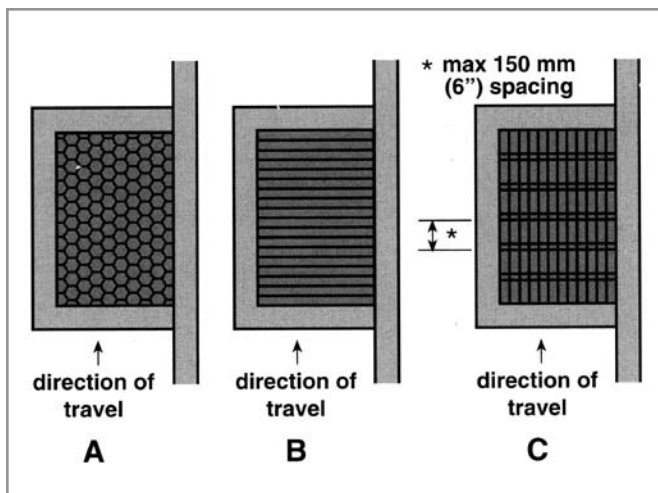
Many of the costs associated with providing and maintaining good bicyclist surfaces should be incorporated into the overall initial project budget or maintenance plan. The costs of hazard identification, short-term sweeping and spot maintenance programs will be minimized if bicyclist concerns are institutionalized within the regular maintenance and repair framework. Special repairs (such as drain grate repair/replacement) will vary considerably by project.



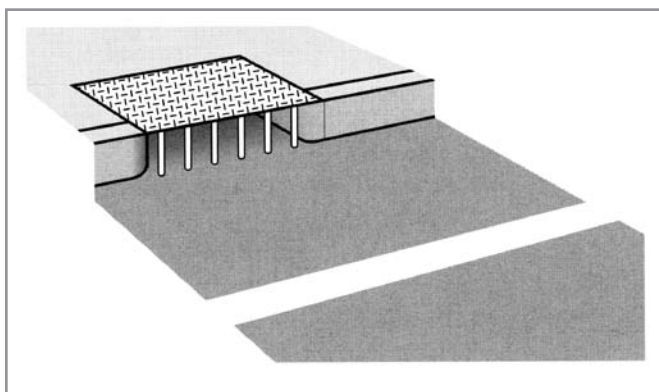
A newer rumble strip design is more bicycle-friendly: 400 mm (16 in) grooves are cut into the shoulder, 150 mm (6 in) from the fog line. On a 2.4 m (8 ft) shoulder, this leaves 1.8 m (6 ft) of usable shoulder for bicyclists.

pan may unnecessarily reduce bicyclists' space. Paving over the gutter pan is a temporary solution, as seams usually reappear in the pavement within five years. Reflective raised pavement markers also create hazards for bicyclists

ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT



Bicycle safe grates. Note: grates with bars perpendicular to the roadway must not be placed at curb cuts, as bicycle tires could get caught in the slot.



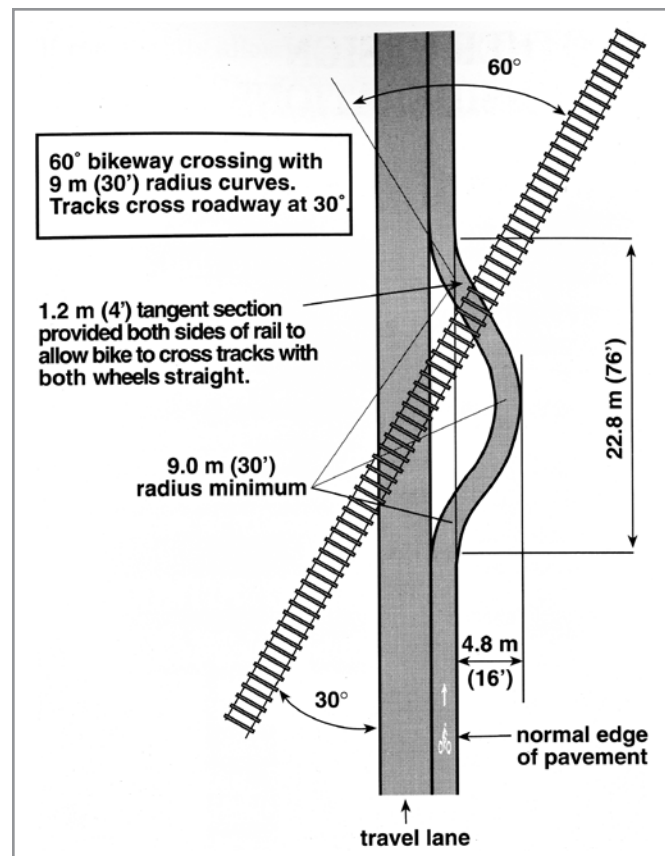
Inlet flush in the curb face. The most effective way to avoid drainage-grate problems is to eliminate them entirely with the use of inlets in the curb face (type CG-3).

and should only be used with appropriate consideration of bicyclists. These can deflect a bicycle wheel, causing the cyclist to lose control.

When rumble strips are used as a motorist alert, for example, along a shoulder, a narrower design placed close to the lane edge line allows more usable bicycle-friendly space. If textured pavers are used, these should not compromise bicyclist safety or comfort.

Finally, care must be taken to provide bicycle-safe railroad crossings. Crossings should ideally be close to 90 degrees. If the crossing is smooth, but non-slippery (concrete paving may work best), and the flange opening is kept as narrow as possible, somewhat more flexibility with the angle may be possible.

The *Oregon Bicycle and Pedestrian Plan* contains more information and illustrations of good surface design prac-



Bike lane or shoulder crossing railroad tracks.

tices under the "Other Design Considerations" section (http://www.oregon.gov/ODOT/HWY/BIKEPED/docs/bp_plan_2_ii.pdf).¹

2. BRIDGE AND OVERPASS ACCESS

Barriers to movement such as rivers, freeways, canyons and railways may present severe impediments to bicyclist travel. According to the Institute of Traffic Engineers' *Innovative Bicycle Treatments*², the City of Eugene, OR, determined through a users' survey that bicycle and pedestrian bridges were needed every 1.6 to 2.4 km (1 to 1.5 mi) to cross a geographic barrier through town – in this case the Willamette River. Bridges built to accommodate all modes of travel are typically preferable since they connect with the existing street network. If separated bicyclist/pedestrian facilities are provided, security issues must be addressed. Bridges must be properly designed to provide safe, accessible approaches, with sufficient space for bicyclists to navigate ascents and descents as well as across the overpass, and safe riding surfaces that take into consideration expansion grate design and seam placement that minimize hazards to bicyclists. Bridges should also be well-lit.

If retrofit measures are needed for existing structures, space on the bridge may be provided on the street, on walkways if they are wide enough to safely accommodate pedestrians and bicyclists, or even on a separate deck as

Purposes

- Provide continuity of access for bicyclists.
- Prevent significant detours for bicyclists due to unsurpassable natural or built barriers.

Considerations

- Width of travel lanes and existing walkways, length and height of span, and motor vehicle travel speeds and volume should all be considered when determining the best place to provide space for bicyclists.
- Extra buffers may be needed for “shy distance” from railings or from traffic to protect bicyclists from sudden wind.
- Bicyclist access on multi-modal bridges should be provided since these bridges connect with the existing street network. Separate facilities may be desirable to prevent long detours for bicyclists (if additional multi-modal bridges are infeasible) or to connect multi-use paths or separate corridors.

Estimated Cost

Varies widely, depending on whether a new bridge is constructed or a retrofit of existing installation is provided. The type of facilities and changes implemented also affect cost. For retrofit treatments, Portland examples include from \$20,000 for restriping to add bike lanes on an existing deck cross section to \$10,000,000 for adding a cantilevered shared path to an existing bridge.



PHOTO BY DAN BURDEN

Separated overpasses may be needed to provide safe access across busy freeways or other barriers.



PHOTO BY DAN BURDEN

This cantilevered, shared-use path was added to the Steel bridge in Portland, OR.

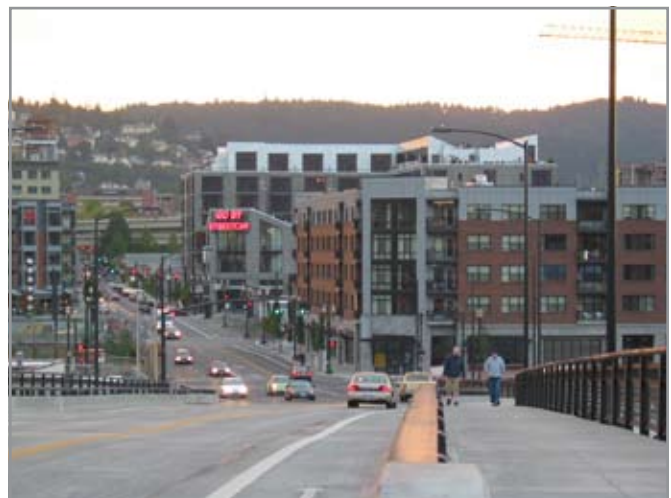
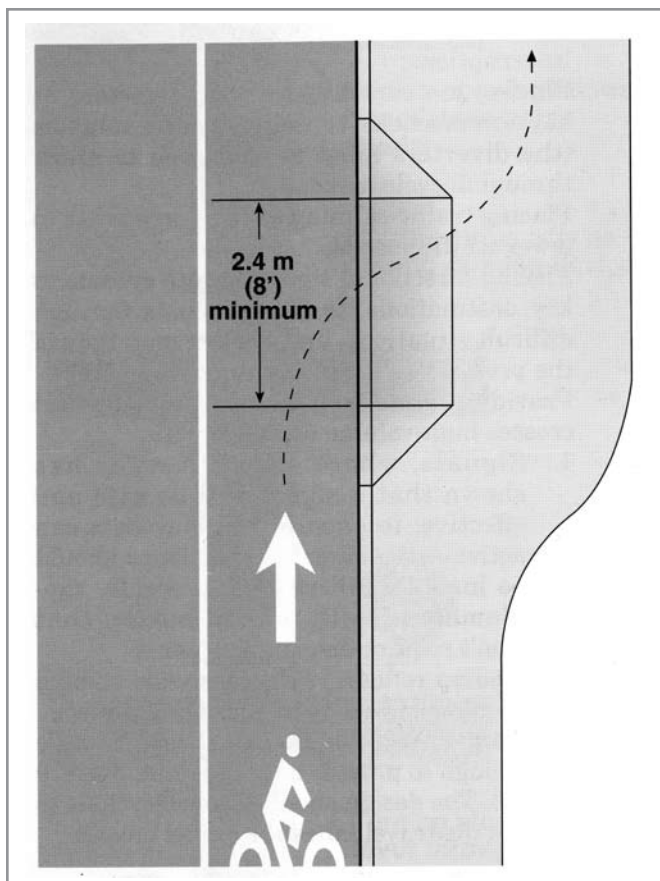


PHOTO FROM ALTA PLANNING + DESIGN

Bike lanes provide space on this bridge.



Ramp provides bicyclist access to shared-use path from the on-street bike lane.

was done on the Steel Bridge in Portland (see case study #2). If sidewalk access is provided, ramps should provide bicyclists direct access from the street. Sidewalk access may be desirable if traffic volumes and speeds are high, the bridge is long, and there is insufficient roadway space (outside lanes or shoulders are narrow) to safely accommodate bicyclists.

When bicyclist space is provided near bridge railings or near motorized traffic, extra horizontal width or buffer of

0.6 m (2 ft) or more is recommended to protect bicyclists in the event of a crash or wind blast, especially on higher speed bridges or high spans where wind gusts may be strong. Railings should also be provided. The American Association of State Highway and Transportation Officials (AASHTO)³ recommends a railing height of at least 1.4 m (4.5 ft).

Access from adjoining streets should be as direct as possible to reduce out-of-the-way detours for bicyclists, and designs should endeavor to minimize conflict points at entrances and exits.



Extra width, concrete barrier, and outside railing protect bicyclists from strong wind gusts. (Seattle, WA)

3. TUNNEL AND UNDERPASS ACCESS

As with bridges and overpasses, safe accommodation should be made for bicyclists to use roadway tunnels and underpasses to prevent impediment to free movement across freeways, railways, and other barriers. Access from adjoining streets should be as direct as possible to reduce out-of-the-way detours for bicyclists, and designs should endeavor to minimize conflict points at entrances and exits. Space should be continued through the facility, with extra consideration for issues such as lighting and personal security. Separate tunnels may also be provided, particularly to connect multi-use or bike paths (also see “Path Intersection Treatments”).



PHOTO BY DAN NABORS

State Street underpass with bike lanes, Santa Barbara, CA. Sidewalk is elevated above the roadway.

Most existing roadway tunnels have, however, been built to accommodate motor vehicle traffic, and retrofit measures may be limited if extra space is unavailable to accommodate bicyclists. Planned improvement or tunnel reconstruction projects are an ideal opportunity to improve conditions for bicyclists. In the absence of major reconstruction, some retrofit measures that may improve bicyclist safety or comfort include providing warnings to motorists that bicyclists are present in the tunnel and providing extra lighting, call boxes, and other measures to improve visibility, safety, and personal security. To activate a “bicyclist present in tunnel” flashing warning light, a bicyclist pull-off area and push button are typically provided before the tunnel entrances (see case study #3). If there are no suitable alternate routes, and safe access cannot be provided through a tunnel facility, creative measures may be called for, such as providing transit or shuttle service through the tunnel on a scheduled basis or at certain high-use periods, or other solutions.

New roadway tunnels and underpasses should incorporate planning to accommodate bicyclists. There are at present

Purposes

- Provide continuity of access for bicyclists across barriers.
- Connect shared-use path across a built or natural barrier.

Considerations

- Security issues must be fully addressed.
- Retrofit measures may be restricted since many existing tunnels may have limited space.
- Upgrades and downgrades will affect the speeds of bicyclists and should be considered in the planning or renovation of a tunnel.

Estimated Cost

Flashing warning signs, “Bicyclist in Tunnel,” along with widened shoulder for bicyclist pull-off were installed for \$5,000 in 1979. Other costs vary widely depending on measures implemented. A variety of cost data can be found at the following Web site: <http://www.bicyclinginfo.org/bikecost/>.

no specific design standards relating to bicycle accommodation in roadway tunnels. General design standards for bicycle facilities would likely apply, but consideration should be given to providing significant extra width for shy distance from walls or other barriers. Bear in mind that bicyclist speeds will be affected by grade, and extra width may also be needed on steep grades. As previously mentioned, lighting and personal security are issues in tunnels, and designs should maintain good visibility without “hidden” recesses or unlit areas that invite security



PHOTO BY DAN BURDEN

Lighting is important for personal safety as well as viewing the riding surface in tunnels and underpasses. (Seattle, WA)



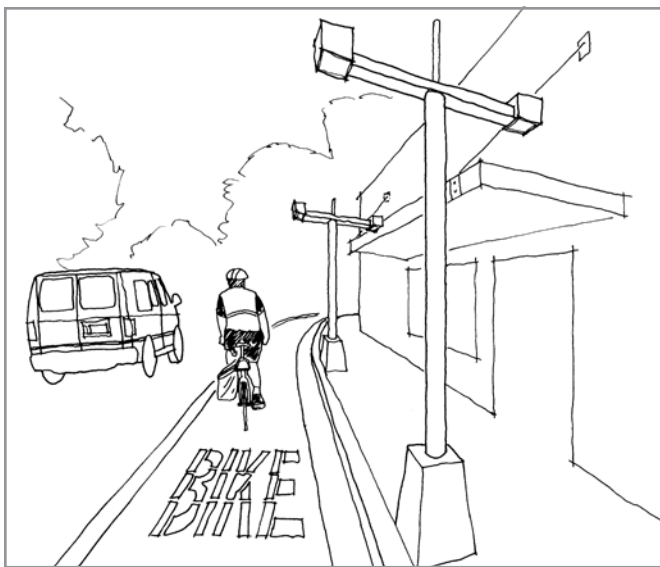
Bicyclists prefer shorter underpasses where the end is clearly visible.

concerns. Other issues, such as air quality, may be particular to tunnels, but should be addressed from the bicyclist's perspective.

If separated bike and pedestrian tunnels are provided, vertical clearance of 3 m (10 ft) is recommended for bicyclist comfort.³ Following general AASHTO structure guidelines for shared-use paths, the Iowa Department of Transportation recommends a width of at least the trail width plus clear zones, or a minimum of 3 m (10 ft) if emergency vehicle access must be provided, but the wider the better for lighting and comfort.⁴ Security issues must also be addressed in separated facilities. Generally, bicyclists are more comfortable if they can see “the light at the end of the tunnel” when they enter, but appropriate lighting should be provided to ensure good visibility both for security and to view the bicycling surface. Diversion of water away from the tunnel and good drainage and non-slippery surfaces in underpasses are also important design considerations to prevent water from becoming a hazard for bicyclists. The City of Davis bicycle plan also provides some guidance for shared-path underpasses.⁵

4. LIGHTING IMPROVEMENTS

Although bicyclists riding during dark conditions are generally required to have appropriate lighting on their vehicles or persons, requirements vary from state to state and many bicyclists do not comply with the requirements. Good illumination also helps nighttime bicyclists see surface conditions and obstacles or people in the path of travel. Data from five years of North Carolina bicycle-motor vehicle crashes indicate that about one quarter of reported collisions and more than half of bicyclist fatalities occurred during non-daylight conditions, probably far exceeding the proportion of riding that occurs under these conditions.⁶ Similarly, estimates referred to by Florida State University⁷ indicate that “nearly 60 percent of all adult fatal bicycle accidents in Florida occur during twilight and night hours even though less than 3 percent of bicycle riding takes place during that time period.” Bicyclists, particularly commuters, may have to ride during early dawn hours or be caught by twilight, particularly in the winter months.



Lighting illuminates the roadway surface as well as other roadway users.

Improved roadway lighting may help to reduce crashes that occur under less than optimal light conditions. Intersections may warrant higher lighting levels than roadway segments. Good lighting on roadways, bridges, tunnels and shared-use paths is also important for personal security. Lighting improvements are typically thought of as an urban and suburban treatment, but there may be situations where lighting improvements are appropriate in rural locations. Examples of such locations might include rural roadways that serve as bicycling connectors between outlying or neighboring population areas and urban centers, and intersections or shared-use trail crossings used by

Purposes

- Illuminate the roadway surface and surroundings.
- Enhance safety of all roadway users.
- Optimize visibility of bicyclists (and pedestrians) during low-light conditions, particularly in locations where high numbers of bicyclists may be expected such as commuter routes, routes to and from universities, intersections and intersections with multi-use trails.
- Improve personal security of bicyclists and pedestrians.

Considerations

- Install lighting on both sides of wide roadways for most effective illumination.
- Provide generally uniform illumination avoiding hot spots, glare, and deep shadows; some intersections may warrant additional illumination.
- Consider rural locations for lighting improvements if nighttime or twilight crashes are a problem.

Estimated Cost

Cost varies depending on fixture type, design, local conditions, and utility agreements.



Lighting is provided for both bicyclists and pedestrians at this location.

significant numbers of cyclists. More research is needed on the safety and mobility benefits of lighting improvements to bicyclists and pedestrians. The American Association of State Highway and Transportation Officials³ guide recommends using average maintained illumination levels of between 5 and 22 lux, and the Florida DOT recommends 25 as the average initial lux for shared-use paths,



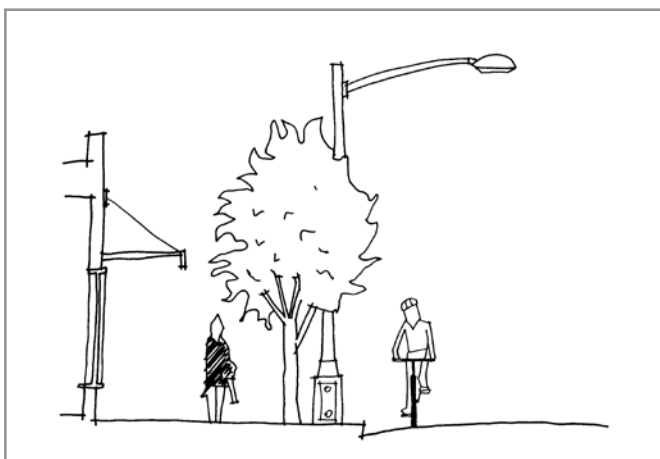
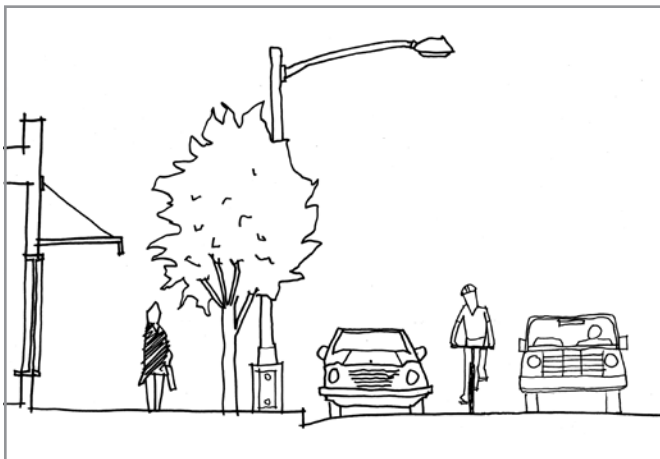
Raised medians provide another option for locating lighting on this shared roadway.

16 for bike facilities on arterial roads, and 11 for all other roadways.⁸ The *Wisconsin Bicycle Facility Design Handbook* also provides guidance for path illumination (p. 4–35 to 4–37).⁹ Other roadway lighting resources include *American National Standard Practice for Roadway Lighting ANSI IESNA (RP-8-00)* and other publications (available from the Illuminating Engineering Society) and AASHTO’s 1984 *An Informational Guide for Roadway Lighting* (update anticipated). A forthcoming NCHRP project will develop guidelines for roadway lighting based on safety benefits and costs.

Lighting is a complex treatment requiring thoughtful analysis. Not only are there safety and security issues for bicyclists, pedestrians and motorists, but potential light pollution, long-term energy costs, and aesthetics also are factors. With good design, lighting can enhance safety of the bicycling (as well as pedestrian) environment and improve the ambience of areas of nighttime activity.

5. PARKING TREATMENTS

Certain policy, design and configuration practices for on-street parking for motor vehicles can facilitate safer bicycling conditions. Removing parking is one option for reducing conflicts between cyclists and vehicles driving into and out of parking, or with motorists entering or exiting parked cars. Removing or narrowing a parking lane on one or both sides of the roadway is also an option for gaining usable space for bicyclists, for example, to create a bike lane. Also, eliminating or reducing parking will improve sight distance along a corridor and may be particularly useful for segments with numerous busy driveways or conflict areas.



Before (top) and after (bottom) parking eliminated to gain space for bikes.

Diagonal on-street parking consumes significant roadway width and may also be hazardous to bicyclists since motorists typically must back into traffic. Diagonal parking may be redesigned to a parallel parking configuration, with a typical loss of less than half the spaces. If angled on-street parking is currently provided and maintaining current on-street parking levels is a priority, another option is to reverse the angle direction and require motorists

Purposes

- Reduce conflicts between bicyclists and parking-related incidents (pulling into and out of parking, opening doors).
- Provide more space or facilities for bicyclists on the roadway.
- Improve sight distance along a roadway.

Considerations

- Overall parking demand and space must be evaluated in light of the community's other needs and values. A number of factors should be considered, including the function of the streets to move people and goods safely, the desire to reduce single-vehicle auto use, the need to promote bicycling or transit use, and the need to accommodate business and residential parking demand.
- Space used for on-street parking may provide usable space for bicyclists. Demand for motor vehicle parking could be reduced if sufficient modal shifts occur. Many European cities are reducing motorized vehicle access to urban centers.
- On-street parking, if carefully designed, does not inherently conflict with safe bicycling and may help slow vehicle speeds and improve the safety of the street.
- Creative solutions to meeting parking demand such as timed sharing of public and private facilities may be required.
- Removing parking might result in an increase in vehicle travel speeds if other measures do not compensate.

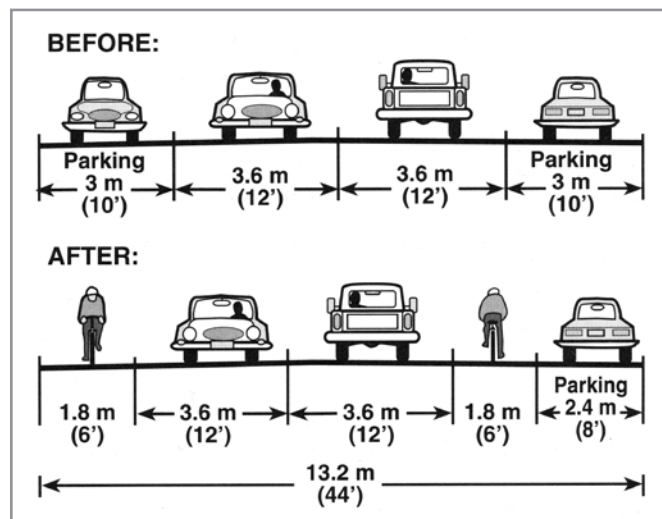
Estimated Cost

Costs may involve only restriping expense. More extensive work such as adding curb bulb-outs to enclose parking spaces and provide landscape space may increase the cost of parking treatments.

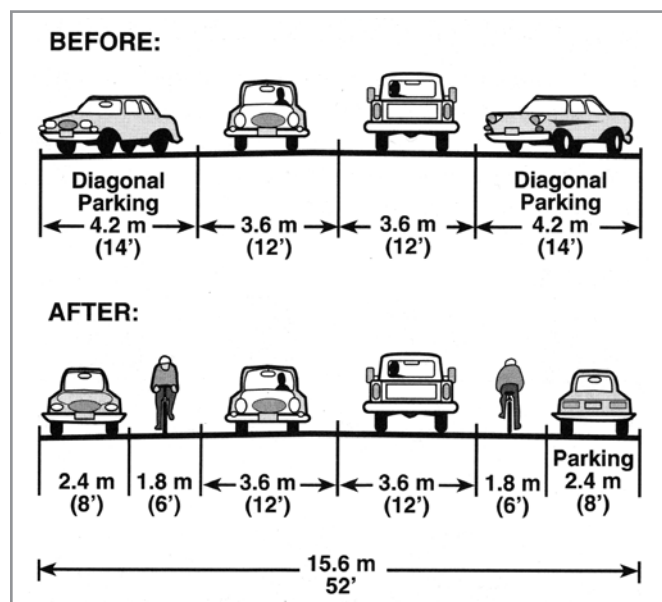
to back in when entering the parking space. Motorists are then facing forward when re-entering the roadway and better able to view both oncoming bicyclists and other motorists (see case study #4).

Policies that may help reduce parking demand or maximize efficient use could be considered if on-street parking is reduced.

Other options are discussed more fully under traffic calming. For example, parking may be configured in a chicane-like pattern by alternating spaces from one side of the street to the other. This treatment forces motorists to shift laterally and slows travel speeds if properly designed. (See Chicanes countermeasure.)



Parking removed on one side of a two way street. In some cases, parking may be needed on only one side to accommodate residences and/or businesses. Note: It is not always necessary to retain parking on the same side of the road through an entire corridor.



Diagonal parking takes up an inordinate amount of roadway width relative to the number of parking spaces provided. It can also be hazardous, as drivers backing out cannot see oncoming traffic. Changing to parallel parking reduces availability by less than one-half. Special note: on one-way streets, changing to parallel parking on one side only is sufficient; this reduces parking by less than one-fourth.

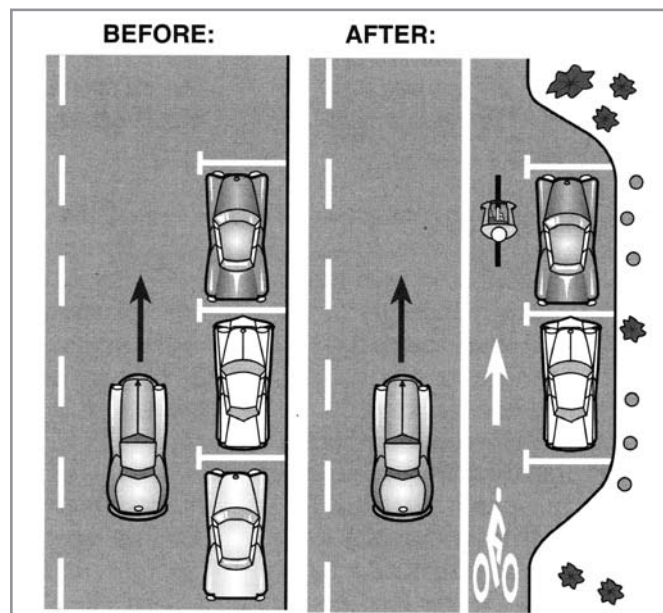


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

Where all of the above possibilities of replacing parking with bike lanes have been pursued, and residential or business parking losses cannot be sustained, innovative ideas should be considered to provide parking, such as with off-street parking. Other uses of the right-of-way should also be considered, such as using a portion of a planting strip, where available.



"Door zone" space was left between bike lane and parking space. (Chapel Hill, NC)

PHOTO BY L. THOMAS

6. MEDIAN/CROSSING ISLAND

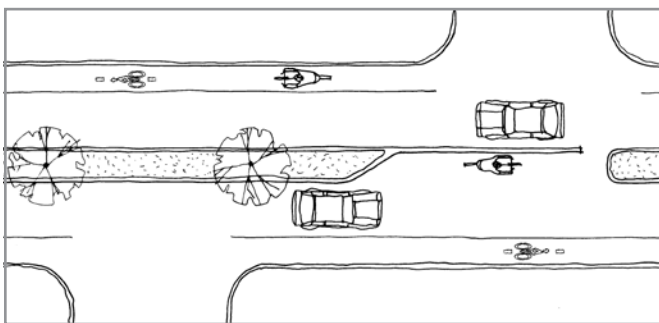
Medians are raised barriers in the center portion of the street or roadway that have multiple benefits for bicyclist, motorist and pedestrian safety, particularly when they replace center, two-way left-turn lanes. Two-way left-turn lanes can create problems for bicyclists and pedestrians as well as opposing left-turn vehicles and may be used as acceleration lanes by some motorists. A median (or median island) helps manage traffic, particularly left-turn movements, and reduces the number of conflict areas. Left-turn bays may be incorporated at specific locations. The restricted access to side streets may also help to reduce cut-through traffic and calm local streets. Raised medians are most useful on high-volume roads. Bicyclist (and pedestrian) access to side streets, transit stops, or shared-use paths should be maintained by providing access pockets through the median.

PHOTO BY DAN BURDEN



While this median treatment provides a crossing point and a refuge for pedestrians, space is still available for bicyclists.

ILLUSTRATION BY A.J. SILVA



This design allows bicyclists to make a left turn at a location where motorist left turns are prevented.

Another use of median islands and bicycle crossings is to provide a refuge for bicyclists crossing a busy thoroughfare at unsignalized locations where gaps in traffic in both directions are rare. The median should be at least 2 m (6.6 ft) wide to provide sufficient waiting space for bicyclists.² If a full 2 m (6.6 ft) is not available, the bicycle storage area may be angled across the median with bicyclists di-

Purposes

- Manage motor vehicle traffic and reduce the number of conflict areas. Provide comfortable left-hand turning pockets with fewer or narrower lanes. May help to slow traffic if roadway is narrowed sufficiently.
- Assist bicyclists in crossing high-volume streets at non-signalized locations by providing a protected refuge for bicyclists crossing or making left turns.
- Provide space for street trees and other landscaping.

Considerations

- Provide bicyclist access to cross streets (or shared use paths) where a median restricts motor vehicle movements.
- Evaluate whether there is sufficient width for appropriately wide sidewalks, bike lanes, and planting strips before proceeding with median construction. Intermittent median islands may be a preferable option for some locations.
- Landscaping in medians should not obstruct visibility between bicyclists (and pedestrians) and approaching motorists.
- Pedestrian median crossings should also be provided at appropriate midblock and intersection locations and designed to provide tactile cues for pedestrians with visual impairments. Examples of good and bad designs for raised median crossings can be found in Chapter 8 of *Designing Sidewalks and Trails for Access: Part II of II, Best Practices Design Guide*.¹¹
- Desired turning movements need to be carefully provided so that motorists are not forced to travel on inappropriate routes, such as residential streets, or make unsafe U-turns.
- Bicyclist median access pockets may be difficult to keep clear, depending on width.
- Continuous medians may not be the most appropriate treatment in every situation. In some cases, separating opposing traffic flow and eliminating left-turn friction might increase traffic speeds by decreasing the perceived friction of the roadway.

rected toward oncoming traffic for crossing the second half of the roadway. Railings may be provided for bicyclists to hold so they need not put their feet down to aid in quicker start-ups.

Estimated Cost

From PEDSAFE: The cost for adding a raised median is approximately \$15,000 to \$30,000 per 30 m (\$15,000 to \$30,000 per 100 ft), depending on the design, site conditions, and whether the median can be added as part of a utility improvement or other street construction project.¹⁰



PHOTO BY DAN BURDEN

Medians and median islands can help narrow roadways and potentially slow motorist speeds.

If travel lanes are sufficiently narrowed, installation of medians may also help to slow traffic speeds. Finally, medians provide space for street trees that may improve the aesthetic environment.



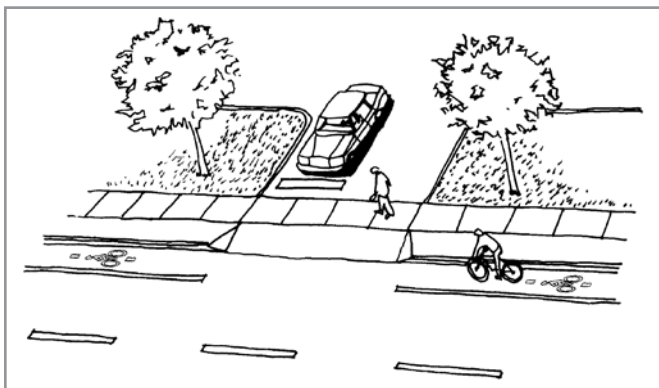
PHOTO BY DAN BURDEN

Pocket in median island maintains access for bicyclists.

7. DRIVEWAY IMPROVEMENTS

Consideration for bicyclists' needs should cover from the trip origin to the destination. A significant proportion of bicycle-motor vehicle crashes occur when either the bicyclist or motorist rides or drives out from a driveway without properly yielding to oncoming traffic. Motorist left turns into driveways and side streets also account for a sizeable portion of crashes involving bicyclists. Thus, the design of connections to the street network has a significant impact on bicyclist safety and access.

ILLUSTRATION BY A.J. SILVA



Good driveway design provides for safe access to the street network.

Driveway design affects sight distance for both motorists and bicyclists accessing roadways, as well as the speed and perhaps care with which drivers enter or leave the roadway. Right-angle connections are best for visibility of approaching traffic as well as slowing the turning speed for vehicles exiting or entering the roadway. Tighter turn radii at driveways, as well as ramps to sidewalk level, also slow vehicle speeds. *Designing Sidewalks and Trails for Access* provides more information and design alternatives for driveway/sidewalk crossings.¹¹ Paved driveway aprons of at least 3 m (10 ft) may be desirable for unpaved connections to contain gravel and debris and prevent it from accumulating in the bikeways. Curb cuts should have sufficient flare, however, for bicyclists to complete turns into the driveway or into the nearest lane without 'swinging wide' into the adjacent lane. On streets with sidewalks, the walkway should continue at grade across driveways to provide for through pedestrian movement, slow vehicles, and make it clear to motorists and bicyclists that sidewalk users have the right-of-way.

Stop bars, signs, and other measures may be useful at commercial driveways, but sight distance should not be impaired with too many or improperly-placed signs. Driveway rights-of-way should also be kept cleared of foliage and other objects that obscure visibility.

Purposes

- Provide good visibility for motorists and bicyclists accessing the roadway.
- Slow motor vehicles entering/exiting the roadway and establish pedestrian right-of-way.
- Reduce the chances of a bicycle-only fall or turning error when bicycles enter or leave the roadway.

Considerations

- Local landscape ordinances and other driveway guidelines may be needed to establish clear zones for driveway rights-of-way, and to maintain sight distance and roadway surfaces.
- Driveway crossings of sidewalk corridors should be wide enough to provide a level pedestrian crossing and a suitable ramp to the street.

Estimated Cost

No additional costs when incorporated into original plan and construction.



PHOTO BY DAN BURDEN

Good sight distance helps reduce the potential for conflict between the vehicle emerging from the driveway and a bicyclist in the bike lane.

Every driveway connection is a potential conflict point among motorists, bicyclists and pedestrians. Thus, driveway consolidation or other measures should also be considered for arterials and collector roads. See the Access Management countermeasure for more discussion.

8. ACCESS MANAGEMENT

Every driveway and street connection is a potential conflict point among motorists, bicyclists and pedestrians. Therefore, managing the number, spacing, access, directional flow, and other aspects of driveway and side street connections protects those traveling along the corridor from conflicts with those entering or leaving the corridor. Access management strategies such as providing raised/non-traversable medians and limiting driveway access may be useful in promoting safe bicycle travel, particularly on arterial or major collector streets, since they help reduce the number of potential conflict points.



PHOTO BY DAN BURDEN

Raised medians and driveway consolidation are two access management tools that reduce the number of conflict points.

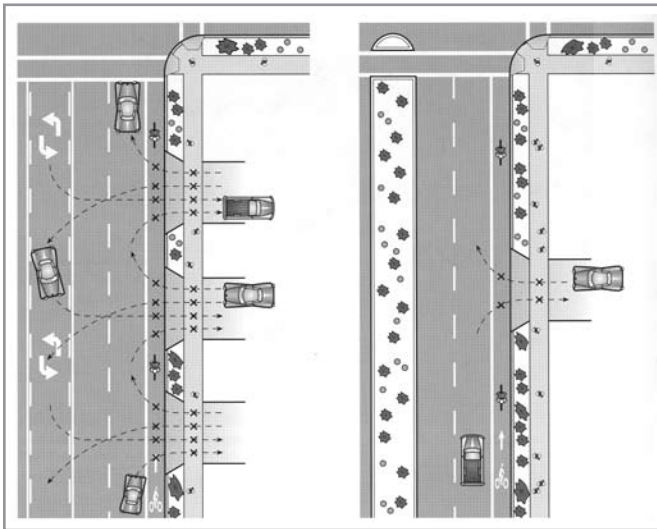


ILLUSTRATION FROM OREGON BICYCLE AND PEDESTRIAN PLAN, OREGON DOT

Before (left), uncontrolled accesses create eight potential conflict points at every driveway. After (right), a raised median and consolidating driveways reduce conflict points.

The principles of access management incorporate providing specialized roadways appropriate to their intended use. The trade-off is between providing direct access and promoting through movement. For example, the main pur-

Purposes

- Reduce conflicts between those traveling along the corridor and those entering or leaving the corridor.
- Provide access appropriate to the function of the roadway and area it serves.
- Maintain flow of traffic along a corridor.

Considerations

- Consider whether the street's intended function is primarily to move through vehicles (freeways, arterials, collectors) or to provide direct access (neighborhood and local streets).
- Providing for free-flow of traffic by reducing connections may result in increased travel speeds.

Estimated Cost

If included in initial design and construction, access management measures might raise or decrease costs compared to other designs. Cost of retrofit measures would depend on the type and extent. Adding a raised median, for example, is estimated to cost \$15,000 to \$30,000 per 30 m (\$15,000 to \$30,000 per 100 ft). Prohibiting left turns with diverters may cost from \$15,000 to \$45,000 each.

pose of freeways and arterials is to move through traffic, and access should be restricted to necessary interchanges. Local streets should generally serve all destinations and access should not be limited. There are exceptions, however, if management is needed to reduce non-local traffic or create preferential bicycle boulevards (see Traffic Diversion). Access management includes such measures as limiting the number of or establishing minimum spacing between driveways; providing for right-in, right-out only movements; locating signals to favor through movements; restricting turns to certain intersections; and using non-traversable medians to manage left- and U-turn movements. Other measures such as provision of left and right turn lanes at intersections to remove slowing/turning vehicles from the traffic stream could also be included. Hodgson, et al., have provided an in depth discussion of potential impacts (positive and negative) of access management strategies on bicyclists and pedestrians.¹² The Transportation Research Board (TRB) Committee on Access Management identifies 10 principles or strategies of access management altogether, along with the rationale and elements of a comprehensive program (see <http://www.accessmanagement.gov/>). TRB also published the

Access Management Manual in 2003 that provides a comprehensive description of access management principles, techniques and effects, and rationale and steps toward developing an access management program and policies.¹³ Safety and other impacts of access management are documented in *National Cooperative Highway Research Report 420*.¹⁴



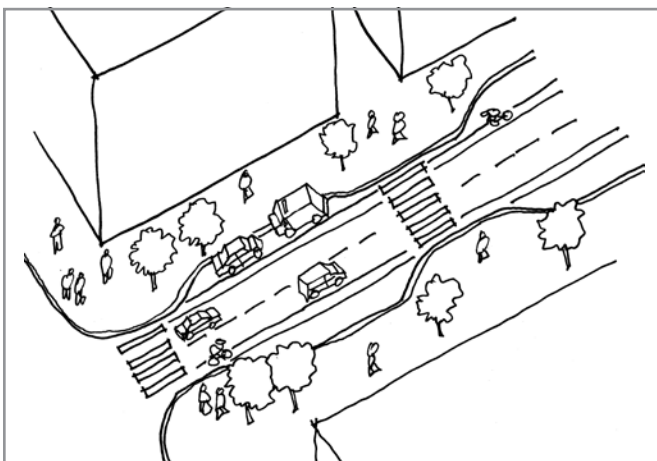
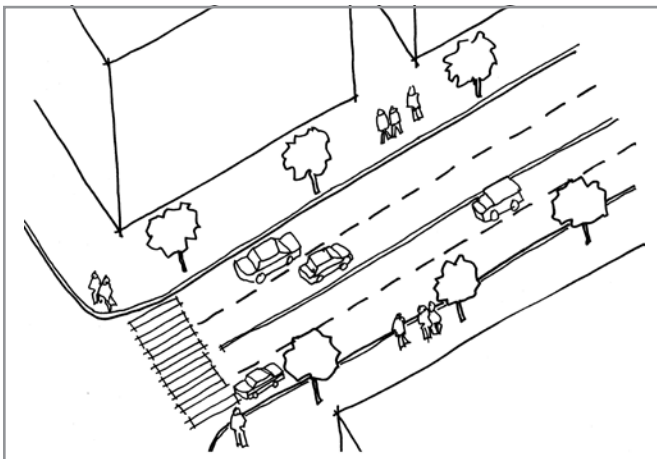
Restricted access can provide for relatively uninterrupted bicycle travel along arterials and collectors.

9. REDUCE NUMBER OF LANES

Some roads have more travel lanes than necessary, and the width of the excess lanes could be freed up for other uses. Space may be better used for bicycle lanes, parking, or wider pedestrian buffers or sidewalks (with curb realignment). A traffic analysis should be done to determine whether the number of lanes on a roadway (many of which were built without such an analysis) is appropriate. Reducing the number of travel lanes may also slow travel speeds.

A typical “road diet” may involve converting an undivided four-lane roadway to one travel lane in each direction, with an ongoing center left-turn lane. Road diets have also replaced the second travel lanes with a raised median and turn pockets, and bike lanes in each direction. A raised median allows greater control of turning movements and may enhance bicyclist as well as motorist safety in some circumstances (see Medians/Crossing Islands).

A variety of reconfigurations are possible for lane number reductions depending on the current configuration,



Before (top) and after (bottom) road diet.

Purposes

- Remedy a situation where there is excess capacity.
- Provide space for bicyclists, pedestrians, or parking.
- Reduce apparent width of the road; provide median refuge.
- Improve social interaction and enhance livability of the street.

Considerations

- Traffic studies should determine whether there is excess capacity.
- Studies that include safety effects as well as traffic operations should help to determine preference for an on-going left turn option or whether intermittent left turns will provide the level of service needed.

Estimated Cost

The cost for restriping a kilometer of four-lane street to one lane in each direction plus a two-way, left-turn lane and bike lanes is about \$3,100 to \$12,400 (\$5,000 to \$20,000 per mi), depending on the amount of lane lines that need to be repainted. The estimated cost of extending sidewalks or building a raised median is much higher and can cost \$62,000 per km (\$100,000 per mi) or more. If a reconfiguration is done after repaving or with an overlay, and curbs do not need to be changed, there is little or no cost for space reallocations accomplished through new striping.



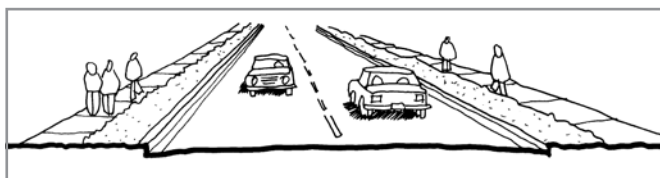
Lane reduction in Toronto, Canada, from two to one lane in each direction, bike lanes, and center two-way, left-turn lanes.

user needs, and potential operational and safety outcomes. Other measures could be implemented simultaneously to complete the overall redesign for the street.

10. REDUCE LANE WIDTH

Roadway lane narrowing may help to reduce vehicle speeds along a roadway section and enhance movement and safety for bicyclists as well as pedestrians. Lane narrowing is best used where motor vehicle speeds are low to encourage shared lane travel and prevent motorists from attempting to pass bicyclists within the same lane if there is insufficient width. Another use would be to gain space to stripe a bicycle lane or paved shoulder where motor vehicle speeds and volume are higher. Lane width reductions can be achieved in several different ways:

- Lane widths can be reduced to 3.0 or 3.4 m (10 or 10.5 ft) and excess pavement striped with a bicycle lane or shoulder.
- Excess lane width can be reallocated to parking.
- The street and lanes can also be physically narrowed by extending the curb for wider sidewalks and landscaped buffers, or by adding a raised median.



Before (top) and after (bottom) width of lanes is reduced.



Narrow lanes contribute to slow design speed and shared lane use in downtown Eugene, OR.

Purposes

- Redistribute space to other users, such as to gain space for bike lanes.
- Narrowing travel lanes may lower motor vehicle speeds and encourage safer sharing of the roadway in low speed areas.

Considerations

- Bicyclists must be safely accommodated. Bike lanes, wide curb lanes, or paved shoulders are needed if motor vehicle volumes and speeds are high.
- Road narrowing must consider school bus and emergency service access as well as truck volumes.
- Besides narrowing lanes, tightening curb radii is another way to reduce speeds of turning vehicles.
- Evaluate whether narrowing may encourage traffic to divert to other local streets.

Estimated Cost

Adding striped shoulders or on-street bike lanes can cost as little as \$620 per km (\$1,000 per mi) if the old paint does not need to be changed. The cost for restriping a kilometer of street to bike lanes or to add on-street parking is \$3,100 to \$6,200 (\$5,000 to \$10,000 per mi), depending on the number of old lane lines to be removed. Constructing a raised median or changing the curb alignment (widening a sidewalk or buffer) can cost \$62,000 or more per km (\$100,000 or more per mi).

ON-ROAD BIKE FACILITIES

Bicycles are vehicles and need to be safely accommodated on our streets and roadways. FHWA has supported routine accommodation of bicyclists (and pedestrians) since 2000. This means that our streets should be designed to accommodate all modes, including motor vehicles, transit, bicycles, and walking. Facilities that are safe, accessible and aesthetically pleasing attract bicyclists. Evidence is increasing that bicyclist safety improves as more bicyclists are part of the traffic stream.¹ The countermeasures related to on-road bicycle facility design include:

- Bike Lanes
- Wide Curb Lanes
- Paved Shoulders
- Combination Lanes
- Contraflow Bike Lanes



PHOTO FROM ALTA PLANNING + DESIGN

Bike lanes provide bicyclist access on roads connecting with bridges and overpasses. (Portland, OR)



PHOTO BY ANDY CLARKE

Wide curb lanes provide room for both bicyclists and motor vehicles.



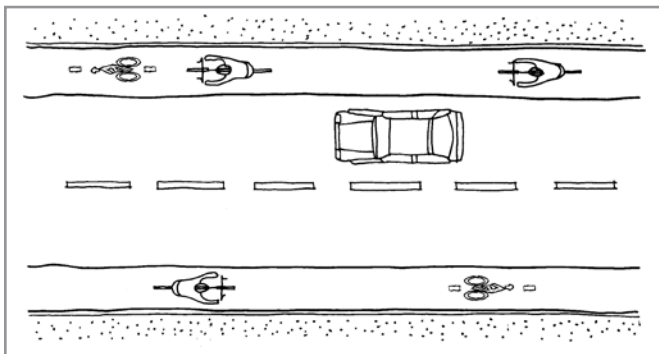
PHOTO BY DAN BURDEN

Paved shoulders provide space for bicyclists.

11. BIKE LANES

Bike lanes indicate a preferential or exclusive space for bicycle travel along a street. Bike lanes are typically 1.2 to 1.8 m (4 to 6 ft) in width and are designated by striping and/or signs. Colored pavement (for example, blue or red bike lanes) or a different paving material has also been used in certain situations to distinguish bike lanes from the motor vehicle lanes. Use of colored bike lanes is being considered but is not yet an accepted MUTCD standard.² Bike lanes are usually marked along the right side of the roadway and should be designated to the left of parking or right-turn lanes. Sometimes bike lanes are marked on the left side of a one-way street.

Adaptations to bike lanes have been used to solve local problems. An innovative bike lane transit stop treatment in Portland, OR, is used to reduce conflicts between bicyclists and streetcar transit stop users adjacent to a bike lane (see case study #13). (Adaptation for this treatment should be possible for a shared roadway situation.) Some communities also employ combination bike and bus lanes, a single lane nearest the curb that is shared by the two modes. This is generally workable unless there is considerable bike and bus traffic.



Bike lanes on a two-lane roadway.



In Madison, WI, bike lanes have been placed to the left of bus and right-turn lanes to reduce conflicts for through bicyclists.

Purposes

- Create on-street, separated travel facilities for bicyclists.
- Provide separate operational space for safe motorist overtaking of bicyclists.
- Reduce or prevent the problems associated with bicyclists overtaking motor vehicles in narrow, congested areas.
- Narrow the roadway or roadway motor vehicle traffic lanes to encourage lower motor vehicle speeds.

Considerations

- Where bike lanes are to be considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide adequate bike lane width.
- Provide a smoothly paved surface and keep the bike lane free of debris.
- Provide adequate space between the bike lane and parked cars so that open doors do not create a hazard for bicyclists.
- Avoid termination of bike lanes where bicyclists are left in a vulnerable situation.
- Determine if special signs or markings are necessary for situations such as a high-volume of bike left turns on a busy roadway.

Estimated Cost

The cost of installing a bike lane is approximately \$3,100 to \$31,000 per kilometer (\$5,000 to \$50,000 per mile), depending on the condition of the pavement, the need to remove and repaint the lane lines, the need to adjust signalization, and other factors. It is most cost efficient to create bike lanes during street reconstruction, street resurfacing, or at the time of original construction.

Bike lanes have been found to provide more consistent separation between bicyclists and passing motorists than shared travel lanes. The presence of the bike lane stripe has also been shown from research to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both motorists and bicyclists.³ The extra space created for bicyclists is also a benefit on congested roadways where bicyclists may be able to pass motor vehicles on the right.

12. WIDE CURB LANES

A wide curb lane (WCL) is the lane nearest the curb that is wider than a standard lane and provides extra space so that the lane may be shared by motor vehicles and bicycles. These facilities can also be placed on roads without curbs and are sometimes called wide outside lanes. WCLs may be present on two-lane or multi-lane roads. A desirable width is 4.3 m (14 ft), not including the gutter pan area. Lanes wider than 4.3 m (14 ft) sometimes result in the operation of two motor vehicles side by side. However, the WCL may need to be 4.6 m (15 ft) in width where drainage grates, raised reflectors, or on-street parking reduce the usable lane width. WCLs are sometimes designated when right-of-way constraints preclude the installation of “full width” bike lanes. WCLs are sometimes put in place by re-striping, especially when a section of roadway is resurfaced, by narrowing the other travel lanes.



PHOTO BY DAN BURDEN

Wide curb lane in Ft. Lauderdale, FL.

WCL advocates believe that these wider lanes encourage bicyclists to operate more like motor vehicles and thus lead to more correct positioning at intersections, particularly for left-turning maneuvers. A previous FHWA publication recommends WCLs in many kinds of roadway situations where most bicyclists are experienced riders.⁴ Since WCLs are a shared-lane traffic situation, they are not signed or marked like a bike lane would be. As a result, many bicyclists do not know of their existence or utility as a bicycle facility. More detail on the comfort and safety of WCLs can be found in Hunter et al., 1999, and Harkey et al., 1996.^{3,5}

Purposes

- Create on-street travel facilities for bicyclists.
- Create a lane wide enough so that motor vehicles and bicycles have adequate room to share the lane during overtaking.

Considerations

- Where WCLs are to be considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide appropriate WCL width, especially where drainage grates or other factors reduce the usable lane width.
- Consider the use of “Share the Lane” signing if used on a heavily traveled roadway.
- Consider the use of a stencil such as the Shared Arrow or the SHARROW (developed in San Francisco) to help with proper bicyclist placement within the WCL and to encourage bicyclists to travel in same direction as motor vehicle traffic.
- Truck traffic should not exceed five percent of the total motor vehicle traffic.

Estimated Cost

Normally, the only cost associated with WCLs is for re-striping the roadway. A ballpark cost for large striping is \$5,500 per km (\$3,470 per mi). It is most cost efficient to create WCLs during street reconstruction, street resurfacing, or at the time of original construction.

13. PAVED SHOULDERS

Paved shoulders are very similar to bike lanes as a bicycle facility. The pavement edge line for the paved shoulder provides separated space for the bicyclist much like a bike lane. Depending on the situation, the width of the shoulders may vary. If the paved shoulder is less than 1.2 m (4 ft) in width it should not be designated or marked as a bicycle facility. Widths are typically a function of amount of bicycle usage, motor vehicle speeds, percentage of truck and bus traffic, etc., although widths are sometimes purely a function of available right-of-way. More paved shoulder design details are given in the AASHTO Green Book.⁵ Prior research has shown that paved shoulders tend to result in fewer erratic motor vehicle driver maneuvers, more predictable bicyclist riding behavior and enhanced comfort levels for both motorists and bicyclists.³

Colored shoulders have been used in Europe to visually narrow the roadway. This technique has been tried in Tavares, FL, where a section of roadway added painted red shoulders (see case study #14). The intent was to provide increased room and comfort for walkers and bicyclists. The 0.6 km (1 mi) treated section of roadway was a two-lane rural roadway with approximately 1,700 vehicles per



Red shoulders in Tavares, FL.



Bike pocket striped to the left of a right-turn lane aids through bicyclists using a paved shoulder facility.

Purposes

- Create travel facilities for bicyclists.
- Create separated space for bicyclists.
- Reduce or prevent the problems associated with bicyclists overtaking motor vehicles in narrow, congested areas.

Considerations

- Provide adequate width by taking into account factors such as the amount of bicycle usage, motor vehicle speeds, percentage of truck and bus traffic, etc.
- Provide ride-able space for bicyclists if rumble strips are used.
- Examine alternative space for bicyclists if there are intersecting side streets.
- Provide a smoothly paved surface and keep free of debris.

Estimated Cost

Paved shoulder costs can be quite variable. Using data from Iowa DOT average contract prices for calendar year 2000, a minimum design width of 1.2 m (4 ft) of paved shoulder width to accommodate bicycle traffic was estimated at \$44,000 per km (\$71,000 per mi).⁸

day and had a 56 km/h (35 mi/h) speed limit. Even after the roadway was widened, the use of the red shoulders resulted in motor vehicle speeds similar to the before (narrower roadway) situation.⁶

Broward County, FL, has experimented with another paved shoulder variation. Undesignated lanes 0.9 m (3 ft) have been implemented on a number of roadways which formerly had wide 4.3 m (14 ft) curb lanes in place (i.e., 3.4 m (11 ft) travel lane and 0.9 m (3 ft) undesignated lane). The lanes were left as undesignated because they were too narrow to be referred to as bike lanes. The striping resulted in a delineated, although sub-standard, space for bicyclists to operate on these roadways (see case study #15).⁷

Rumble strips are often used on shoulders to alert sleepy or inattentive motorists, but there is considerable debate about what kinds of designs are safe or appropriate for bicycles. AASHTO recommends that 1.2 m (4 ft) of ride-able surface should be present for bicyclists if rumble strips are used on a shoulder.

14. COMBINATION LANES

A combination lane usually refers to a lane nearest the curb which serves various modes of traffic or movements. An example would be a transit-bicycle lane. Generally such multiple uses are operationally acceptable unless there is considerable bus and bike traffic. Signs might identify this lane as a priority BUS AND RIGHT TURNS ONLY EXCEPT BIKES. Another signing alternative is BICYCLES BUSES AND RIGHT TURNS ONLY. The lane would accommodate bus traffic, motor vehicles making right turns, and bicycles where it is not feasible to provide separate facilities.

These combination lanes are not without problems. If there is a shortage of bus and bike traffic, the lane can become another peak hour traffic lane. Provision of combination lanes on arterial streets with on- and off-ramps creates a difficult riding situation for bicyclists.



PHOTO BY ARTHUR ROSS

This combination lane in Madison, WI, has little bus and bike traffic, which can result in use of the lane by other motor vehicles at peak hours.

If bus and bike traffic need to be separated, the bus lane is usually nearest the curb, which reduces conflicts between buses accessing stops and bicycles traveling through, and between bus passengers and bicyclists. Separated lanes should reduce conflicts associated with buses moving in and out of a single bus and bike lane.

Communities with shared bike/bus lanes include Santa Cruz, CA; Philadelphia, PA; Tucson, AZ (case study #16); and Toronto, ON.

Purposes

- Create on-street travel facilities for bicyclists where it is not feasible to provide a completely separate bicycle facility or lane.
- Create separated space from higher-speed traffic lanes for bicyclists.

Considerations

- Provide appropriate lane width.
- Provide appropriate signs.
- Evaluate the amount of right-turning motor vehicles to determine if the use of a combination lane is appropriate.
- Determine if special signs or markings are necessary for situations such as a high volume of motor vehicle right turns.
- Ample bus and bike traffic may create a “leap frog” effect with buses and bikes passing each other frequently.

Estimated Cost

The cost for markings and signs for a bus-bike lane is in the range of about \$100 per sign, posted about every 0.2 km (eighth of a mile), and painted pavement symbols spaced throughout.



Use of a bike lane next to a bus lane in Madison, WI.

PHOTO BY SHAWN TURNER, ITE PEDESTRIAN AND BICYCLE COUNCIL

15. CONTRAFLOW BIKE LANES

Bicyclists are expected to follow established rules-of-the-road. A particular example is riding in the same direction as motor vehicle traffic. However, there are certain situations where the placement of a bicycle lane counter to the normal flow of traffic may increase safety or improve access for bicyclists. For example, connectivity may be enhanced, and out-of-the-way detours and wrong-way riding reduced, if a contraflow bike lane is designated on some one-way streets, allowing bicyclists to ride against the main flow of traffic.

It should be made clear that there are safety concerns associated with contraflow riding, as this places bicycles in a position where motorists do not expect to see them. Thus, a careful assessment should be made before installation. However, there is precedent for opposite direction riding that emanates from Europe, where cyclists are often allowed to ride in the opposite direction on one-way streets, usually with slow motor vehicle traffic. The contraflow bike lane is a specialized bicycle facility that can be used in particular situations and is intended to reduce the number of conflicts between bicycles and motor vehicles. The facility also would be intended to save time by preventing cyclists having to travel an extra distance to ride in the same direction as motor vehicles. Contraflow lanes may also alleviate riding on a high speed, high volume route.

Contraflow bike lanes can be found in cities in the United States with large numbers of bicyclists, including Cambridge, MA (see case study #18); Boulder, CO; Madison,



Blue pavement was used to increase conspicuity of this contraflow lane in Cambridge, MA.

Purposes

- Create specialized on-street facilities for bicyclists.
- Enhance bike connectivity.
- Reduce out-of-direction riding on a one-way street network.

Considerations

- Install contraflow lanes on the correct side of the street, i.e. on the left side facing the one-way traffic.
- Where contraflow bike lanes are considered, the road or street should be evaluated to determine if this facility is appropriate.
- Provide adequate bike lane width.
- Provide appropriate pavement markings and signing along the route.
- Consider whether colored pavement in the contraflow lane is needed.
- Avoid termination of contraflow bike lanes where bicyclists are left in a vulnerable situation.
- Avoid situations where there are many driveways, alleys, or streets that would intersect with the contraflow lane.
- Determine if there is room for a regular bike lane in the direction of motor vehicle travel on the opposite side of the street.
- Determine if existing traffic signals need to be modified with loop detectors or push buttons to accommodate bicyclists.
- Ensure contraflow bike lanes are legal under local traffic laws.

Estimated Cost

The cost of installing a normal bike lane is approximately \$3,100 to \$31,000 per kilometer (\$5,000 to \$50,000 per mile), depending on the condition of the pavement, the need to remove and repaint the lane lines, the need to adjust signalization, and other factors. Depending on complexity, such costs could also be associated with contraflow bike lanes. However, the most likely additional costs would pertain to thermoplastic bike symbols and arrows or inlay bike symbols and arrows. It is most cost-efficient to create contraflow or normal bike lanes during street reconstruction, street resurfacing, or at the time of original construction.

WI; and Eugene, OR. A Madison contraflow lane exists on a street with high traffic volumes. In this case, the contraflow lane is separated from motor vehicle traffic with a raised median (see case study #17).

PHOTO BY DAN BURDEN



Separated contraflow bike lane in Boulder, CO.

INTERSECTION TREATMENTS

Over half of all bicycle-motor vehicle crashes occur at or near intersections or other junctions. Improvements at these locations have the potential to significantly increase safety. Specialized intersection markings that may help bicyclists and motorists safely navigate through intersections and use of innovative techniques, such as bike boxes, are gaining more prominence in some communities. Other measures are designed to reduce conflict areas at intersections. It is also important to try to slow motor vehicle speeds through intersections to reduce both the number and severity of intersection collisions, and some of the treatments described below pertain to this objective. Other measures to slow speeds may be found in the Traffic Calming section. The countermeasures included in this section are as follows:

- Curb Radii Revisions
- Roundabouts
- Intersection Markings
- Sight Distance Improvements
- Turning Restrictions
- Merge and Weave Area Redesign



PHOTO BY DAN BURDEN

A roundabout intersection design should force slow travel speeds.

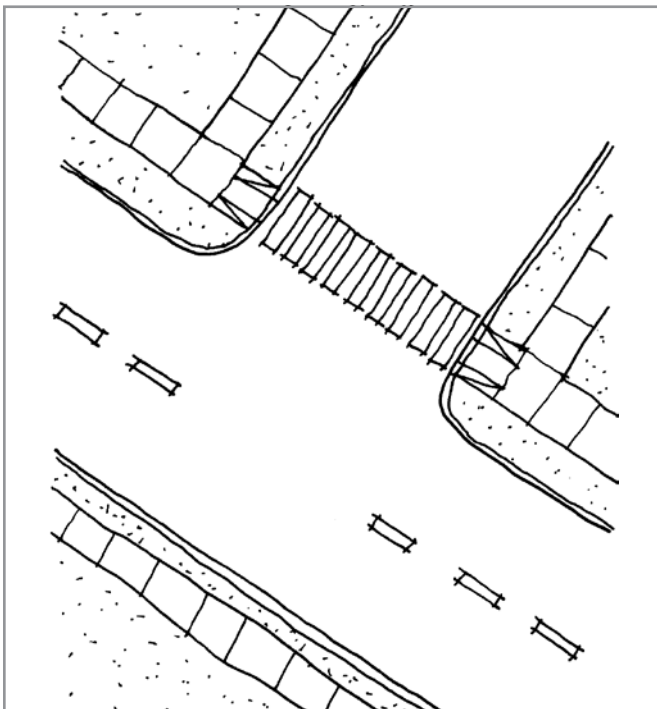
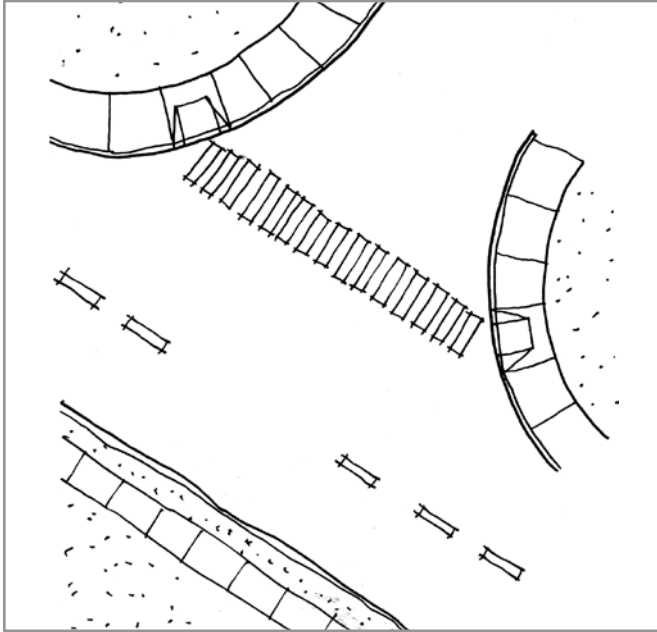


PHOTO BY PETER LAGERWEY

Reducing the curb radius by extending the curb and realigning skewed intersections can improve intersection safety.

16. CURB RADII REVISIONS

Motor vehicles turning at a high rate of speed pose problems for bicyclists (as well as pedestrians). This is a common problem when motorists traveling on an arterial street turn onto a residential street. A typical bicycle-motor vehicle crash type, sometimes called a “right hook,” occurs when a motor vehicle passes a bicycle going straight ahead and then turns right shortly after making the passing maneuver. Reducing the radii of curbs at these high speed right turns provides a remedy. Creating 90-degree intersection corners or corners with tight curb radii tend to slow motorists.



Before (top) and after (bottom) curb radius is reduced.

Purposes

- Create a safer intersection design.
- Slow right-turning motor vehicles.
- Lessen likelihood of “right hook” crashes.

Considerations

- Where curb radii revision is to be considered, the road or street should be evaluated to determine if appropriate for this facility.
- Make sure that public maintenance vehicles, school buses, emergency vehicles, and typical trucks and buses can be accommodated.
- Determine if the presence of on-street parking and/or bike lanes help to tighten the radii more than the norm.

Estimated Cost

Costs for reconstructing a curb to a tighter radius can vary from approximately \$5,000 to \$40,000, depending on site conditions (e.g., the amount of concrete and landscaping that is required, whether drain grates and other utilities have to be moved, and whether there are other issues that need to be addressed).

Some communities routinely reduce curb radii at locations where the routes: (1) are used by schoolchildren or the elderly, (2) are in neighborhood shopping areas with high bicycle and pedestrian volumes, and (3) are at particular intersections known to have a safety problem (see case study #20). A logical step is to evaluate the curb radii along a corridor frequented by bicyclists, along with a



Tighter curb radii at obtuse angle corners forces slower motorist turns. (Seattle, WA)

study of the crash types. Care must be used when revising curb radii on routes with truck and bus traffic. If a curb radius is made too small, large trucks and buses may ride over the curb or may veer out into an adjacent traffic lane to make the turn.

When there is parking and/or a bike lane, curb radii can be tighter, because the motor vehicles will have more room to negotiate the turn. Older cities in Europe and in the northeast United States frequently have curb radii of 0.6 to 1.5 m (2 to 5 ft) without suffering any detrimental effects. More typically, however, in new construction the appropriate turning radius is about 4.6 m (15 ft) and about 7.6 m (25 ft) for arterial streets with a substantial number of turning buses and/or trucks. Tighter turning radii are particularly important where streets intersect at a skew. While the corner characterized by an acute angle may require a slightly larger radius to accommodate the turning maneuvers, the corner with an obtuse angle should be kept very tight to prevent high-speed turns.

17. ROUNDABOUTS

A modern roundabout is built with a large, usually circular, raised island located at the intersection of two or more streets and may take the place of a signalized intersection. Traffic maneuvers around the circle in a counterclockwise direction, and then turns right onto the desired street. Entering traffic yields to traffic in the roundabout, and left-turn movements are eliminated. Unlike a signalized intersection, vehicles generally flow and merge through the roundabout from each approaching street without having to stop. If properly designed, roundabouts force slow intersection speeds and reduce the number of conflict areas.¹

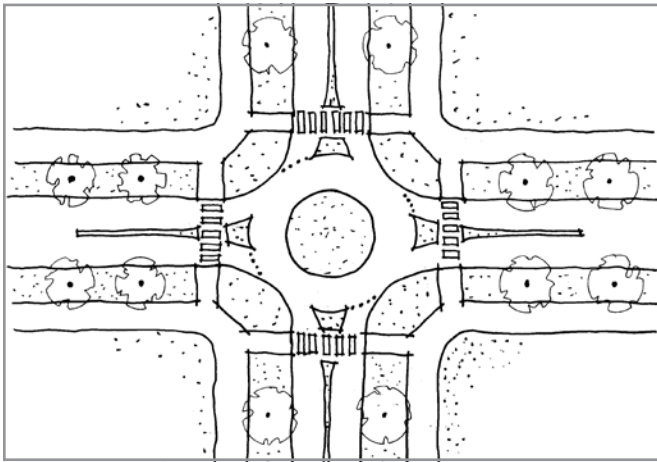


ILLUSTRATION BY A.J. SILVA

Bicyclists may safely share space with motor vehicles in low-speed, single-lane roundabouts.

Roundabouts need to accommodate bicyclists and pedestrians. It is important that motor vehicle traffic yields to pedestrians crossing at the roundabout. Splitter islands at the approaches slow vehicles and allow pedestrians to cross one traffic lane at a time. Single-lane approaches can be designed to keep speeds down to safer levels and allow pedestrians to cross. Multi-lane roundabouts tend to have higher motor vehicle speeds and create more conflicts between bicycles (and pedestrians) and motor vehicles.

Unless the road leading to a roundabout has two lanes, slow motor vehicle traffic speeds, and low traffic volumes, bicyclists may have difficulty navigating the roundabout. Marking bike lanes through the roundabout has not been shown to be safer and may actually be less safe. In high volume, multi-lane roundabouts, an off-road shared path may be needed for bicyclists. Such a treatment delays and inconveniences bicyclists but may improve safety.

National Cooperative Highway Research Program Project 3-65, "Applying Roundabouts in the United States," is scheduled to be completed in 2006. The objectives of

Purposes

- Provide good traffic management where the intersection is large and complex.
- Replace a traffic signal that is experiencing heavy traffic backup and congestion.
- Reduce speeds at intersection.
- Create a gateway into an area.

Considerations

- Bike lanes should generally be discontinued when leading to low-speed roundabouts. Bicycles are expected to merge with the flow of traffic—a low design speed is required.
- Street widths and/or available right-of-way need to be sufficient to accommodate a properly designed roundabout.
- Roundabouts often work best where there is a high percentage of left-turning traffic.
- Deflection on each leg of the intersection must be set to control speeds to 24 to 29 km/h (15 to 18 mi/h).

Estimated Cost

The cost for a landscaped roundabout varies widely and can range from \$45,000 to \$150,000 for neighborhood intersections and up to \$250,000 for arterial street intersections, not including additional right-of-way acquisition. Yet, roundabouts have lower ongoing maintenance costs than traffic signals.



PHOTO BY DAN BURDEN

Mountable curbs provide access for buses, trucks, and emergency vehicles.

this project are to: (1) develop methods of estimating the safety and operational impacts of U.S. roundabouts, in-

cluding a thorough examination of interactions between motor vehicles and pedestrians and bicyclists, and (2) refine the design criteria used for them.²

PHOTO BY DAN BURDEN



Bike lanes should be discontinued before roundabouts.

PHOTO BY DAN BURDEN



Splitter islands and narrow curb radii slow speeds approaching the roundabout.

18. INTERSECTION MARKINGS

Some 50 to 70 percent of bicycle-motor vehicle crashes occur at intersections or other junctions such as driveways. Intersection markings are one method of helping bicyclists negotiate these problem areas. The *AASHTO Guide for the Development of Bicycle Facilities* discusses recommended placement of bike lane striping for various kinds of intersections.³ The guide also covers special situations where there are high numbers of right-turning motor vehicles and where auxiliary right-turn lanes are needed. Bike pockets may be used to direct bicyclists to the best placement in the intersection. Bike pockets placed next to a roadway centerline may also be used to make it easier for bicyclists to negotiate an offset intersection.



PHOTO BY DAN BURDEN

This bike pocket positions bicycles to the left of right-turning motor vehicles.

Sometimes dashed lines are used to indicate the proper path for the bicycle in a complex intersection. Colored pavement may also be used for this purpose, as well as to indicate the weaving area for bicycles and motor vehicles when right-turning motor vehicles cross the path of bicycles in a bike lane. The intent is to increase awareness and safe behaviors by both cyclists and motorists and yielding behaviors by motorists.

Other kinds of markings are available for use at intersections. Bike box is the term that has gained popularity in the United States for a European treatment usually known as the advanced stop bar. The box is a right-angle extension to a bike lane at the head of the intersection (see drawing). The box allows bicyclists to get to the head of the traffic queue on a red traffic signal indication and then proceed first when the traffic signal changes to green. Such a movement is beneficial to bicyclists and eliminates conflicts when, for example, there are many right-turning motor vehicles next to a right-side bike lane. Being in the

Purposes

- Create on-street travel facilities for bicyclists.
- Create separated space for bicyclists.
- Increase awareness and safe behaviors by both cyclists and motorists.

Considerations

- Where intersection markings are to be considered, the road or street should be evaluated to determine what markings are appropriate.
- Provide adequate width if space is created for cyclists.
- Provide appropriate signs.
- Use marking and sign configurations that encourage the weaving of bicycles and motor vehicles where there are adequate gaps in traffic, usually in advance of the intersection proper.

Estimated Cost

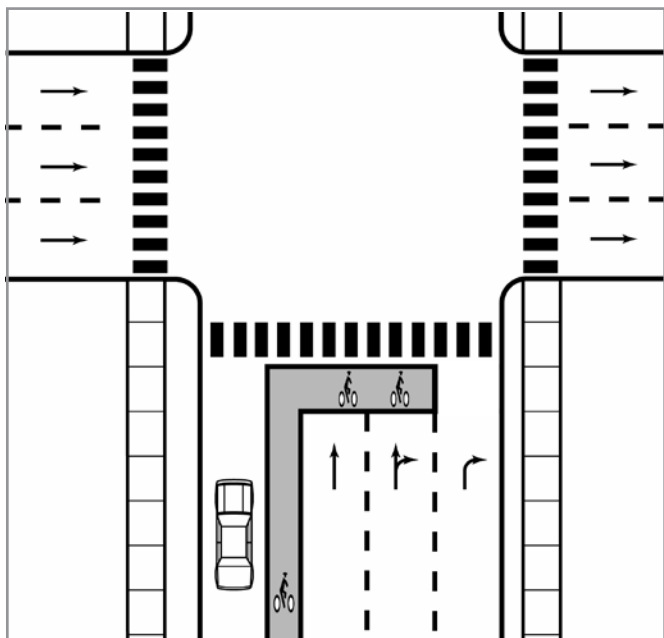
Costs will be variable, depending on the type of marking used. For a combination bike lane-right turn lane, costs include paint (regular, not thermoplastic) removal, new thermoplastic paint, one sign placed in ground and another sign up next to signal head for approximately \$1,500 parts and labor. If traffic loops have to be moved, the cost would be an extra \$1,000 per lane.



PHOTO BY DAN BURDEN

Dashed lines may assist both bicyclists and drivers in complex intersections.

box, and thus at the front of the traffic queue, also tends to make bicyclists more visible to motorists. Recessed stop lines operate similarly. These treatments should only be considered where there are a considerable number of daily bicycle commuters. Multi-lane streets with high traffic volume should be carefully evaluated to be sure the treatment would be safe. (See case study #26.)



This innovative bike box was used in a one-way street with a left side bike lane in Eugene, OR.

Another example is a combination bicycle lane-right-turn lane at an intersection. There are many intersections where using a minimum-width bike lane is not possible due to limited right-of-way. The use of a shared, narrow right-turn lane in combination with a bike lane in a limited right-of-way situation is a novel approach. This treat-

ment could be applied in initial intersection design, when retrofitting a bike lane to an existing right-of-way, and when adding an auxiliary right-turn lane. This innovative application is used in Eugene, OR, to allow straight-through bicyclists to share a narrow right-turn lane with motorists. At the intersection proper, the total right-turn lane width is 3.6 m (12 ft), which includes a bike lane (pocket) of 1.5 m (5 ft) and a 2.1 m (7 ft) space to the right of the bike pocket. Depending on the size of the motor vehicle, the bicycle could be positioned in front of, beside or behind the motor vehicle in this combination lane. (See case study #21.)

The city of Portland, OR, has used special markings to direct bicycles around a street car transit stop in the vicinity of a bike lane (see case study #13) and to provide bicycle access through an offset intersection (see case study #23).

PHOTO BY CITY OF PORTLAND, OR, OFFICE OF TRANSPORTATION



A bicycle-only center-turn lane in Portland, OR, helps bicyclists navigate an offset intersection.

19. SIGHT DISTANCE IMPROVEMENTS

Adequate sight distance is vital for safe bicycling. Bicyclists need to see the movements of motor vehicles, and vice versa. Intersections are often areas where a number of sight distance problems occur. For example, on-street parking of motor vehicles can restrict the view. Trees, shrubbery, and other flora can also impede the line of sight. Improper placement of signs can decrease sight distance. Skewed intersections, where cross streets are greater or less than 90 degrees, can make it difficult to see other vehicles, as well as increase the exposure of bicyclists (or pedestrians) crossing the street. Problems similar to the above also often occur where driveways intersect with streets.

PHOTO BY PETER LAGERWEY



Realigning skewed or obtuse-angle intersections improves sight angles for intersecting roadways.

Sight distance problems can also occur away from intersections due to vertical curves. Use of the SHARE THE ROAD sign (see case study #41) would be appropriate on roads or streets with significant bicycle traffic.

PHOTO BY CHARLES HAMLETT



Transit stop placement can impact sight distance at junctions.

Purposes

- Improve the ability to see other modes of traffic.
- Increase awareness and safe behaviors by both cyclists and motorists.
- Increase reaction time.
- Decrease stopping distance.

Considerations

- Determine whether on-street parking is necessary.
- Determine the most appropriate kind of parking if necessary.
- Provide appropriate signs at street intersections and problem driveways.
- Provide the appropriate kinds of trees, shrubbery, and flora.
- Place street furniture so sight distance is not reduced.
- Determine if skewed intersections should be realigned.

Estimated Cost

Costs will vary depending on the treatment. Re-striping may be all that is necessary to eliminate unnecessary parking. The cost of sign removal or relocation is dependent on the size of the signing. The same would also be true for removal of trees, shrubbery, and other flora.

20. TURNING RESTRICTIONS

A frequent crash type involves a collision between a bicycle and a turning motor vehicle. One scenario involves a bicyclist going straight ahead and an oncoming motorist turning left at an intersection or into a driveway. If the motorist is intent on finding a gap between oncoming motor vehicles, he or she may fail to recognize an approaching bicyclist. Another scenario involves motor vehicles turning right on red. This is a particular problem for bicycles riding against traffic.



ILLUSTRATION BY A.J. SILVA

A permissible Right Turn On Red (RTOR) was introduced in the 1970s as a fuel-saving measure and has sometimes had detrimental effects on bicycling. While the law requires motorists to come to a full stop and yield to cross-street traffic, including bicyclists (and pedestrians), before turning right on red, many motorists do not fully comply with the regulations, especially at intersections with wide turning radii. In addition, motorists are so intent in looking for traffic approaching on their left that they may not be alert to bicyclists (or pedestrians) approaching on their right. Motorists also often pull into the crosswalk area to wait for a gap in traffic, which may put them directly in the path of bicyclists (or pedestrians) crossing in the crosswalk.

In locations where there is bicycle traffic, use of signs prohibiting certain turning movements may be warranted. One example is the standard sign preventing motor vehicles from turning left, usually placed over the roadway or at a left-hand corner of the intersection. The sign may be installed adjacent to a signal face viewed by motorists in the left lane. Prohibiting RTOR should be considered as well (also with high pedestrian volumes). This can be done with a simple sign posting at the right-hand corner of the intersection. The sign may also be installed adjacent to a signal face viewed by motorists in the right lane.

There are some options that are more effective than a standard sign. For example, one option is a larger 762

Purposes

- Increase bicycle (and pedestrian) safety and decrease crashes with turning motor vehicles.
- Increase safety in crosswalks.

Considerations

- Signs should be used where necessary and not overused. Overuse of signs breeds non-compliance and disrespect.
- Traffic signs used on public property must comply with the *Manual on Uniform Traffic Control Devices* (MUTCD).
- Signs should be placed in clearly visible locations.
- Signs should be checked to assure adequate nighttime reflectivity.

Estimated Cost

Sign costs are variable but typically range from \$30 to \$150. Installation may cost another \$200. Electronic signs are appreciably more expensive.

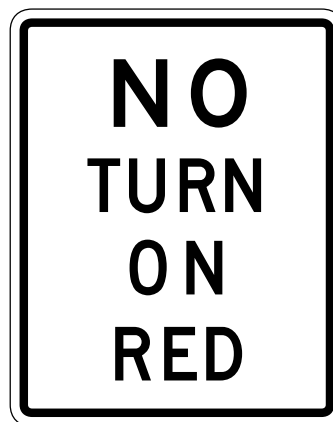


ILLUSTRATION BY A.J. SILVA

mm by 914 mm (30 in by 36 in) NO TURN ON RED sign, which is more conspicuous. For areas where left and right turns are acceptable during certain times, time-of-day restrictions may be appropriate using variable-message signs.

A partial restriction may prohibit left turns except for bicycles and transit. Such signs could be used in conjunction with bicycle boulevards or other low-volume, low-speed streets to not only reduce conflicts at the intersection, but help create a preferential bicycling cross-street. Turns may also be restricted with diverters and partial diverters.

21. MERGE AND WEAVE AREA REDESIGN

Merge areas that affect bicyclists are typically associated with intersections. Generally the pavement markings are for lane separation, for indicating an assigned path or correct position for the bicyclist, and for information about upcoming turning and crossing maneuvers. The *Manual of Uniform Traffic Control Devices* (MUTCD) is the national standard for all pavement markings (as well as signs and signals).⁴

Pavement markings, such as bike pockets adjacent to left- or right-turn motor vehicle traffic lanes, can be used to make bicycling safer. Double left- and right-turn lanes are particularly difficult for bicyclists. Long merge areas or high speed merges for motorist left turns are also problems for bicyclists needing to make left turns. Local geometric design tailoring may be needed on streets with these characteristics that also have a considerable number of bicyclists in the traffic stream.

In addition to intersection problems, bicyclists often ride on arterials or urban parkways which may contain some freeway-style designs such as merge lanes and exit ramps. If there is bicycle traffic on these roadways then it is likely that a bike lane or paved shoulder will be available. The 1995 *Oregon Bicycle and Pedestrian Plan* has a good description of the problems that can occur and potential solutions, and the description below is adapted from the plan.⁵

For the merge lane or entrance lane situation, several problems exist:

- The angle of approach creates visibility problems.
- Motor vehicles are accelerating to merge with traffic

Purposes

- Provide for safer merging of bicycles with motor vehicle traffic.
- Improve sight distance and awareness for bicycles and motor vehicles involved in potential conflicts at entry and exit ramps.

Considerations

- Where entry and exit ramp revisions are to be considered, the road or street should be evaluated to determine if appropriate for this facility.
- Determine if other sight distance improvements need to be made.
- Try to avoid double left- and double right-turn situations for bicyclists.

Estimated Cost

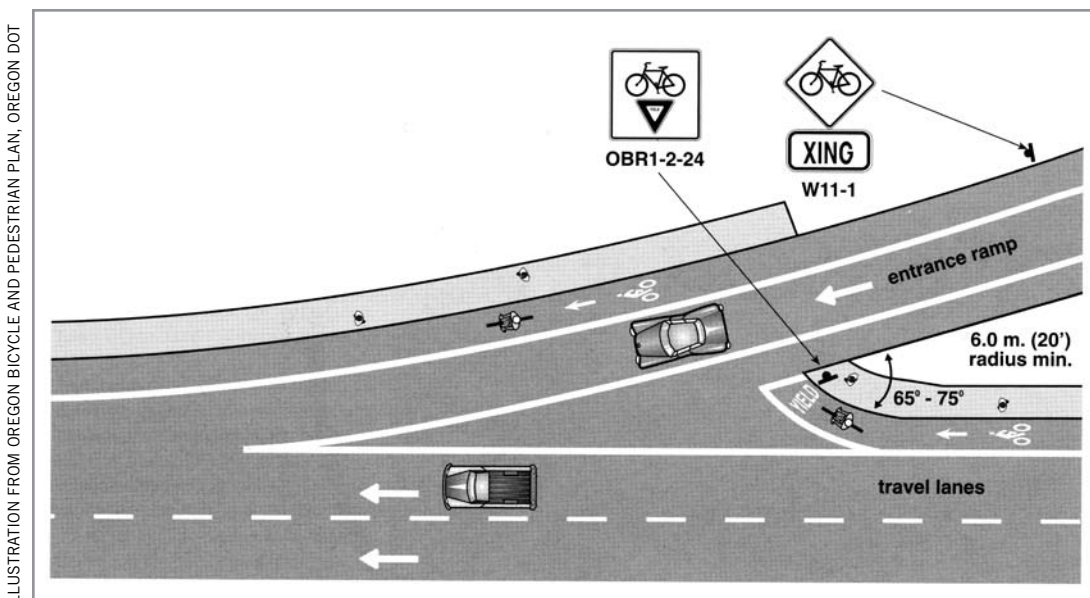
Construction costs for reconstructing a tighter turning radius are approximately \$2,000 to \$20,000 per corner, depending on site conditions (e.g., drainage and utilities may need to be relocated). Costs for reconstructing entrance and exit lanes on arterials or urban parkways are also dependent on site conditions.

on the main road.

- Motor vehicles are typically traveling much faster than bicycles.

The Oregon DOT offers the design shown below as one alternative to the entrance lane problem.⁵

This design creates a short distance across the ramp for the bicyclist at nearly a right angle for improved sight distance, as well as providing a crossing in a location before drivers' attention is focused on the upcoming merge with motor vehicles.

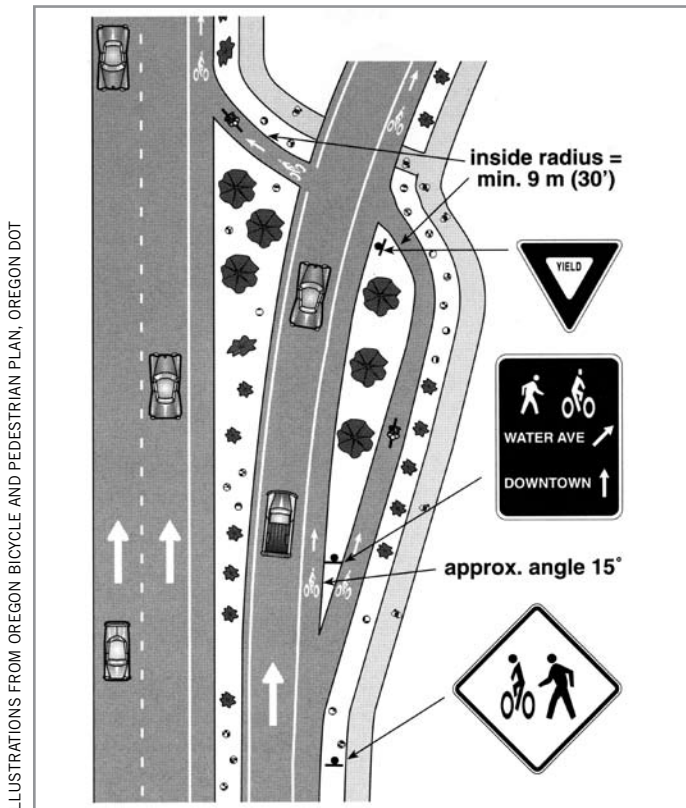


Design solution for bicycles and motor vehicles at an entrance ramp.

Similar problems exist for the exit lane situation:

- Motor vehicles are often exiting at high speeds.
- The exit angle creates visibility problems.
- Exiting drivers may not use their turn signal to indicate their desired movement.

The Oregon DOT offers the design shown below as one alternative to the exit lane problem.



Design solution for bicycles and motor vehicles at an exit ramp.

MAINTENANCE

The availability of bicycle facilities is one of the components that can lead to increased riding in a community—if you build it, bicyclists will come. However, if you build it, it will also need to be maintained. Thus, maintenance needs require planning and budgeting. Sample maintenance activities include keeping roadways and bike lanes clean and free of debris, identifying and correcting roadway surface hazards, keeping signs and pavement markings in good condition, maintaining adequate sight distance, and keeping separate shared-use paths in good condition.

Maintenance is an area where planning and attention can provide significant benefits for bicyclists at relatively modest additional cost. Identification of maintenance needs for roadways and bicycle facilities and institutionalization of good maintenance practices are key elements in providing safe facilities for bicyclists. The countermeasures in this category have been divided into the following categories:

- Repetitive/Short-Term Maintenance
- Major Maintenance
- Hazard Identification Programs

The types of activities that will be carried out under each heading will be similar among communities in many cases, but should be identified, categorized, prioritized in terms of urgency and frequency, and budgeted for by each community since local conditions will dictate exact needs. For example, local flora, climate, weather, soil types, and other conditions may dictate frequent landscape maintenance and debris sweeping in some areas but be less frequently needed elsewhere. Winter snow removal may be important in northern communities but irrelevant in warmer climates.

The importance of good planning and initial design also cannot be overstated with respect to long-term maintenance needs. It is easier to obtain outside funding for facilities construction than for on-going maintenance, so plan and build correctly at the outset to reduce future maintenance problems and expense.



PHOTO BY BRIANNA LEON

Well-maintained roadway surface and bike lane free of debris and surface irregularities. (Phoenix, AZ)

22. REPETITIVE/SHORT-TERM MAINTENANCE

Repetitive and short-term maintenance includes activities such as sweeping, landscape maintenance, pavement markings maintenance, drain systems clearance and pothole repair that must be performed at some routine frequency, generally at least once per year, but some much more often. Such activities are crucial to maintaining safe riding surfaces, adequate sight distances and clearance, and clear and visible markings. Activities such as landscape maintenance, sweeping, graffiti removal, emergency telephone repair and general trash pick up also affect the aesthetic environment and promote bicycling through maintaining a more secure and pleasing environment. Regular inspections of structures and general surface conditions should also be performed to detect major maintenance needs.

Maintenance activities related to the safe operation of a facility should always receive top priority. The American Association of State Highway and Transportation Officials *Maintenance Manual*¹ identifies seven maintenance activities that should be carried out on a routine basis:

Signs and Traffic Markings

Signs warning both the motorist and bicyclist should be inspected regularly and kept in good condition; and striping should be kept prominent.

Sight Distance and Clearance

Sight distances on parallel roadways and trails should not be impaired leading up to crossings and curves. Trees,



PHOTO BY LIBBY THOMAS

Sight distance has been impaired due to poor landscape design and insufficient landscape maintenance.

Purposes

- Maintain surfaces and other riding conditions in a safe and inviting condition for bicyclists.
- Identify, plan, and budget for routine maintenance activities that are critical to 1) maintaining the safety of a facility; 2) protecting the investment in a facility; and 3) protecting aesthetics and the environment.

Considerations

- Good maintenance practices preserve the investment in facilities and keep them in safe, useable condition.
- If facilities are well-maintained for bicyclists, they are apt to be in suitable condition for all shared uses.
- Annual maintenance needs and costs should be considered at the time facilities are constructed since it is more difficult to secure outside funding specifically for maintenance.
- Institutionalizing good maintenance practices may increase bicycling and reduce government liability.
- Develop an annual budget for repetitive maintenance that reflects current and new facilities to prevent unexpected increases.

shrubs and tall grass should be regularly inspected and either removed or trimmed if they can interfere. Adequate clearances on both sides and overhead should be checked regularly. Tree branches should be trimmed to allow enough room for seasonal growth without encroaching onto the street or trail.

Surface Repair

Streets and trails should be patched or graded on a regular basis. It is important that finished patches be flush with the existing surface. Skid resistance of the repaired area should be the same as the adjoining surface. Ruts should be removed by whatever measures are appropriate to give a satisfactory result and avoid recurrence.

Drainage

Seasonal washout, silt or gravel washes across a street, or trail, and sinking should be watched for, and appropriate measures should be taken to prevent them. Installing culverts or building small bridges could be considered a maintenance function to achieve an immediate result and avoid the expense of contracting. Drainage grates should



Sunken pavement patch and shoulder drop-off to below-grade drainage grate contribute to bicyclist discomfort and possible hazards for bicyclists.

not have parallel openings that could catch narrow bicycle tires. Maintenance personnel should be especially instructed to ensure that grates are positioned so that openings are at angles to the bicyclist's direction.

Sweeping and Cleaning

The tires of a bicycle can be easily damaged by broken glass and other sharp objects. Bicycle wheels slip easily on leaves or ice. Sand or loose gravel on an asphalt surface can cause a serious fall. When mechanically sweeping roadways, there should also be concern that material is not thrown onto a bike lane, shoulder or trail.

Structural Deterioration

Structures should be inspected annually to ensure they are in good condition. Special attention should be given to wood foundations and posts to determine whether rot or termites are present.

Illumination

Lighting improvements should be made at busy arterials. Once installed, the lights should be maintained to not only ensure reliable operation, but that they are kept clean and replaced as required to keep the desired luminescence.

A thorough assessment of all bicycle facilities should be performed to generate a list of repetitive and short-term required maintenance activities. Preferably such processes would occur at the design phase so maintenance activities will be budgeted and planned for in advance. Some maintenance activities may be incorporated under regular roadway and public facilities maintenance, although care should be taken to consider the special needs of bicyclists and provide appropriate standards. For example, when re-

Estimating Cost

Historic costs provide the best roadmap for determining future costs. When estimating costs, there are four things to consider:

- **Frequency:** Reports of hazards on bicycle facilities are going to come in at about the same rate each year with some increase as new bicycle facilities come on line and the number of bicyclists increases. They are also likely to increase in the spring and summer when more bicycling occurs. Getting a handle on the total number is the first step in developing a budget.
- **Types of hazards:** Reported hazards should be put into basic categories such as potholes, longitudinal cracks in the pavement, debris that needs sweeping, etc.
- **Cost per incident:** Once reported hazards have been put into categories, an average cost per incident can be determined. For example, it is relatively easy to come up with an average cost for fixing a pothole.
- **Budget:** The final step is to develop a budget based on the frequency and cost per incident.

Existing maintenance budgets can often be used to cover the costs of fixing hazards. Once a budget has been determined, it may be possible to simply increase existing budgets proportionally. Some communities create separate budgets for addressing bicycle-related hazards.

pairing utility cuts, the City of Seattle requires an initial paving, then after allowing time for settling, the area is repaved to ensure that the cut area is made level with the surrounding pavement (see case study #1). Sweeping may also need to occur more frequently for bicyclists than would be necessary for motorists. Institutionalizing regular bicycle facility and shared roadway maintenance practices through scheduling, budgeting and inter-departmental cooperative agreements will ensure that the needs of bicyclists do not "slip through the cracks."

23. MAJOR MAINTENANCE

Activities such as repaving a trail surface, replacing bridges and fixing major drainage problems that have a frequency of two or more years will fall into the category of major maintenance. While major maintenance occurs infrequently, it should be budgeted for on an annual basis to avoid large, unexpected budgetary demands.

Once major maintenance categories have been identified, set maintenance priorities by identifying which activities are critical to the safe operation of the facility and which ones are critical to other objectives such as protecting the investment in the infrastructure, protecting the environment and protecting aesthetics. While some priorities may vary to reflect local community expectations, safe operation of the facility should never be compromised. The *AASHTO Maintenance Manual* recommends that maintenance should seek to maintain conformance with the design guidelines used to build the facility.¹ Where proper guidelines were not used, maintenance should include improvements to the facilities' safety and operation.



PHOTO BY LIBBY THOMAS

Bridge replacement offers an opportunity to add space for bikes. (Durham County, NC)

The final major maintenance budget and plan should include a checklist of all maintenance items, the frequency of and cost for each activity, the annual cost of each activity and an indication of who will perform the activity. Priorities related to safe operation of the facility should be clearly identified and a tracking procedure clearly outlined.

Purposes

- Identify major maintenance activities that are critical to maintaining the safety of a facility; protect the investment in a facility; and protect the aesthetics and the environment.
- Develop an annual budget for major maintenance to avoid the periodic need for a major infusion of cash.

Considerations

- Securing maintenance dollars is difficult. Therefore, focus on designing and constructing facilities correctly at the outset to minimize future maintenance costs. In particular, make sure all drainage issues are fully addressed at the time of construction since water is the culprit for many major maintenance problems.
- Make sure that major maintenance is reflected in an annual budget that can be carried over from year to year. By definition, the amount spent on major maintenance will vary from year to year (i.e. a new bridge on a trail is not going to occur every year). Avoid "emergencies" if possible.

Estimating Cost

When developing a major maintenance plan for a new facility, the first step is to check current costs for maintaining an existing facility. The key is to obtain the costs for maintaining a facility that is most similar to the facility you plan to construct.

The next step in developing a maintenance budget and plan is to create a list of all possible maintenance activities. A good way to begin is to list major items included in the facilities' design. Most major items will have a measurable life expectancy. For example, asphalt pavement on a trail may have a 15-year life expectancy. Taking the total miles of asphalt trail and dividing it by 15 will give a good estimate of how much pavement needs to be replaced on an annual basis. Bridges are better handled on a case-by-case basis. Make a list of all bridges on trails, estimate their probable life, and then devise a multi-year plan for major maintenance or replacement. Listing all major maintenance items, while a lot of work, is a one-time activity that will allow you to develop a realistic budget.

24. HAZARD IDENTIFICATION PROGRAM

Roadways and off-road facilities can be made safer and more appealing to bicyclists by developing methods to identify hazards and repair needs and institutionalizing practices to address them. Different and combined approaches have been taken by communities but include developing bicyclist hazard reporting programs, hiring personnel to conduct regular inspections of bikeways, and providing for routine accommodation or scheduling and performance of regular activities such as sweeping, inspection and spot repairs, inspection and landscape maintenance, etc. Public hazard reporting programs typically involve developing a hazard identification reporting form such as a postcard and publicizing the program and procedures to report problems through bicycle shops, bike maps, bike clubs, and other venues. A staff coordinator (may be part-time) will be needed to administer the program, ensure that the problem is referred to the correct department and follow-through on resolution, including contacting the reporting person to advise them of the repair or other outcome.



PHOTO BY LIBBY THOMAS

Below-grade drain grates create hazards for bicyclists.



PHOTO BY LIBBY THOMAS

Short term solution of pavement marking highlights the hazard until unsafe drain grates can be replaced or repaired.

Purposes

- Provide a regular method of identifying hazards for bicyclists.
- Provide procedures for ensuring that maintenance hazards are addressed on a timely basis.

Considerations

- Responding to reported hazards in a timely way is critical to protecting public safety and reducing liability exposure.
- Prioritizing hazards requires a basic understanding of what problems are likely to cause crashes. For example, loose gravel on a curve is likely to cause a crash. Overgrowth that impairs sight distance at a busy intersection should be addressed immediately.
- The level of effort put into responding to bicycle-related hazards should be equal to or slightly greater than the effort put into responding to motor vehicle-related hazards. In other words, be able to demonstrate parity when developing a well-rounded program.

Estimated Cost

Providing paid staff to perform hazard identification program activities for 26 weeks cost one around \$10,000. Setting up a volunteer bicyclist hazard reporting program with a coordinator, training and materials printing cost around the same, including a pilot test and evaluation of the program (see case study #28).

See Repetitive/Short-Term Maintenance and Major Maintenance countermeasures descriptions for procedures to establish costs of actual maintenance and repair activities.

Along with identifying problems, it is imperative that effective policies and procedures are in place to resolve them. Much routine maintenance might be accommodated through regular roadway maintenance (and the costs absorbed by, or at least shared within, the regular roadway maintenance budget). It is important that identification methods and maintenance procedures specify issues that are particular or more stringent for bicyclists, and that might otherwise not be detected or repaired to the necessary standard. Examples of issues that require particular attention are drain grates; cracked, uneven, or unswept surfaces—particularly of outside curb lanes, paved should-

ders, or bike lanes; poor drainage; and slippery surfaces such as pavement markings, railroad crossings, utility covers, damaged pavement and others.

TRAFFIC CALMING

Traffic calming is a way to lower traffic speeds or volume using physical measures. Traffic calming creates physical and visual cues that induce drivers to travel at lower speeds and is intended to be self-enforcing. The design of the roadway results in the desired effect, without relying on compliance with traffic control devices such as signals and signs, and without enforcement. While added elements such as landscaping and lighting do not force a change in driver behavior, they might supplement the visual and perceptual cues that encourage people to drive more slowly. Slower motorist speeds help reduce the severity and number of crashes and help bicyclists feel more comfortable cycling in traffic.

Traffic diversion uses physical measures to restrict or divert traffic, typically to reduce cut-through motor vehicles, while not blocking local access. Traffic diversion measures may be used if other traffic calming measures do not sufficiently slow vehicles or reduce cut-through traffic. Often the tools of traffic calming and diversion are complementary and are used together. Ideally, streets would be designed and built for the desired travel speed and volume. Unfortunately, many existing local and neighborhood streets that should have slow design speeds and carry only local traffic were not designed to reflect this priority.

Traffic calming is such a powerful and compelling tool because it is very effective if properly applied. Some of the effects of traffic calming, such as fewer and less severe crashes, are clearly measurable. Other outcomes, such as enhanced community livability, are less tangible, but are also important.

Bicyclists deserve special consideration when planning, designing, and implementing traffic calming and diversion measures. Roadway narrowing or vertical or horizontal deflections of traffic to slow vehicles may have adverse impacts on bicyclists unless carefully done. Thoughtfully designed and used traffic calming measures, on the other hand, are valuable tools to enhance bicyclist safety and access. When traffic diversion is used, bicyclist and pedestrian access must be maintained. Typically, traffic calming and diversion measures are most appropriate on local streets that should have low speeds based on residential or intense commercial land uses. Traffic calming measures may also help to reduce traffic volumes on residential streets, where children and casual cyclists ride and other activities are carried out.

There are also some circumstances where traffic calming measures may be effective tools to enhance bicyclist safety and access on collector and arterial streets – those

meant to carry higher volumes of traffic at higher speeds. These situations will be discussed under the individual countermeasures.

Traffic calming and diversion should be implemented and evaluated on an area-wide basis to avoid “diverting” problems to other streets or neighborhoods. It is also imperative to involve the community and all stakeholders in the process.

Other Internet resources on traffic calming:

- <http://www.ite.org/traffic/index.html>—This traffic calming Web site was developed by the Institute of Transportation Engineers (ITE) with financial support from the Federal Highway Administration (FHWA) in the interest of information exchange.
- http://safety.fhwa.dot.gov/speed_manage/traffic_calming.htm—This is FHWA’s speed management Web site.
- <http://www.fhwa.dot.gov/environment/tcalm/>—This FHWA site includes links to local traffic calming program sites.
- <http://www.bikewalk.org/assets/pdf/CASE19.PDF>—Case Study 19: *Traffic Calming, Auto-restricted Zones and other Traffic Management Techniques* [FHWA-PD-93-028]
- http://www.pps.org/buildings/info/how_to/transit_tool/livememtraffic—Project for Public Spaces

The countermeasures related to traffic calming include:

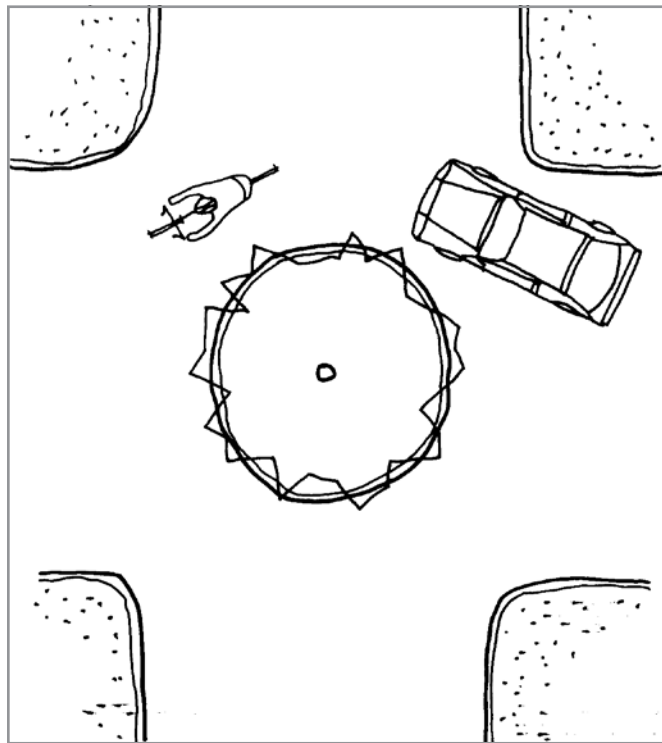
- Mini Traffic Circles
- Chicanes
- Speed Tables/Humps/Cushions
- Visual Narrowing
- Traffic Diversion
- Raised Intersection



A mini traffic circle in Charlotte, NC.

25. MINI TRAFFIC CIRCLES

Mini traffic circles are raised circular islands constructed in the center of residential or local street intersections. Mini circles are a traffic calming intersection treatment employing yield control. They may also be used at uncontrolled junctions. Signs should be installed directing motorists to proceed to the right around the circle before turning right, passing through or making a left turn. Entering traffic yields to traffic in the circle and both entering and exiting vehicles should yield to pedestrians crossing the legs of the approaches to the intersection. Mini circles are commonly landscaped (often with a center tree and low-growing shrubs, flowers, or grasses). In some communities, the city may require the neighborhood to maintain the plantings. In locations where landscaping is



Mini traffic circles are widely used at neighborhood junctions in Seattle, WA.

Purposes

- Manage traffic at intersections where volumes do not warrant a stop sign or a signal.
- Reduce crash problems at the intersection of two local streets.
- Reduce vehicle speeds at the intersection.

Considerations

- Mini circles are typically not used on arterial streets.
- Consider whether bicyclists may be “squeezed” in traffic circles by overtaking motor vehicles.¹ This type of problem is not likely on low-volume streets, but should be considered where vehicle and bicycle volumes are higher.
- Keep the turning radii low to reduce turning speeds and improve pedestrian and bicyclist safety.
- Larger vehicles that need access to streets (e.g., school buses and fire engines) may need to make left turns in front of the circle, or accommodation may be made with mountable curbs on the perimeter of the circle.
- Use yield, not stop, controls.
- Midblock speeds may not decline, or may even rise, if intersections and mini circles are widely spaced and no midblock traffic calming measures are introduced. Traffic circles are primarily used to manage traffic flow at intersections and reduce intersection speeds, but may be combined with other measures or frequent mini circles to achieve street-long traffic calming.
- Pedestrians with vision impairments will find fewer cues to identify a gap to cross when traffic does not stop.

Estimated Cost

The cost is approximately \$6,000 for a landscaped traffic mini circle on an asphalt street and about \$8,000 to \$12,000 for a landscaped mini circle on a concrete street (using existing curb radii).

infeasible, traffic circles can be made more aesthetically pleasing by using special paving materials.

Generally, mini circles are not intended for use where one or both streets are arterial streets (see section on Roundabouts, page 81). The primary benefit to bicyclists is that, like roundabouts, mini circles slow traffic approaching the

junctions by forcing motorists to maneuver counterclockwise around them. Mini circles also reduce the number of conflict points at intersections. Mini circles have been found to reduce motor vehicle crashes at the involved intersections by 90 percent or more in Seattle, WA. Mini circles may provide one of the largest safety benefits of all the traffic calming devices. Most impact studies suggest they have a nominal impact on traffic volumes, so the reduction in crashes is apparently not due to diverting traffic to other streets.²

Mini circles must be properly designed with enough deflection to slow vehicles to provide safety benefits to bicyclists, pedestrians and motorists. Pedestrians with vision impairments will, however, find fewer cues to identify a gap to cross when traffic does not stop. Additionally, right-turning vehicles are not (stop) controlled at intersections with mini circles, potentially putting pedestrians at risk. Therefore, narrow curve radii should complement this treatment to discourage fast right-turn maneuvers. Adding splitter islands with pedestrian cuts to the legs of the intersection makes crossing easier for pedestrians, especially wheelchair users. Splitter islands also direct vehicles entering the intersection but require additional space.

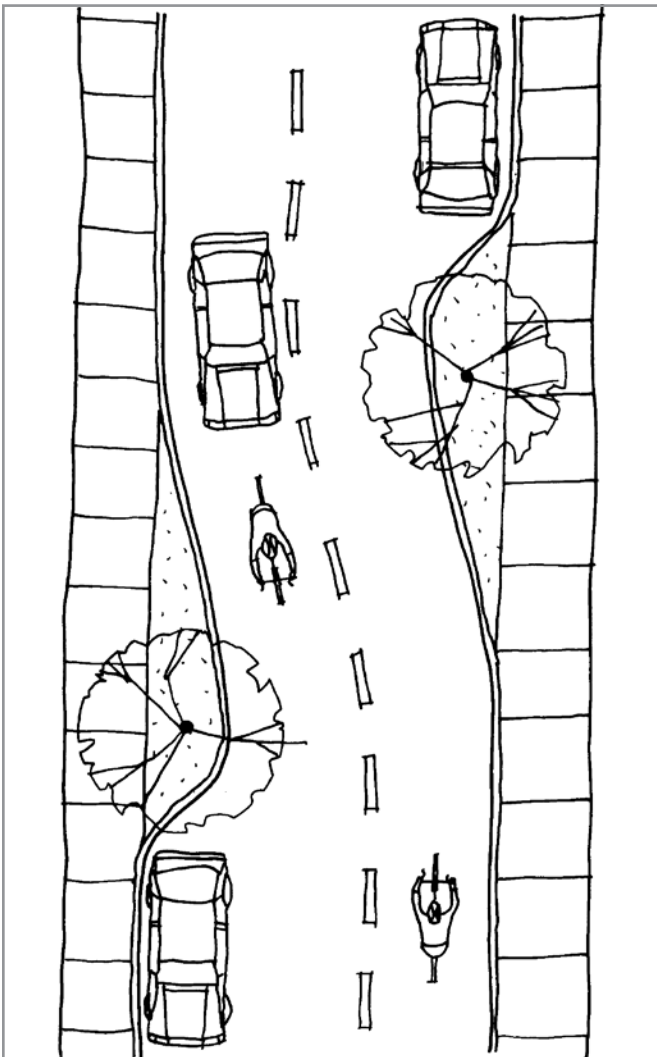
The occasional larger vehicle going through an intersection with a traffic circle (e.g., a fire truck or moving van) can be accommodated by allowing these vehicles to make left turns in front of the circle or by creating a mountable curb in the outer portion of the circle. Other possible solutions are discussed in *Traffic Calming: State of the Practice*, chapter 7.²



Motor vehicles must slow to navigate through mini circles such as this one in a Seattle, WA, neighborhood.

26. CHICANES

Chicanes, as the term is used here, create a serpentine, horizontal shifting of travel lanes, without reducing the number of lanes or lane width, by alternating curb extensions from one side of the roadway to the other. Shifting a travel lane has an effect on travel speeds by interrupting straight stretches of roadway and forcing vehicles to shift laterally. Chicanes must be well designed so that the taper is not so gradual that motorists can maintain speeds through the curve or by cutting a shortcut path across the center line. For traffic calming, the taper lengths may be as much as half of what is suggested in traditional highway engineering. According to Ewing², “European design manuals recommend shifts in alignment of at least one lane width, deflection angles of at least 45 degrees, and center islands to prevent drivers from taking a straight ‘racing line’ through the feature.”



Alternating parking can provide a chicane-like effect.

Shifts in travel-ways can be created by building landscaped islands or extended walkways, or less expensively,

Purposes

- Reduce vehicle speeds by interrupting straight stretches of roadway.
- Add more green (landscaping) to a street.

Considerations

- Chicanes may sometimes be used on minor arterial streets, but should not be used on high-speed, high-volume arterials.
- Chicanes may reduce on-street parking.
- Maintain good visibility by planting only low shrubs or trees with high canopies.
- Ensure that bicyclist safety and mobility are not diminished.
- Effect of chokers (with narrowing or lane restrictions) on bicyclists should be carefully evaluated prior to implementation; use should typically be restricted to lower-volume local streets to prevent bicyclist-motorist conflicts at pinch points. Chokers should not be used on streets heavily used by bicycles (or with bike lanes) unless design provides for bicyclist accommodation.

Estimated Cost

Costs for landscaped chicanes are approximately \$10,000 (for a set of three chicanes) on an asphalt street and \$15,000 to \$30,000 on a concrete street. Costs should be far less for chicane-like parking configuration. Costs for chokers are estimated at \$5,000 to \$20,000. Drainage and utility relocation often represent the most significant cost consideration.

by shifting parallel or angled parking from one side of the roadway to the other. Landscaped bulb-outs or expanded walkways can also effectively enclose parking bays and supplement the parking shift. If there is no restriction or narrowing (i.e., the number and width of lanes is maintained), chicanes can be created on streets with higher volumes, such as collectors or minor arterials, as well as on neighborhood streets.

A new or re-constructed roadway could also be designed in a serpentine fashion to keep sight lines short and force vehicles to make lateral shifts. Such a design could even be used where there is no curb such as in parks or rural areas where the scenic qualities also would support such a design.



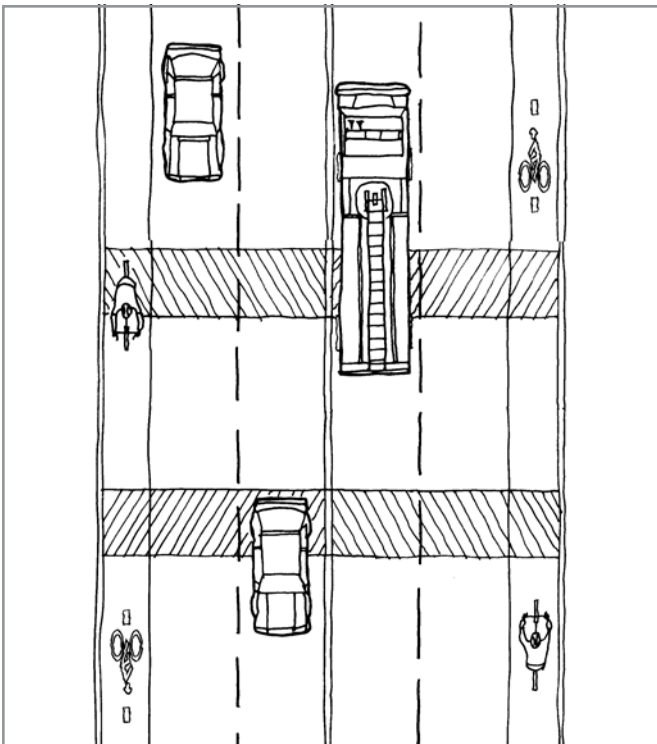
A serpentine design was created with landscaped islands.
(Boulder, CO)

Chokers

Diverting the path of travel plus restricting the lanes (often called “chokers”) usually consists of a series of midblock curb extensions, narrowing the street to two narrow lanes or one lane at selected points and forcing motorists to slow down to maneuver between them. Chokers or lateral shifts that create pinch points or reduce the number of lanes, which may be accomplished through the addition of landscaped islands or sidewalk bulb-outs, are intended for use only on local streets with low traffic volumes. Chokers may be used to simultaneously create a narrowed pedestrian crossing zone. Use of chokers should be carefully evaluated to avoid creating potential conflict zones between overtaking motorists and bicyclists.

27. SPEED TABLES/HUMPS/CUSHIONS

Raised traffic calming devices are typically used on local streets, primarily to reduce traffic speeds. Raised devices may provide the greatest impact of traffic calming devices on lowering speeds, but effectiveness is dependent on the geometrics of the devices and how widely spaced they are.² Some traffic may also be diverted through the use of raised devices, depending on how much of current traffic is non-local, the availability of alternate routes, the extent of area-wide treatment, and the type of treatment implemented (that is, humps may divert more traffic than longer and greater tables). Designs should consider bicyclist needs. More gradual and/or longer humps are less uncomfortable for bicyclists as well as other vehicle drivers and passengers, but also tend to have somewhat less slowing effect. Bicyclists may pass between speed cushions, but this and the other devices should be clearly marked for visibility.



Raised devices may have the greatest impact on lowering traffic speeds.

Speed humps are paved (usually asphalt), approximately 7.6 to 10.2 cm (3 to 4 in) high at their center, and usually extend the full width of the street with height tapering near the gutter for drainage. (ITE suggests an approximate 3.5 in maximum height due to the jarring that occurs at 4 in.¹) Space near the curb may also be provided to allow unimpeded bicycle travel or for a bike lane (but motorists may be tempted to use the area). (Speed humps should not be confused with the narrow speed “bump” that is of-

Purposes

- Reduce vehicle speeds. Raised measures tend to have the most predictable speed reduction impacts.
- Enhance the pedestrian environment at crossings.
- May divert some (cut-through) traffic.

Considerations

- Raised treatments are not typically suitable for use on arterial streets.
- Do not use if on a sharp curve or if the street is on a steep grade.
- The effect on speed reduction is inversely related to the comfort of the device. Higher and shorter devices have the greatest slowing effect, but are the most uncomfortable to traverse.
- Markings and signs should promote nighttime visibility of raised devices for bicyclists and motorists.
- If the street is a bus route or primary emergency route, the design must be coordinated with operators. Speed cushions show promise here. Usually, some devices are acceptable if used prudently—one device may be appropriate and may serve the primary need (e.g., if there is a particular location along a street that is most in need of traffic slowing).
- The aesthetics of speed humps and speed tables can be improved through the use of color and special paving materials. Designs that complement neighborhood aesthetics will be more readily accepted by the public.
- Noise may increase, particularly if trucks use the route regularly, but some noise assessments have found little impact, and noise may be reduced overall because of cars traveling at lower speeds.
- Raised treatments such as speed tables may contribute to drainage problems on some streets.
- Speed humps, tables, and cushions should be properly designed and installed to reduce the chance of back problems or other physical discomfort experienced by vehicle occupants.

ten found in mall parking lots.) There are several designs for speed humps. The traditional 3.7 m (12 ft) hump has a design speed of 24 to 32 km/h (15 to 20 mi/h), a 4.3 m (14 ft) hump a few miles per hour higher.



Speed humps should be clearly marked for visibility.

Speed table is a term used to describe a very long and broad, or flat-topped, speed hump. Sometimes a pedestrian crossing is provided in the highest or flat portion of the speed table. A speed table can either be parabolic, making it more like a speed hump, or trapezoidal, which is used more frequently in Europe. A 6.7 m (22 ft) table has a design speed of 40 to 48 km/h (25 to 30 mi/h). The longer humps/tables are much gentler for larger vehicles. Speed tables can also be used in combination with curb extensions, where parking exists, to create pedestrian crossings.



Midblock speed table, also serves as a pedestrian crossing.

Speed cushions, resembling a cushion or pillow placed longitudinally in the travel lane, are modified speed humps that do not span the entire roadway or lane width. The intent is to slow most motor vehicles similarly to speed humps and tables, but allow wide-axled vehicles such as buses and fire trucks to span and pass over the traffic calming device. These devices have been used to slow motor vehicles in Vancouver, WA, on a collector street used by emergency response and transit (see case study #30). Bicyclists typically ride between the cushions.

Speed humps and tables should probably be considered as “Plan B” on streets that are thoroughfares for bicyclists. Speed cushions may be somewhat more suitable for bicyclists. Use of other treatments such as mini circles, chi-

Estimated Cost

The cost for each speed hump is approximately \$1,500 including markings. Speed tables are \$2,000 to \$15,000, depending on drainage conditions and materials used. Speed cushions also cost approximately \$2,000 each.



A speed cushion is placed longitudinally in the travel lane. Vehicles with wider axles straddle the cushion.

canes or chicane-like parking treatments, median islands, and curb radii reduction should also be examined. Bicyclists may, however, be more concerned with traffic speeds on local streets than with traversing raised devices, but should be included in traffic calming planning processes.

28. VISUAL NARROWING

Some communities have begun combining traffic calming and other techniques with treatments designed to create a visual perception of a narrow, multi-use roadway in an effort to slow speeds and increase motorist attentiveness. Treatments such as adding street trees, vertical lighting elements, street furniture, special paving treatments or roadway markings, even striping bike lanes, that may create a perception of a narrow roadway or travel lanes (but do not necessarily physically narrow it) have been implemented. Effectiveness of these techniques at lowering speeds is somewhat inconclusive since multiple treatments are usually implemented simultaneously. Communities may nevertheless desire to implement such treatments as part of the overall design or aesthetic of the roadway and neighborhood.



PHOTO BY CHRIS HENRY, CITY OF EUGENE, OR

Street furniture was used to visually narrow the roadway through this plaza in Eugene, OR.

Use of contrasting paving materials might also enhance the functional separation of different portions of the roadway. For example, different paving treatment from that used for other lanes might emphasize a bike lane and increase motorists' perception that bicyclists should be expected.

Purpose

- Suggest to motorists that the street is a narrow, low-speed street and other users should be expected.

Considerations

- Maintain adequate sight distance, especially at intersections.
- Maintain adequate sidewalk clearance for pedestrian volume.

Estimated Cost

Costs, including maintenance costs, would vary widely depending on the specific treatments implemented.



PHOTO BY DAN BURDEN

Use of contrasting paving materials highlights this bike lane and visually narrows the roadway space in Sacramento, CA.

29. TRAFFIC DIVERSION

Traffic diversion techniques are remedies intended primarily to reduce traffic volumes on residential neighborhood streets when traffic calming or other measures have not sufficiently reduced cut-through traffic. Traffic diversion should only be used as a last resort, and then only in conjunction with area-wide traffic analyses and management. The prime beneficiaries of traffic diversion are bicyclists, pedestrians, and those who live on the treated streets, but local residents are also most negatively affected by traffic diversion.



Diverter should allow bicycle access.

Raised, island diverters may be used for area-wide traffic management. Four types of island diverters are diagonal, star, forced turn and truncated. A diagonal diverter breaks up cut-through movements and forces right or left turns in certain directions. A star diverter consists of a star-shaped island placed at the intersection, which forces right turns from each approach. A truncated diagonal diverter is a diverter with one end open to allow turning movements. Other types of island diverters can be placed on one or more approach legs to prevent through and left-turn movements and force vehicles to turn right. Neighborhoods with a grid-type pattern may benefit most from use of one or more of these types of



Diverter and toucan signals help create a bicycle boulevard in Tucson, AZ.

Purposes

- Limit motor vehicle traffic on certain streets.
- Prevent turns from an arterial street onto a residential street.
- Reduce traffic volume by discouraging or preventing traffic from cutting through a neighborhood.
- Restrict access to a street without creating one-way streets.

Considerations

- Part of an overall traffic management strategy.
- Design diverters to allow bicycle, pedestrian, and emergency vehicle access. If this cannot be done and the street is a major bicycle corridor, a diverter should not be used.
- At full closures, provide a turnaround area for motor vehicles, including service vehicles, and provide for surface drainage.
- Full street closures may be considered for local streets, but are not appropriate for collector streets.
- Consider whether less restrictive measures would work. Local residents will be most affected.
- Assess whether other local streets would receive diverted traffic and/or access into or out of the neighborhood would be adequate.
- The impact on school bus routes and service vehicles should also be considered.
- Diverters generally do not effectively address midblock speeding problems¹; use in conjunction with traffic calming measures if speeding is a problem.
- Diagonal diverters may be used in conjunction with other traffic management tools and are most effective when applied to the entire neighborhood street network.
- Partial or full street closures and area-wide use of diverters should have strong neighborhood support. There may be legal issues.

diverters to reduce the appeal of neighborhood streets to cut-through traffic.

Diverters may also be used in conjunction with other measures to create *bicycle boulevards*, specialized streets that give priority to through movement of bicyclists, but at intervals divert motorized traffic in order to provide a

preferential bicycling environment. Local access for motor vehicles is maintained, but traffic calming and traffic control devices help to keep motorized speeds low and reduce conflicts between motor vehicles and bicycles. Examples of bicycle boulevards may be found in Palo Alto, CA (see case study #32).

A partial street closure uses a semi-diverter to physically close or block one direction of motor vehicle travel into or out of an intersection; it could also involve blocking one direction of a two-way street. Partial street closures at the entrance to a neighborhood or area should consider the traffic flow pattern of the surrounding streets as well. The design of this measure should allow for easy access by bicyclists and all pedestrians. A partial closure provides better emergency access than a full closure. Since this design also allows motorists to easily violate the prohibition, police enforcement may be required. If the partial closure only eliminates an entrance to a street, a turnaround is not needed; closing an exit will generally require a turnaround.



A partial closure limits cut-through traffic but allows bicyclist access.

A full street closure is accomplished by installing a physical barrier that blocks a street to motor vehicle traffic and provides some means for vehicles to turn around. There are a number of considerations before implementing a full street closure, which should be used only in the rarest of circumstances. Neighborhoods with cul-de-sac streets require extensive out-of-the-way travel, which is not a mere convenience issue, but has serious implications for impacts on other streets. All traffic is forced to travel on feeder streets, which has negative consequences for the people who live on those streets and forces higher levels of control at critical intersections. If a street closure is implemented, it should always allow for the free through movement of all pedestrians including wheelchair users, and bicyclists. Provision for emergency vehicle access should also be made. Such provision can be accomplished

Estimated Cost

The cost for a full, landscaped street closure varies from approximately \$30,000 to \$100,000, depending on conditions.

A well-designed, landscaped partial street closure at an intersection typically costs approximately \$10,000 to \$25,000. They can be installed for less if there are no major drainage issues and landscaping is minimal.

Diverter cost in the range of \$15,000 to \$45,000 each, depending on the type of diverter and the need to address drainage.



Bollards restrict motor vehicles from a neighborhood connector between cul-de-sac streets.

with a type of barrier or gate that is electronically operated, or by installing barriers that permit only large or wide-axled vehicles to traverse them.

30. RAISED INTERSECTION

A raised intersection is essentially a speed table for the entire intersection. This treatment may improve intersection safety by forcing vehicles approaching the intersection to slow down and could be part of a street-wide traffic calming effort. Construction involves providing ramps on each vehicle approach, which elevates the entire intersection to the level of the sidewalk. They can be built with a variety of materials, including asphalt, concrete, stamped concrete or pavers. The crosswalks on each approach are usually also elevated as part of the treatment to enable pedestrians to cross the road at the same level as the sidewalk, eliminating the need for curb ramps. Detectable pedestrian warnings should be used to mark the boundary between the sidewalk and the street. Gradual approaches should reduce the impact on bicyclists.

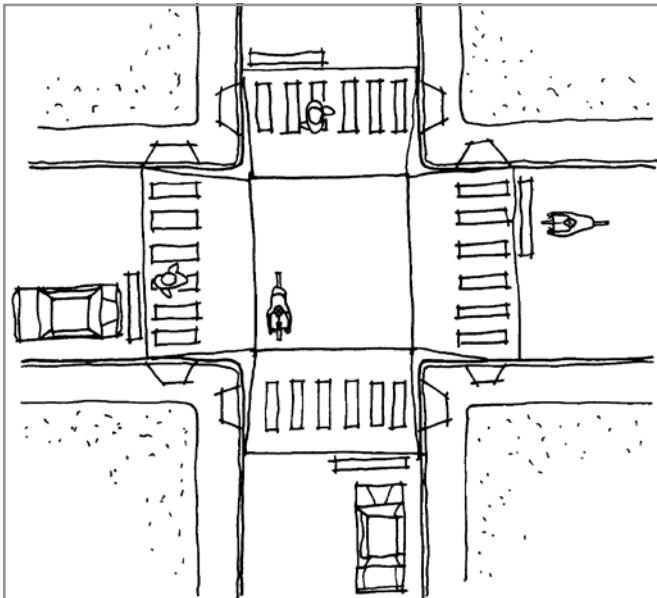


ILLUSTRATION BY A.J. SILVA

Sketch of a raised intersection.



PHOTO BY ITE PEDESTRIAN BICYCLE COUNCIL

A warning sign and pavement markings alert traffic to this raised intersection.

Purposes

- Reduce vehicle speeds; improve intersection safety.
- Enhance the pedestrian environment at the crossings.

Considerations

- Considerations are generally the same as for other raised devices.
- Don't use if on a sharp curve or if the street is on a steep grade.
- May not be appropriate if the street is a bus route or emergency route. One device may be necessary and serve the primary need. Several raised devices may be disruptive, so other measures should be considered.
- Speed tables and raised crosswalks and intersections can be an urban design element through the use of special paving materials.
- Detectable warning strips at edges enable pedestrians with vision impairments to detect the crossing.
- Care must be taken to manage drainage.

Estimated Cost

Raised crosswalks are approximately \$2,000 to \$15,000, depending on drainage conditions and material used. The cost of a raised intersection is highly dependent on the size of the roads. They can cost from \$25,000 to \$75,000.

TRAILS/SHARED-USE PATHS

Bike or shared-use paths are complementary to the road network and serve recreational, child, and perhaps commuter bicyclists if well-planned and connected to the street network and destinations. As with on-road facilities, junctions are a particular challenge to design and build so bicyclists and other users have safe access and crossings of roadways and other intersecting corridors. Additionally, providing for safe sharing of trails among diverse user groups requires good design and educational measures to promote good behavior.

Shared-use paths can enhance the quality of life in a community or region by providing additional opportunities for activity, recreational riding, or commuting choices. Trails should not be thought of as an alternative to providing safe on-street facilities for bicyclists since they can never connect to all the destinations reached by the street network. Some bicyclists will cycle preferentially on the street network since it suits their speed, skill, and trip needs better. Paths should nevertheless be designed to user-appropriate engineering standards, similarly to roadways, or safety will be compromised. Since it is rare to create a path that will be used by bikes only (perhaps some long-distance rural paths are an exception), guides, including the American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities*, now recommend that paths be designed for bi-directional mixed use, and recommend a minimum trail width of 3 m (10 ft) (up from 2.4 m (8 ft)) and encourages the use of 3.7 m (12 ft) or more where heavy or mixed uses are expected.¹

Countermeasures described in this section include:

- Separate Shared-Use Path
- Path Intersection Treatments
- Intersection Warning Treatments
- Share the Path Treatments



PHOTO BY DAN BURDEN

Recreational riders are attracted to trails through natural and other scenic areas.



PHOTO BY DAN BURDEN

Diverse users, including child bicyclists, should be expected on shared-use paths.



PHOTO BY DAN BURDEN

Sign encourages slower cyclists to keep right on this Austin loop trail.

31. SEPARATE SHARED-USE PATH

Bike paths and shared-use paths are typically paved bi-directional pathways that are separate from the road right-of-way. Ideally, shared-use paths will follow a distinct course in a separate right-of-way, often along former rail-road beds, along water courses or other rights-of-way that usually have few crossing roadways.¹ Trails immediately adjacent to roadways may cross numerous intersecting roads that create hazards and other problems for trail users (see <http://www.bicyclinginfo.org/de/shared.htm> for more information). There should, however, be sufficient access points from the road network.²

PHOTO BY CHUCK FLINK, GREENWAYS INC.



Separate shared-use paths provide opportunities for recreational riding for diverse bicyclists as well as potential utilitarian connections.

Bicycle paths or shared-use trails offer opportunities for recreational cycling and commuting that differ qualitatively from on-street riding. Paths may be designed to flow through natural or scenic areas, connect town to town or even region to region, or allow bicyclists to travel through urban areas away from motorized traffic. Bicycle and shared-use paths also may tend to attract bicyclists with a wide range of skill levels, including young children. A path, even if designed primarily as a bike facility, also likely will attract a mix of other users including pedestrians, in-line skaters and others, depending on location and access. Special care must therefore be taken in the planning and design of such trails to provide a satisfactory experience for bicyclists, and safe sharing of the facility with a variety of users of differing speeds and abilities.

Good planning and design of bicycle and shared-use paths are crucial to provide for safe use, to maximize long-term benefits, and reduce future maintenance problems (such as erosion, water or edge deterioration). Pathways will never replace the road network for connecting to destinations and some cyclists will prefer the road network for

Purposes

- Provide off-roadway recreational or commuting bicycling opportunities.
- Connect destinations that may be inaccessible for bicyclists via the road network.

Considerations

- Paths sited along roadways present numerous design safety challenges due to intersecting roadways.
- Good initial design will minimize future maintenance needs as well as access and safety problems.
- A good public process can help in designing a path that best meets local needs and suits local conditions.

Estimated Cost

Many factors, including regional materials and construction costs, topography, complexity of the environment and need for structures, and others affect trail costs. For a 3-km-wide (10-foot-wide) asphalt paved path with signs, minor drainage, and limited urban road crossings, the cost per kilometer could be around \$155,300 (\$250,000 per mile). Costs as high as \$1,000,000 per mile have been reported.

Design typically runs about 18 percent of the total construction value.



PHOTO BY CHUCK FLINK, GREENWAYS INC.

The public planning process is important to establish bicycle paths and shared-use trails that meet local needs and suit local conditions.

most riding. Separate trails may be a destination for riding in themselves. Separate paths may also offer alternative routes for some bicyclists, provided they link origins and destinations or fill a gap that connects other bicycle facilities or routes on the street network. Creating safe and accessible intersections between paths and the road network is one of the most challenging aspects of design (see Path Intersection Treatments).

A good process that incorporates input from future users and property owners may be the most important element to realizing a path that will maximize recreational and travel benefits and minimize potential problems. Good initial design is also crucial for minimizing future maintenance costs and problems. The process should engage the community so that the facility that is ultimately designed fits with local needs and with the local cultural, natural, and built environments.

32. PATH INTERSECTION TREATMENTS

Since an off-road path lures users by the opportunity to bicycle away from traffic or through scenic settings, or to connect with destinations unavailable on the road network, it is important to minimize the number of roadway crossings or other intersections, both for safety reasons and to minimize delays and enhance patrons' enjoyment. Where paths must cross roadways, driveways, or other paths, it is important that the trail design facilitates the safest and most convenient crossing movements possible. Where there is a conflict between safety and convenience, safety should take precedence. Trail intersections with roadways offer special design challenges, especially since trail users may have a wide range of cycling skills and diverse characteristics. The *AASHTO Guide for the Development of Bicycle Facilities* provides design guidelines for midblock, adjacent path and complex intersection trail crossings where the path crosses a roadway at an existing intersection or driveway.¹ Signs and signals for the roadway and path, end of path transitions, markings, sight and stopping distance, ramp widths, and other intersection design issues are discussed, but each situation requires judgment on the part of the designer.



PHOTO BY DAN BURDEN

A median refuge enables path users to cross one direction of traffic at a time.

Both path-to-path and path-to-roadway intersections require careful planning and construction to maximize safety. Where crossings must occur, priority right-of-way should be established based on the type of intersecting travel-way, traffic volumes, speed, and other factors. Path users should be counted in the volumes, and where paths cross low-volume roadways or driveways and path use is high, priority should be given to the path. Warning and regulatory signs, traffic signals, and pavement treatments or markings should be used to clearly delineate which corridor has the right-of-way, coordinate interactions, and guide path users to safe crossing locations. A traffic control device (sign or signal) should be installed at all path-roadway intersections. Efforts should be made to

Purpose

- Provide safe multi-use path crossings of roadways and other corridors.

Considerations

- Design paths to minimize the number of crossings.
- Crossings should clearly delineate right-of-way; depending on use and type of facility being crossed, the trail may warrant the right-of-way.
- On occasion, directness may have to be sacrificed to maximize safety.
- Off-grade crossings may be safest for crossing some roadways, but good design is crucial to creating an appealing secure facility that will invite use. Expense of new off-grade crossings may be prohibitive.

Estimated Cost

Intersection costs are part of the overall cost of the trail. Some treatments may be incorporated into roadway or intersection upgrades.



PHOTO FROM ALTA PLANNING + DESIGN

Path users are directed to an existing signalized intersection for crossing.

minimize crossing delays to path users as some may be unwilling to tolerate significant delays.

Pathways must link to the street network and access points should be clearly marked and signed. Curb cuts should be flared to allow bicyclists to make safe turns onto or to exit the trail. On unpaved paths, a paved apron should extend at least 3 m (10 ft) from the edge of paved roadways. To prevent motorized traffic from inadvertently or

intentionally accessing the trail, signs clearly noting that motorized traffic is prohibited, as well as brightly painted bollards or medians, should be installed in the center of a 3 m (10 ft) wide or less path, or no less than 1.5 m (5 ft) apart on a wider path. Access for maintenance and emergency vehicles must be provided.

Railroad corridors are often desirable locations for paths because they generally have few roadway crossings and built-in off-grade crossings (overpasses and underpasses) of roadways, streams, and other barriers where crossings do occur. At railroad crossings, active devices such as bells and flashing lights, or automatic gates triggered by the approach of a train may be warranted.³ For new construction, the cost of off-grade crossings may be considered prohibitive but may be the best alternative where a trail needs to cross a busy or high-speed corridor or if trail use is expected to be high. Some communities such as Boulder, CO (see case study #35), have used off-grade crossings extensively for bike and pedestrian corridors. For safe and effective overpasses and underpasses, adequate lighting is important for travel and for personal safety. (See Tunnels/Underpasses countermeasure.)

When trails must cross roadways at grade, it may be desirable to design the crossing at an existing intersection to minimize incidences of wrong-way riding along the roadway to the trail access. The crossing distance should be minimized. If the trail crosses a busy, multi-lane or high-speed road, a refuge island is a treatment that enables trail users to cross one leg of the roadway at a time. The crossing may be angled so that trail users turn toward oncoming traffic to cross the second direction of travel lanes. Lighting can also enhance the safety of path intersections with roadways, railways, and other paths, especially if extensive nighttime use is expected (such as in a busy urban area or near a college or university campus).



PHOTO BY DAN BURDEN

A stop sign controls right-of-way, while crossing markings and warning signs on the roadway alert that path users should be expected.

33. INTERSECTION WARNING TREATMENTS

Advance warning treatments let bicyclist path users know they are approaching an intersection with a roadway, another path, a railway, or other crossing. Since some bicyclists will be among the highest speed users of paths, sight and stopping distance, signs, and intersection design guidelines for bicyclists should be used in designing shared-use paths, including intersection approaches.¹ Passive warning devices including pavement markings, special pavement “alerts” such as textured treatments, and warning signs may be used. See the *Manual of Uniform Traffic Control Devices* (MUTCD) for signs that may be appropriate for warning of at grade crossings, including railroad crossings.⁴



PHOTO BY DAN BURDEN

A flat grade and bollards with painted markings warn path users to slow on approach to junction, as well as prevent motor vehicle access to the path.

A flat grade should be used on intersection approaches to improve sight distance and provide bicyclists with a chance to reduce speed. Bollards should be placed so bicyclists have adequate clearance and the placement does not force bicyclists into an incorrect position on approach to the intersection. Vegetation and other obstructions should be kept clear near intersections for adequate sight distance.

Roadway treatments such as warning signs and pavement markings also let road users know they are approaching an area where bicyclists, pedestrians, and other path users may be crossing or present.

Purpose

- Warn bicyclists and other path users that they are approaching a junction where they should be prepared to stop or yield.

Considerations

- Assess sight distance requirements for path-roadway intersections.
- A flat grade on the path should precede junctions to provide good sight distance and sufficient stopping distance for bicyclists.
- Vegetation and other landscape features should allow adequate sight distance near intersections.

Estimated Cost

Costs would be included in overall path costs. Retrofit measures such as signs or changes in pavement markings would depend on treatment.

34. SHARE THE PATH TREATMENTS

The diverse types, multiple skill and age levels, and other characteristics of shared-use path users may contribute to conflicts, falls, and crashes. Good path design, as well as shared-use policies, education, and perhaps enforcement may help bicyclists and other path users share off-road paths more safely and enhance their enjoyment.



A number of treatments and markings are available to encourage safe shared use as needed.

Design and policies for accommodating multiple types of users should be developed on a case-by-case basis depending on local demand for different uses, expected volumes, and other factors. For example, if the path is expected to serve both commuter bicyclists and local pedestrians and child bicyclists, and there is sufficient corridor right-of-way, separate facilities may be desirable. For joggers, a gravel or dirt path may be provided beside a paved path. In most situations, separate facilities will, however, likely be considered infeasible or cost-prohibitive.

Other engineering treatments may encourage safer sharing of a single, two-way, multi-use facility. These include center-line striping to separate directions of travel with broken markings that indicate safe passing zones; special paving treatments to separate users; pavement markings at trail and roadway junctions that channelize users to appropriate crossings; signs, marking and paving treatments to clearly indicate right-of-way; and others.

Appropriate path use policies should also be developed since behaviors of users have much to do with preventing crashes and conflicts. Trail rules or etiquette may be posted at entrances and included on bicycling maps. Such path use guidelines include:

Purpose

- Reduce conflicts and crashes on multi-use trails.

Considerations

- Do not diminish the trail experience by over-designing specialized treatments.
- Incorporate various user groups in planning and programs to enhance shared-use cooperation and enjoyment.
- If enforcement is used, more positive, educational types of interventions may work better than penalizing trail users.

Estimated Cost

Costs depend on program but would at a minimum include funding for staff planning time.

- Slower users keep right
- Use audible signal when passing
- Pass only where sight-distance allows a safe maneuver
- Use caution when riding near young children, pets, and other unpredictable path users, etc.

User guidelines might be promoted through a variety of community resources in addition to postings along the



Path use rules or guidelines are posted along the Galloping Goose Trail in Victoria, BC, Canada.

PHOTO BY TODD LITMAN, VICTORIA TRANSPORT POLICY INSTITUTE



Pavement markings were used to designate separate spaces for shared use on this heavily used Long Beach, CA, path.

trail. Traditional traffic enforcement methods may be inappropriate for paths since non-motorized users typically do not require a license and many users are children, but more positive, educational types of interventions may help if conflict or crash problems arise.

Guidelines for bicyclists produced by the League of American Bicyclists on sharing paths are available at <http://www.bikeleague.org/educenter/factsheets/sharingthepath.htm>. The International Bicycle Fund (<http://www.ibike.org/education/trail-sharing.htm>) has also posted guidelines for trail sharing including a model trail use ordinance.

MARKINGS, SIGNS, AND SIGNALS

Traffic control devices, including a variety of pavement markings, signs, and traffic signals, are used by traffic engineers to improve safety and access for bicyclists. Besides traditional treatments such as installation of a traffic signal, innovative treatments are also being installed and evaluated, including separate bicycle signal heads and bicycle and pedestrian crosswalk signals, sometimes known as toucan signals. School speed zone and traffic control devices may also be implemented to improve safety for children bicycling and walking to school along designated routes.

The countermeasures included in this section are:

- Install Signal/Optimize Timing
- Bike-Activated Signal
- Sign Improvements
- Pavement Marking Improvements
- School Zone Improvements

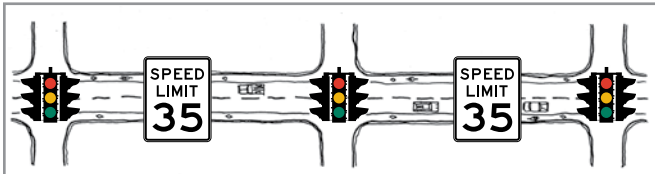


Warning signs may enhance safety in special situations.

35. INSTALL SIGNAL/OPTIMIZE TIMING

Traffic signals create gaps in traffic flow, allowing bicyclists, pedestrians, and motorists to access or cross the street. Signals are particularly important for crossing higher speed roads, multi-lane roads or highly congested intersections. National warrants from the *Manual on Uniform Traffic Control Devices* (MUTCD) are typically used for new signal installation.¹ Part 9 of the MUTCD focuses on “Traffic Calming for Bicycle Facilities.” Some states have their own supplement to the MUTCD.

ILLUSTRATION BY A.J. SILVA



Appropriate signal timing may help create gaps for bicyclists at midblock or unsignalized side streets as well as the signalized intersections.



Bicycle signals provide a distinct crossing phase for bicyclists in particular circumstances.

In downtown areas, signals are often closely spaced, sometimes at every block. A problem for bicycles is that signals are timed to accommodate typical motor vehicle speeds and flows. The motor vehicle speeds can be significantly faster than bicycle speeds. In addition, the clearance interval for motor vehicles crossing a wide intersection may not be long enough to ensure safe clearance by bicycles.

Although little research is available, timed sequencing of signals may take bicycling into account. Some cities time their downtown urban traffic signals to account for speeds of 20 to 25 km/h (12 to 16 mph), which allows bicycles to easily ride with traffic.

Purposes

- Optimize signal timing to slow down motorists trying to get through a signal at a high rate of speed.
- Provide intervals in a traffic stream where bicycles can cross streets safely.
- Provide enough time for a bicyclist to clear a wide street at the end of a green phase.
- Accommodate both motor vehicle and bicycle traffic in dense urban areas through optimal signal timing.

Considerations

- Studies are necessary to determine if a traffic signal is needed. However, warrants need to take into account local conditions, such as the volume of bicycle (and pedestrian) traffic.
- Determine if the signals in a dense urban area can be timed to accommodate both motor vehicle and bicycle flow.
- Determine if bicycle volumes are large enough to warrant a bicycle traffic signal.

Estimated Cost

Typical traffic signal costs range from \$30,000 to \$140,000.



PHOTO BY LIBBY THOMAS

Loops being installed in advance of intersection with limited sight distance may detect vehicles and delay the green indication for cross-street traffic. (Chapel Hill, NC)

In locations with high volumes of bicyclists, traffic signals for bicycles can be used. These have been popular in Europe and China for many years. The City of Davis, CA,

where bicycling accounts for approximately 17 percent of the mode share, has effectively employed a bicycle traffic signal to reduce conflicts and crashes between bicycles and motor vehicles at a location with very high volumes of bicycles and pedestrians. The bicycle signal provides a separate phase for bicyclists and pedestrians, with motorists following after the intersection has cleared (see case study #39). “NO RIGHT TURN ON RED” signs are also used.

36. BIKE-ACTIVATED SIGNAL

Bicyclists often have difficulty crossing streets with high-speed and/or high-volume motor vehicle traffic. The problem is worsened if these streets have multiple lanes. These situations can be greatly improved by placing bike activation devices on the minor street. These give bicyclists preference on demand without causing undue delay to motorists. Activation devices can also be used on a main line street to prolong the green phase and extend the time needed for the bicycle to clear the intersection.



PHOTO BY CHERYL SCHMITT, CITY OF SANTA CRUZ

Pavement symbol shows bicyclists where to position to be detected for a signal change.

Bicycle loop detectors are the norm as the activation device. Loop detectors can be placed in a traffic lane or bike lane on the side street to trip the signal. These detectors can also be placed on the major street to prolong the green phase and allow a cyclist to clear a wide intersection. It may also be necessary to increase the sensitivity of existing loops, as well as paint stencils on the pavement to point out the most sensitive loop locations to cyclists. Another alternative is the use of push buttons near the roadway such that the cyclist does not have to get off the bike. Video cameras and infrared motion detection sensors are other options but are more expensive.

The City of Seattle, WA, has made extensive use of pedestrian/bicycle crosswalk signals (formerly called half-

Purposes

- Provide intervals in a traffic stream where bicycles can cross streets safely.
- Prolong the green phase to provide adequate time to clear the intersection.

Considerations

- Determine where activation devices are needed and the most appropriate type.
- Determine if activation devices are needed to prolong the green phase.

Estimated Cost

Costs will vary depending on size and complexity of the intersection, but in general are comparable to the installation of conventional traffic signals.

signals) in locations where bicyclists using residential streets have a need to cross an arterial street at an unsignalized intersection (see case study #40). These signals are actuated by bicyclists (or pedestrians) and stop traffic only on the arterial, leaving the lower volume cross street unsignalized. This allows bicyclists (and pedestrians) to cross safely upon demand without creating unnecessary delays on the arterial street. These crosswalk signals have also been used to facilitate “bicycle boulevards” in various communities. The boulevards are routes to facilitate fast and safe bike movement while discouraging through motor vehicle traffic.

37. SIGN IMPROVEMENTS

Signs often convey important information that can improve road safety. The intent is to let bicyclists and motorists know what to expect, thus improving the chances that they will react and behave appropriately. For example, the use of a “No Parking in Bike Lane” sign is intended to keep this space clear for cyclists. Sign use and placement should be done carefully, in that overuse often results in non-compliance and/or disrespect. Excessive use of signs can also create visual clutter and lead to the intended sign and message getting “lost.”

PHOTO BY MICHAEL KING



Regulatory sign restricts curb lane use to buses, bicycles, and right-turning vehicles.

PHOTO BY MICHAEL KING



Warning sign alerts bicyclists and motorists to an upcoming lane shift.

with significant bicycle traffic but relatively hazardous conditions for riding, such as narrow travel lanes with no shoulder, roads or streets with poor sight distance, or a bridge crossing with no accommodation for bicycles. Special signs are sometimes used to indicate the presence of a bicyclist.

All signs should be periodically checked to make sure that they are in good condition, free from graffiti, reflective at night, and continue to serve a purpose.

Regulatory signs, such as STOP, YIELD or turn restrictions require driver actions and are enforceable. NO TURN ON RED signs can improve safety for bicyclists (and pedestrians). Problems often occur at RTOR locations as motorists look to the left for a gap in traffic, especially if bicyclists are riding wrong way either in the street or on a sidewalk or path.

Warning signs can also provide useful information. An example is the SHARE THE ROAD sign, which serves to let motorists know that bicyclists may be on the road and that they have a legal right to use the road. This sign is typically placed along roads

Purposes

- Provide warning and regulatory messages, as well as useful information.
- NO TURN ON RED signs can increase bicycle safety and decrease crashes with right-turning vehicles.
- SHARE THE ROAD signs can make motorists more aware of bicyclists on roads with poor bicycle accommodations.

Considerations

- Streets with bicycle traffic should be evaluated to determine if sign improvements could improve safety.
- Prohibiting RTOR is a simple, low-cost measure. The change can benefit bicyclists on streets with considerable through bicycle traffic with minimal impact on motor vehicle traffic.
- Part-time RTOR prohibitions during the busiest times of the day may be sufficient to address the problem.
- RTOR signs should be clearly visible to right-turning motorists stopped in the curb lane at the crosswalk.
- Carefully evaluate use of both regulatory and warning signs. Avoid overuse which may lead to non-compliance or visual clutter

Estimated Cost

Costs range from \$30 to \$150 per typical sign plus installation at \$200 per sign. Electronic sign costs vary widely but tend to be significantly more expensive.



PHOTO BY DAN BURDEN

Flashing warning signs such as this “Bicyclist on Bridge” sign could be used to alert motorists to the presence of bicyclists ahead.

38. PAVEMENT MARKING IMPROVEMENTS

A variety of pavement markings are available to make bicycling safer. Generally the markings are for lane separation, for indicating an assigned path or correct position for the bicyclist, and for information about upcoming turning and crossing maneuvers. The *Manual of Uniform Traffic Control Devices* (MUTCD) is the national standard for all pavement markings (as well as signs and signals), and Part 9 focuses on “Traffic Controls for Bicycle Facilities.”¹ Some states may have their own supplement to the MUTCD.

Examples of pavement markings include the striping and identification associated with bike lanes, striping for paved shoulders, turning lanes at intersections, railroad crossings, and drainage grates or other pavement hazards or irregularities. A general guideline for improved bicycle safety is to make sure the markings are durable, visible, and non-skid. Markings are usually done with paint or thermoplastic. Paint is cheaper but tends to fade quickly, while thermoplastic lasts longer but may be slippery. If thermoplastic is used for bicycle markings, a thin, non-skid type is preferred. The State of Oregon has four different types of legend markings that can be used for bike lanes—hot poured thermoplastic, preformed thermoplastic, tape, and methyl methacrylate. Use varies by geography, weather, traffic volumes and pedestrian and bike counts. Amount of skid resistance varies with each product. Sometimes glass beads, crushed glass and aggregate can be added during placement to increase skid resistance, but the skid resistant particles tend to sink before the thermoplastic cools.



Blue pavement highlights a contraflow bike lane.

Purposes

- Indicate a traffic lane to be shared between motor vehicles and bicycles.
- Indicate the presence of a bike lane.
- Indicate an assigned path or correct position for the bicyclist.
- Provide information about upcoming turning and crossing maneuvers.
- Indicate other specialized bicycle facilities or situations.

Considerations

- Use of thin, durable, non-skid thermoplastic material improves conditions for bicyclists.
- Careful placement of markings (e.g., away from bus and truck traffic, away from driveways) will increase their longevity.

Estimated Cost

A rough cost estimate of labor and materials for arrow and chevron markings applied using methyl methacrylate is \$100 each. Costs of other markings would depend on type and materials used.



The “bike and chevron,” or SHARROW, is used to indicate both the presence of bicycles and the correct placement of bicycles in the traffic lane.

Care in the placement of painted markings will increase their longevity. For example, avoid placement of markings near far-side bus stops or near driveways or other locations, particularly those with high truck traffic, to avoid wear from tires.

More symbols are now being used to indicate the presence of bicycles in the traffic stream, as well as the cor-

rect riding position in the traffic lane. There are many international examples. In the United States, the City of Denver, CO, introduced the “bike-in-house” marking for shared lane situations many years ago. An experimental evaluation of a modified version of this symbol, the “Shared Arrow,” was performed on a wide curb lane corridor in Gainesville, FL, in 1999.² In February 2004, the City of San Francisco completed an evaluation of a modified “bike-in-house” and “bike-and-chevron” markings (see case study #37). The Gainesville and San Francisco evaluations showed benefits for the markings. The “bike and chevron” markings have come to be known as the SHARROW, and this symbol has been approved by the California Traffic Control Device Committee for use in California.

Other known U.S. cities with some variation of the markings described above include Chicago, IL; Cambridge, MA; Portland, OR; Warren and Waitsfield, VT; Seattle, WA; and Sacramento, CA. There continues to be movement toward adoption of some form of the arrow or chevron as a national standard, but as of this writing this is not complete.

39. SCHOOL ZONE IMPROVEMENTS

A variety of roadway and other improvements may be used to enhance the safe mobility of children in school zones. The countermeasures pertinent to children walking to school also generally apply to children bicycling to school.



PHOTO BY DAN BURDEN

Young bicyclists as well as walkers will benefit from slow school zones and other safety improvements.

Sidewalks or separated walkways and paths are ingredients for a safe trip from home to school on foot or by bike. Children can also be taught safe riding techniques that will enable them to ride on low-volume neighborhood streets. Speeds of motor vehicles also need to be controlled on these streets. Signs and marking treatments to control motor vehicle speeds in and around schools include the school advance warning sign (which can be fluorescent yellow/green), school speed zone and flashing speed zone signs, flashing yellow warning signals, and in-street “Yield to Peds” signs (generally dropped into a holder in the street). Police enforcement in school zones may be needed in situations where drivers are speeding or not yielding to children in crosswalks. Sometimes localities double the fines for speeding in school zones.

Other helpful measures include parking prohibitions near intersections and crosswalks near schools. Marked crosswalks can help guide children to the best routes to school. Sometimes these crosswalks have additional pedestrian crossing signs mounted at the side of the street as well as overhead. Flashing beacons may also be used. School administrators and parent-teacher organizations need to educate students and parents about school safety and access to and from school. Education, enforcement, and well-designed roads must all be in place to encourage motorists to drive appropriately. Safe Routes to School Communities are using Safe Routes to School (SR2S) programs to work toward making walking and bicycling safe and appealing ways for children to get to school. A

Purpose

- Provide enhanced safety around schools.

Considerations

- Safety must be a combined effort between local traffic officials, police, school officials, parents, and students.
- Care must be taken to make sure students understand the various signs and markings and not be lulled into a false sense of security.

Estimated Cost

Costs would depend on the school zone treatment selected. For example, if signs were chosen, costs might include \$50 to \$150 per sign plus installation costs. Adult crossing guards may cost around \$10,000 each per year.

new course developed by the Pedestrian and Bicycle Information Center (PBIC) for FHWA is designed to help communities and states create sound programs that are based on community conditions, best practices and responsible use of resources. The course concludes with participants developing an action plan. The course is supported through a partnership of funding from the Federal Highway Administration, the National Highway Traffic Safety Administration, the Centers for Disease Control and Prevention and the Environmental Protection Agency. (See <http://www.pedbikeinfo.org/sr2s/> for more.)

The use of well-trained adult crossing guards has been found to be one of the most effective measures for assisting children, whether bicyclists or walkers, in crossing



PHOTO BY DAN BURDEN

A crossing guard helps child bicyclists and walkers safely cross an intersection.

streets safely. Adult crossing guards require training and monitoring and should be equipped with a bright and reflective safety vest and a STOP paddle. Florida has a state-level crossing guard program. The Florida School Crossing Guard Training Guidelines, produced by the Florida DOT and administered by the Florida Department of Highway Safety and Motor Vehicles, are available at http://www.dot.state.fl.us/Safety/ped_bike/training/ped_bike_training.htm.

One of the biggest safety hazards around schools is parents or caretakers dropping off and picking up their children. There are two immediate solutions: (1) there needs to be a clearly marked area where parents are permitted to drop off and pick up their children, and (2) drop-off/pick-up regulations must be provided to parents on the first day of school. Drop-off areas must be located away from where children on foot or bicycle cross streets or access the school. Parent drop-off zones must also be separated from bus drop-off zones. If parents can be trained to do it right at the start of the school year, they are likely to continue good behavior throughout the year.

For a longer-term solution, it is preferable to create an environment where children can walk or bicycle safely to school, provided they live within a suitable distance. One concept that has been successful in some communities is the concept of a “walking bus,” where an adult(s) accompanies children to school, starting at one location and picking children up along the way. Soon, a fairly sizeable group of children are walking in a regular formation, two by two, under the supervision of responsible adults, who are mindful of street crossings. Parents take turns accompanying the “walking school bus” in ways that fit their schedules.

EDUCATION AND ENFORCEMENT

Providing education, training, and reinforcement are key strategies in improving bicyclist and motorist traffic skills and behavior. The primary goal of an educational strategy is to give people both the means and the motivation to alter their behavior and reduce reckless actions and crashes. To implement the strategy, an integrated, multi-disciplinary approach that links hard policies (for example, changes in infrastructure) and soft policies (for example, public relations campaigns) and addresses both bicyclists and motorists has the greatest chance of success.

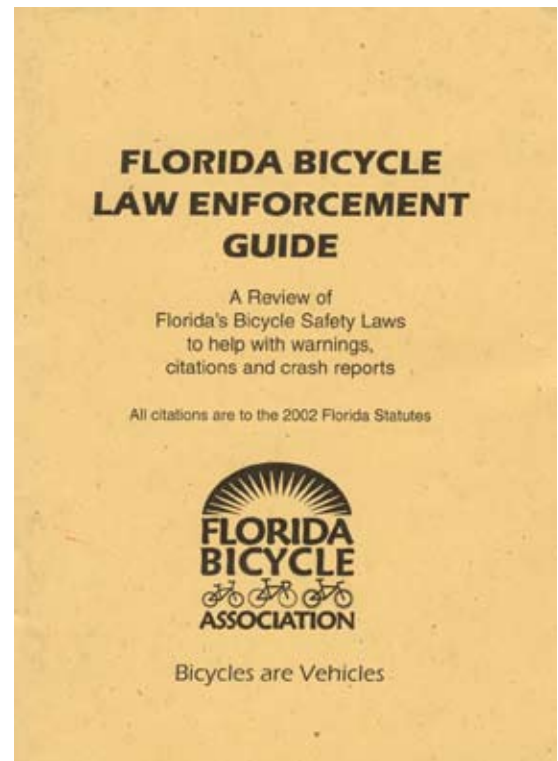
Police enforcement is a primary component in reinforcing proper behaviors and maintaining a safe environment for all modes of travel. Well-publicized enforcement campaigns, combined with public education programs, can be effective in deterring careless and reckless driving and encouraging drivers to share the roadway with bicyclists (and pedestrians). Most importantly, by enforcing the traffic code, police reinforce a sense of right and wrong in the general public and lend credibility to traffic safety educational programs and traffic laws and control devices. Law enforcement officers sometimes find it difficult to “ticket” bicyclists, and even to stop a young child. However, warnings, in lieu of citations, can be effective in deterring inappropriate bicyclist behaviors. The education and enforcement countermeasures covered in this section include:

- Law Enforcement
- Bicyclist Education
- Motorist Education
- Practitioner Professional Education



PHOTO FROM DUVAL COUNTY INJURY PREVENTION PROGRAM OFFICE

A wide range of bicycle safety training programs is available for adaptation. These children are participating in an on-bicycle program in Duval County, FL.



Law enforcement should play an active role in supporting a safe bicycling environment. Funding for this brochure was provided by sales of a special “Share the Road” license plate (see case study #57).

40. LAW ENFORCEMENT

Along with engineering and education approaches to improving bicyclist safety, enforcement of traffic laws can help to create a safer riding environment, whether this enforcement is directed at the motorist or the bicyclist. With respect to motorists, efforts to reduce speeding in residential areas and along roadways frequented by bicyclists, and to enforce proper yielding, passing and overtaking maneuvers, can make roadways safer places for bicyclists, and also safer for other motorists and pedestrians sharing the roadway. Similarly, efforts to curb running of red lights at intersections will benefit all road users.

PHOTO BY DAN BURDEN



On-bike police officers set a good example and can help to reinforce obedience to traffic laws by communication as well as direct enforcement.

Although law enforcement officers sometimes find it difficult to “ticket” bicyclists, and even to stop a young child, such actions as riding facing traffic, weaving in and out of traffic, ignoring stop signs, and riding without proper lights at night are dangerous, and they can create ill will with motorists. Law enforcement officers can take advantage of the opportunity to stop and educate the offending bicyclist about the importance of obeying traffic laws. It is especially critical that officers enforce any helmet wearing law in effect, in order to increase the effectiveness of the laws.

A judicial program especially targeted to the intended audience can be a key to encouraging greater participation by police in bicycle law enforcement activities. On college campuses, a special “student court” can be set up to address traffic violators, including bicyclists. Young children (and their parents) might be asked to attend a bicycle safety education class in lieu of paying a traffic fine. Typically, the focus of special bicycle judicial programs is on education rather than punishment.

Purposes

- Educate law enforcement officers about factors contributing to bicyclist crashes and about ways they can interact with the public to reduce these factors and ultimately the number of bicycle-motor vehicle traffic crashes.
- Improve cyclists’ knowledge, attitudes, and behaviors with respect to safe bicycling.
- Educate the motoring public about their rights and responsibilities when sharing the road with bicyclists.
- Deal effectively with young children as bicyclists.

Considerations

- Because of the many demands placed on law enforcement officials’ time, it may be difficult to convince police departments of the importance of officers receiving training in enforcement of laws relating to bicycle safety.
- Although “education” is emphasized over “ticketing,” the problem of how to handle young offenders especially can be a roadblock to effective bicycle law enforcement. (See case study #47.)
- Bicycle law enforcement programs are most needed in communities and areas with high levels of bicycling, such as on and around college campuses.

Estimated Cost

The estimated cost for an officer to participate in the two-day Wisconsin officer training course is \$90 to \$100, with discounts available to sponsoring departments and some training costs covered by the state. If another state wanted to initiate a similar program, there would be startup costs involved, primarily associated with “train the trainer” activities. WE BIKE, the developer of the course, also offers instructor training (see case study #44). NHTSA has recently begun to offer a similar program.

Special educational programs offered to bicyclists in lieu of conviction or traffic court appearances are a form of diversion program since the offender (often a juvenile) is diverted from normal court procedures. Diversion programs have long been used with respect to juveniles, teens, and other special populations. There are a number of examples of bicyclist diversion programs in place across

the country, including programs in:

- Corvallis, OR, http://www.bicyclefriendlycommunity.org/press_corvallis.htm
- Palo Alto, CA, <http://www.city.palo-alto.ca.us/transportation-division/safe-bicycle-pedestrian-edu.html>
- Walnut Creek, CA, <http://www.nhtsa.dot.gov/people/outreach/safedige/spring2000/spr00-16.html>

A recent article appearing in the International Police Mountain Bike Association newsletter supported increased police enforcement of traffic laws for bicyclists. It states:

The focus of any bicycle enforcement program should be educational, not punitive. A successful enforcement program should improve a cyclist's knowledge and attitudes, and, most importantly, behavior. A good program also educates the motoring public concerning their rights and responsibilities when sharing the road with bicyclists (see <http://www.ipmba.org/printables/case-for-bike-enforcement.PDF>).¹

Although law enforcement officers are trained to make traffic stops for speeding, red light running, and other dangerous behaviors by motorists, they typically do not receive any special training with respect to bicycle safety. It is not surprising, then, that there is very little active enforcement of traffic laws affecting bicyclists in U.S. communities. In the state of Wisconsin, however, the situation is improving because of an innovative training program that is offered upon request to individual police departments. Officers who participate in the two-day Enforcement for Bicycle Safety Course significantly improve both their knowledge and attitudes about enforcement for bicycle safety, and are more likely to make enforcement contacts in their communities (see case study #44).

On a national level, the National Highway Traffic Safety Administration (NHTSA) now offers a similar course entitled "Community Bicycle Safety for Law Enforcement" to provide guidance to officers interested in working with their communities to encourage bicycling and improve bicycle safety. A CD-ROM training course is also under development that may be offered by a training officer or taken via self-instruction on a personal computer. (See http://www.bicyclinginfo.org/ee/enforce_officer03.htm.) Another source of support to law enforcement officers is the Law Enforcement Bicycle Association (LEBA), an organization "run by cops



PHOTO FROM AAA

"Cops on Bikes" have a conspicuous presence in the community and may interact with bicyclists and pedestrians more readily.

for cops" (<http://www.leba.org>).

Trained, adult crossing guards are another fairly benign but effective method of providing correction and education to motorists, bicyclists, and pedestrians, particularly children en route to and from school. Crossing guards educate on safe walking and bicycling behaviors, assist children in crossing at certain locations, and may help to encourage use of these modes in traveling to school since they provide a measure of safety that engineering treatments alone cannot provide. Additionally, well-trained adult guards may assist in enforcing motorist speed limits, yielding, and other laws (through reporting offending motorists). Since 1992, the State of Florida requires most localities to provide minimum training by using the Florida School Crossing Guard Training Guidelines (see http://www.dot.state.fl.us/Safety/ped_bike/training/ped_bike_training.htm).

Finally, NHTSA has compiled a resource guide on laws related to pedestrian and bicycle safety. The guide is available for downloading at <http://www.nhtsa.gov/people/injury/pedbimot/bike/resourceguide/index.html>.

41. BICYCLIST EDUCATION

Although many of the countermeasures identified in this guide have focused on improving the roadway environment for bicyclists, a comprehensive approach to bicyclist safety encompasses education and enforcement as well as engineering. Not only do bicyclists need safe places to ride, they need to know how to ride skillfully and how to interact safely with motorists on the roadway, whether at intersections or midblock. This is true regardless of the age of the bicyclist. For example, bicyclists can be taught the importance of following traffic rules and regulations, the hazards of riding at night without proper lights, the hazards of wrong-way and sidewalk riding, and other skills and behaviors important to safe riding. Bicyclists can also be trained to be aware of maneuvers motorists tend to make at intersections that can be dangerous for a bicyclist, such as speeding through an amber signal indication or running a red light, turning right on red, making a right turn soon after overtaking a cyclist, etc. Similarly, bicyclists need to be aware of potentially dangerous midblock motorist maneuvers, such as turning across lanes of traffic, turning into or out of a driveway, turning into or out of a parking space, etc.



PHOTO BY LIBBY THOMAS

The BikeEd Hawaii program offers five lessons of on-bike training geared toward teaching safe neighborhood riding skills.

Bicyclist educational programs can be carried out at many levels, from distributing brochures or showing videos to comprehensive school-based on-bike programs, and target audiences can range from young preschool-age children to seniors.

In 1998, the Federal Highway Administration (FHWA) convened a steering group of bicycle safety experts to develop a National Bicycle Safety Education Curriculum.² The resulting guide (also available on CD-ROM from NHTSA) identifies and prioritizes the specific topic areas that should be addressed for various target audiences, and includes a resource catalog with information on train-

Purposes

- Teach cyclists of all ages safe bicycling skills, including how to interact with motorists in traffic, both at intersections and midblock.
- Teach cyclists the importance of having a bike that fits, maintaining the bike in good condition, and always wearing a helmet when riding.
- Encourage bicycling as part of a healthy lifestyle.

Considerations

- Although many bicycle safety education materials and programs exist, it is important to choose the right program for your particular needs and situation.
- For children, a comprehensive bicycle safety education program should include an on-bike component.
- Available funding, time, space, and teacher education and training are all important considerations when selecting a bicycle safety education program.
- It is also important that once implemented, program effectiveness be evaluated.
- As with other education and enforcement initiatives, a long-term commitment is required, both to reinforce learned behaviors and to accommodate new bicyclists.



PHOTO BY LIBBY THOMAS

Students in the BikeEd Hawaii program practice signalling right turns on neighborhood streets.

ing programs that address each of the various topics. The Resource Catalog is also available as an online search-

able database (<http://www.bicyclinginfo.org/ee/fhwa.html>). Users can search the database by key word(s), by a specific target audience (e.g., young bicyclists ages nine through 12; adult bicyclists; motorists), and by selected topic or subtopic areas (bicycle-riding skills, rules of the road, essential equipment, riding for health and fitness, etc.) to find an education curriculum that is suited to their needs.

More recently, FHWA has developed a *Good Practices Guide for Bicycle Safety Education* (<http://www.bicyclinginfo.org/ee/bestguide.cfm>) that contains case study descriptions of 16 programs spanning riders of all ages, along with helpful information on planning, funding, implementing, and evaluating a program in your own community or state.³

FHWA's [bicyclinginfo.org](http://www.bicyclinginfo.org) Web site also contains links to many bicyclist safety education programs, tools and resources that can be used by professionals planning a program as well as by individual bicyclists (<http://www.bicyclinginfo.org/ee/index.htm>). For example, the section for young cyclists ages nine through 12 contains links to sites with information on choosing the right bike and helmet and how to park and secure your bike, among others. The section for adult cyclists contains links to materials available from the League of American Bicyclists covering areas ranging from "A Guide to Commuting for the Employee" to "How to Shift and Change Gears" to "Bike Maintenance 101." With ready access to these resources, program developers do not need to reinvent the wheel to implement a bicycle safety education program, and young and old riders alike can readily find the information they need to be safer riders.



Specialized equipment helps make on-bicycle training available to more students in this school-based program in a Nevada community.

Estimated Cost

Costs will vary greatly, depending upon the type and scope of the educational activity. Disseminating safety brochures or simply showing a bike safety video will be much less expensive than, for example, a system-wide school-based program that includes on-bike instruction.

Among coalition-provided programs, the Hawaii Bicycling League estimates that Bike Ed Hawaii costs between \$23 and \$28 per student which provides three instructors per class for a week-long on-bicycle safety and skills training course of approximately 45 minutes per day. All instructor salaries, equipment (fleet of bikes, helmets, safety jerseys), vehicle costs, and a percentage of office support is covered under the Bike Ed budget. Bikes and helmets are replaced every other year. The Oregon Bicycle Transportation Alliance estimates that their Bicycle Safety Education Program, a 7 to 10 day course of 45 to 60 minutes daily involving classroom and on-bicycle training, costs approximately \$800 per class (for anywhere from 12 to 30 students). This program also provides instructors (one per class), bikes and helmets, and transportation of the bikes to program sites.

In North Carolina, the Office of Pedestrian and Bicycle Transportation provided \$5,000 mini-grants to elementary schools wanting to teach the Basics of Bicycling, an on-bike bicycle safety education program for elementary school age children. The amount covered the cost of trailers for storing and transporting bicycles (\$2,000 to \$2,500 depending on length); the purchase of 20 to 30 bicycles at \$105 to \$120 each (a discounted price negotiated with a local bicycle shop); and helmets at a cost of \$5 each (recommend purchasing 35 helmets for a class of 30 students, with varying sizes to allow for proper fitting). The program also required some props (traffic signs, bike fronts, etc.), which schools generally made themselves for a minimal cost.

42. MOTORIST EDUCATION

In addition to educating bicyclists about how to ride safely in traffic, it is important that motorists be educated about how to share the road with bicyclists. This is especially important for motorists who are not bicyclists themselves and who may be less familiar with the risks bicyclists face when operating in traffic.

The FHWA Bicycling Safety Education Resource Guide and Database described in the section on Bicyclist Education also contains information on programs and materials for educating motorists.² Example topic areas of importance to motorists are communications and sharing the road, the impact of large motor vehicles on bicycles, children's basic riding skills, how to pass groups of bicyclists, and how to operate in the presence of bike lanes.



Motorist educational materials may include information on the importance of obeying low speed limits in neighborhoods and being alert for child bicyclists who may ride out without yielding.

FHWA's [bicyclinginfo.org](http://www.bicyclinginfo.org) Web site contains additional tips for educating motorists about cycling, along with links to Web-based resources and materials (http://www.bicyclinginfo.org/ee/ed_motorist.htm). In discussing education programs for motorists, the site urges that emphasis be given to the benefits of sharing the road (safer, more inviting streets, a better environment, etc.), the fact that bicycling is a viable means of transportation, and the bicyclists' right to use the roadway. The Web site also contains links to many bicyclist safety education programs, tools and resources that can be used by professionals planning a program as well as by individual bicyclists. For motorists, there is a section on "Understanding Cyclist Behavior in Traffic" with links to the following materials from the League of American Bicyclists:

- 10 Commandments of Cycling
- Principles of Traffic
- How to Avoid Motorist Errors

Purposes

- Educate motorists about how to safely share the road with bicyclists and motivate them to act on this knowledge.
- Promote bicycling among motorists who otherwise might not consider bicycling as a viable transportation mode and a way to be physically active.

Considerations

- The target audience of motorists is much broader than that of bicyclists, and not all may have a positive mindset towards bicyclists. It is important that bicyclists not aggravate the situation by disobeying traffic laws or otherwise not riding responsibly in traffic.
- As with bicyclist education, motorist education requires a long-term commitment.

Estimated Cost

Costs for motorist education programs or initiatives are generally less than those for bicyclist education, especially on-road bicycling instruction. The primary cost is for any print materials and any additional costs associated with updating educational materials (such as the state driver license manual or state driver education program materials).

- Bike Lanes—What They Are and How They Work
- Riding Right—On the Right
- Driving at Night—Look for Their Lights

In addition to providing information in the form of brochures and other print materials, motorists can also be educated through signs (e.g., reminders to "Share the Road") (see case studies #41, 45, and 47), through information provided on walking or bicycling maps (see case study #51), and through information contained in driver license handbooks. The primary goal of these efforts is to create a safer, more positive climate for cycling among the general motoring public and possibly to recruit additional cyclists.

43. PRACTITIONER EDUCATION

State and local bicycle coordinators and other professionals whose responsibilities include planning, designing, building, and maintaining safe facilities for bicycling need current information upon which to base their decisions and guide their actions. The 1999 American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities* remains the primary resource for bicycle transportation professionals responsible for planning, designing, and building facilities to enhance and encourage safe bicycle travel.⁴ The *Manual on Uniform Traffic Control Devices* (MUTCD) also contains guidance with respect to recommended signs and pavement markings for bicyclists and bicycle facilities.⁵



Workshops and other training opportunities can increase effectiveness of professionals involved in bicycle planning, design, engineering, education, or enforcement.

The Association of Pedestrian and Bicycle Professionals (APBP) offers a one-day training course to “bring bicycle and pedestrian professionals up-to-date with the very latest technical information: the AASHTO Guide for the Development of Bicycle Facilities, the MUTCD, TEA-21, and the Uniform Vehicle Code.” It also sponsors professional development seminars that provide an opportunity for professionals to discuss specific technical issues in greater depth (<http://www.apbp.org/>).

FHWA has also developed a training course for graduate and undergraduate transportation planning and design students. The course “provides current information on pedestrian and bicycle planning and design techniques, as well as practical lessons on how to increase bicycling and walking through land-use practices and engineering design” (see http://safety.fhwa.dot.gov/ped_bike/univcourse/pbcrsbroch.htm). The course contains 24 modules that can form the basis for a “stand alone” course or be incorporated into other courses.

Purpose

- Provide transportation planners, designers, and others the training and tools needed to create safer, more inviting environments for bicycling.

Considerations

- Availability of training opportunities, costs to participate, and time requirements are important considerations in efforts to encourage greater professional training. Also, professionals must first be motivated to want to engage in such training.

Estimated Cost

The resources and materials identified in this section are generally available in electronic format at no cost, or can be ordered from their developers at minimal cost.

NHTSA and FHWA have combined to produce the NHTSA/FHWA Bicycle Safety Resource Guide, which contains information about problem areas, bicyclist and motorist errors, target groups, and countermeasures. The resource guide (over 15,000 pages of material), now available entirely on the FHWA Web site, also contains information on facility design, planning, guidelines, good practices, tools and outreach materials to aid in problem identification, countermeasures development and raising awareness (see http://safety.fhwa.dot.gov/tools/docs/welcome_bsg.pdf).

Other initiatives such as Safe Routes to School training programs and even on-bicycle tours for planners and engineers are being used to train practitioners (see case study #9).

SUPPORT FACILITIES AND PROGRAMS

The measures discussed in this section support access to bicycling by providing trip beginning or destination necessities such as bicycling maps for trip planning, secure bicycle parking, showers, lockers and other facilities. To enable longer multi-modal trips, providing access to transit and space for bicycles on transit is also necessary. These measures, plus promotional activities and programs, may help to increase the amount of riding in a community. Support activities or policies can take many forms, some of which naturally fall in line with a comprehensive community program. For example, provision of nice places to ride with wayfinding or destination signs is one way that a community can promote or encourage riding. In addition, special events such as “Bike to Work Days” or mentoring programs help to support bicyclists and encourage new bicyclists to give it a “spin.” Other programs may help to raise money to support bicycling.

Specific countermeasures in this section include:

- Bike Parking
- Transit Access
- Bicyclist Personal Facilities
- Bike Maps
- Wayfinding
- Events/Activities
- Aesthetics/Landscaping



PHOTO BY DAN BURDEN

Ramps such as this one in Japan facilitate bicyclists' access to off-street-level parking.



PHOTO BY DAN BURDEN

Transit access expands the reach of bicyclists.

44. BIKE PARKING

Access to secure bike parking is critical to encouraging greater use of bicycles. Without safe and convenient places to park, bicyclists are much less likely to commute to work or school, run errands, and engage in other utilitarian trips by bike. Bicycle parking facilities run the gamut from simple hitching posts installed outside buildings or on downtown sidewalks to covered parking facilities, bike lockers, and full service bike stations.



PHOTO FROM AAA

Bike lockers provide secure parking at this D.C. area metro station.

As with other strategies for promoting bicycling, this is an area where much of the legwork has already been done by others, and helpful guidance is only a mouse-click away on the Internet. The International Bicycle Fund provides helpful information on its Web site, including guidance on locating bicycle parking facilities, choosing the most suitable parking device to install, and publicizing parking once it is available. Properly locating bicycle parking facilities can help reduce bicyclist-pedestrian conflicts and crashes and enhance utility of bike parking. The site also maintains a list of bicycle parking suppliers along with their contact information. See <http://www.ibike.org/engineering/parking.htm>. *Bicycle Parking Guidelines* from the American Association of Pedestrian and Bicycle Professionals is also available from <http://www.bicyclinginfo.org/pdf/bikepark.pdf> with guidance on racks and location and design of parking areas.

Another good source of information is the City of Portland's Bicycle Master Plan (<http://www.portlandonline.com/shared/cfm/image.cfm?id=40414>). The plan describes Portland's assessment of short- and long-term bicycle parking needs and facilities and resulting objective and action items for addressing deficiencies.

Purpose

- Encourage greater use of bicycles by providing secure and convenient parking at destination sites (shopping, schools, libraries, parks, businesses, etc.).

Considerations

- It is important that the right parking equipment be installed for a given location and purpose. In general, the more long-term the parking, the more secure (and expensive) the required equipment. See Web sites in main text for guidance.
- To help determine where parking is needed, look for where bikes are already being parked illegally, and survey bike club members to learn what destinations are most lacking in parking.

Estimated Cost

Costs depend on the type of facility provided. In general, bike racks will cost about \$50 to \$100 per bike, while bike lockers will cost from \$500 to \$1,500 per bike. Locker costs can sometimes be offset by charging rental fees, although these should not be so high as to discourage would-be commuters. Employers and businesses can also be encouraged to support bicycle parking facilities, since providing even the best locker facilities is much cheaper than providing motor vehicle parking. (A good Web site for cost information is <http://www.bikeparking.com>.)



PHOTO BY CHRIS HENRY, CITY OF EUGENE, OR

Convenient parking should be located out of the pedestrian thoroughway. Demand should be periodically re-assessed.

In general, for meeting short-term parking needs, such as at shopping locations, a sturdy bike rack will suffice. The bike rack should be located near an entrance, in a location that is protected from pedestrian and vehicle traffic but still visible enough to passers-by to increase security. For longer-term parking, such as at transit stations or workplaces, bicycle lockers are generally recommended. In addition to providing safe parking that is protected from the elements, lockers allow bicyclists to leave extraneous gear (helmet, lights, panniers, tool bags, etc.) with their bikes, rather than having to carry it with them.



PHOTO BY PAUL DEMAIO, TRAFFIC CALMING COORDINATOR

A functional U-style rack may still be creative, such as this one in Alexandria, VA.

45. TRANSIT ACCESS

In cities that have bus, light rail or subway service, making these services bicycle-friendly can greatly expand options for bicyclists, allowing them to commute longer distances while also reducing car traffic to and from commuter stations. For buses, the most frequent option is an exterior rack mounted on the front of the bus that can accommodate two bicycles; however, other options exist, including interior bike racks or simply allowing bicyclists to bring their bike onboard an unequipped bus when conditions are not crowded.



PHOTO BY DAN BURDEN

A two-bike, front-mounted bus rack is the most commonly used rack. The driver can see bicyclists mounting their bikes. (Phoenix, AZ)

For rail transit, selected cars are generally equipped with interior bike racks, with the number of racks dependent on demand. During off-peak travel times and on weekends, bikes may be allowed on all cars. Each transit system sets its own policies and rules. In most cases, no additional fee is charged to carry a bike on board.



PHOTO FROM PETER TANNEN

A decal on the outside of the train lets bicyclists know which car to use.

Purposes

- This strategy promotes bicycling by greatly expanding the range of accessible destinations.
- It also promotes transit use, by expanding options for accessing and using transit.

Considerations

- Successful integration of bikes and transit requires a comprehensive approach that begins with an assessment of needs.
- In addition to providing direct access to transit (e.g., via bike racks on buses or in trains), consideration should be given to improving safe and convenient bike access to transit locations and providing secure bike parking facilities at all transit locations.
- Although liability is always a potential concern, at this point there is sufficient accumulated experience and sufficient product safety evidence that it should not be a deterrent to providing bike access on transit.

Estimated Cost

The *TDM Encyclopedia* notes that bicycle racks suitable for buses typically cost \$500 to \$1,000 for a high-quality model that can carry two bicycles. The Nashua, NH, transit plan developed in December 2003 included an estimate of \$1,000 per bike rack, installed.

While somewhat dated, the <http://www.BikeMap.com> Web site contains a listing of all locations in the U.S. where bikes are accommodated on transit, either on intercity rail, intercity bus, local transit, or ferries (see <http://www.bikemap.com/transit/usa.pdf>). The site also offers a discussion of why bikes should be linked with transit and offers examples of bikes on transit solutions. In the future, the developer of the site hopes to offer a searchable database where one can type in a location and find information on available bike and transit options.¹

According to information on the BikeMap.com Web site, the two most active regions of the country for providing bike access to transit are the West Coast states (California, Oregon and Washington), and the Northeast corridor, especially along the Atlantic coast from eastern Virginia to southern Maine. Many cities and local planning authorities have excellent Web sites providing information on available services, maps, hours of operation, fares, etc.

A good example is the Santa Clara Valley Transportation Authority (VTA) in California (see <http://www.vta.org/services/bikes.html>).

It should be noted that even if bike access on transit (rail or subway) is not an option, transit can still support bicycling by providing lockers or other secure parking at transit stations, as well as providing safe routes to the transit station from nearby residences and destinations.

A good resource on this topic is the *Online TDM* [Transportation Demand Management] *Encyclopedia*, maintained by the Victoria Transport Policy Institute (see <http://www.vtpi.org/tdm/tdm2.htm>). The chapter on bike/transit integration discusses bikes on transit, bicycle parking at transit stops, bicycle access to transit stations, bikes on taxis, and bicycle rentals. It also summarizes available data on how integration of bikes with transit has promoted transit use and provides information with respect to costs and benefits. Another resource is the Pedestrian and Bicycle Information Center (<http://www.bicyclinginfo.org/transit/index.htm>). Transit Cooperative Research Program Synthesis 62, *Integration of Bicycles and Transit*, is also available online at http://gulliver.trb.org/publications/tcrp/tcrp_syn_62.pdf.

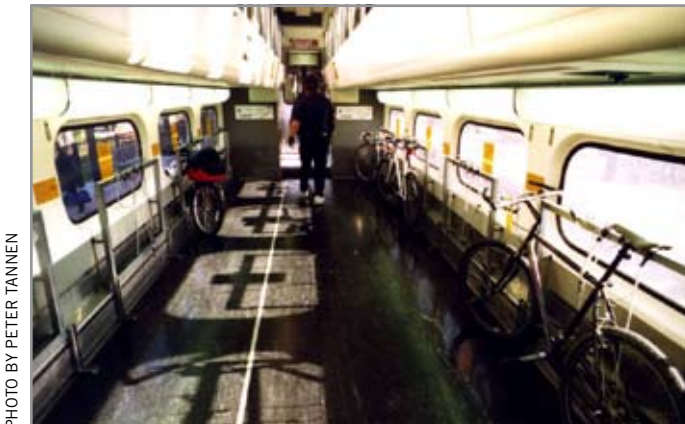


PHOTO BY PETER TANNEN

Bicycle cars on CalTrain may accommodate up to 32 bicycles.

46. BICYCLIST PERSONAL FACILITIES

Along with secure and convenient bike parking and transit access, another prerequisite for encouraging bicycle commuting is facilities for cyclists to shower, change clothes, or otherwise “freshen up” once they arrive at the workplace. Ideally, such facilities will be located on or very near to the worksite premises and will also include lockers for storing clothing and personal items.



More communities and bicycling organizations are developing bike stations as a way of providing facilities for bicyclists in urban areas.

Since constructing showers and locker rooms can be an expensive undertaking, especially for smaller employers, some creative options might be to partner with other nearby businesses to provide facilities, or make arrangements with a nearby health club to allow bicyclists to use its facilities for a nominal fee (which the employer can opt to cover). For larger employers interested in promoting a healthy work force, bicyclists can be given free or discounted use of a company health club or workout facility. Another high-end option is to incorporate changing facilities and bike rental and repair options along with parking facilities, such as is done at the privately

operated Bike Station in Long Beach, CA, and other facilities (see <http://www.bikestation.org>).

At Stanford University in Palo Alto, CA, over 21 percent of the staff bikes to work. Showers are available in several buildings and gymnasiums on campus, and most buildings also have commuter clothes lockers that can be rented for \$16 per year. Other “perks” for nonmotorized commuters include a “Clean Air Cash Reward” and a guaranteed ride home in case of an emergency (see http://transportation.stanford.edu/alt_transportation/BikingAtStanford.shtml).

Purpose

- Encourage bicycle commuting by providing places where employees can shower and change clothes once they arrive at the workplace.

Considerations

- Before investing in facilities, employers should take stock of what is already available (both at the workplace and nearby) and survey employees to learn what facility characteristics are most important to them.
- Like other countermeasures included under the general heading of support facilities and programs, this countermeasure is most likely to be successful if combined with other measures that make it easier or more attractive to bicycle to work. Examples include bike parking (especially bike lockers), cash incentives or other rewards, and bike to work days.

Estimated Cost

Costs will be highly variable depending upon the level of existing resources and the type of facility provided.

47. BIKE MAPS

Bike maps can be a useful tool for helping bicyclists get around in a new or unfamiliar riding environment, whether seeking a different route for getting to their destination, exploring a new section of town, or negotiating another city or town while on a vacation. Bike maps come in many shapes and sizes, from small “strip maps” designed to fit in the pocket of a front pannier so they can be read while riding, to larger fold-out maps looking much like a traditional road map. They can be statewide maps, regional, or local.



Detail of Raleigh, NC, bike map.

There are two primary types of bike maps: route maps, which indicate preferred roadways for bicyclists, and suitability maps, which are more like regular maps, but with the roadways coded (through the use of colors, dashed or dotted lines, etc.) based upon their relative safety or attractiveness to bicyclists. Both types can be extremely beneficial to bicyclists (and even non-bicyclists simply looking for the best way to negotiate a new city environment).

A well-designed bike map is typically in high demand and can serve many functions. In addition to showing the best route for getting places, bike maps often contain information or advertising for a variety of resources including a calendar of bike events, locations of bike shops, points of interest in the community, laws and local ordinances pertaining to bicycles, and safety tips for the rider and motor vehicle driver. Thus, a good bike map can be a tool for promoting bicycling as well as for educating and informing riders and motorists.

Purposes

- Encourage and enable bicyclists to ride in new environments.
- Assist bicyclists in selecting appropriate roadways for their skill level.
- Provide safety tips for bicyclists as well as motorists.
- Inform bicyclists about available resources within a community, region, or state.

Considerations

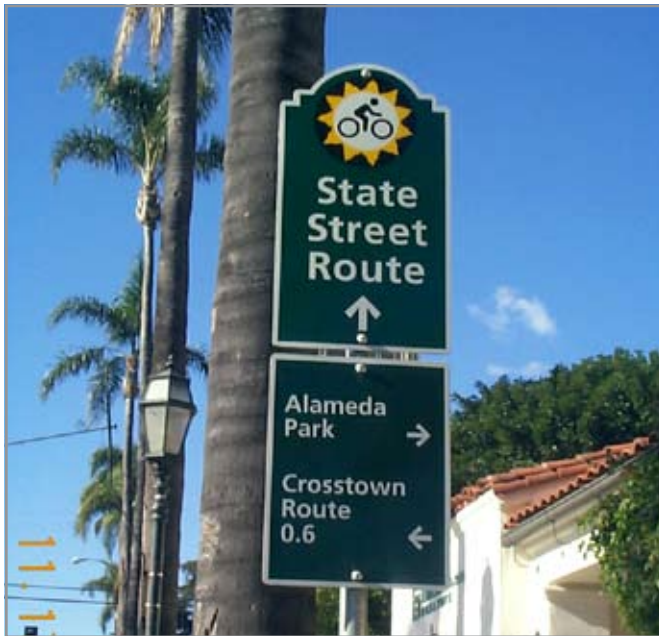
- Computer mapping capabilities have greatly reduced the costs involved in producing attractive bike maps, and today many bike maps may be downloaded from the Internet. Still, care must be taken in recommending specific routes for bicyclists. For suitability maps, care must be taken in developing guidelines and a rating system for distinguishing among the various roadways their suitability for bicycling.

Estimated Cost

The primary cost lies in the development of the map. In North Carolina, cost for the trip-tics (strip maps) for the original “Bicycling Highways” maps were minimal — just ink and paper. Recent updates include digitizing the information, undertaken by a consulting cartographer at an average cost of \$1,000 per segment for two-color artwork. The four-color map/brochures for county route systems, produced by outside cartographers and graphic designers, cost \$20,000 for production and about \$.50 for each printed copy. Urban maps produced by outside cartographers and graphic designers have ranged from \$30,000 to \$60,000 for production and \$.34 to \$.78 per copy for printing. These costs do not reflect staff time spent in administering the projects, developing routes, coordinating with local committees, preparing text, or reviewing and proofing the product throughout the production process.

48. WAYFINDING

Wayfinding pertains to directional signs, distance markers, posted maps, information kiosks and other aides for getting people places. In their broadest application, wayfinding systems help all road users (including motorists and pedestrians as well as bicyclists) find their way in a city. For example, as part of its downtown improvement efforts, the City of Atlanta is developing a wayfinding sign system that will include uniform geographically oriented maps, signs, and kiosks designed to serve all modes of transportation accessing the area (see http://www.atlantadowntown.com/CapAdidInitiatives_Wayfinding.asp). Another example is the City of Seattle, which has been awarded a three-part Federal Transit Administration (FTA) grant to design and implement a downtown wayfinding system. When completed, the system will include kiosks, signs, maps, and a Web site “to enhance everyone’s ability to navigate the Center City and find destinations whether by foot, transit, bicycle or car” (see http://www.ci.seattle.wa.us/dclu/CityDesign/DesignLeadership/Conn_n_Places/).



Wayfinding signs help bicyclists navigate or discover new routes to common destinations.

Wayfinding systems can also be more narrowly focused. For example, Contra Costa County in California is working to develop a wayfinding system to guide pedestrians and cyclists in and around its Bay Area Rapid Transit (BART) system station, and many communities with well-defined bike networks are looking to wayfinding signs both to publicize their system and to help people access and use it. When placed along bike trails or routes, wayfinding signs typically include easy-to-read arrows pointed to-

Purposes

- Provide travel information (nearby destinations, directions, distances) to users of a given pathway or facility.
- Publicize the existence of a bicycle network.
- Make it easier for people to find and access bicycle facilities.

Considerations

- Wayfinding projects can be carried out at many levels; however, it is important that a systemwide approach be taken so that different signs, maps, information kiosks, etc. do not appear in different parts of a city, thereby confusing rather than enlightening users.
- Web sites containing wayfinding information are becoming more important.

Estimated Cost

Estimated costs will be variable, depending on the nature and scope of the system being developed. More elaborate kiosks and map postings will be more expensive depending on materials and installation costs.

ward specific nearby destinations and distances to these destinations. A frequent location for such signs is where a bike path may cross or intersect with a roadway—the sign both informs the bicyclist and alerts passing motorists and pedestrians of the existence of the bike path.

49. EVENTS/ACTIVITIES

Special bicycle events and activities lie at the heart of bicycle promotion. They reinforce the efforts of current bicyclists and seek to attract new bicyclists to the fold. Sample events include bike to work days, fun rides, bicycling competitions or races, trail openings, commuting help lines, and “short courses” on how to ride in traffic. Bicycling can also be promoted at health fairs as part of a more active and healthy lifestyle and at environmental events like Earth Day as a form of transportation that is good for the environment.

Many of these events are planned by local, state, or national advocacy groups and are just one part of a larger plan to promote increased bicycling for transportation as well as recreation, fun and fitness. For example, the Chicagoland Bicycle Federation hosts an annual car-free “Bike the Drive” Sunday. In 2002, over 16,000 bicyclists participated, taking over the city’s famous Lake Shore Drive (see <http://www.bikethedrive.org/>). During the months of May and June, the Chicago Mayor’s Office of Special Events helps sponsor over 100 separate events promoting the health, economic and environmental benefits of bicycling as part of its annual Bike Chicago.

“Bike to Work” days are well-established events in many communities. They typically draw a mix of established and first-time commuters and can be combined with other activities such as competitions, “how to ride in traffic” workshops, and breakfast gatherings. The events raise community awareness of bicycling as a legitimate mode of transportation, bring cyclists together, and, ideally, convert some participants to regular bike commuters.

Also included under the general topic of supporting activities and programs are efforts to raise community awareness of and support for bicycling and investment in bicycling facilities and activities or safety. Two example case studies are included: (1) a program that used financial incentives to encourage developers to build higher-density neighborhoods near transit stations, thus increasing the opportunity for bicycling, and (2) a special vehicle license plate program that serves as a source of sustained financial support for improving bicycle safety (see case studies #57 and 58).

Purposes

- Promote bicycling through support programs and activities.
- Help to establish bicycling as a legitimate form of transportation.
- Help attract people to bicycling.

Considerations

- The primary consideration for this countermeasure is deciding what type of promotional event or activity to conduct. Factors impacting this decision include the target audience to be reached by the event, level of community support, the membership and goals of the sponsoring organization(s), available funding, and even weather conditions.

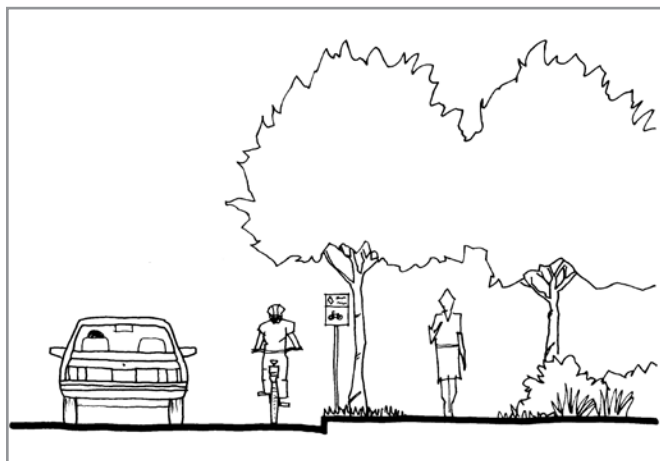
Estimated Cost

Estimated cost will vary depending on the particular event or program selected, the scope and time frame for the event, level of volunteer involvement, etc. As an example, the total cost of a Bike to Work promotion held in Hartford, CT, in 2002 was just under \$12,500, which covered the costs of food, two advertising banners, a brochure, a payroll insert, signs on buses, T-shirts, and a bicycle to raffle (see case study #53).



50. AESTHETICS/LANDSCAPING

Well-designed and well-landscaped bicycle facilities can be an important attraction, especially for the recreational bicyclist. Whereas bicycle commuters will typically choose routes based upon their directness and safety, recreational riders are more likely to be drawn to routes that are aesthetically pleasing and where they feel comfortable riding. The aesthetic of the riding environment is also of critical importance to attracting new riders—an individual is much more likely to try commuting to work if his route takes him along an attractively maintained greenway or roadway than along an unkempt, urban street.



Aesthetics are an integral part of building a livable, bikeable, and walkable community. Streets and bicycle facilities that are well-designed and well-maintained, buffered from traffic, attractively landscaped, and that are either a destination in their own right (e.g., a popular off-road trail in a park) or that connect popular destinations (e.g., houses with shopping, neighborhoods with schools) will attract bicyclists.



Downtown areas can be appealing bicycling locations.

Purposes

- The primary goal in designing and building aesthetically pleasing bicycle facilities is to create an attractive environment—not only for bicyclists, but for everyone.
- By building such environments, one hopes to encourage more people to bike for recreation, fitness, and trip-making.

Considerations

- Landscaping is integral to good design. It is important for the overall aesthetics of a project, but also the day-to-day safety, operation and maintenance of the project.
- The services of a landscape architect or other professional may be beneficial in planning and building a facility that is aesthetically pleasing and that contributes to the overall goal of a livable community.

Estimated Cost

Estimated costs will vary widely, depending on the specific type of facility, its location, original conditions at the site, the overall scope and timeframe for the project, availability of volunteer labor, etc.

Well-designed and landscaped facilities are also easier to maintain, lead to fewer safety and security problems, and are more likely to be supported by the neighborhoods and businesses they access.



Shoreline Park bike path in Santa Barbara, CA, provides an off-road option connecting a park with a business district.

Chapter 6 – Case Studies



The 50 engineering, education, enforcement and promotional countermeasures are described in Chapter 5. Included in this chapter are case studies that illustrate these treatments or programs as implemented in a state or municipality. Examples are included from many States. Provided on the following pages is a list of the 59 case studies by countermeasure group. A more detailed matrix showing the case studies by specific countermeasure is included in Appendix B.

Each case study includes a description of the problem that was addressed, relevant background information, a description of the implemented solution, and any quantitative results from evaluation studies or qualitative assessments.

Many communities find it difficult to conduct formal evaluations of projects due to staff and budget limitations, but assessing whether a treatment has helped toward the intended objectives and not caused unexpected adverse impacts is critical to long-term improvement. We tend to think that some evaluation is better than none but occasionally may be misled by short-term or single-event types of assessments. In these cases, the judgment of experienced practitioners may help to fill in the gaps in knowledge or interpret results that seem “too good to be true.” By far, longer-term evaluations (bicyclist/traffic counts, speed studies, etc.) are preferable to short-term project assessments. Multiple short-term studies of the same types of facilities do, however, build on each other and help to provide a more complete picture of the effectiveness of bicycling countermeasures. These cautions should be borne in mind when reviewing the case studies that follow.

Included for each study is a point of contact in the event that further information is desired. Please note that in some cases the specific individual listed may have left the position or agency. There should still be someone at the municipal or state agency who is familiar with the project and can provide any supplemental information.

Not all traffic control devices (TCDs) in the case studies comply with the *Manual on Uniform Traffic Control Devices* (MUTCD). The Federal Highway Administration (FHWA) does not endorse the use of non-compliant TCDs except under experimentation, which must be approved by the FHWA Office of Transportation Operations.

Page Number	Case Study Title	Shared Roadway	On-Road Bike Facilities	Intersections Treatments	Maintenance	Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement	Support Facilities and Programs
145	#1 – Roadway Surface Hazards for Bikes	X			X					
148	#2 – A Tale of Portland Bridges	X	X	X			X	X		
155	#3 – Lighting in the Knapps Hill Tunnel	X								
157	#4 – Back-in Diagonal Parking with Bike Lanes	X						X		
164	#5 – Valencia Street Road Diet—Creating Space for Cyclists	X	X					X		
168	#6 – Shoreline Park Expansion Project—Provision of Bicycle and Pedestrian Enhancements	X	X				X			X
171	#7 – Bicycle Treatments on a Former Pedestrian Mall	X				X		X		X
176	#8 – Bike Lane Safety Evaluation		X						X	
181	#9 – Establishing Bike Lanes—Chicago’s Streets for Cycling Plan		X		X				X	X
185	#10 – How Hampshire Street Pavement Markings Influence Bicycle and Motor Vehicle Positioning		X							
190	#11 – Raised Bicycle Lanes and Other Traffic Calming Treatments on Ayres Road	X	X			X				X
196	#12 – Floating Bike Lanes in Conjunction with Part-time Parking	X	X					X		
199	#13 – Incorporating a Bicycle Lane through a Streetcar Platform		X							
201	#14 – Red Shoulders as a Bicycle Facility		X			X				
204	#15 – Conversion of 14-foot-wide Outside Lanes to 11-foot Travel Lanes with a 3-foot Undesignated Lane	X	X					X		
207	#16 – Preferential Transit-Bicycle Lanes on Broadway Boulevard		X					X		
209	#17 – Taming the Urban Arterial	X	X					X		
212	#18 – Contraflow Bicycle Lanes on Urban Streets		X					X		
216	#19 – Left Side Bike Lanes on One-Way Streets		X					X		
221	#20 – Curb Radii/Curb Revisions			X						
223	#21 – Combined Bicycle Lane/Right-Turn Lane		X	X				X		
226	#22 – Blue Bike Lanes at Intersection Weaving Areas		X					X		
230	#23 – Crossing an Arterial on an Offset Intersection: Bicycle-Only Center-Turn Lane		X	X						
232	#24 – Improving Sight Distance between Cyclists and Motorists	X		X			X	X		
235	#25 – Grandview Drive Roundabout and Corridor Improvements	X	X	X				X		
238	#26 – Innovative Application of the Bike Box			X				X		
242	#27 – Comprehensive Maintenance Planning for Bicycle Facilities	X			X			X		
246	#28 – Road Hazard Identification Project				X					
249	#29 – Bikeway Speed Humps					X				
252	#30 – Speed Cushions for the Evergreen Corridor Bike Lane Project					X				
258	#31 – Neighborhood Mini Traffic Circles					X				

Page Number	Case Study Title	Shared Roadway	On-Road Bike Facilities	Intersections Treatments	Maintenance	Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement	Support Facilities and Programs
260	#32 – Bicycle Boulevards—Bryant Street Example			X		X		X		
265	#33 – Planning, Designing and Implementing a Shared-Use Path						X			
268	#34 – Path and Roadway Intersections	X					X	X		
273	#35 – Grade Separated Crossing Treatments	X					X			
278	#36 – Share the Trail: Minimizing User Conflicts on Non-motorized Facilities						X		X	
283	#37 – Shared Lane Markings		X					X		
286	#38 – Bicycle Detection Program							X	X	
289	#39 – Bicycle Signal Heads							X		
292	#40 – Pedestrian/Bicycle Crosswalk Signals (Half-Signals)							X		
294	#41 – Share the Road Sign Initiative							X		
296	#42 – Placement of 20-mph School Zone Signs							X	X	
302	#43 – Shared-Use Arrow									
305	#44 – Enforcement for Bicycle Safety								X	
308	#45 – Bicycling Ambassadors and Bike Lane Education								X	X
310	#46 – Comprehensive Child Bicycle Safety Program								X	
316	#47 – Share the Road: Motorist/Bicyclist Traffic Education and Enforcement Programs								X	
320	#48 – Hitching Posts for Bicycle Parking									X
323	#49 – Bicycle Access on Caltrain									X
327	#50 – Bike and Bus Program									X
333	#51 – Mapping for Bicyclists									X
336	#52 – Commuter Coach: Commuter Bicyclist Recruiting								X	X
339	#53 – Bike to Work Promotion				X				X	X
344	#54 – Free Cycles Program									
347	#55 – Bicycle Destination Signing System							X		X
349	#56 – Urban Forestry									X
351	#57 – Raising Funds for Bicycle Safety Programs through Specialty License Plates									X
355	#58 – A Transit Oriented Development Financial Incentive Program—A Tool to Encourage More Bicycling and Walking									X

Minimizing Roadway Surface Hazards for Bikes

BACKGROUND

The goals of the city of Seattle's Bicycle Program are to get more people bicycling more often and to reduce the number of crashes involving bicyclists. To accomplish this, the city of Seattle has adopted two main objectives: 1) to complete a comprehensive urban trails system (rail-trails and other trail facilities); and 2) to make all streets and bridges bicycle-friendly. The second objective was developed with the knowledge that up to 80 percent of all bicycle trips within the city will always be on streets shared with motor vehicles, regardless of how many trails are completed. There is simply no way to build a trail to every residence and every place of business. Even bicycle trips that involve the use of a trail typically involve on-street elements getting to and from the trail.

Bicyclists riding on city streets often encounter road hazards that can cause them to suddenly weave, possibly causing a conflict with motor vehicles, or even fall. In other cases, it discourages people from even attempting to ride. Typical road hazards include drainage grates that can catch bicycle tires, drainage grates that are either above or below the road surface, gaps between pavement seams, gutter pans that are too wide, poorly placed or slippery utility covers, railroad tracks that cross streets at obtuse angles, textured crosswalks that are slippery or excessively bumpy, pot holes, bad pavement around utility patches, and broken pavement caused by tree roots.

COUNTERMEASURES

Seattle's solution has been to "institutionalize" good design practices into standard plans and specifications and to establish a "Bike Spot Safety Program."

Peter Lagerwey, Pedestrian & Bicycle Program Coordinator, City of Seattle



Surface irregularities become hazards for bikers long before they become so for automobile drivers.

INSTITUTIONALIZE GOOD INITIAL DESIGN

The intent of the program, to institutionalize good design practices into standard plans and specifications, is to make sure that as streets are re-built and maintained, the right designs happen automatically (typically referred to as "routine accommodation"). The following are examples of how the city has incorporated and adopted standard practices that benefit bicyclists by removing road hazards:

- drain grates—standard, required specification grate is baffled in a way that prevents bike tires from getting caught in the gaps; drain grates are required to be flush with the street;
- seamless curbs—new, concrete streets have seamless curbs that are integrated into the curb lane (no gutter pan);
- utility covers—where possible, utility covers are located outside the travel area for bicyclists (1.2 m (4 ft) from curb or, if there is parking, to the left of the parked cars); utility covers must be flat, have texture and be void of unnecessary protrusions that could divert a bicycle tire;

- utility cuts—utility cuts must be repaired twice, once with a temporary patch to allow for settling, and later, with a permanent patch.

The effort to do an even better job of “routine accommodation” continues. Over the next three years, the “Cities Street Design Manual” will again be completely revised.

BIKE SPOT SAFETY PROGRAM

The intent of the Bike Spot Safety Program is to make low-cost repairs and improvements that enhance bicycle safety and access on Seattle’s streets. The program relies on citizens to identify problems that need attention. Utilizing citizen input is done with the recognition that the bicycling public is going to have the best knowledge and information as to where problems exist. Additionally, city staff simply does not have the time to spend riding the streets to identify all problems that need attention.

The city has developed a Citizen Bicycling Improvement Request form that is distributed to bike shops, community centers, and published in the local bicycle club newsletter. On one side is space for an individual to fill out the location and nature of the problem and their name, address and phone number. The other side has the address of the bicycle program and a place for a stamp, which allows the request form to be mailed without the use of an envelope. When the form is received by the bicycle program, a staff person makes a quick assessment of the request and calls the person who filled out the form to let them know that: a) the problem will be fixed; b) the problem needs further investigation; or c) the problem is something that the Bike Spot Safety Program cannot address. In all cases, the staff person makes sure to let the resident know about how long it will take to respond to their request. A pothole, for example, may be filled in 24 hours while a bike rack request might take six weeks to install. After the resident has been contacted, the next step is to determine whether a field check is needed. Typically, a field check is not needed on routine maintenance items such as a request to sweep a bike lane. Field checks, however, are required for requests involving other improvements such as the installation of signs and bike racks. Once the field investigation is completed and a determination is made to make an improvement, a work instruction is filled out and electronically sent to the appropriate city crew. The crews then do the work and electronically notify the bicycle program that the improvement has been completed. Bike Spot Safety Program staff then call the resident who originally made the request to complete the loop.

BROWARD COUNTY, FLORIDA

The importance of institutionalizing good design practices is brought home by the experiences of a few localities in Florida and probably other states. These jurisdictions attempted a retrofit measure to create more space for bikes and eliminate the bike-unfriendly seam between the pavement and the gutter pan by paving over the seam to the curb face. Initially, the treatment seemed successful. As the pavement aged and shifted, the lateral seam returned, however, as well as cracks in the asphalt at expansion joints in the gutter pan. In addition to the seams reappearing, the asphalt gutter gives the impression that this is usable riding space and encourages inexperienced cyclists to ride in the gutter too close to the curb. Because the effectiveness of this fix degrades over time, this treatment should only be considered as a short-term fix (five years or less), and even then as a last resort. (The placement of an edge stripe will help delineate the gutter and may reduce gutter riding.) Other considerations: In areas with heavy rains, paving over the gutter pan may reduce the drainage capacity of the gutter. Also, additional care needs to be taken during resurfacing to prevent asphalt from covering the drainage inlets.

Information provided by Mark Horowitz, Bicycle Coordinator, Broward County Dept. of Planning and Environmental Protection

EVALUATION AND RESULTS

Eliminating road hazards for bicyclists reduces the number of locations where bicyclists can fall or be diverted into the path of motor vehicles. However, Seattle has not been able to draw a direct cause and effect relationship between the Bike Spot Safety Program and institutionalization program and a reduction in crashes or an increase in bicycle ridership.

CONCLUSIONS AND RECOMMENDATIONS

The Bike Spot Safety Program is the single most important program administered by the Seattle Bicycle Program to improve safety. Additionally, residents appreciate the quick turnaround on the initial phone call and don’t



Gaps are minimized, but metal surfaces of this railroad crossing may be slippery when wet.



Relatively small bumps in a road or path surface may be enough to cause a bicyclist to lose control.

mind waiting a few months for an improvement as long as they know when it is coming. In many cases, they are delighted just to have someone who listens and responds to their concerns. The program has won many friends by making a special effort to give priority to requests from persons with disabilities. The program is also popular with elected officials and other decision-makers since it generates thank-you letters and phone calls. Something is always occurring on the street, which demonstrates that “something” is being done. Finally, it helps the city defend itself against liability claims since it can be demonstrated that there is a safety program which quickly responds to maintenance concerns.

The results of the program to institutionalize good design practices into standard plans and specifications, have been equally successful. In almost all cases, streets are be-

ing re-built in a more bicycle-friendly design as a matter of routine accommodation. This is true of both public and private projects. One of the keys to success is to make sure that on private projects the city inspectors know the design requirements and are willing to stay on top of the contractors to make sure they do it right.

COSTS AND FUNDING

One key to the Bike Spot Safety Program’s success has been to work with existing maintenance programs that pay for many of the bike spot projects. For example, Seattle has a “Pothole Ranger” program where a crew does nothing but respond to pothole requests. The bike spot program simply adds a few requests to this existing program. The Bike Spot Safety program spends a minimum of \$200,000 per year. Since individual improvements are relatively cheap, the amount dedicated to the program is flexible. More money means more improvements. In lean years when funds are scarce, fewer improvements are completed.

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A Tale of Portland Bridges

BACKGROUND

There are 10 bridges spanning Portland's Willamette River, which cuts through the heart of Portland and provides social, economic, and recreational benefits. The Willamette River bridges connect the city's east and west sides—on the west side is Portland's vibrant and economically critical downtown and on the east side are light industries, emerging business districts and pedestrian and bicycle-friendly neighborhoods. The bridges simply are critical for mobility (see map, figure 1). They include five local bridges providing downtown access (Hawthorne, Morrison, Burnside, Steel and Broadway), three other local bridges (Ross Island, Sellwood, and St. Johns), and two limited-access freeways (Fremont and Marquam). Multnomah County is responsible for five of the bridges, the Oregon Department of Transportation (ODOT) for four, and the Union Pacific Railroad for one. The city of Portland is responsible for installing signs, striping, and facilitating access to all bridges.

Eight bridges (all but the limited-access freeways) provide some level of pedestrian and bicycle access (see table 1). In the early 1990s, a year-long partial closure of the Hawthorne Bridge galvanized cycle advocates to press for access during the closure. At the same time, the city embarked upon a major program to engage cyclists and potential cyclists in a dialogue about ways to increase cycling as a means of transportation. Overwhelmingly, improvements to the bridges' approaches and spans were seen as the highest priority because of the poor bicycle and pedestrian conditions.

At the time, the eight non-freeway bridges were a major barrier for pedestrian and bicycle travel. Bicyclists and



Figure 1. Key Portland Bridges.

pedestrians shared narrow sidewalks, and all bridges had access problems, such as the following:

- Cyclists having to cross motor vehicle ramps with no markings or yield control.
- Lack of bikeway facilities on approaching congested streets and structures.
- Conflicts between bicyclists and pedestrians on narrow sidewalks and other points.

On two bridges (Sellwood and Steel), the sidewalks were so narrow that bicyclists were supposed to walk their bikes (which they rarely did) through conflict areas. On several of the bridges, bicyclists could theoretically use auto travel lanes. On one downtown bridge (Burnside) this required sharing the relatively narrow 3 m (10 ft)-wide outside travel lanes on a six-lane span. On three other downtown bridges, sharing the travel lanes was (and still is) a danger-

Mia Birk¹, Principal, Alta Planning + Design
With assistance from Jeff Smith, City of Portland
Transportation Options



Broadway Bridge, 1992: Westside, westbound. Bike signal, no bike lanes.



Broadway Bridge, 2002: Westside, westbound. New bike signal splits bike movements.

ous undertaking given the narrow lane widths, traffic volume and speeds and sight distance. On three non-downtown bridges, sharing lanes meant bicycling on slippery grating (not a good option in rainy Portland).

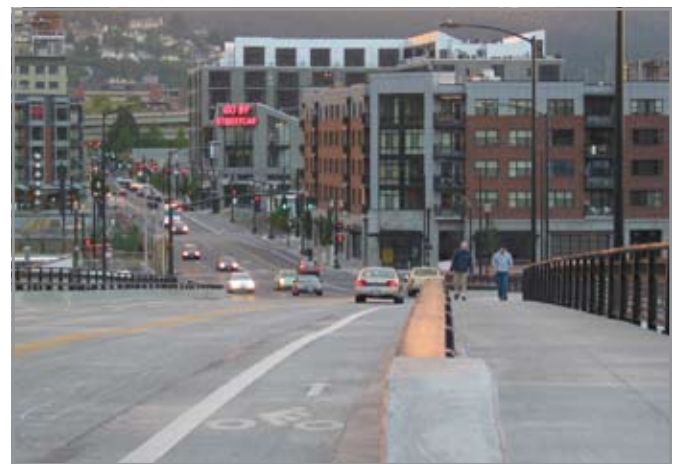
These problems translated to low bicycle and pedestrian use of the bridge. Surveys of cyclists found the number-one problem cited was bridge facility quality and access. In response, Multnomah County, ODOT and the city of Portland collaborated on an ISTEA-funded study called the Willamette River Bridges Access Project (WRBAP). Consultants CH2MHill identified over \$15 million in potential bicycle, pedestrian, and ADA improvements. The city and county subsequently implemented many of these via grants from ODOT, ISTEA, and through routine city of Portland, Multnomah County, and ODOT bridge and approach maintenance work.

COUNTERMEASURES

Over \$12 million worth of improvements have been implemented, primarily on four of the downtown bridges—Hawthorne, Burnside, Steel, and Broadway. Preliminary design for improvements on the fifth downtown bridge—Morrison—is underway as of fall 2002. Limited improvements were suggested for the Sellwood, St. Johns, and Ross Island bridges; no major improvements have resulted. The measures implemented on the four main bridges are shown in the photos below and described for each bridge in table 1.

The measures include:

- Improvements to off-street facilities (widening sidewalks on Hawthorne, sidewalk in-fill in approach areas, replacement of slippery sidewalk surface on both Hawthorne and Broadway, addition of shared-use path on Steel).



Bike lanes on approaches and connecting streets.

- Striping bike lanes, signs (on the bridge span on Burnside, and on most approaches and access streets).
- Focusing on safety at conflict areas (closure of on-ramp from Naito to Hawthorne Bridge, reconstruction of conflict areas on approaches to Hawthorne and Broadway, blue bike lane implementation in conflict zones on approaches to Broadway and Hawthorne).
- Redesigning sidewalk ramps to meet ADA (all bridges).

It should be noted that many of the improvements were made in conjunction with other bridge upgrade or reconstruction projects; thus costs for specific bike and pedestrian improvements are not always available. Also note that the City used blue pavement areas in bike and motor vehicle conflict areas on the approaches from the east-side for two bridges (Broadway and Hawthorne). Blue bike lanes as a safety technique are discussed in the City of Portland publication, *Blue Bike Lanes for Cycling Safety* (City of Portland, 1997).

Table 1. Bridge countermeasures, costs, funding sources

Bridge	Owner ²	Status Before	Measures Implemented	Cost	Funding Source
Hawthorne*	Multnomah County	Cyclists and pedestrians sharing 1.8 m (6 ft)–wide sidewalks. No bike lanes and minimal sidewalks on approaches. Bicyclists shared roadway or used sidewalks to access. Problematic interaction between cyclists and motor vehicles in several areas.	Sidewalks widened to 3 m (10 ft) on each side. Bike lanes striped on all approaches. Sidewalk in-fill on approaches. Curb ramps rebuilt to meet ADA. Eastbound approach, Westside: First ramp from Naito Parkway closed, eliminating conflict area. Second ramp reconfigured to force motorists to stop and give cyclists and pedestrians priority, separate bike and pedestrian crossing areas. Blue bike lanes introduced in conflict zones on east side.	Sidewalk widening: \$1.2 million Other changes: \$200,000	ODOT Bike/Ped Grants, TEA-21 STP funding
Burnside*	Multnomah County	Bikes and pedestrians on 3 m (10 ft)–wide sidewalks. Bike access via surface street without bike lanes.	Deck restriped with bike lanes by removing one travel lane in non-peak direction	\$20,000	Local transportation funding
Steel*	Upper Deck: Multnomah County. Lower Deck: Union Pacific Railroad	Bikes and pedestrians sharing about 1.5 m (5 ft) sidewalk on south side, upper deck. Some cyclists on roadway.	New 3.7 m (12 ft) bike and pedestrian path added to lower deck, along with new shared-use path (Eastbank Esplanade) and bike lanes on eastside approaches. “Bikes on roadway” signs on upper deck.	\$10 million	ISTEA & TEA-21 Enhancements, local tax increment financing
Broadway*	Multnomah County	Bikes and pedestrians on 3 m (10 ft)–wide sidewalks with slippery surface. No bike lanes on connecting surface streets. Approaches with numerous ill-defined conflict areas.	Sidewalk surface replaced (sidewalk width same). Bike lanes added to all connecting surface streets and ramps. Conflict areas on approaches modified and defined (by blue bike areas in two cases).	\$300,000	Multnomah County & Portland transportation funding
Sellwood	Multnomah County	Bikes and pedestrians on 1.2 m (4 ft)–wide sidewalk on one side. Very constrained. Access from eastside via surface street without bike lanes. Access from Westside via shared use path.	None. Bridge to be rebuilt within 20 years		

Bridge	Owner ²	Status Before	Measures Implemented	Cost	Funding Source
St. Johns	ODOT	Bikes and pedestrians on narrow 1.2 m (4 ft)–wide sidewalks. Access horrible via major highway.	None. ODOT studying restriping potential.		
Ross Island	ODOT	Bikes and pedestrians on 1.2 m (4 ft)–wide sidewalk on one side. Very constrained. Access from westside near impossible. Access from eastside via crowded surface streets without bike lanes.	Bridge rebuilt, but bikes & pedestrians still share narrow sidewalk. No improvements made.		
Morrison*	Multnomah County	Bikes and pedestrians on narrow sidewalks. Very constrained. Dangerous conflict areas at highway ramps.	Preliminary design study underway as of fall 2002	\$250,000	TEA-21
² On all bridges, approaches, signing, and striping controlled by the city of Portland					
* Connects eastside to downtown Portland.					

EVALUATION AND RESULTS

The city of Portland collected bicycle counts on the bridges over time, as shown in figure 2 and table 2. These counts are based on the daily peak two-hour period, and thus primarily reflect commute trips. The counts show an enormous increase over time in bicycle use on the four main bridges, while in comparison, counts for the bridges without bicycle access improvements remain extremely low. Recreational trips have increased enormously as well. Joggers and cyclists frequently use the Hawthorne and Steel bridges and their connecting paths as a downtown exercise loop during the day and on weekends.

A clear link can be made between the increased bike use and improved facilities on the four bridges discussed. On the Hawthorne, Burnside, and Broadway bridges alone, bike use went up 78 percent in the 1990s, compared with a 14 percent increase in the population and an 8 percent increase in motor vehicle use on these bridges. The following results should be noted:

- On the Burnside Bridge, bike use tripled from 300 daily cyclists to about 1,000 once the improvements were made.
- On the Hawthorne Bridge, many improvements were made over a multi-year period. The most significant jump in use occurred in 1999 after the sidewalks were

widened, from about 2,400 cyclists to over 3,100—a 32 percent increase in one year.

- On the Broadway Bridge, a 54 percent increase in cycling occurred the year after the major improvements were made.
- On the Steel Bridge, bike use went up 220 percent after the Steel Bridge Riverwalk and Eastbank Esplanade opened in May 2001.

Table 2. Bridge Bicycle Traffic

	before 1990	1990–92	1993–94	1995–96	1997	1998	1999	2000	2001
Hawthorne Bridge	830	1445	1920	2040	2025	2471 ³	3154 ⁴	3125	3675
Burnside Bridge	300 ¹	600 ¹	995 ²	1065	1375	905	920	1075	965
Broadway Bridge	495	755	715	950	1205	1854 ⁵	1476 ⁶	1405 ⁷	1625 ⁷
Steel Bridge		215	220	350	475	350	360	410	1312 ⁸
Totals	1825	3015	3850	4405	5080	5580	5910	6015	7577
Ross Island Bridge*				100			90		
Morrison Bridge*					100		100		
Sellwood*					260		315		

Notes: counts are either from 24-hour hose counts, or from extrapolated 4 to 6 PM manual counts (estimated at 20 percent of total daily bicycle volume based on 24-hour video and manual verification). Where more than one count is available in a given year, counts are averaged. All counts taken in the summer months, on good weather weekdays.

* No significant bike and pedestrian improvements made.

¹ Burnside Bridge counts pre-1993 are estimates based on 7–9am counts.

² Burnside Bridge is restriped with bike lanes on-street.

³ Hawthorne Bridge 1998 count was conducted on the Morrison Bridge Detour, as the Hawthorne was closed.

⁴ Hawthorne Bridge reopens with widened sidewalks and access improvements.

⁵ Broadway Bridge sidewalks resurfaced, eastside approaches improved, westbound bike lanes added to Lovejoy Ramp.

⁶ Broadway Bridge 1999 count conducted during Lovejoy ramp demolition.

⁷ Lovejoy Ramp not yet open.

⁸ Steel Bridge Riverwalk opens.



Before: Steel Bridge, upper deck. Bicyclists and pedestrians sharing one 1.5m (5 ft) sidewalk with guardrail.



After: Steel Bridge Riverwalk on lower deck. It's a cantilevered 3m (10 ft) shared use path connecting to paths.



Before: Eastbound Hawthorne Bridge access to sidewalks—bicyclists make sharp turn, yield to motorists.
Note 1.8 m (6 ft)–wide sidewalks.



Hawthorne: Bike lanes added on all approaches. Bike lanes added to all connecting streets: SW Main, SW Madison, SE Hawthorne, SE Madison.



After: Eastbound Hawthorne Bridge access to sidewalks—bicyclists proceed straight, motorists yield,
Note 3.2 m (10.5 ft)–wide sidewalks.



Blue bike lane on eastbound viaduct at off-ramp. Used at areas where motorists cross bicycle lane.

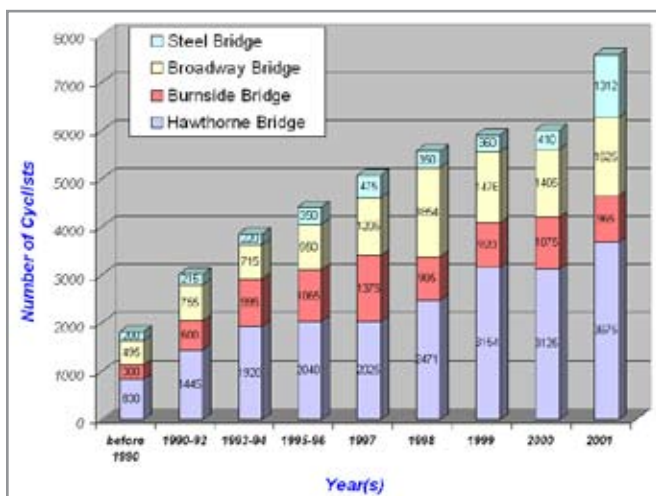


Figure 2. Bridge bicycle traffic on four main Willamette River bridges.

CONCLUSIONS AND RECOMMENDATIONS

This decade-long effort has been a major factor in Portland's increasing bicycle use because of the crucial links these bridges provide into downtown. It also has been positive for pedestrians and people with disabilities, for several reasons:

- Bike and pedestrian conflicts have either been largely eliminated through the installation of on-street bike lanes, or reduced through the provision of more or alternative space.
- All curb ramps have been upgraded to meet ADA standards.
- Missing sidewalk connections have been installed.
- Pedestrian-motorist conflict areas at approaches were improved.

The most dramatic and expensive improvements have had the most significant impact. Relatively low-cost improve-

ments such as the blue bike markings in conflict zones, bike lanes on certain approaches, and signs were not as significant to increasing bike use as were the major cost items, such as providing a new shared-use path, widening the sidewalk, and replacing sidewalk surfaces and approaches. For example, bike use on the Burnside Bridge tripled when bike lanes were installed in 1993 (at a cost of \$20,000), but has remained flat since that time at less than 1,000 daily cyclists. In comparison, bike use on the Hawthorne Bridge tripled to more than 3,000 daily cyclists because of the much-improved sidewalks and access improvements (at a cost of more than \$1.3 million). Similar increases were seen on Broadway Bridge (a cost of \$300,000) and Steel Bridge (a cost of more than \$10 million) following improvements.

A key to the heavy and increasing concentration of bicyclists on the Hawthorne, Steel, and Broadway bridges as opposed to the Burnside and other bridges is that on these three bridges' spans, bicyclists are off-street on either wide sidewalks or shared-use paths, with bike lanes on the approaches. In addition, the city added bicycle lanes to all streets connecting to the Hawthorne, Steel and Broadway bridges, overcoming a major hurdle in getting people to the bridges. In contrast, on the Burnside Bridge, cyclists operate in striped bicycle lanes adjacent to traffic, which is uncomfortable for some cyclists. And, there are no connecting bike lanes on the approaches or connecting streets.

COSTS AND FUNDING

The total cost of bridge improvements to date is over \$12 million, funded through a variety of sources (see table 1 above).

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Lighting and Advance Warning of Bicyclists in the Knapps Hill Tunnel

BACKGROUND

The Knapps Hill tunnel is located on U.S. 97A in the North Central region of Washington State. U.S. 97A is a scenic route that parallels the Columbia River north from Wenatchee through the resort city of Chelan on the south shore of Lake Chelan. This route offers views of wildlife including deer, bighorn sheep, eagles and an occasional moose, making it an attractive ride for the weekend biker and large bicycle groups. The Knapps Hill tunnel was originally constructed in 1936. The tunnel is approximately 214 m (700 ft) long on a 6 percent grade and, unfortunately, only 7.6 m (25 ft) wide. The steep grade and narrow width of the tunnel meant that slower moving bicycles would be in the driving lanes during their ride through the tunnel.

COUNTERMEASURES

The tunnel had no illumination until 1957 when a contract was let to place fluorescent lights through the length of the tunnel. The original bicycle/pedestrian warning system



Greg Morehouse, WSDOT North Central Region



may have been installed at the same time, but is thought to have been in place at least by 1967. The system consists of a push button at each portal that activates flashing beacons on a "PED OR BIKES IN TUNNEL" sign located in advance of each end of the tunnel. The flashing beacon operates for a period sufficient for the bicyclist to travel through the tunnel. The shoulder was widened to allow bicyclists to pull off the road safely to activate the push-button. The system has been modified since the original was installed but remains basically unchanged. In 1988, the illumination system was upgraded with 400-watt, high-pressure sodium luminaries. The upgrade also allows the internal tunnel

lighting to adjust based on the ambient lighting conditions outside. This minimizes the blinding effects of driving into vastly different lighting conditions.

EVALUATION AND RESULTS

No specific studies have been performed to evaluate these improvements, but adding flashing beacons for advanced warning and illumination systems are common components in our established safety standards.

CONCLUSIONS AND RECOMMENDATIONS

This system is performing well for the current levels of bicycle and vehicular traffic, and there is no plan for an upgrade at this time. The tunnel structure itself is currently being retrofitted with a concrete liner that maintains the current width and stabilizes the rock behind the existing wooden structure. Any future upgrades for bicycle safety would more than likely involve moving the bicycle traffic to an alternate route.

COSTS AND FUNDING

Information obtained from: <http://inform.enterprise.prog.org/p22.html>

The flashing warning system cost \$5,000 to build and install in 1979. These costs were relatively low as a power supply was already in place to provide lighting on the tunnel. Had this not been the case, installation costs would have been significantly higher.

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Back-in Diagonal Parking with Bike Lanes

BACKGROUND

McLoughlin Boulevard, a minor arterial laid out at the turn of the century, was no longer serving the surrounding land uses and users well. Along segments, this arterial was wider than its traffic volume necessitated, especially in the area of Clark College. The segments under study had one to two wide lanes in either direction and often no parking or parking limited to parallel stalls (see figure 1). Complaints typically focused on problems with driver speeding, lack of bicycle facilities, strong parking demand in areas with limited supply, and long pedestrian crossing distances to reach transit stops. Complaints about conventional diagonal parking focused on the restricted line of sight parkers had when leaving a stall and the insecurity of bicyclists in cycling along zones with conventional diagonal parking.



Figure 1. Four lane configuration before back-in parking.

Diagonal parking in the City up to the point of this demonstration project was laid out conventionally by staff to allow drivers to enter 45-degree stalls head-in along some of the wider arterials. Research by the City in the 1970s documented the risk of vehicle-to-vehicle collisions

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Contributions by Ali Goudarz Eghtedari PE; John
Manix PE, PTOE

when using head-in diagonal parking on an arterial street. To mitigate this concern, City engineers separated diagonal parking lanes from travel lanes with a full 3.7 m (12 ft) buffer lane for vehicle queuing (figure 2). The McLoughlin Boulevard corridor also lacked bike lanes, with the result that some bicyclists chose to ride on the sidewalk along this street (figure 3). Over time, this layout became less opportune as head-in diagonal parking facilities were difficult to combine with bicycle lanes. This demonstration project moved forward because of the desire of our Parks and Recreational Department for both additional on-street parking and enhanced bicyclist access to their facilities along a segment of McLoughlin Boulevard that lacked parking.



Figure 2. Traditional diagonal parking with buffer lane, no bike lanes and incomplete sidewalks (1 block east of back-in zone).



Figure 3. Bicyclist access before bike lanes.

In the treatment section, McLoughlin Boulevard:

- is a minor arterial,
- had two striped lanes in each direction and no parking,
- was identified as a facility with future bike lanes in the city's bike plan,
- had an ADT of 6,800 in 2000.

In a zone to the east of the demonstration area, McLoughlin Boulevard has head-in diagonal parking with a 3.7 m (12 ft) buffer lane (shown in figure 2).

This demonstration project had three objectives, to assess whether:

1. back-in diagonal parking would function as well as head-in diagonal parking in regard to safety and community acceptance,
2. back-in diagonal parking would allow bike lanes to replace vehicle buffer lanes for motorist maneuvering space, thereby improving bicyclist access, and
3. the narrower street cross-section devoted to motor vehicle travel would lower the 85th percentile speeds.

The existence of back-in diagonal parking in other cities was not widely known in Vancouver at the time of the original proposal in 2000. Staff became aware of this option in 1997 when bicycling in Seattle's Queen Anne district and from other cities (see figures 4–7). Interactions between parkers with motor vehicles, bicyclists and pedestrians were photographed and videotaped in other locations, although the combination with a bike lane was not observed during several annual observational visits. Other sections of Seattle used back-in parking along streets with very steep grades. Initial proposals were developed using photo simulations in Adobe Photoshop® overlaying photos of Seattle parked cars with Vancouver project sites.

Staff primarily relied on Seattle staff's written positive collision experience with this layout of parking,¹ as repeated literature review and research did not find many other examples to evaluate until the project was well underway. Soon after 2002, articles began to appear in the ITE Journal concerning renewed interest in back-in parking (Edwards, 2002) and concern about its rediscovery (Box, 2002). Over the last four years, staff has exchanged information with over 10 jurisdictions with back-in parking and those contemplating it. Through site visits and e-mail discussions, 23 communities in the US have been identified as having some form of back-in diagonal parking, and at least four of



Figure 4. Seattle—Merchants prefer the view.



Figure 5. Washington, DC—Back-in parking used on streets with bike lanes.



Figure 6. Seattle—back-in parking with neighborhood commercial land use.



Figure 7. Tucson standard for mixed-use downtown—bicycle and back-in angle parking.

those have combined back-in parking with bike lanes as of 2004 (see Appendix).

Initial treatment sites along McLoughlin Boulevard were selected during a Neighborhood Traffic Management planning process in 1999–2000. The initial parking concept proposal languished until a facility plan for a public swimming pool proposed tearing down a heritage house for parking lot expansion in Hough. Community support for back-in diagonal parking grew, as it would allow neighborhood associations to improve the surrounding parking supply while providing bicycle access to surrounding public facilities and protecting existing housing stock. The site of this demonstration was relocated one half-mile east of the original site, after a request by the Parks & Recreation Department for more parking in front of another pool guaranteed funding for the striping demonstration project. Additionally, engineering staff considered this site to be less politically risky for a long evaluation period as it had a greater supply of off-street parking, thus allowing drivers uncomfortable with back-in parking other parking options.

COUNTERMEASURES

The demonstration project relied primarily on new bike lane striping, stenciling and signs to create back-in, diagonal parking stalls along a zone that did not have pre-existing parking. The pre-project lane configuration generally was four lanes with a striped center line for an 18.6 m (61 ft)–wide street (shown in figure 1) classified as a ‘minor arterial’ with 7,000 vehicles per day. The post-project lane



Figure 8. After conversion—two lane configuration with back-in parking on one side.

configuration has added separate lanes for parking and bike lanes while removing one lane in each travel direction (see figure 8 and table 1).

The proposed addition of street textures for traffic calming and bulb-outs for reduction in pedestrian crossing distances could not advance until engineering evaluation of the parking demonstration was completed and additional construction funding was found. The project was initiated in the summer of 2002.

Time and understanding of the opportunities of this type of parking was important for many of the stakeholders in order for trust to develop. Initial interactions among stakeholders could be best summed up by one council member’s comment on the idea; “cockamamie.” Others suggested that it belonged downtown where more parking supply was needed and the speeds were slower. Support for the demonstration project was developed through repeated dialog with surrounding neighborhood associations and large institutional property owners, and then waiting for them to request project initiation at a later date. The bicycle community had guarded support for the project, as it provided 0.8 km (0.5 mi) of additional bike lanes in an area with many residences and civic facilities (two swimming pools, a college, a high school, and a recreational center). Outreach to other stakeholders (elderly recreation facility clients, students, bicyclists, transit riders, pedestrians, and parkers) was accomplished by posting information on the City Web site, holding neighborhood newsletter discussions and a televised council session, and the posting of flyers on windshields, bus stops, and sidewalk A-boards along the project area. Final institutional support for the project was found after the transportation manager visited Seattle and observed back-in parking in use. The project then advanced to City Council for final, though guarded, approval.

EVALUATION AND RESULTS

This demonstration project has been evaluated using video analysis of vehicular interaction with parking (30 hours over six weekdays while college was in session), observational studies, feedback from users, review of collision rates and speed surveys, and review of citizen complaint files.

Table 1. Lane Configurations Pre- and Post-Project

Lane Type	Bike Lane	Parking Lane	Travel Lane	Travel Lane	Parking Lane	Bike Lane
Before	None	None	4.6 m (15 ft)*	4.6 m (15 ft)*	None	None
After	1.8 m (6 ft)	4.9 m (16 ft)	3.7 m (12 ft)	3.7 m (12 ft)	2.4 m (8 ft)	1.8 m (6 ft)
Notes: Prior to 2002 there were two lanes in each direction.						

DIAGONAL BACK-IN PARKING (FIGURE 9)

- Some drivers had difficulty backing into spaces when few cars were parked versus when stalls surrounded by other parked cars, as there was less spatial reference as to where the stalls were located while executing the turn unto a stall.



Figure 9. Driver backing into stall.

- A few drivers preferred to pull into a back-in space by looping in through empty adjacent stalls versus stopping in the bike lane and backing up into a stall—this behavior was not forecast before design.
- The 1.8 m (6 ft) bicycle lane was adequate to provide drivers space for reversing into the parking stall with traffic.
- Drivers that violated (drove through them without parking) the bike lanes and parking zones were typically leaving or entering the driveways nearest the parking zone versus drivers that were just driving through the zone.
- No drivers were observed violating the parking zone when cars were parked in it or when bicyclists were using the bicycle lane.
- Loading and unloading from parked vehicles is easier from the curb area (figure 10).



Figure 10. Easier unloading at the curb with back-in parking.

VEHICLE TO PARKER CONFLICT (FIGURES 11 AND 12)

- No bike to parking or exiting parking vehicle conflict was observed on the video footage, but there were too few joint actions to judge this interaction between these street users.
- No vehicle to parking or exiting parking vehicle conflict was observed on the video footage.



Figure 11. Bicyclist's view along back-in parking zone.



Figure 12. Exiting driver's view of approaching traffic along back-in parking zone.

BICYCLE TRAFFIC FLOWS

- Bicycle traffic increased from 1 to 6 percent of all east-bound vehicular traffic along the project area (tube counts pre- and post-project—10h00 to 11h00) during an average hour of use.
- Total bicycle traffic increased 235 percent from 17 bicycles (hose count—April 24, 2002) to as many as 44 bicyclists (video analysis—Oct. 16, 2002, 10h00 to 14h00, clear warm weather) after the bike lanes were added.

- Bikeway facilities provided more direct benefit than on-street parking facilities at this location (44 bicyclists versus eight drivers who parked during period with highest parking utilization—Oct. 15, 2002 video analysis).
- No recognized avoidance of back-in parking zone versus conventional parallel parking zone by either advanced (A type) or experienced (B type) bicyclists riding next to parked cars—and both zones had similar traffic flows (19 versus 25 riders on Oct. 15, and 19 versus 21 riders on Oct. 16).

LANE CONFIGURATION EFFECT ON SPEEDS

The secondary objective of adding bike lanes and parking lanes was to reduce the traffic speeds along this corridor. The travel speeds along this section of McLoughlin Boulevard are historically higher than posted, causing concern among neighborhood leaders and other street users such as pedestrians and bicyclists, as identified during the Neighborhood Traffic Management planning process.

- The post-project travel speeds were not calmed. They increased slightly (see table 2). There is a visual break between the section west of the project area, which is a much more pedestrian-scaled, shared-use neighborhood. The project area, by contrast, is bordered by open-space land uses (sports fields) with few driveways and long blocks. In the next phase, enhanced pedestrian crossings with calming measures will be implemented.

Table 2. Eighty-Fifth Percentile Speed Pre- and Post-Project

	East-Bound Traffic	West-Bound Traffic
Before	35.1 mph	36.7 mph
After	38.5 mph	38.3 mph
Notes: This street is posted as a 25 mph zone.		

COLLISION HISTORY

- There were few collisions in both the pre- and post-time periods, so the project's influence on the collision rate along the parking zone is inconclusive. During 2000–2002 there were two collisions versus three collisions in the 2002–2004.
- All except one of the collisions in both periods involved two vehicles, where one vehicle turning left into a driveway failed to yield to oncoming traffic.
- Both periods had one injury reported closest to the parking zone. The entire bike lane zone (which ex-

tends beyond the parking project area) had a total of six injuries before the addition of the bike lanes and one injury after.

- None of the reported collisions or injuries involved a bicyclist or driver undertaking a parking or exiting parking maneuver.

Our office is currently working on extending this back-in parking and bike lane zone further to the west and the east for 2440 m (8000 ft) total, as requests for work are generated by property owners and neighborhood associations. Two projects are currently in the design stages. Both should be constructed during the summer of 2005.

CONCLUSIONS AND RECOMMENDATIONS

Recommendations for future Vancouver projects included the following:

1. Widen the standard parking stalls from 2.7 m to 2.9 m (9 ft to 9.5 ft) or provide other stall position guidance (raised markers, etc.).
2. Adopt a supplemental back-in parking sign adapted from Salt Lake City (figure 13).
3. Adjust striping layout to add turn lane for west bound traffic into western entrance of parking lot (site specific).

This treatment has been very effective at balancing bicyclist access (increase in trips) while providing for growing parking demand. The adoption of recommendations #1 and #2 has met resistance from our maintenance crews ('another sign to stock' and 'if the drivers need the pavement markers, then there must be a problem with this type of parking...'). The proposed projects will be using the wider stall (2.9 m (9.5 ft)).



Figure 13. Salt Lake City sign adapted for use in Vancouver.

The use of photo simulations of the planned parking scenario was very helpful during the staff and public process stages, as few if any stakeholders had experienced this type of parking before or remembered doing so while visiting Seattle in the past (figures 14 and 15). This type of parking demands a lot of public discussion and process, more so than any other striping project we have typically under-



Figure 14. Simulation before back-in parking.



Figure 15. Simulation after back-in parking.

taken, especially since we were adding parking and not removing it. It would be ideal if a stakeholder group (business, engineers, residents, etc.) were able to visit a city with this type of parking before adopting it on a district-wide basis.

Vancouver plans to adopt the back-in form of diagonal parking along wider arterials where bike lanes are desirable and the surrounding land uses support pedestrian trips and shared uses. The use of conventional diagonal parking with bike lanes is not acceptable. Where bike lanes are required and back-in parking is not adopted, (low resident and business support) parallel parking shall be used. Back-in parking with bike lanes might be thought of as a kind of “road diet plus”—having parking and bike lanes but still keeping a narrower cross section to constrain car traffic. Road diets usually involve choosing between parking or bike lanes with the extra space going to center turn lanes.

COSTS AND FUNDING

An original budget of \$5,520 for signs, striping and traffic control was established. This cost was split between the Transportation Services and the Parks and Recreation departments (the parking was located in front of their recreation facilities and at their request). We are applying for the second portion of \$100,000 Community Development Block Grant (Federal funds) money to fund pedestrian crossings. These funds join \$80,000 funded for the striping and refuge islands.

REFERENCES

- John Edwards, Angle Parking Issues Revisited, 2001 *ITE Journal*, February 2002
- Paul Box, Changing On-Street Parallel Parking to Angle Parking, *ITE Journal*, March 2002

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¹ “It is my understanding, the last research on accident history in the 1970s indicated a 3-1 ratio of more reported accidents occurring in relation to head-in parking spaces as distinct from back-in,” wrote Billy Jack, City of Seattle to Todd Boulanger in 2001.

APPENDIX

CITIES WITH BACK-IN DIAGONAL PARKING

- Seattle, WA★
- Olympia, WA
- Tacoma, WA
- Vancouver, WA ★
- Everett, WA
- Portland, OR
- Salem, OR
- Ventura, CA
- San Francisco, CA
- Tucson, AZ
- Salt Lake City, UT
- Honolulu, HI
- Charlotte, NC
- Indianapolis, IN
- Montreal, QC
- Pottstown, PA★
- Plattsburgh, NY
- Knoxville, TN
- Birmingham, MI
- Marquette, MI
- Washington, DC★
- Arlington, VA
- Wilmington, DE

Valencia Street Road Diet—Creating Space for Cyclists

BACKGROUND

Bicycle lanes and wide curb lanes are common on-street facilities for accommodating and attracting bicyclists. As it is a goal of the city and county of San Francisco to encourage cycling as a viable transportation option, efforts are constantly made to find and create opportunities for the installation of bicycle facilities. However, with a population of about 780,000 people in a 47-square-mile space, San Francisco is a very dense and congested city where a variety of mode users compete for limited street space. While this reality is one reason that bicycling is a popular way to travel through the city, it also complicates the installation of bicycle facilities.

In order to implement the city's bicycle route network, motor vehicle lanes must often be removed to create space for bicycle facilities (often referred to as a "road diet"). San Francisco is a walkable city where mass transit is heavily used and elevated freeways are being torn down rather than constructed. The effects of such road diets on all road users must, however, be considered and sufficiently studied before final approval and implementation.

Although road diets have been implemented to create room for bicycle facilities on at least 16 streets throughout the city, this case study will focus primarily on the experience with Valencia Street, with passing reference to another road diet on Polk Street. Additionally, experiences with proposing and studying road diet projects in general will be shared as appropriate.

Michael Sallaberry, Assistant Transportation Engineer, San Francisco Department of Parking and Traffic

VALENCIA STREET

Valencia Street is a 19.1 m (62 ft 6 in)–wide street through a shared-use area of mostly two- to three-story buildings with commercial at street level and residential units above, and metered on-street parking on both sides. The street lies in a grid pattern and is paralleled by four other north-south arterials. Before the project, the arterial was a four-lane street with an Average Daily Traffic (ADT) of approximately 22,000 vehicles per day. A motor coach transit line with a headway of 15 to 20 minutes travels along the street. There is a heavy pedestrian presence because the street is a popular area with restaurants, nightclubs, and a variety of shops. All intersections have signals. A photo of Valencia Street with four lanes before the road diet is shown below.



Figure 1. Valencia Street before road diet.

COUNTERMEASURES

Though the bicycle community wanted a road diet performed along Valencia Street, the local department of transportation was not willing to reduce capacity along this important north-south corridor. Valencia Street can be used as a surface street alternative to the Central Freeway, which was damaged by the 1989 Loma Prieta earthquake. Eventually, after a series of community meetings and public hearings, the city Board of Supervisors voted

on a resolution in November 1998 calling for the removal of two travel lanes and the installation of bicycle lanes and a median lane for left turns on a one-year trial basis. In March of 1999, work was completed on Valencia Street with the road diet performed from Market Street at its north to Tiffany Avenue to the south, a length of approximately 1.8 miles.

Please see figure 2 below for a picture of Valencia Street after the road diet.

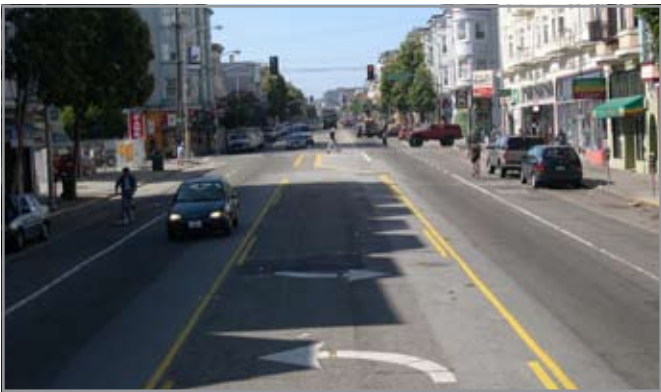


Figure 2. Valencia Street after road diet.

To minimize the loss of capacity along Valencia Street and reduce the impacts to parallel streets, changes were made to the signal timing along Valencia Street and Guerrero Street one block to the west. On Valencia Street, the green time was maximized for the Valencia Street split while still maintaining time for pedestrians crossing Valencia Street. On Guerrero Street, the signal offsets were modified to promote a smoother progression at 25 mph, as the speed limit was lowered from 30 mph to address citizen concerns along the primarily residential street. The speed limit change and signal timing modifications were intended to address speeding concerns and help mitigate the likely increase of traffic along Guerrero Street.

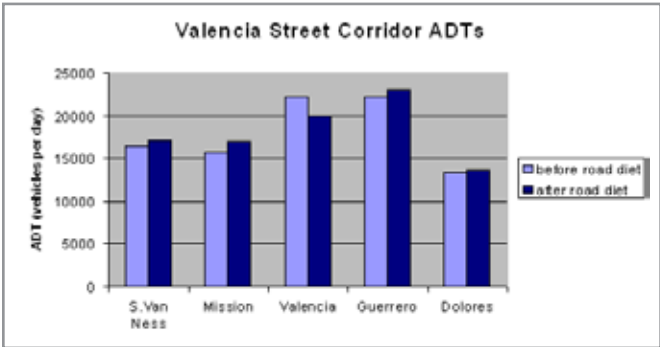
EVALUATION AND RESULTS

Before the work was started, baseline data were collected for use in a before-after report evaluating the road diet. As the project was done temporarily for a one-year trial period, the results of the report would be presented at various public hearings with the project to be voted on by the Board of Supervisors. If the project were rejected, the street would be returned to its previous four-lane configuration.

Traffic volumes were recorded along Valencia Street and the four parallel arterials surrounding it to determine if there

was spillover traffic from Valencia Street and where it went. The counts were taken using pneumatic devices laid across the roadway that automatically counted vehicles. The counters were installed at the same location on all five streets.

After determining the green times for Valencia Street, it was predicted that 10 percent of Valencia Street traffic would divert to parallel streets after the road diet was performed. Following is a table showing before and after ADTs for the five roadways along the corridor. As expected, Valencia Street traffic volumes dropped by 10 percent.



Collision data were also collected to determine if safety was improved with the new design. As the trial was for one year, it was difficult to come to any statistically significant conclusion for the before-after report. However, as it has now been a few years since the installation of the bike lanes, the collision data analyzed include a larger sample size.

The table below summarizes the collision data results. The values in the table are average monthly collision totals for each respective collision type, and not rates.

Table 1. Collision Data for Valencia Street, Before vs After Road Diet*

	Before 1/95-12/98	After 3/99-12/01	Percent Change
Total Collisions	5.9	4.7	-20
Midblock Collisions	1.1	1.4	27
Intersection Collisions	4.9	3.4	-31
Bicycle Collisions**	0.67	1.0	49
Pedestrian Collisions	0.83	0.53	-36
* Collisions per month			
** Bicycle collisions not included during 1996 and 1997 due to lack of reporting so the before period reflects only 1995 and 1998 data.			

Total collisions declined by 20 percent, though the overall drop was less dramatic when one considers that the ADT along Valencia Street dropped by approximately 10 percent. Also, a signal upgrade project was completed along Valencia Street in 1997 that increased signal visibility and helped reduce the overall collision rate. Thus, it is difficult to come to any definite conclusions regarding the effect of this road diet on overall collision patterns along Valencia Street.

Although bicycle collisions increased by approximately 50 percent, the increase was outpaced by the 140 percent rise in ridership along the street. This net decrease in collision rate for cyclists mirrors the increased comfort cyclists report feeling along the street.

Collisions involving pedestrians dropped by 36 percent. This could be viewed as a byproduct of the traffic calming effect people along the street have anecdotally observed. With lower speeds and fewer lanes, motorists are able to avoid collisions with pedestrians more easily. According to anecdotal accounts, pedestrian volumes on Valencia Street have increased the past few years as the street has thrived commercially and attracted even more foot traffic.

Bicycle counts were taken along Valencia Street before and after. Ideally, counts also would have been taken on parallel streets to determine how much of the rise in cyclists along Valencia Street was attributed to new cyclists or to cyclists transferring from parallel routes. Also, a number of counts should have been taken to come up with an average that better accounts for fluctuations in cycling volumes that occur with time of year, weather conditions, etc.

A bicycle count taken on Valencia Street prior to the road diet showed 88 bicyclists per afternoon peak hour. After the road diet, a count yielded 215 bicyclists per hour, a 140 percent increase. As no counts were taken on parallel streets before the road diet, it is difficult to know what percentage of these cyclists were new cyclists or cyclists from parallel streets. Speaking with cyclists, however, it is clear that many were new cyclists willing to try bicycling once they saw the bike lanes installed.

Public response was recorded using a hotline voicemail system that was advertised on two signs installed prominently along the roadway. The number of e-mails and letters submitted were also considered. Care must be taken to ensure that the source of public input is considered. For instance, do 200 form letters sent as part of a mail in campaign outweigh 20 individually written letters? Regardless, the ability to directly hear from the public

was instrumental in understanding how various people responded to the changes and what successes or problems were associated with the changes.

Public response to the road diet project was supportive. A hotline was advertised along Valencia Street on two prominent signs directly after the road diet. From the 286 recorded calls, 259 were supportive of the project while 27 were opposed. Of letters and e-mails received, 39 supported the project while three did not. A postcard campaign led by the local bike coalition yielded 484 supportive post cards and four not supportive.

As this was the first road diet studied in San Francisco, there were some data that could have been collected for a more complete study but were not. They include: transit travel time and delay data, travel time and delay data for motorists, double parking observations, and spot speed surveys. Other data that could have been collected for a very thorough before-after study could include: noise levels, cyclist compliance with laws, and surveys of residents, merchants, cyclists, motorists, and pedestrians.

CONCLUSIONS AND RECOMMENDATIONS

Although the project was initially controversial within the local department of transportation and some members of the community, the general consensus is that the project is a success. Bicycling along the street has increased dramatically and has made the street the second most heavily used bicycle route in the city. Collision rates for cycling have dropped on the street. The merchants association has shown support for the road diet that has made the street seem like more of a destination rather than through arterial. Although some traffic has spilled over to adjacent streets, it is likely that much of that traffic is through traffic with no intention of stopping along the street anyway. Thus, merchants' fears that less traffic meant less business were not substantiated, in general.

With public outreach initiated by the bicycle coalition and mandated by the nature of a one-year trial, giving stakeholders plentiful opportunities to be involved in the process was an important aspect of the project's success. Also, the use of a trial allowed everyone to see how the project operated in real life, especially useful for skeptics. It is important to have a trial of sufficient length to allow any changes in traffic patterns to come to an equilibrium. One year is a good length, with six months as a possibly sufficient length of time. With any trial, the process should be made clear to the community so that there are no misguided expectations.

As this was the first trial road diet in the city, some data was not collected that would have been helpful. The effect on transit was not sufficiently studied. Travel time and delay studies for both transit and motor vehicles would have been helpful. Also, bicycle counts on parallel streets would have provided a better picture of where the increase of cyclists originated. While speed data would be helpful on road diet projects in general, the nature of Valencia Street is such that speeds are so variable given the short blocks, the changing traffic levels, the presence of double parking, etc. that collecting consistent before and after data would have been difficult.

Although the road diet created significantly more work when it was designated a trial, it was worthwhile to study and thoroughly discuss the project. Since the Valencia Street project, the city government and public has been generally more receptive to the idea of road diets. One example of a road diet whose approval was made more likely by Valencia's success was Polk Street, a similarly controversial project.

Polk Street is a 13.6 to 15.1 m (44 ft, 9 in to 49 ft, 9 in)-wide street with metered on-street parking on both sides. Like Valencia Street it travels through a shared-use area and lies in a grid pattern with one and two-way parallel arterials. Before the project, the street was a three-lane street with two lanes serving the heavier southbound direction. Depending on which section of Polk Street, the ADT ranged from 11,000 to 16,000 vehicles per day. A motor coach transit line with a headway of 10 to 20 minutes travels along the street and pedestrian presence is significant. Nearly all intersections have signals. Polk Street was installed as a six-month trial and also underwent a review of a before-after report. As with Valencia Street, the road diet on Polk Street was also eventually approved as a permanent installation.

REFERENCE

Valencia Street Bicycle Lanes: A One Year Evaluation, Michael Sallaberry, San Francisco Department of Parking and Traffic, December 14, 2000

COSTS AND FUNDING

For paint and sign work, and labor spent writing the report, the road diet cost \$130,000.

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Shoreline Park Expansion Project—Provision of Bicycle and Pedestrian Enhancements

BACKGROUND

A segment of Shoreline Drive, designed and constructed as a California Department of Transportation (Caltrans) facility, provided excess vehicle capacity that was atypical of a Santa Barbara street. Furthermore, with only a 1.5 m (5 ft) sidewalk, this coastal connection between residential neighborhoods, Leadbetter Beach Park and the Santa Barbara Waterfront, was inadequate for the thousands of pedestrians accessing the Waterfront each week. Pedestrians commonly stepped into the street or onto the coastal bluff top to avoid one another on the sidewalk. Finally, bicyclists riding the existing bike path which terminated to the east of the project were frequently observed riding on the sidewalk or riding the wrong way on the street.

This project's goals reflect those in the Local Coastal Plan, the Shoreline Master Plan and the Circulation Element of the General Plan. These are: reducing the speed on the roadway and improving the transition for pedestrians and bicyclists between Shoreline Park and Leadbetter Beach Park.

This roadway segment, with no intersections or driveways, carried 8,600 average vehicle trips per day (ADT). The already existing two-lane portion of Shoreline Drive contiguous with the project carried slightly less traffic (8,400 ADT) and operated at a Level of Service (LOS) B during peak times with no roadway link delays, with the exception of the occasional left-turning vehicle. The project section of the roadway was expected to operate at the same LOS B or better because there are no opportunities for left turns in the project section of the roadway.

No changes were proposed to entering lane configurations at any intersections connected to the project. There-



Road diet created off-road space for bicyclists and pedestrians to connect an ocean-front park with a marina and shopping district.

fore, the LOS at Shoreline Drive's intersections with Loma Alta Drive and La Marina Drive, which operated at LOS A and B respectively during the afternoon peak weekday hours and weekends, were not expected to change.

The new section of the roadway was anticipated to operate at slower, safer speeds. At two lanes in each direction, the project section of the roadway was signed for a maximum speed of 35 mph and experienced 85th percentile speeds of 37 mph eastbound and 40 mph westbound. Because the roadway was wide and invited speeding, speed spiking occurred above 50 mph.

The primary objective of the project was to provide increased capacity for pedestrians and bicycles. Therefore, alternatives to the project also had to meet this objective. Because of public demands to retain the roadway's capacity while still improving the pedestrian facility, two alternatives were considered that would have allowed the existing four-lane roadway to remain: widening the existing sidewalk and constructing a Class 1 bike path to the south (toward the ocean); and constructing a new, wide sidewalk and Class 1 bike path on the north side of the existing roadway (toward the coastal bluff).

Drusilla van Hengel, PhD. Mobility Coordinator,
City of Santa Barbara



Four lanes separated by a median provided excess vehicle capacity. Space was needed for bicyclists and pedestrians.

The alternative to construct the project to the south was determined to be infeasible because of coastal resource and environmental impacts. The existing sidewalk runs along a coastal bluff and cliff with drop-off varying from 4.6 m (15 ft) to 13.7 m (45 ft). Below the cliff lies the beach and the Pacific Ocean. Staff of the Coastal Commission stated that construction of retaining walls on the beach to widen the sidewalk and construct a Class 1 bike path would not receive staff support and most likely would be defeated by the Coastal Commission.

The second alternative was to construct a new sidewalk on the north side of Shoreline Drive. Although the cost would be significantly higher than the proposed project, a 2.4 m (8 ft) sidewalk could be constructed in this location. However, there was inadequate width for a bike path without extensive retaining walls. A coastal bluff about 12.2 m (40 ft) high lines the north side of Shoreline Drive, within the project area. Beyond the bluff are privately-owned residences and three condominium complexes. The city's experience with other sidewalks that are across the street from the beach is that they are less desirable by the public compared to beachside walkways. Therefore, the city did not pursue this alternative.

COUNTERMEASURES

In spring 2004, the city of Santa Barbara modified and improved this half-mile, four-lane section of Shoreline Drive by providing pedestrian enhancements and bicycle facilities for novice cyclists, as well as landscaping that allows pedestrians to enjoy the ocean while separated from motor vehicles. The excess road capacity on the ocean side of the existing median was converted to meet the

demand placed on the segment by pedestrians and bicyclists. Both directions of mixed-flow motor vehicle traffic now travel on the north side of the existing median as a two-lane road with an uphill Class II bike lane. The existing eastbound travel lanes, with a tremendous ocean view, were converted to a 3.4 m (11 ft) bikeway, a 4.6 m (15 ft) parkway, and an expanded pedestrian promenade within the portion of Shoreline Drive that is south of the existing median between Loma Alta and La Marina Drive. A midblock pedestrian crossing is provided and the existing sidewalk was substantially widened to create a promenade. The Class I bikeway is separated from the walkway by turf.

EVALUATION AND RESULTS

The project was constructed in spring 2004 and had not yet been evaluated at the time this case study was written. Two obvious results of the project are the elimination of wrong-way bicycle riding on the street and increased capacity for pedestrians. A beaten path adjacent to the widened sidewalk on the new turf indicates that many pedestrians are using the grass for walking or jogging as well. Finally, the project eliminated the opportunity to pass slower cars, as motorists driving at excess speeds are forced to slow down when trailing other motorists driving at or below the speed limit.

CONCLUSIONS AND RECOMMENDATIONS

Although early planning and engineering design efforts were difficult because of the lack of public support for change in the area, especially the lane reduction, overall



Two lanes on one side of original median were converted to a two-way off-road bikeway and a pedestrian facility.

public response to this project has been favorable since its opening. In addition to the increased capacity for bicyclists and pedestrians, the lane reduction had some effect on lowering vehicle speeds, which may allow the city to reduce the speed limit in this area.

COSTS AND FUNDING

This project was funded through the Coastal Resources Enhancement Fund, the California Resources Agency, Transportation Enhancement Funds and the City of Santa Barbara.

Source	Funds
Coastal Resources Enhancement Fund	\$50,281
California Resources Agency	\$273,295
Transportation Enhancement	\$570,000
City of Santa Barbara	\$228,719
Total Cost	\$1,122,295

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Bicycle Treatments on a Former Pedestrian Mall

BACKGROUND

This paper describes a unique street project in downtown Eugene, OR. The city staff and the community have moved up a “learning curve” during the past decade in regard to on-street treatments for bicyclists and motorists sharing the same lanes. This project presented an opportunity to combine very narrow lanes and other design elements in a way that resulted in a truly slow-traffic, pedestrian-oriented street in the heart of downtown.

In 2002 a three-block section of Broadway in downtown Eugene, OR, was reconstructed and reopened to vehicular traffic. This portion of Broadway had been part of the downtown pedestrian mall created in the early 1970s. Two other street segments were previously rebuilt and reopened to traffic—a two-block section of Olive Street in 1992, and two blocks of Willamette Street in 1996.

While there was widespread agreement in the community that the pedestrian mall had failed to achieve the goal of revitalizing downtown Eugene, all three street reopening projects were somewhat controversial, and each project went forward only after winning approval at a city-wide election. Now that all portions of the former mall have been converted to pedestrian-oriented streets with slow-moving auto traffic, the overall results have been received favorably. However, the mix of vehicle and bicycle traffic on each street has been the topic of much discussion and feedback. Experience with the Olive and Willamette Street projects led the project team to modify the street design for Broadway, and the results appear to be more agreeable to most of the bicyclists, pedestrians and motorists using the street.

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City of Eugene, OR
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Over the past three decades Eugene has developed an extensive system of bikeways. The network includes off-street paths, on-street striped lanes on busy streets, and designated bike routes on selected neighborhood streets to help provide continuity. Within the downtown area several of the busiest one-way streets have bicycle lanes but there are still some gaps in the network, leading to increased use of sidewalks as well as bicycling on unstriped streets. City ordinances required bicyclists to dismount and walk their bikes on the former pedestrian mall, though enforcement was minimal. For these reasons, when the decision was made to begin converting segments of the mall to reopened streets, city staff recognized the opportunity to enhance the downtown bicycle network by providing for bicycles on these street segments.

EARLIER STREET DESIGNS

The designs for Olive and Willamette Streets were developed with significant input from the general public as well as major stakeholders such as downtown businesses. Early on, it was decided that on-street parking should be provided and the curb-to-curb street width should be as narrow as possible to maximize pedestrian space on the sidewalks and discourage speeding and excessive through traffic. Each street segment was designed as a two-way, two-lane cross-section. The designs also made use of techniques such as brick crosswalks; and, on Willamette, raised mid-block crosswalks to enhance pedestrian visibility and discourage high speeds. Lane Transit District buses also use Olive and Willamette Streets for several bus routes connecting to the central downtown Eugene station, so the design needed to accommodate buses as well as emergency vehicles.

The general treatment for bicycles on both Olive and Willamette could be described as a sort of hybrid “mixing” of vehicles and bicycles without using striped bicycle lanes. Each of the two-block segments begins or ends at a signalized intersection with a three-lane cross section that includes a left-turn pocket. In the middle of each segment (where these two streets cross Broadway) the street narrows to a minimal 6.7 m (22 ft) width for about 45.7 m (150



Earlier Olive Street design (4.3 m (14 ft) lanes along parking, 3.4 m (11 ft) lanes approaching Broadway) is not favored by bicyclists.

ft). In between, each street widens to provide parking bays on each side, generally 2.1 m (7 ft) in width, and the travel lanes are widened up to 0.9 additional meters (three additional feet) to provide wider lanes for the mix of autos and bicycles. The overall concept is thus a blend in which cars and bikes share the same lanes at each end and the middle, along with wider lanes in between where cars can pass bikes when the volume and speed of the auto traffic makes this feasible, such as off-peak times of the day.

As with many situations where a compromise is used to provide “the best of two worlds,” the design used for both Olive and Willamette ends up being the worst of both worlds in the opinion of Eugene’s bicycling community. Widening the travel lanes for several hundred feet tends to produce the unintended effect of “anti-traffic-calming,” particularly at off-peak periods when the volume of auto traffic does not provide enough congestion to prevent higher speeds. Some cyclists report that it feels as if certain motorists intentionally intimidate the cyclists. The overall result is that many cyclists feel uneasy or unwelcome on these two streets. (One other outcome is the continued heavy use of the adjacent sidewalks by many cyclists, which is unfortunate given the good intentions embodied in the design of each street for mixed traffic.)

For these reasons, the design of Broadway was approached in a different way, as described in the next section of this paper.

COUNTERMEASURES

The design for the three-block Broadway reopening project came together over a period of several months in the fall and winter of 2001–2002. The process involved an

unprecedented degree of interaction and cooperation among city staff and private design consultants, many of whom have their businesses along this stretch of Broadway or within a block or two. This enabled the group to use a process that came to be known as a “rolling charrette” in which 10 to 20 people at a time would walk slowly from one end of the project to the other, discussing issues and design options, and seeking agreement on the key design features for Broadway. After several of these rolling charrettes and many other informal and formal opportunities for input and dialog, the following major features emerged:

NARROW LANES

Travel lanes as narrow as 3 m (10 ft) would be used throughout the length of the three-block segment of Broadway. Unlike Olive and Willamette Streets, travel lanes would not be widened to provide for side-by-side motorists and cyclists. Instead, the expectation of very slow-moving vehicular traffic would be reinforced by having cars and bikes use the same space.

RAISED MEDIAN ISLAND

This feature, which was abandoned for the earlier designs of Olive and Willamette Streets, was re-introduced based on its overall success and widespread popularity on several older segments of Broadway and Willamette just one block away from the mall. A raised median island about 1.2 m (4 ft) in width was viewed as having several advantages. It provides more space for landscaping, thereby reducing the glare and related drawbacks to the added “hardscape” of the newly built street. By planting trees and shrubs in the median, the motorist’s view down the street is interrupted. The overall effect tends to reinforce the notion of moving slowly down a narrow street, rather than being able to see uninterrupted pavement several



Raised median islands narrow the street and offer a safe pedestrian refuge.

blocks ahead. The median provides a safe landing spot for pedestrians, who are thus encouraged to cross at multiple locations, not just intersections. And the median provides a left edge for each travel lane that helps visually narrow the lane, encouraging slower speeds.

VARIATIONS IN PAVEMENT HEIGHT AND TEXTURE

The design for Broadway uses different colors and textures of paving materials, as well as raised crossings, much more extensively than Olive or Willamette. Each block of Broadway features a mid-block crossing raised to the full height of the curb (though with a gradual transition for motorists and cyclists, to avoid a speed hump effect). The intersection of Broadway and Willamette is raised 15.2 cm (6 in) and the portion of Broadway just east of Willamette is paved in brick and raised to the height of the adjacent brick plaza, extending the raised intersection into an at-grade street section. In addition to its



Raised crossing, pavement color changes, street furniture at edge of street encourage slower speeds.



At-grade intersection and street section blend in with adjoining outdoor plaza.



The new Broadway—10 ft lanes, median islands, and parking bays.

traffic calming effect, this enhances the use of the street as an extension of the plaza on those occasions when the streets are closed for major events.

JUDICIOUS USE OF STOP SIGNS

Before the reopening of Broadway, the two locations where Olive and Willamette Streets cross Broadway were not stop-controlled. The fact that Broadway was only a pedestrian “street” meant that warrants for stop control were not met. This led to a number of complaints by pedestrians who felt cars were going too fast, or that too many motorists would not stop for pedestrians at these crossings. During the design process for Broadway, city staff estimated that the traffic volumes after completion of the project would warrant all-way stop control at the two new four-way intersections, along with the intersection of Broadway and Charnelton at the west end of the project. (The intersection of Broadway and Oak Street at the project’s east end is controlled by a traffic signal, since volumes are much higher on Oak Street, a minor arterial). The presence of stop signs at regular one-block intervals is one more feature that tends to reinforce slow speeds along Broadway, and to some extent on Olive and Willamette now that traffic on those two streets must stop at Broadway.

EVALUATION AND RESULTS

The combined visual effect of all these features provides significant reinforcement for the concept of a slow-moving, very pedestrian-oriented street. As a motorist, one tends to travel slowly and somewhat uncertainly down Broadway, perhaps because it looks so different from a typical street. It feels okay to be there only if you are going slowly enough to allow for surprises and to share the space with others who are going even slower than you.

Speed studies conducted mid-block at two locations in this three-block project indicate favorable results. The 85th percentile speed was 17 mph at one location and 18 mph at the other. Highest speeds were 23 mph. This compares favorably to the speed studies of Willamette and Olive streets at the completion of their openings where, even with raised mid-block crossings on Willamette, the 85th percentile speeds were 20 mph on Willamette Street and 22 mph on Olive.

Informal feedback from other city staff, downtown businesses, bicyclists, and the general public seems very supportive of the overall design and the specific techniques used to provide a safer and slower mix of auto and bicycle traffic. Some of this positive feedback may relate more to the favorable impression most of the community has about the look and feel of the new street. However, the general impression and community “buzz” about a project are important aspects of the project’s effectiveness and public acceptance of innovative design features.

CONCLUSIONS AND RECOMMENDATIONS

PUBLIC INVOLVEMENT

Encouraging participation by private sector consultants, key stakeholders, and interested public as full participants in the design of the project from the beginning can be a powerful tool for gaining acceptance and moving forward with strong support for the project. By the time the city Planning Commission reviewed and approved the design concept, nearly all the issues had been resolved and the various stakeholder groups all strongly supported the project as presented. Many property owners believed the opening of Broadway to automobiles was critical to their success. Their interest helped sustain the forward movement of the project.

TRAFFIC CALMING

Getting the motorists to slow down so bicyclists can share the space and pedestrians feel safe when crossing

the street appears to depend on narrowing the travel lanes as much as possible. The lanes need to be narrow in an actual, physical sense (e.g. 10 or 11 ft wide), and they need to look and feel narrow to motorists. The look and feel can be achieved by a combination of narrow lanes along with conspicuous edges (e.g. use of a median island) and design elements like trees and shrubs at the edges and in the median to eliminate the look of a long straightaway. Other components of the design included parking bays along both sides of the street, minimizing the pavement markings; lane lines and signs along the street, to avoid the look and feel of a major traffic artery; and raising the major intersection of Broadway and Willamette to meet the grade of the adjacent public plaza and create a speed table.



Parking bays, raised intersections, narrow lanes help calm traffic.

CONTINUING UP THE LEARNING CURVE

While it appears the city has developed a winning design in the case of Broadway, this example also serves to illustrate that there are probably other still-undiscovered “templates” for street designs that can meet these kinds of objectives. The best approach involves being open to experimentation and recombining various design techniques to achieve the best mix of outcomes. Broadway seems to reinforce the notion that the two best ways to provide for bikes on streets are a) striped lanes with adequate, separate spaces for cyclists and motorists, or b) very narrow lanes shared by bikes and autos. However, there are likely to be situations in Eugene and other locations where wider, shared lanes work better, or some other combination of features should be tried, especially in view of the needs of transit and emergency vehicles. Each project provides an example that can be copied or borrowed from to create even better designs for future projects.

COSTS AND FUNDING

Total cost of the project was \$2.1 million, including preliminary and construction engineering. Landscaping, irrigation, and street furniture accounted for about \$185,500. Accommodating an existing brick outdoor plaza at the center of the project and incorporating it into the street design increased the project cost considerably. A breakdown of project costs is available upon request.

Generally the city assesses a certain portion of a project's cost to adjacent property owners. Since this area had previously been a street before it became a pedestrian mall, a second assessment was not possible. However, the business owners along the project were anxious for the conversion back to a city street and donated \$200,000. The county provided \$1.6 million in road funds and the city of Eugene paid the balance from former Commercial Revitalization Loan funds.



Street furniture, bicycle racks, and landscaping were considered part of the cost of the project.

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Bike Lane Safety Evaluation

BACKGROUND

Phoenix, AZ, is the sixth largest city in the United States with a population of 1.32 million and an ideal climate for cycling. In the mid-1980s Phoenix had a very small system of bike facilities, consisting of only 75 miles, including off-street paths, signed bike routes, and a few miles of on-street bike lanes.

COUNTERMEASURES

In 1987, the City Council approved an aggressive bicycle system of 700 miles of bike lanes, bike paths, and signed bike routes to be installed over the years. The plan included providing many new miles of bike facilities as well as upgrades to existing facilities. Funding for new bike facilities increased from \$300,000 per year to \$500,000 per year in fiscal year 2000–2001. By 2000, Phoenix had developed

over 450 miles of bike facilities, including over 222 miles of on-street bike lanes. While many of the on-street bike lanes have been installed on collector streets, bike lanes are also provided on arterial streets. Furthermore, the standard cross-section for new arterial streets built in Phoenix was modified to include on-street bike lanes.

EVALUATION AND RESULTS

Traffic engineering staff wanted to determine if the new bike facilities were associated with an increase in bike crashes with motor vehicles. In addition to wanting to learn more about the how, where, and why of all bicycle crashes, staff wanted to determine how many collisions occurred in the on-street bike lanes and how these crashes were occurring. There was also a desire to know if younger children were involved in the bike-lane collisions on busy arterial streets.

A comprehensive manual review of all police reports involving bicyclists on Phoenix streets in 2000 was conducted to determine where bike collisions occurred and the age of the bicyclists in the crashes. Additional data was collected to determine the classification of the street where the crash occurred and if a bike facility existed on that street. The police report was further reviewed to determine if the bicyclist was riding on the sidewalk, along the street or in an on-street bike lane, or crossing the street when the collision occurred.

This analysis was, unfortunately, limited to collisions between bicyclists and motor vehicles on the public right-of-way based on the Arizona Department of Transportation (ADOT) Accident Location Identification Surveillance System (ALISS) computerized database. Bike crashes with fixed objects, other bicyclists, or pedestrians are not in the state database, nor are private property crashes. Furthermore, non-injury bike crashes below the reporting threshold (\$1,000) are not in the statewide computerized collision database.



Michael J. Cynecki, P.E., Traffic Engineering Supervisor, City of Phoenix Street Transportation Department



About two percent of the 36,400 vehicle collisions reported in Phoenix during 2000 involved a crash between a motor vehicle and a bicycle. While this may not seem like many, this resulted in 682 bike collisions with motor vehicles. Thus, a motor vehicle or bike collision was reported every 12.8 hours on Phoenix streets, roughly two per day. Of the reported collisions, 35 (five percent) involved no injury, 532 (78 percent) involved ‘minor’ or ‘moderate’ injuries, 107 involved a serious or incapacitating injury (16 percent), and eight (one percent) resulted in a fatality. The number of total and fatal vehicle or bike crashes in Phoenix remained relatively stable over the five years of the study period, but peaked in 1999, as shown in the table below:

Motor vehicle/bicycle crashes reported in Phoenix (1996–2000)

Year	Total Bike Crashes	Fatal Bike Crashes
1996	683	9
1997	743	9
1998	760	6
1999	811	9
2000	682	8

During these same five years, Phoenix population increased about 15 percent from 1.15 million in 1996 to 1.32 million in 2000. The total number of reported collisions increased about 13 percent from 32,200 in 1996 to 36,400 in the year 2000.

WHICH BICYCLISTS ARE MOST COMMONLY INVOLVED IN MOTOR VEHICLE COLLISIONS?

The crash data revealed that bicyclists ages 11 to 20 were most frequently involved in motor vehicle collisions (32 percent). This age group had double the number of crashes of the next highest 10-year age group. A vast major-

ity of bicyclists involved in collisions with motor vehicles are males (81.5 percent), and this is relatively consistent among all age categories. This largely reflects that more bicyclists are males.

WHO IS AT FAULT IN BIKE COLLISIONS WITH MOTOR VEHICLES?

Fault in the collision was determined based on the comments of the investigating police officer (Figure 1). The investigating officer could designate either the motorist or the bicyclist or both were at fault in the crash. The inexperience or errors made by bicyclists is evident by the police report results, which indicated that bicyclists were partially or entirely at fault in nearly 79 percent of the collisions with motor vehicles, with the motorists involved in an unsafe action in 43.5 percent of the crashes. This disproportionate blame for collisions largely being attributed to bicyclists reflects the young age of bicyclists involved in many crashes. It also indicates a need for more training and education on the rights and duties of bicyclists. In some instances, the police officers may not fully understand the traffic laws as they apply to bicyclists in the right-of-way, which may result in an erroneous designation of fault.

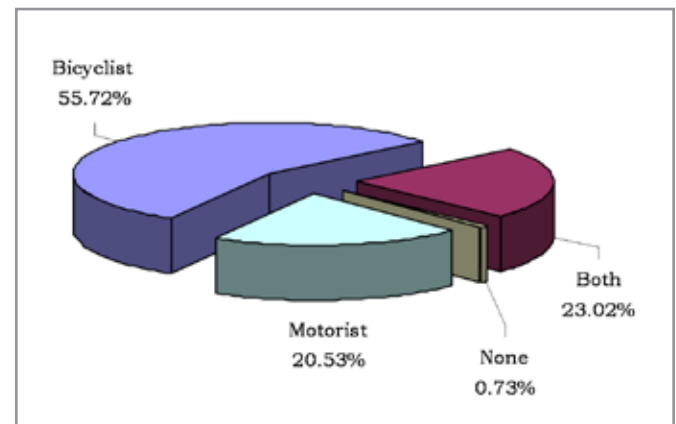


Figure 1. Police designation of fault in bicycle-motor vehicle collisions.

HOW DID THE BIKE CRASHES OCCUR?

Figure 2 shows the breakdown of bicycle collision types in Phoenix. Angle crashes comprised 38 percent of reported bike collisions, with 27 percent involving right-turn motorists, and 25 percent involving vehicles entering or leaving private driveways.

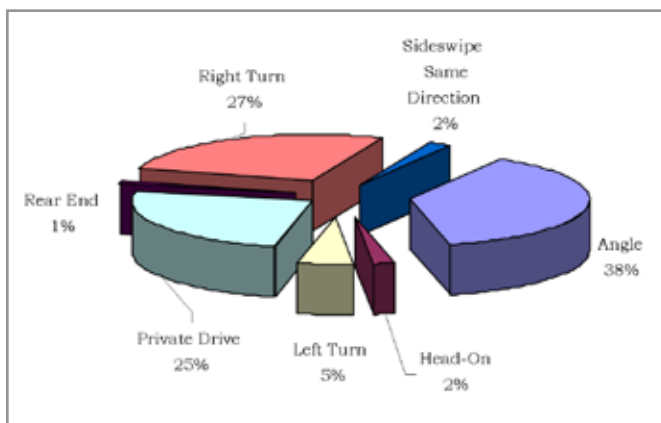


Figure 2. Type distribution of reported bicycle-motor vehicle crashes.

WHERE DID THE BIKE CRASHES OCCUR?

The classification of street where each bike crash occurred (local, collector, or arterial street) was identified. Figure 3 shows that only 10 percent of reported bike crashes occurred on local streets, which are the overwhelming majority of the streets in Phoenix (74 percent). These are the safest streets for bicyclists because of lower speeds, narrower street crossings, and fewer conflicting motor vehicles. Fifty-five percent of the bike crashes occurred on arterial streets, which comprise only about 15 percent of Phoenix streets. Collector streets comprise about 11 percent of our total streets but were the location of 35 percent of the reported bike crashes.

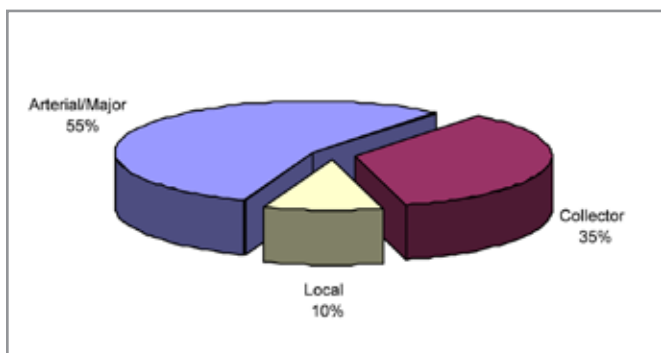


Figure 3. Street classifications of bicyclist collision locations.

The police reports were reviewed to determine if the bike crashes took place on streets with designated bike facilities (on-street bike lanes, striped shoulders, or signed bike routes). Of the 682 crashes with motor vehicles, 95 percent of the crashes occurred on streets with no designated bike facilities. Figure 4 shows where the bicyclist was riding when struck. About 40 percent of the bike/motor vehicle crashes occurred in the crosswalk area, with a similar percentage of bicyclists hit when riding in the street outside of a crosswalk or bike facility (bike lane, striped shoulder or signed route). Almost 18 percent of

the bicyclists were struck while on a sidewalk. Many of the bicyclists struck crossing the street rode off a sidewalk into the street and were in the crosswalk when hit. Less than 2 percent of the bicyclists were struck while riding in an on-street bike lane, and a smaller percentage of bicyclists were struck while riding in a striped shoulder (not signed as a bike lane).

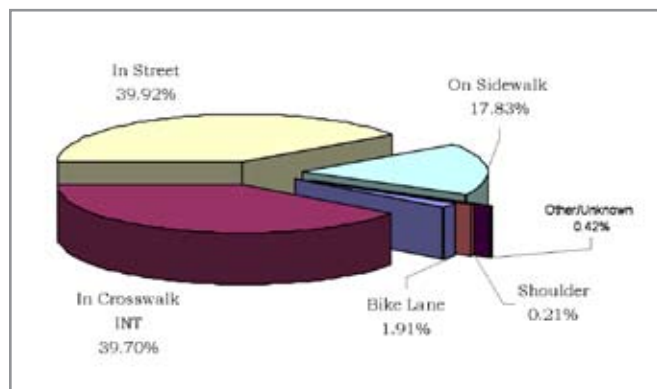


Figure 4. Bicyclists riding location when bicycle-motor vehicle crashes occurred.

The actions of bicyclists involved in crashes is illustrated in Figure 5. Slightly more than half of the bicyclists struck were attempting to cross a street. For those bicyclists not crossing the street, the most common action was a bicyclist who was riding in a sidewalk 'against' traffic (22.6 percent). While riding in either direction on a sidewalk is legal in Phoenix, motorists generally do not expect bicycle traffic coming from the 'wrong' direction, especially when turning out of a driveway or side street. Most drivers are looking to their left for approaching traffic and do not expect traffic coming from their right. Generally the speeds of bicyclists on the sidewalk do not provide motorists

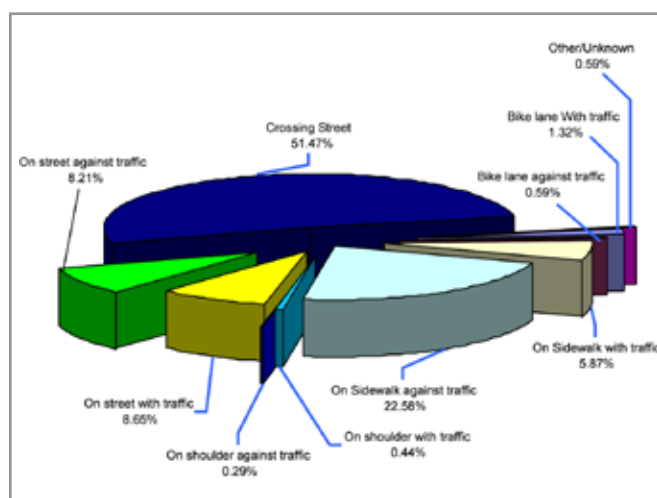


Figure 5. Pre-crash riding direction and position of bicyclists involved in crashes with motor vehicles.

much time to react. Only 5.8 percent of bicyclist-motor vehicle crashes involved cyclists riding on the sidewalk in the same direction as motor vehicle traffic.

State law requires bicyclists, when in the street, to obey the traffic laws established for motor vehicles and ride with traffic (ARS 28-812). About 8.7 percent of bicyclists were struck when riding in the street with traffic, and about the same percentage were riding in the street against traffic (not in bike lanes). Very few bicyclists were struck in on-street bike lanes (about 1.8 percent of total bike crashes), with 1.3 percent riding with traffic and 0.6 percent riding illegally against traffic.

A special analysis was conducted to further identify where the on-street bike lane crashes occurred, how they occurred, and the age of the bicyclists. There were 13 bicyclist crashes in on-street bike lanes during 2000. Of these, five occurred at midblock locations and eight occurred at intersections. The age of bicyclists struck while riding in bike lanes ranged from 16 to 70 years old, with the median age of 38. With the exception of the 16-year-old bicyclist, all other bicyclists struck in bike lanes were adults. Six of the bike-lane crashes occurred on arterial streets while seven occurred on collector streets. Three of the crashes involved 'wrong way' bike riding in the bike lane. All but two of the bike-lane crashes involved collisions with motorists turning into or out of driveways or side streets. The other two bike-lane crashes were rear-end collisions where the motorist struck the bicyclist from behind. Three of the bike-lane crashes occurred during nighttime conditions, and in two of these collisions the investigating officer noted that the bicyclist did not have a front headlight (in violation of State law when riding at night). None of the on-street bike lane crashes involved alcohol, but one did involve a hit-and-run motor vehicle.

CONCLUSIONS AND RECOMMENDATIONS

The Phoenix bike program has been highly successful in preserving more space in the right-of-way for bicycle travel and identifying desirable bicycle travel routes. While the population of Phoenix is growing, the number of crashes involving bicyclists in 2000 was virtually the same as five years earlier, despite an increase in the interim years. The number of fatal crashes involving bicyclists has remained unchanged.

The most common safety problems for bicyclists involved crossing streets, riding the 'wrong way' on sidewalks, colliding with right-turning motorists, and crashing into

motor vehicles entering or leaving driveways. These problems should be addressed through bicyclist training and bicyclist/driver education, as well as police enforcement of unsafe bicyclist and driver actions.

The results of the study indicate that the new bike facilities in Phoenix, particularly on-street bike lanes, are not associated with motor vehicle or bicycle safety problems. Furthermore, there is not a problem with inexperienced children being encouraged to ride in busy streets with on-street bike lanes, resulting in crashes. Observation confirms that the bicyclists who use on-street bike lanes along arterial streets are mostly adults, while children most commonly ride on neighborhood streets. Because so many of the bike crashes occurred on arterial streets outside of bike lanes, the addition of bike lanes along arterial streets may result in safer conditions for bicyclists. This is especially true where the curb lane of the arterial street is only 12 ft wide, which is not conducive for a bicyclist and a motor vehicle to "share" the lane.

Phoenix has actively promoted bicycling as an alternative transportation mode that is healthy, non-polluting, and does not rely on fossil fuel. These activities will continue. There is a need to quantify the amount of bicycle travel throughout the city and monitor usage.

COSTS

This evaluation of police reports for all bike/motor vehicle crashes in Phoenix was made possible through an internship program within the Street Transportation Department. Tim Cook, who was completing his Bachelor's Degree at Arizona State University, accomplished the analysis. The cost of the study was approximately \$7,000.



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Establishing Bike Lanes—Chicago's Streets for Cycling Plan

BACKGROUND

In 1992, Mayor Richard M. Daley's Bicycle Advisory Council adopted Chicago's *Bike 2000 Plan*. A key recommendation was to "develop a network of a minimum of 300 miles of bikeways" including on-street bike lanes, signed routes, wide curb lanes, and bike paths. This case study will focus on how 100 miles of bike lanes have been established as of October 2004 in Chicago, presenting seven strategies to help other jurisdictions successfully establish bike lanes.

COUNTERMEASURES

1) PLANNING

Chicago's first bike lanes were established in the mid 1990s with minimal public and political consultation and without a comprehensive plan. Some locations were criticized. Chicago's Bicycle Program Coordinator, soon after he was hired, secured \$125,000 to hire a professional consultant to prepare a plan identifying the best streets for bicycling in Chicago. This *Streets for Cycling Plan* identified a network of 150 miles of bike lanes and 300 miles of signed routes. Critical success factors include the following:

- Proposed bikeways were "field tested" by bicycle to ensure the best streets were selected.
- All streets proposed for bike lanes were measured to ensure they were wide enough for bike lanes with minimal effect on traffic movements. Bike lanes were primarily accommodated on streets by reducing travel and parking lane widths.

Nick Jackson, Director of Planning, Chicagoland Bicycle Federation
Ben Gomberg, Bicycle Program Coordinator, Chicago Department of Transportation



Bike lane next to parking. Chicago's *Bike Lane Design Guide* provides designs for various cross-sections.

- Only streets with traffic controls at all major intersections were considered, to provide safe crossings for cyclists.

2) PROMOTION

Preparation of the *Streets for Cycling Plan* was very inclusive, involving thousands of cyclists, presentations to thirty-five Chicago Aldermen and twenty-five senior CDOT staff, and even front-page coverage in the *Chicago Tribune*. The process was dynamic and widely known, with a result that the plan was largely supported upon its completion.

3) FUNDING

Any plan is only as good as its implementation. Funding is critical.

Fortunately, perhaps in part because of the "buzz" while developing the *Streets for Cycling Plan*, the City of Chicago was able to secure \$3.825 million of federal Congestion Mitigation and Air Quality (CMAQ) funds for implementation.

4) STAFF

With the federal funding, Chicago was able to hire three full-time consultants to help with establishing the net-

work of bicycle lanes: an urban planner to arrange political and community support, a designer to prepare pavement marking plans, and a “bikeway technician” to perform detailed site visits and coordinate construction. In addition, two student interns were hired to work with the program and assist as needed. The designer and bikeway technician were Chicagoland Bicycle Federation employees who were passionate about improving conditions for cycling. The Chicagoland Bicycle Federation is a nonprofit organization dedicated to improving the bicycling environment of the region.

5) MAP

More than one million copies of a map featuring the *Streets for Cycling Plan* were published. The *Chicago Sun-Times*, at no cost to the city, publishes the map every year as an insert in its Sunday edition following Bike to Work Day in June. Copies were also distributed throughout the Chicago Transportation and Planning Departments. Laminated (display) maps were mailed to 100 local engineering and planning firms with a letter from the transportation department’s commissioner asking them to consider the recommended routes in their projects.

6) RESURFACING PROGRAMS

Every year in Chicago more than 50 to 75 miles of roads with poor pavement are resurfaced. Each year, thanks to the bikeway technician’s efforts in reviewing the bicycle network included in this program, five to 10 miles of new or upgraded bike lanes are established during resurfacing. Advantages include costs being absorbed by the resurfacing agency and excellent (vs. potholed) pavement for bicycling. Ribbon-cutting ceremonies are often staged, and letters are written to acknowledge the efforts of the resurfacing agency to help ensure their continued support.

Additionally, Chicago streets are frequently repaved after utility or construction work (e.g., sewer main repair, fiber optic cable installation). Bikeway technicians arrange for new lanes to be striped or existing lanes upgraded as a condition of approval for this work.

7) ENGINEERING OUTREACH

A plan will only be implemented if engineers and planners embrace it. Education and outreach are especially important since most agencies and their staff have little experience planning and designing for bike lanes. Two Chicago strategies:

- Staging three *Bicycle Facility Tours* a year for engineers and planners to see that bike lanes work. Are they worth staging? Consider what one participant stated: “I’m going to include bike lanes in my project now



More than 1 million copies of the *Chicago Bike Map* have been published.

that I see that they work. Thanks for getting me on a bike for the first time in years.”

- Developing comprehensive design guidelines with typical cross-sections, intersection configurations, and specifications for line types and bicycle symbols. Guidelines are compiled in the *Bike Lane Design Guide* and distributed for engineers’ reference. Plans are underway to follow-up these guidelines with a 2-hour interactive training session.

EVALUATION AND RESULTS

Results of our efforts are evaluated by the miles of bike lanes established, the partnerships developed, the changes

in awareness among engineering and planning staff in advocating for bike lanes, and the changes in bicycling on Chicago's streets with bike lanes.

The following table illustrates the results of partnerships with other agencies to install bike lanes from 2000–2004:

Implementing Agency	Division	Program	Miles of Bike Lanes
Chicago Department of Transportation	Bureau of Traffic	CMAQ	40
	Bureau of Highways	ASRP	17
	Bureau of Highways	Reconstruction	2
	Bureau of Signs and Markings	Request	5
	Bureau of Bridges and Transit	Streetscape	2
	Bureau of Under-ground	Utility	1
City of Evanston	Collaborative project with Evanston Department of Public Works and Chicago Department of Transportation	Resurfacing	1
Illinois Department of Transportation	Local Roads	Resurfacing	5
Subtotal			72
Pre-2000			31
Total			103

Over 100 miles of bike lanes have been established in Chicago to date with 32 of those miles established through partnering and at minimal cost. Eight *different* agencies have established bike lanes as part of their resurfacing or road reconstruction projects. The federal CMAQ program has been so successful that another \$1,500,000 was recently awarded to guarantee completion of the project and establish colored bike lanes, signed bike routes, and

upgrade existing bike lanes to higher standards. Engineers now typically ask bicycle program staff about installing bike lanes as part of their projects, even if the streets were not included in the *Streets for Cycling Plan*. The bike lane tours have turned engineers and planners previously hesitant about bike lanes into advocates for bike lanes on future projects. And, most importantly, bike use on Chicago's streets continues to grow.

CONCLUSIONS AND RECOMMENDATIONS

The *Streets for Cycling Plan* was a valuable tool in creating partnerships to diversify the funding of construction of a bike lane network. Through the *Streets for Cycling Plan*, bicycle facilities are now incorporated in the multi-year planning for infrastructure improvements.

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How Hampshire Street Pavement Markings Influence Bicycle and Motor Vehicle Positioning

BACKGROUND

Bicycle lanes have been established on city streets throughout the United States as a way of improving conditions for cycling and ensuring that motorists understand that bicyclists belong on the street. Multiple surveys have shown that bicyclists strongly prefer marked bicycle lanes when traveling on urban streets (figure 1). Some people have raised a concern about whether bicycle lanes are more likely to put cyclists at risk of coming in conflict with motorists opening car doors into the path of the cyclist. Although motorists parking a car are responsible for not opening a car door unless it is safe to do so, the reality is that many motorists have not been well educated about this. Attention has thus focused on whether pavement markings have an impact on bicyclist safety by influencing whether bicyclists ride closer to parked cars.

The purpose of this study was to determine how pavement markings influence where bicyclists and motorists



Figure 1.

Cara Seiderman, Transportation Program Manager, City of Cambridge
Ron Van Houten, Professor, Mount Saint Vincent University, Halifax, Nova Scotia, CA

position themselves on the road, particularly with regard to how far bicyclists travel from parked cars. The research examined the effects of sequentially adding the component markings that constitute a bike lane on Hampshire Street in Cambridge, MA. Hampshire Street has on-street parking and a substantial number of cyclists who travel on it. The street had just been repaved, offering the ideal opportunity for testing a variety of pavement markings. The study looked at what impacts the various markings had on parked motor vehicles, traveling motor vehicles and traveling bicyclists.

PREVIOUS RELATED RESEARCH

Research on bicycle facilities has often focused on examining bicycle lanes installed on roads without on-street parking (Harkey & Stewart, 1997; Harkey, Stewart, & Stutts, 1999). Several studies have shown that drivers make fewer wide swerves or close passes when passing bicyclists on streets with bicycle lanes (Kroll & Ramey, 1977; McHenry & Wallace, 1985) and have found that bike lanes reduced the percentage of encroachments by motorists into the next lane and resulted in less variation in the wheel path for bicycles and motor vehicles (McHenry & Wallace, 1985). McHenry and Wallace (1985) also found that motorists swerved less when passing cyclists when there was a marked bike lane.

Harkey and Stewart (1997) found that bicycle lanes as narrow as 0.9 m (3 ft) provide sufficient space for bicycles and motor vehicles to interact safely and that lanes of 1.2 m (4 ft) worked best. They also found that a stripe separating motor vehicles and bicycles produced fewer erratic maneuvers by motorists. Hunter, Stewart and Stutts (1999) discovered that there was more wrong-way cycling and more sidewalk riding at wide curb lane sites than at bicycle lane sites and that more cyclists obeyed stop signs at locations with bicycle lane sites. These studies involved comparisons of existing sites and did not involve comparisons of cyclist and driver behavior before and after facilities were installed.

One recent study did look at streets with on-street parking. The San Francisco Department of Parking & Traffic engaged Alta Planning & Design to study the effects of “shared use” markings on cyclists’ and motorists’ road position, cyclists’ riding behavior, and bicycle/motorist conflicts. The report, *San Francisco’s Shared Lane Pavement Markings: Improving Bicycle Safety*, (February, 2004) concluded that the markings increased the distance of cyclists from parked cars as well as the distance between cyclists and passing vehicles. One of the marking types, the “bike and chevron,” significantly reduced the number of wrong-way riders.

COUNTERMEASURES

Hampshire Street in Cambridge was the chosen location for implementing the series of pavement markings. Hampshire Street is 13.4 m (44 ft) wide, with parking on both sides of the street, an average daily traffic (ADT) of about 15,000 and bicycle volumes of 120 to 150 in peak periods.

The pavement marking treatments were implemented sequentially. First, data was gathered when the street was newly repaved and the only markings were a center line and crosswalks. Then, edge lines were established 3.7 m (12 ft) out from the curbs, creating 3 m (10 ft) travel lanes, and data collected with this measure. Then, bicycle symbols and arrows were put to the right of those lines, and data collected. Finally, inner lines were established, creating 2.1 m (7 ft) parking lanes, 1.5 m (5 ft) bicycle lanes and 3 m (10 ft) travel lanes. Figures 2–5 show these treatments.

The work was done between April and October of 2003.

EVALUATION AND RESULTS

Data measured were the distance cars parked from the curb, the distance bicyclists rode from the curb, and the distance traveling motor vehicles drove from the curb. The data on bicyclists and moving motor vehicles were gathered by videotape. The data on parked cars were gathered in the field. Data were collected at each stage of the implementation, so there were four sets of data collected: baseline, line alone, line with symbol, and full bicycle lane.

Surveys of bicyclists and motorists also were administered. An intercept survey of bicyclists and motorists was conducted during the baseline and final treatment condition.



Figure 2. Only center lane markings.



Figure 3. Edge lines installed.



Figure 4. Edge lines with bicycle symbols and arrows.



Figure 5. Inner lines added.

All intercept surveys were conducted at traffic signals on Hampshire Street. After the signal turned red, the research assistant or volunteer approached the stopped cyclist or driver and said, “Good morning/afternoon. I am doing a survey for the City of Cambridge and have a few brief questions to ask you. It will take less than a minute. May

I proceed?” If the potential respondent refused, the surveyor approached the next person. There were few refusals. Cyclists who agreed to participate were asked to stay against the curb, out of the line of traffic. The baseline bicyclist survey (n = 117) had participants rate their comfort level on a five-point scale; how often they cycled on a five-point scale; and what they would change to improve cycling on Hampshire Street (an open-ended question). During the after survey (n = 123; 115 were scored for the rankings), cyclists were again asked to rate their comfort level on a five-point scale; how often they cycled on a five-point scale; if they noticed street markings on Hampshire Street over the course of the past few months (yes/no); and to rank each of the four conditions with “1” being most preferred and “4” being least preferred.

The baseline survey was administered to 129 motorists, and 120 received the “after” survey. The motorist survey asked drivers whether they were aware of bicyclists while driving on Hampshire Street; what about the street made them aware of bicyclists (an open-ended question); and how often they drove on Hampshire Street (five-point scale).

The three pavement marking treatments—an edge line demarcating the travel lane, the edge line and bicycle symbols, and a full bike lane—were all effective at influencing bicyclists to ride farther away from parked cars than when no pavement markings were present. Here are some details.

PARKED VEHICLES

With the installation of the lane line (treatment 1), motorists parked significantly farther from the curb in both directions. The motorists moved in with each additional marking and in the end, there was no statistically significant difference between where motorists parked in the baseline condition and the full bike lane condition.

BICYCLE POSITION

When one looks simply at an *average* position, the cyclists did move further away from parked cars in all circumstances, but only by a couple of inches—not as significant as might be hoped. However, the critical evaluation is the effect of the treatments on the *distribution* of where cyclists rode. Under all test markings, the distributions narrowed so that there were fewer outliers on either side (which is why the average did not change dramatically) (Van Houten and Seiderman, 2005). Most importantly, cyclists who were riding the closest to parked cars in the baseline condition moved further away, so the percentage of people riding more than 0.6 or 0.9 m (2 or 3 ft) from parked cars went up significantly.

The data also needed to be adjusted to account for the placement of the parked cars. At first blush, it looked as though the “line only” marking had the most influence on cyclist position, with the highest percentage of people riding more than 2.7 or 3 m (9 or 10 ft) out from the curb. However, when the data were adjusted to account for the change in where cars were parked, the three interventions became more equal in their impact of how far cyclists were from the parked cars.

There was also a difference among the locations, particularly between the locations near the signalized intersection and those near unsignalized intersections. The influence of the markings was greater on the cyclists near the former, because they started out closer to the parked cars. At the end of the study, the locations were similar as to where cyclists were riding.

MOVING MOTOR VEHICLES

The data revealed that the treatments had little effect on driver wheel path. Because Hampshire Street is relatively narrow and is busy at rush hour, when the data was collected, there may not have always been room for drivers to move into the opposing lane. The data on the mean distance between bicyclists and through vehicles show that the distance between bicyclists and the nearest through vehicle was greatest during baseline and significantly less at three of the four sites during the lane line alone condition. Since bicyclists were moving toward the travel lane with successive treatments, this finding is consistent.

SURVEY DATA: CYCLISTS

Because this is a commuter route and because data were collected during commuting periods, it is not surprising that the vast majority of riders rode their bikes on Hampshire on a daily basis, and virtually all respondents rode at least several times a week. It was therefore reasonable to expect them to be aware of the various interventions.

Rider comfort ratings, on a five-point scale, averaged 3.4 during baseline survey and 3.3 during the after study survey—not statistically significant. Ratings in this range fall between neutral and fairly comfortable. When respondents were asked (in an open-ended question) what they would change to improve bicycling on Hampshire Street, by far the most common response was to “add a bike lane.”

During the after study survey, 80 percent of cyclists indicated they had noticed the markings. When asked to rank the various conditions from 1 (most preferred) to 4 (least preferred), cyclists ranked the full bike lane the highest (average rank of 1.25), the lane line plus bike symbol next

(average rank 1.97), followed by the lane line alone (average rank of 2.95), and then no markings at all (average rank 3.78).

Another way of looking at this is to summarize which of the options were chosen as riders' first preferences. Eighty-two percent of the respondents chose the full bike lane, and 8 percent chose the line with bike symbol. Since the latter is also a bike lane, 90 percent of the respondents preferred a bicycle lane.

SURVEY DATA: MOTORISTS

Most drivers in both surveys drove on Hampshire on a daily basis. A similar percentage of drivers in both surveys responded that they were aware of cyclists on Hampshire (86 percent of the baseline respondents and 84 percent of the end of study survey respondents—not statistically different).

When asked, “What about this street makes you aware of bicyclists?” motorists during baseline responded most frequently “nothing” (68 percent). After all of the treatments had been introduced the most frequent response was “bike lanes” (42 percent) and the second most frequent response was “I see them (the cyclists).”

CONCLUSIONS AND RECOMMENDATIONS

This study shows that all three pavement marking options encouraged cyclists to ride farther away from parked cars. The bicycle lane was the most effective at keeping cars parked closer to the curb and encouraging cyclists to ride in a consistent position at intersections. Given that cyclists prefer marked lanes and have indicated that they make them feel welcome on the street, and that motorists do notice them, bicycle lanes can be seen as a preferred and positive way of providing for bicyclists in the transportation network.

COSTS AND FUNDING

This research was funded by the city of Cambridge. The project cost approximately \$25,000 for the research effort, plus staff time, including markings done by staff and most of an intern's time for about six months.

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Raised Bicycle Lanes and Other Traffic Calming Treatments on Ayres Road

BACKGROUND

This paper describes an unusual design for a street improvement project in Eugene, OR. City staff and the community have moved up a “learning curve” during the past several decades in regard to on-street treatments for bicyclists in combination with traffic calming techniques. This project presented an opportunity to combine a number of design features in a new way on a suburban collector street.

In 2001–2002 the city of Eugene, OR, fully improved Ayres Road, a collector street in the northern suburban part of the city, using a number of unconventional design techniques. Ayres Road is a half-mile long collector street in a developing residential neighborhood, and the only street that provides a usable east-west connection between two north-south major collectors—Delta Highway North on the west, and Gilham Road on the east.

Ayres Road is similar to many other collector and minor arterial streets the city has inherited from Lane County through annexation. It was a two-lane, narrow oil mat roadway with no curbs, drainage, or sidewalks. The roadway functioned reasonably well for many years in its rural setting, but was not adequate to serve the suburban residential development called for in the city’s adopted land use plan. The city began efforts to design an improved cross-section in the early 1990s when residential development began to accelerate on adjacent farm land. The project was delayed a number of years because of other projects having a higher priority for scarce funds and an extended public involvement process over the proposed design.

Dave Reinhard, Transportation Consultant (formerly City of Eugene Transportation Engineer, Division Manager)

Over the past three decades Eugene has developed an extensive system of bikeways. The network includes off-street paths, on-street striped lanes on busy streets and designated bike routes on selected neighborhood streets to help provide continuity. The classification of Ayres Road as a major collector street and the need for bicycle connectivity in the area led to a decision to incorporate on-street striped lanes in the design for the street reconstruction project.

In addition, Eugene has developed a number of strategies over the past decade to incorporate traffic calming features in street improvement projects. Experience with a number of techniques in various settings, in retrofit examples as well as new construction, helped shape the public input and the decision-making by city staff on the Ayres Road project. The project provided an opportunity to combine a number of bike-friendly components with proven traffic calming features in a unique way.

EARLIER STREET DESIGNS

During the 1970s and 1980s a number of collector and arterial streets in Eugene were improved to upgrade the cross-section from a two-lane asphalt mat to an urban section including curbs, gutters, and sidewalks. In a few cases, multi-lane streets were built to respond to existing or forecasted traffic volumes, but the majority of projects were built as two- or three-lane streets, the latter using a striped center continuous two-way left turn lane. In some cases parking was retained on one or both sides of the street, and in nearly all cases, on-street, striped bicycle lanes were included in the project. Therefore a somewhat typical, default cross-section of three lanes and bicycle lanes became the norm for upgrading former county roadways to urban standards in developing areas of the city.

In the early 1990s, several active neighborhood associations began petitioning the city for relief from excessive traffic speeds on collector streets in residential areas. The city went through a process of initial experimentation with speed humps, evolving to the use of other techniques



A typical 1970s–80s 3-lane urban street with on-street bike lanes used in Eugene.

that have proven more acceptable to emergency service providers. As these projects were carried out in retrofit situations in older neighborhoods, interest also began to grow rapidly in incorporating traffic calming features as part of the design of major street improvement projects. Public perception shifted, and the earlier “default” design of two lanes, a center turn lane, bike lanes and (usually) no on-street parking came to be viewed as a very unattractive design that encouraged speeding and diminished neighborhood livability.

In response to these issues, city staff began modifying design practices to incorporate traffic calming features in major improvement projects. Several projects were built in the 1990s that included some or all of the following:

- narrower lanes (more use of 3.4 m (11 ft) lanes than 3.7 m (12 ft) or wider)
- raised median islands
- chicanes or similar curves introduced into the alignment of otherwise straight sections of street
- provision of on-street parking, either continuously or in intermittent parking bays
- use of setback sidewalks and extensive street tree plantings between curb and sidewalk, instead of curb-side sidewalks



A more recent (1990s) design with chicanes and wide curb and gutter for bike lane (example from Terry Street).

As the city gained experience with these types of design features, they were incorporated in the major update of design standards and guidelines, adopted in 1999. While some of the traffic calming features still generate controversy, the improved look and feel of major street projects has met with a high level of public acceptance.

BICYCLES LANES VS. TRAFFIC CALMING

The greatest disappointment with the “new” street design was that by continuing to include on-street bicycle lanes, the overall look and feel of the street still gave the perception of a fairly wide roadway that did little to discourage speeding. To provide a safe place for cyclists on streets with moderate to heavy vehicular traffic, an additional 3 to 3.7 m (10 to 12 ft) of pavement width was being added, which tended to cancel out the visual enhancement brought about by the other features such as narrower lanes, medians and landscaping.

As part of the updated design standards mentioned earlier, the city revisited its practice of requiring on-street bike lanes on all street classifications other than local streets. The new standard established a category for collectors through residential areas, termed the “neighborhood collector.” This street type calls for mixed, slow-moving bike and auto traffic, rather than requiring striped lanes on these lower-volume streets. However, on-street bicycle lanes are still the standard for major collectors and all arterial streets in Eugene. Since Ayres Road is a major collector, the city faced a challenge to come up with a design that would achieve the best balance of competing objectives—such as the goal of a bike-friendly design along with one that discourages traffic speed.

COUNTERMEASURES

The design for the Ayres Road major improvement project evolved over a period of nearly 10 years. In about 1991 city staff initially proposed a typical three-lanes-plus-bicycle-lanes cross section. Residents of the area protested that this would result in too wide a street and increased traffic speeds in the neighborhood. The process was put on hold for several years due to other priorities, but occasional discussions took place with residents and local developers who were carrying out subdivision projects on land adjacent to Ayres Road. Eventually the city initiated a series of meetings and design charrettes with representatives of the adjacent residential neighborhoods and other interested stakeholders. The design that emerged from this process included the following elements:

NARROW LANES

Travel lanes as narrow as 3.2 m (10.5 ft) would be used on Ayres Road.

CHICANES

Horizontal curves with bulb-outs and centerline changes on a fairly straight segment of roadway would be used to discourage high speeds.

RAISED MEDIAN ISLANDS

Oval-shaped, raised median islands were used to interrupt the center line and create a “veer” to the right, then back to the left as the island tapered and then vanished at the far end. The islands also provide space for landscaping, which helps reduce the glare and related drawbacks to the added pavement of the newly built street. By planting trees and shrubs in the median, the motorist’s view down the street is interrupted and the overall effect tends to reinforce the notion of moving slowly down a narrow street, rather than being able to see uninterrupted pavement a long distance ahead. The median islands provide a safe landing spot for pedestrians, enabling them to cross at multiple locations, not just intersections. Also, where a median island runs along the left edge of the travel lane it helps visually narrow the lane, encouraging slower speeds.

RAISED INTERSECTIONS AT ENTRANCES TO MAJOR SUBDIVISIONS (MEADOWVIEW AND RIVER POINTE)

The intersections were raised to full curb height in order to provide a visual cue as well as a tactile message that helps discourage speeding in these areas. The raised intersections were an important design component in order to prevent the image of Ayres Road simply being a new and improved road race course from one end to the other.

RAISED BICYCLE LANES

The most unusual and controversial design feature is the use of raised bicycle lanes. City staff knew of this technique

being used in Europe, and after a great deal of internal discussion, decided to use this feature on Ayres Road. The primary reason for using raised bicycle lanes instead of the conventional on-street lane at normal street grade was the desire to provide a very strong, visible, right-hand edge to the vehicle travel lanes. Eugene’s experience on many other streets has been that on-street bike lanes tend to be seen as another 1.5 to 1.8 m (5 to 6 ft) of pavement on each side of the road. Even though most motorists don’t physically occupy this space when driving along tangent sections, most use it when they create their own transitions on curved road segments.

The additional space also adds to the image of a wide roadway where it feels OK to drive fast. Since the raised bicycle lane is constructed of concrete and has a left edge that is beveled up to a height of half the normal curb height, it adds a very visible edge to the travel lane that a normal, striped bike lane does not provide. The 4:1 slope of the left edge is very forgiving for both bicyclists and motorists who get too close to the edge, but is visually nearly as powerful as a vertical curb.



Raised bike lane and other traffic calming features utilized on Ayres Road.



Vehicles tend to intrude into bike lanes on curved roadways (Crescent Avenue).

ISSUES IN DESIGN, CONSTRUCTION, AND OPERATIONS

Design

When it was decided that a raised bike lane would be a design feature for the Ayres Road improvement project, several design issues became apparent right away: how wide and elevated should the riding surface be, how wide and at what slope should the beveled edge or transition surface be, what type of material should it be constructed of, and how should transitions at accessible ramps and intersections be designed. The only information on

raised bike lanes available at the time came from the Oregon Bicycle and Pedestrian Plan, which was limited to a photo of one constructed in Switzerland and a cross-section sketch showing how the raised bike lane separates bicyclists from motorists and bicyclists from pedestrians. No details or dimensions were specified in the plan. The photo as well as the sketch depicted a raised bike lane constructed of asphalt concrete, the same material used in the motor vehicle travel lane, with a sloping concrete ribbon separating the two. The city's desire was to have at least 1.4 m (4.5 ft) of bicycle-riding surface, the same accommodated by a wide curb-and-gutter option that is used as a bike lane. It was also decided that the raised bike lane would be constructed of concrete because a narrow lane of asphalt concrete would be hard to construct and to maintain. The design of the beveled edge determined how high the raised bike lane would be, and it was based on how well it would deter casual intrusion by motorists but still be traversable by motorists and bicyclists alike. Designers chose to use a 4:1 beveled edge with a transition width of 30.5 cm (1 ft) (a 7.6 cm (3 in) rise in a 1 ft run). The treatment at intersections became a challenge also. At one intersection, the raised bike lane continues around the curb return, which brought up accessibility



Transition design for accessible ramp locations.



Water ponding created by asphalt paving created challenges around curb return.

requirements. At this location, it was decided to transition the beveled edge near the curb return from a 4:1 slope to a straight grade all the way to the bottom of curb. This choice complies with accessibility guidelines and seems to satisfy riding conditions as well.

At another intersection, the raised bike lane transitions to a standard on-street bike lane at the curb return. This option did not introduce any riding or accessibility issues, but it did bring up constructability issues for the asphalt paving operation.

Construction

When the design of the raised bike lane was completed, the city did not specify how it would be constructed. As it turned out, the contractor who was awarded the project elected to extrude the raised bike lane as is done for most curb and gutter installations. However, this proved to be more complicated since it was untried with no similar projects to use as an example. The first challenge for the contractor came when the company asked for a shoe from the extruding machine manufacturer based on the city's design. The manufacturer stated that its machine was not designed to handle that much concrete volume (three times as much) through a shoe and therefore would not provide one. At that point, the contractor elected to fabricate a shoe on his own and take his chances. It eventually worked, after minor modifications with the structural supports, but several yards of concrete were wasted because the extruding machine operators were learning how to control the operation. The finished product did not fully meet city specifications and the surface smoothness for ride-ability was less than desired. Nevertheless, the City chose to accept it since the end product did not seem to present safety hazards. Had the contractor chosen to construct the raised bike lane by using traditional wood forms, it would likely have met specifications, but would probably have been more costly, mostly due to labor expense.

Another challenge for the contractor was the narrow curvilinear travel lanes. Most paving contractors have large highway type mechanized pavers, but a narrow mechanized paver would have provided better results in this application. As a result of the contractor using a standard 3 m (10 ft)-wide paver, the end product had many undesirable surface conditions (poor cross slope, poor longitudinal slope, raveling, flushing, etc.) in the final lift of the asphalt concrete.

Operations

A few operational considerations must be kept in mind when choosing a raised bike lane — street sweeping, road drainage, and driveway access. The final version of Eu-

gene’s raised bike lane requires two passes for the city’s 2.4 m (8 ft)–wide street sweepers. The first pass is done along the raised bike lane, which pushes all of the debris to the bottom of the beveled edge. The second pass is along the bottom of the beveled edge. Another operational consideration is to be aware that the road drainage is along the joint, which can reduce the life of the asphalt pavement and create long-term maintenance headaches. The last operational consideration, driveway access, was addressed during the design phase, but had to be re-evaluated after construction. During the design phase, it was determined that no special consideration would be given for vehicle access at driveways. However, because the raised bike lane was constructed out of specification (a rise of 10.2 cm (4 in) to as much as 11.4 cm (4.5 in) in 30.5 cm (1 ft) run), some homeowners complained that their vehicles were “bottoming out” during ingress and egress. Based on this information, the City elected to have each driveway access location reconstructed using the same design parameters done for accessible ramps, i.e., the beveled edge dropped out at driveways.

EVALUATION AND RESULTS

The combined visual effect of all these features provides reinforcement for slower vehicle speeds on Ayres Road. Motorists who use the street, especially those not already familiar with it, are greeted with a set of visual cues that imply, “something is really different about this street,” and are probably more likely to proceed somewhat slowly and cautiously. At the same time, the raised bicycle lanes, median islands and other features help bicyclists and pedestrians feel relatively safe and at home as users of the street.

Informal feedback from motorists, bicyclists, neighborhood residents and the general public has been mixed. A number of initial comments during the construction of the project and immediately afterward were critical, partly because the street looked so different from other typical Eugene streets, not to mention very different from the narrow Ayres Road that this project replaced. As people have gotten more used to the street and some of its visual newness has worn off, public reaction seems to be cautiously supportive or at least neutral. City staff continues to receive comments about how unusual the street looks, but there is also a growing acknowledgment that the design does help slow down traffic. In general, feedback from the bicycling community has been positive.

Before 1992, Ayres Road was under county jurisdiction, and like most roads that did not have formal speed studies conducted, operated under basic rule—up to 88 km/h (55 mph) dependent upon road and weather conditions. When the road was transferred to the city in 1992, a speed study was completed, which resulted in a speed zone of 56 km/h (35 mph). After the reconstruction of Ayres Road, the posting was changed to 40 km/h (25 mph), which more closely reflects the traffic calming design features and the average speed of vehicles.

Ayres Road speed zone history

	1992	2002 (Post Reconstruction)
Average Speed (mph)	36	26
85th % Speed (mph)	39	29
Maximum Speed (mph)	46	37
Posted Speed (mph)	35	25

CONCLUSIONS AND RECOMMENDATIONS

PUBLIC INVOLVEMENT

As with many other projects, the process of arriving at a final design for Ayres Road reinforces the notion that it’s generally better to approach the neighborhood and major stakeholders at the beginning, with no preconceived design proposal, and let the public help develop the design. Only by struggling with the choices and trade-offs in the design process can the public come to appreciate the difficult task city staff and consultants face in designing a street to meet a number of conflicting goals and objectives. Additionally, staff cannot assume that citizens are able to fully understand engineering plans and drawings. Illustrations and 3-D pictures may be necessary to convey the “look and feel” of a design element, particularly one that is unique to an area.

TRAFFIC CALMING

Getting motorists to slow down so bicyclists can share the space and pedestrians feel safe when crossing the street appears to depend on narrowing the travel lanes as much as possible. The lanes need to be narrow in an actual, physical sense (e.g. 3 or 3.4 m (10 or 11 ft) wide), and they need to look and feel narrow to motorists. The look and feel, in turn, can be achieved by a combination of narrow lanes along with conspicuous edges (e.g. use of a center island), introducing curves and chicanes, and design elements such as trees and shrubs at both the edges and in the median, to eliminate the look of a long, straight

road. Use of speed tables or raised intersections at strategic locations is also a key element of traffic calming, especially when there are very few intersections or other interruptions to continuous traffic flow along the street.

BIKE LANES THAT COMPLEMENT TRAFFIC CALMING

The most significant new feature in the Ayres Road design was the use of raised bicycle lanes. This enabled the city to meet the objective of a safe facility for bicyclists along a moderately busy roadway, while at the same time avoiding the pavement-widening effect of the typical on-street bike lane. The strong visual edge provided by the left edge of the raised bike lane helps reinforce the narrow travel lanes and discourage excessive speeds.

CONTINUING UP THE LEARNING CURVE

While it appears the city has developed a successful design in the case of Ayres Road, this example also serves to illustrate that there are probably other undiscovered “templates” for street designs that can meet these kinds of objectives. The best approach involves being open to experimentation and re-combining various design techniques to achieve the best mix of outcomes. Each project provides an example that can be copied or borrowed from to create even better designs for future projects.

COSTS AND FUNDING

The total construction costs for the reconstruction of Ayres Road came to just under \$1 million. The unit costs for each of the bid items compared well with other local projects similar in size and nature despite the innovative design treatments utilized. The raised bike lane component came in at \$15 per lineal foot as compared to the City’s standard curb and gutter with asphalt street section at \$13.50 per lineal foot. A majority of the project costs were funded by Transportation System Development Charges (a.k.a. transportation impact fees) but about 20 percent of the project costs were paid by abutting property owners through assessments.

REFERENCES

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Floating Bike Lanes in Conjunction with Part-Time Parking

BACKGROUND

The Embarcadero is a waterfront arterial in San Francisco that replaced a freeway heavily damaged by the Loma Prieta Earthquake of 1989. The roadway varies from four to six lanes (two to three in each direction) and now handles weekday traffic volumes of 40,000–50,000 vehicles per day.

After the roadway was constructed and while the area along the waterfront continued its evolution, it was determined in some areas that there was a need for on-street parking during non-peak traffic periods. During peak periods, there would be a tow-away restriction to uncover a third travel lane in each direction. While the accommodation of bicyclists was intended along the length of the roadway, there was a problem with how to stripe or designate space for cyclists to use along the sections with part-time parking.

One option was to stripe two rows of shared lane markings along each direction of the roadway, one along the curb to show where cyclists would ride when there was no parking allowed and the other farther away from the curb when parking was allowed. This was rejected on the basis that two rows of bicycle specific markings would be confusing to road users. Also, it generally is desirable to explore options which give cyclists their own striped space on the roadway before accepting shared lane markings in narrow lanes.

COUNTERMEASURES

To give cyclists a designated space along the section of roadway with part-time parking, the design shown in

Michael Sallaberry, PE, Associate Transportation Engineer, San Francisco Department of Parking and Traffic

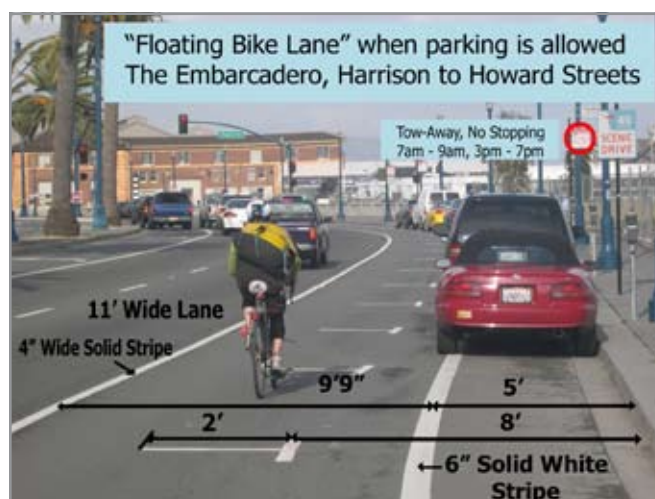


Figure 1. Cyclist using space between parked cars and first lane.



Figure 2. Northbound Embarcadero floating bike lane during tow-away.

figures 1 and 2 was chosen. When parking is allowed, cyclists use the space between the parked cars and the solid 10.2 cm (4 in)–wide white stripe, a space about 2.1 m (7 ft) wide depending how close cars park to the curb. When parking is not allowed, as shown in Figure 2, cyclists move to the right and use the 1.5 m (5 ft)–wide shoulder. Motorists are able to use the third lane,



Figure 3. Cross-hatching at beginning of part-time bike-parking lane, northbound Embarcadero.

which at 3 m (10 ft) wide is narrow, but wide enough to accommodate the generally slower traffic speeds one would expect during peak hours.

Before this design, there was some trial and error along the way. The 10.2 cm (4 in) solid white line shown 4.5 m (15 ft) from the curb in Figure 1 initially was farther out at 4.7 m (15 ft, 6 in) and broken, like a typical lane line. While this allowed for a 3.2 m (10 ft 6 in) motor vehicle lane when no parking was allowed, it also created a wider space alongside the parked cars when parking was allowed. The space looked like a typical travel lane but actually was too narrow to accommodate traffic. The result was that motorists used the space and sideswiped parked cars, filling the space intended for cyclists.

To make the space between the first 10.2 cm (4 in)-wide lane line and the parked cars seem less like a travel lane to motorists when parking is allowed, the 10.2 cm (4 in)-wide white line was moved closer to the curb face. It was also made solid to discourage crossing and make the lane seem less like a travel lane. The parking T's, initially 2.1 m (7 ft) from the curb, were relocated to be 2.4 m (8 ft) from the curb and painted with longer stems. The placement was meant to further narrow the space by encouraging people to park their cars farther from the curb while the longer stems were to make the space seem less like a travel lane. And finally, cross hatching was added in the 3 m (10 ft) space at the beginning of the floating bike lane sections to further discourage motorists from using the space when parking was allowed (see figure 3). While this was meant to make the space narrower and less attractive to motorists when parking is allowed, it still remains wide and attractive to cyclists.

Would these efforts to make the space less attractive to motorists when parking was allowed result in the space not being used by motorists when parking was restricted and they were expected to drive in the third lane? From



Figure 4. Merge sign, southbound Embarcadero at beginning of part-time bike-parking lane.

observations, motorists use the 3 m (10 ft)-wide third lane as intended when parking is not allowed. The theory is that while it does not look like a conventional lane, motorists, especially when traffic congestion reaches certain levels (such as during peak hours), will use whatever reasonable space is available to them. An analogy is that the design works as a pressure release valve with the unusual-looking third lane used only when traffic levels reach a certain level.

Use of signs associated with this unusual arrangement has been minimal. While it was tempting to place signs along these stretches to explain what is going on, initial sign designs were too complicated or incomplete. Though signs always were an option if the roadway lane markings were not sufficient, it was determined that signs explaining the part-time use of the space were not necessary. The only signs pertinent to the design are the tow-away signs (circled in Figure 1) and the merge sign used in the southbound direction (figure 4). There, three full-time lanes enter the section with the floating bike lane, and the three lanes narrow to two travel lanes when parking is allowed. Bike route signs are also along this area.

There have been some calls to install bicycle markings on the street. But as mentioned earlier, two sets of markings would be necessary for cyclists as they shift from one space to another, resulting in a confusing arrangement.

Cyclists tend to stay to the right, so when there is no parking allowed, they naturally ride in the 1.5 m (5 ft)-wide shoulder. When parking is allowed, they ride in the space between the parking and the 10.2 cm (4 in) solid white stripe.

EVALUATION AND RESULTS

While there has not been a quantitative evaluation of the design, observations indicate the space is now working as intended. Feedback from cyclists, motorists, and employees of the Port of San Francisco along the Embarcadero has been utilized throughout the process. Initial feedback and observations yielded the modifications to the design, while the good feedback and lack of negative feedback have reflected observations that the design essentially works. The primary comment heard now is that there should be pavement markings for cyclists, but the potential confusion caused by trying to mark a shifting space would likely outweigh any benefits.

The design result of this trial and error process to accommodate cyclists along a roadway with part-time parking is shown in Figures 1 and 2. If this approach of creating shifting bike lanes is used, the key is to not make the space between the parked cars and the first 10.2 cm (4 in) lane line too wide. With the 10.2 cm (4 in) lane line initially 4.7 m (15 ft 6 in) from the curb, the space was wide enough to attract motorists when parking was allowed. This 4.7 m (15 ft 6 in) width resulted in sideswipes with parked vehicles and motorists in the space intended for cyclists. Another key is to ensure that traffic levels are reasonably accommodated when parking is allowed so that there is less temptation to try to use the space intended for cyclists.

CONCLUSIONS AND RECOMMENDATIONS

Based on observations, generally good feedback from cyclists and lack of significant negative feedback, the current design is considered effective. While not perfect, with its slightly confusing, unorthodox design, it successfully accommodates cyclists, part-time on-street parking, and motorists needing additional capacity during peak hours. It does so with minimal signs, leading one to conclude that while the design is unorthodox, it uses fairly predictable road-user behavior to its advantage. Cyclists naturally tend to stay to the right, and motorists will use a space even if it is not clearly for their use if traffic congestion reaches certain levels and the space is reasonably accommodating.

COSTS AND FUNDING

Costs of the final design are typical of basic striping and signage projects. However, the amount of re-striping and trial and error did add to the final cost. Costs were not tracked.

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Incorporating a Bicycle Lane through a Streetcar Platform

BACKGROUND

Bicycle lanes on NW Lovejoy Street in Portland have long serviced an important bicycle connection between Northwest Portland and Portland's inner eastside. Northwest Portland is Oregon's most densely developed residential area, includes many shared-use developments and is a gateway to one of the city's industrial employment districts. One edge of the district is also one of Portland's fastest redeveloping shared-use neighborhoods. The neighborhood is connected across the Willamette River to Portland's inner northeast neighborhoods via the Broadway Bridge. The eastside neighborhoods are similar, though not as dense as those on the west, and host many commercial establishments, including the thriving Lloyd District.

The introduction of a streetcar line on NW Lovejoy presented a difficult problem for maintaining bicycle facilities on the street. (Bicycles are not allowed on streetcars.) A streetcar platform at the intersection of Lovejoy and 13th extends to the edge of the travel lane. The streetcar tracks run parallel to the platform and 45.7 cm (18 in) from the curb face. Through cyclists were faced with the potential of a dropped bike lane and 45.7 cm (18 in) of clearance between the parallel tracks and an 27.9 cm (11 in) curb exposure. One consideration was to drop the bicycle lane and implement an out-of direction detour that involved an uncontrolled left-turn onto a busy arterial without bicycle facilities.

COUNTERMEASURES

The solution eventually adopted was to carry the bicycle lane up onto the streetcar platform. We did several things

Roger Geller, Bicycle Coordinator, City of Portland, Oregon



Street level bike lane is diverted to behind a street car platform.

to slow cyclists entering the platform—the on-street lane runs into an area of heavily brushed concrete and the mouth of the ramp entering the platform is narrow and enters the platform at a moderate angle. We made sure to distinguish this area from the rest of the platform to alert pedestrians to the presence of cyclists. The bike lane area on the platform is marked with two bike stencils and is bordered with brick. It also has a different texture than the other areas of the platform. At the end of the platform the bike lane rejoins the street.

EVALUATION AND RESULTS

The facility has been operating for some time with neither incident nor complaint. A more challenging test will



View of bike lane and street car platform.

come when a nearby multi-story residential development is completed and the use of this streetcar platform grows. Another challenge for the platform could be the proposed development of a supermarket, which could dramatically increase cyclists' use of the platform and the street.

CONCLUSIONS AND RECOMMENDATIONS

The innovative placement of the bike lane has operated well so far. More will be learned as nearby development takes place.



Bicyclists travel behind the transit stop platform to reduce potential conflicts with stopped streetcars and passengers.

COSTS AND FUNDING

Project costs are unknown, as changes were part of a larger street improvement project. The platform was to be built as part of the street car project. Additions to adapt the platform to a bikeway involved brickwork, markings and ramp and were not costly.

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Red Shoulders as a Bicycle Facility

BACKGROUND

A scenic road in Lake County, Florida, is the subject of this evaluation. Lakeshore Drive is about 8 km (5mi) in length and lies between Mount Dora and Tavares, a pair of communities located about 56 km (35 mi) northwest of Orlando. The road is under both city and county jurisdiction, although maintenance is performed by the county. The location is popular with bicyclists and walkers. Lake County has some hilly terrain and is frequented by bicyclists riding for physical fitness or preparing for races. Bicycling groups from the Orlando area often ride on Lakeshore Drive as part of longer bike rides. The route is also used extensively during the Mount Dora Bicycle Festival each fall.

In the early 1990s, the road was slated to receive shoulders. Residents who feared that speeds would increase with the addition of shoulders opposed the project. The Florida Department of Transportation (FDOT) suggested that painting the shoulders might be a treatment that could be adapted from Europe. Even though the travel lanes would remain at approximately 2.9 m (9.5 ft), adding shoulders would physically widen the cross-section. The painting of the shoulders was intended to make the road appear no wider than before.

COUNTERMEASURES

In the summer of 1996, a 1.8 km (1.1 mi) section of the road was widened with 0.9 m (3 ft) shoulders. The shoulders were colored red with a paint that is used on tennis courts (figure 1).

William W. Hunter, Senior Research Scientist,
UNC Highway Safety Research Center



Figure 1. View of the red shoulders.

The 1.8 m (1.1 mi) treated section of road has a 56 km/h (35 mph) speed limit and is primarily a two-lane rural roadway with about 1,700 vehicles per day. There are two main intersections along the section where the shoulders have been painted red. In one area a railroad divides the road into two one-lane sections. At the end of this section a roundabout has been added, with the railroad extending through the roundabout and the colored shoulders ending at the entry to the roundabout. Several more intersections (stop-sign-controlled) intersect Lakeshore Drive along the red shoulder section.

EVALUATION AND RESULTS

The evaluation examined several items. The treatment produced a non-slippery surface that maintained its appearance rather well for some time after the initial painting. The most obvious discolorations occurred at locations with frequent motor vehicle traffic, such as mail trucks stopping at mail boxes.

The Lake County Department of Public Services collected speed data before and after the addition of the red shoulders to determine if motor vehicle speeds had changed. Videotape was taken of bicyclists traveling along

the roadway at sections with and without red shoulders. Besides determining whether the shoulder was used by bicyclists, the lateral positioning of bicyclists being passed by motor vehicles was determined, along with the amount and severity of vehicular encroachment into the opposing lane of travel. If encroachment occurred, conflicts between the passing and oncoming motor vehicles were recorded. In addition, any conflicts between motor vehicles and bicycles were recorded. Also, the Lake County Department of Public Works developed a questionnaire that was administered to bicyclists riding along Lakeshore Drive to obtain feedback concerning the red shoulders.

Evaluation of the red shoulders considered a variety of issues. Major findings are highlighted below:

- Full-time bicyclist use of the shoulder tended to be around 80 percent, and another six percent used the shoulder partially.
- The frequency of motor vehicles encroaching over the center line when passing a bicyclist was greater at the site without red shoulders.
- The severity of encroachment was fairly evenly split between minor, moderate, and severe at the red shoulder site. Almost 93 percent of the encroachments were severe at the site without red shoulders.
- There were no motor vehicle-to-motor vehicle conflicts when passing a bicyclist at the red shoulder site, and there were eight (four minor and four serious) at the site without red shoulders.
- Bicyclists positioned themselves about the same distance (about 0.5 m (1.5 ft)) from the edge of pavement on both the red shoulder and non-red shoulder sites.
- The spacing between bicycles and passing motor vehicles was statistically significantly greater (about 0.1 m (0.6 ft)) at the site without red shoulders.
- Mean and 85th percentile speeds showed little difference before and after the placement of the red shoulder.
- Survey responses showed that 80 percent of the respondents thought the red shoulders resulted in no change in the speed of cars and trucks. More than 85 percent responded that there was more space between bicycles and passing motor vehicles with the red shoulders in place, even though actual measurements of spacing distance showed greater clearance between bicycles and motor vehicles on the section

of roadway without red shoulders. A final survey response showed that almost 80 percent thought the red shoulders made them feel safer than ordinary unpainted shoulders. Thus, bicyclist comfort level was increased by installing the red shoulders.

CONCLUSIONS AND RECOMMENDATIONS

The red shoulder section of roadway not only has been well received but also has functioned well in an operational sense. The comfort level of bicyclists appears to be greater on the red shoulder section, which matches the results of a recent Federal Highway Administration study focused on the development of a bicycle compatibility index (BCI), a means of measuring the “bicycle friendliness” of a roadway (Harkey, Reinfurt, Knuiman, Stewart, and Sorton, 1998). In this study the variable with the largest effect on the index was the presence of a bicycle lane or paved shoulder. In other words, the presence of a bicycle lane or paved shoulder increased the comfort level more than any other factors.

Use of the shoulder was quite high. Riders who did not use the red shoulder tended to be part of a group, where the typical placement was to have one or more following cyclists riding to the left of lead cyclists for safety purposes. In addition, cyclists in pairs often rode abreast so they could converse. Children also had a tendency to be partial users of the red shoulders, with a tendency to cross back and forth across the road.

Perhaps the most important evaluation parameter was the speed of motor vehicle traffic before and after the placement of the red shoulders. The primary intent of the red shoulders was to create a visual sense of no widening of the road, which would lead to no increase in traffic speed. This appears to be the case. One could speculate that the general curvy alignment of the roadway could also have a bearing on this result; however, the section of the roadway where the red shoulder was installed is relatively straight.

COSTS AND FUNDING

The cost of painting the 1.8 m (1.1 mi) section of red shoulders (in both travel directions) was approximately \$6,600. The widening and resurfacing costs amounted to \$173,000.

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The modification (red shoulders) that is the subject of this case study is not compliant with the *Manual on Uniform Traffic Control Devices*, nor is it currently being considered for inclusion. Accordingly, it is imperative that any jurisdiction wishing to utilize red shoulders (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

Conversion of 14-foot-wide Outside Lanes to 11-foot Travel Lanes with a 3-foot Undesignated Lane

BACKGROUND

In the early 1990s, the City of Fort Lauderdale redesigned SR A1A, the famous Fort Lauderdale “strip.” It went from a three-lane cross-section with head-in parking on the ocean side and a narrow sidewalk on the commercial side to a four-lane divided roadway with a 4.3 m (14 ft)–wide outside lane and 2.4 m (8 ft)–wide sidewalks on both sides. Shortly after the completion of the initial redesign, the city began receiving complaints about bicyclist and pedestrian conflicts on the beach side sidewalk. While the typical section included a “bicycle facility,” only the proficient bicyclist was comfortable mixing with traffic in the 4.3 m (14 ft)–wide outside lane. As the complaints continued to rise, the city began requesting that the Florida Department of Transportation (FDOT) add 1.2 m (4 ft) bicycle lanes. There was considerable discussion between the city of Fort Lauderdale, the FDOT and the Broward County Bicycling Advisory Committee about reducing the outside travel lanes to 3 m (10 ft) and putting in 1.2 m (4 ft) bicycle lanes. It was decided to try 0.9 m (3 ft) marked bicycle lanes (Figure 2) next to 3.4 m (11 ft) travel lanes. During discussions, concerns were raised that there might be increases in wrong-way riding and turning conflicts at hotel driveways.

COUNTERMEASURES

A 0.9 m (3 ft) bike lane was incorporated into the wide outside lane (figure 1). Because this was a pilot project, the existing edge stripe was left in place. Standard bicycle lane pavement markings and signs were added to identify the lane as a bicycle facility.

Mark Horowitz, Special Projects Coordinator IV,
Bicycle Coordinator, Broward County Dept. of
Planning and Environmental Protection



Figure 1. SR A1A with a 0.9 m (3 ft) marked bike lane. Sub-standard width lanes are no longer marked or designated as a bicycle facility.

EVALUATION AND RESULTS

The project was evaluated by several means. The local bicycle coordinator tested the facility by bicycle; members of the County’s Bicycling Advisory Committee and FDOT Staff conducted observations of the bicyclists on the sidewalk and in the undesignated lane, and surveyed bicyclists using the undesignated lane. In addition, the complaints regarding bicycle and pedestrian conflicts received by the city decreased.

Overall, the evaluation of the facility was positive. The on-bike test by the bicycle coordinator found that while the stripe did provide an additional measure of traffic control and bicyclist comfort level increased, it was the minimum width that should be striped. The observations of bicycle ridership showed a decrease in sidewalk riding and conversely an increase in bicyclists riding in the street. The bicyclist surveys revealed that the majority of bicyclists were glad the lane was present but thought it was too narrow. Before the installation of the lane, the club cyclist typified the bicyclist in the street. After installation, cyclists with a wider variety of experience levels were using the 0.9 m (3 ft) lane. In this instance the concerns about an increase in wrong-way riding were not validated. However, this is



Figure 2. Along US 1 an existing 4.2 m (14 ft) outside lane was converted to an 3.3 m (11 ft) travel lane next to 0.9 m (3 ft) undesignated lane, or urban paved shoulder.

most likely because the major attraction to the area is the beach, and there was a significant amount of wrong-way riding on the beach side before the installation. Additionally, wrong-way riding did not increase on the opposite side of the street, nor was there an increase in turning conflicts at the numerous hotel driveways.

While this test was successful, the FDOT ultimately decided to reduce the widths of all four travel lanes to 3.2 m (10.5 ft) and put in a 1.2 m (4 ft) marked bike lane.

CONCLUSIONS AND RECOMMENDATIONS

The test of the 0.9 m (3 ft) bike lane was successful. It reduced bicyclist and pedestrian conflicts on the sidewalk and increased the bicyclist's comfort level when riding in the street. The predicted negative impacts of increased wrong-way riding and increased conflicts with turning vehicles did not materialize in this instance.

This design has been slightly modified from the original test and does not include bike lane pavement marking or signs. It is now being used by both the FDOT and Broward County Public Works with about 75 km (47 mi) in place in Broward County. Figure 2 shows U.S. 1 in Fort Lauderdale with a 4.3 m (14 ft)-wide outside lane that has been converted to a 3.4 m (11 ft) travel lane with a 0.9 m (3 ft) undesignated lane.

Broward County has included the 0.9 m (3 ft) undesignated lane in its Land Development Code as a design alternative when right-of-way is constrained. Broward County's Traffic Engineering Division has made a special effort to stripe a 0.9 m (3 ft) undesignated-

ing 4.3 m (14 ft) outside lanes. The University of North Carolina Highway Safety Research Center is studying the conversions.

Undesignated lanes are in place or planned for use throughout Broward County on major arterials as well as collectors with ADTs ranging from 25,000 to 45,000 cars per day. As was observed in the original evaluation, the undesignated lane is used by bicyclists of all abilities (figure 4). Because of the 0.9 m (3 ft) width, the design should not be referred to as a bicycle lane but as either a 0.9 m (3 ft) undesignated lane or an urban shoulder.

Because this type of facility provides better direction for the motoring and the bicycling public but does not meet current standards, bicycle signage and pavement markings are not used. Additionally, this facility type has been referred to as an undesignated lane or urban shoulder. It should be noted that referring to this facility as an urban shoulder has occasionally created some confusion during the striping process and has resulted in the lane being placed to the right of a dedicated right turn lane instead of to the left. Additionally, care needs to be taken during the striping process. A slight drift to the right when applying the stripe could easily result in a 0.8 m (2.5 ft) lane.

COSTS AND FUNDING

During new construction the installation cost is slightly more than placing an edge stripe. The cost in Broward County to convert a 4.3 m (14 ft) wide lane to an 3.3 m (11 ft) travel lane with a 0.9 m (3 ft) undesignated lane is approximately \$0.37/ft to stripe the lane. Removal of the edge stripe is approximately \$1/ft. Broward County has chosen not to remove the existing edge stripe.

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Preferential Transit-Bicycle-Right-Turn Lanes on Broadway Boulevard

BACKGROUND

Broadway Boulevard is a major, six-lane divided arterial roadway in Tucson, Arizona, that carries over 30,000 cars per day. All of the lanes were constructed between 3.7 m (12 ft) and 4.3 m (14 ft) wide, except the curb lanes which were constructed between 6.7 m (22 ft) and 7.3 m (24 ft) wide with no parking allowed. Originally, the plan intended the curb lanes to be wide enough to facilitate turns into and out of the numerous driveways along the strip shopping corridors without impacting through traffic along the arterial. The wider curb lane was designed to allow drivers to position their vehicles next to the lane stripe when traveling straight ahead and only pull closer to the curb when turning right into the business driveways, keeping the faster lanes clear. In addition, the wider curb lane was intended to assist public transit vehicle operations by giving them an opportunity to travel more slowly and stop frequently for



A combination bus, bicycle, and right-turn lane was separated from a former 6.7–7.3 m (22–24 ft) multi-use, wide curb lane.

Richard B. Nassi, Transportation Administrator,
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passengers in relative safety next to the curb and not impact the main flow of traffic.

Unfortunately, the actual operation of the wider lanes did not fulfill their design intent. After the construction of the road system, a series of crashes occurred involving right-turning vehicles entering the driveways and colliding with the slower-moving public transit vehicles. In addition, there was no clear area for bicyclists to ride. The wide lane did not provide enough guidance to less-skilled drivers and a number of drivers failed to position their vehicle properly as they began their turn. Approximately 20 percent of these crashes involved turning vehicles and public transit vehicles.

COUNTERMEASURES

The problem was studied and reviewed by transit and traffic practitioners and the decision was made to divide the wide curb lane into two lanes. The wide outside lane was divided and the new curb lane was striped as a priority *BUS and RIGHT TURNS ONLY, EXCEPT BIKES*, lane. This treatment provided clearer direction as to how the lanes were to be used and where drivers should position their vehicles when turning into driveways. Transit vehicle operators can operate in the curb lane, away from the faster through traffic lanes, thus reducing the potential for crashes as they stop to board or disembark passengers.

EVALUATION AND RESULTS

The splitting of the wide curb lane worked very well and eventually was included in the design of other streets with wide curb lanes. The system now has been in operation for over 22 years throughout Tucson on about 22.5 km (14 mi) of arterials. The reoccurring sideswipe, rear-end and turning type crashes fell to very low levels. Transit management also noted that the lanes helped in other areas in addition to service and safety. Sun Tran, the local transit agency, indicated the priority lane seemed

to increase bus driver morale and ultimately made their jobs easier. Equally important, the preferential transit/bike lane provided a means of making the city's transit system more visible to the community, especially in a time of energy conservation, and encouraged alternate modes of transportation.

CONCLUSIONS AND RECOMMENDATIONS

The priority transit lane striping worked as expected and the reoccurring crashes fell to low levels. The lanes have now been in operation, city-wide, for approximately 22 years. Once the lane system was installed in other portions of the city, crash involvement between transit vehicles and other motor vehicles was reduced.

The operation is transferable to other jurisdictions with similar roadway geometric and land use patterns. The mixing of the various transit and bicycle modes has not proven to be a problem. The separation of the turning vehicles, faster through vehicles and the transit vehicles solved the safety problems.

COSTS AND FUNDING

The project was funded under the City of Tucson maintenance budget. The cost for markings and signs is minimal—in the range of approximately \$100 per sign, posted approximately every fifth of a kilometer (eighth of a mile), and painted pavement diamond adjacent to each sign.

REFERENCES

The stripes and signs of the preferential Transit-Bicycle lane can be found in the Federal Highway Administration's *Manual on Uniform Traffic Control Devices*.

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Taming the Urban Arterial

BACKGROUND

The one-mile downtown segment of University Avenue is a major arterial roadway that cuts through the heart of the University of Wisconsin campus. In view of the significance of University Avenue to local pedestrian and other traffic circulation on the University campus, as well as to the broader community traveling to and through downtown Madison, there was a broad-based community input and review process engaging local officials and the public that considered the safety and accommodation needs of pedestrians, bicycles, and motor vehicles along this corridor before selection of the recommended design cross-section and reconstruction in 1983.

Before reconstruction, there were three eastbound through traffic lanes, a curb lane designated for buses, bicycles and right turns only, plus a 3.4 m (11 ft)–wide contraflow bus lane, which eastbound bicycles were also permitted to share. Roadway facilities and infrastructure were out of date and in poor condition. Accommodations for buses, bicycles, and pedestrians were considered inadequate. Numerous design concepts, alternatives, and cross-sections, especially for accommodating eastbound bus and bicycle traffic, were developed for the University Avenue corridor that also included consideration of the parallel one-way Johnson Street. A detailed safety review and conflict analysis was conducted before the selection of a design cross-section. The selected cross-section provided for complete reconstruction within the existing right-of-way and included relocation of eastbound bus traffic to West Johnson Street. This made it possible to increase the spatial accommodations for pedestrians and bicyclists while minimizing the number of conflicts between motorized and non-motorized traffic.

Arthur Ross, Pedestrian-Bicycle Coordinator
Tom Walsh, Traffic Engineer
City of Madison Traffic Engineering Division



University Avenue at Park Street – Before condition with curb bicycle, bus and right turn only lane. Lane to left of concrete divider is a contraflow bus lane.

COUNTERMEASURES

The countermeasures/improvements implemented include the following:

- 2.4 m (8 ft)–wide westbound bike lane adjacent to a 4 m (13 ft)–wide bus and right turn only curb lane
- 2.4 m (8 ft)–wide exclusive eastbound contraflow bike lane and barrier median between this lane and westbound through traffic lanes.
- Expansion of 1.8 m (6 ft)–wide pedestrian walkways to between 2.4 m (8 ft) and 3 m (10 ft).
- Barrier railing between sidewalks and roadway to prevent midblock pedestrian crossings.
- Wider and enhanced pedestrian crosswalk markings including zebras at the most desirable crossing locations
- Signal timing improvements to provide progressive traffic flow and reduce bicycle and motor vehicle conflicts
- Widened barrier median at intersections to provide refuge for left-turning bicyclists



Two views of University Avenue at Park Street today.

EVALUATION AND RESULTS

University Avenue traffic conditions have changed over the past 20 years. Average weekday motor vehicle traffic volume increased from about 22,000 vehicles per day in 1980 to 32,000 in 2001. The total number of buses was reduced by the elimination of the contraflow bus lane, but westbound bus traffic has remained stable at about 50 buses per hour in peak hours. The combined eastbound and westbound bicycle lane volumes increased from an average weekday low volume of 25 and high volume of 6,310 in 1980 to an average weekday low volume of 3,198 and high volume of 12,749 in the year 2002. (Low bicycle counts typically are in January when students are on break and weather is cold and snowy; high bicycle counts typically are in September when University classes resume after the summer break.) Pedestrian volume is extremely high, although no counts are available. The University Avenue corridor is located in the heart of the University campus, with an enrollment of more than 40,000 students. The number of pedestrian users along and crossing University Avenue likely exceeds the number of motor vehicle users on a typical day when classes are in session.

The corridor improvements resulting from reconstruction include:

- Fewer conflicts between pedestrians on widened sidewalks.
- Fewer conflicts between westbound buses and bicycles that played leapfrog prior to reconstruction.
- Fewer conflicts between westbound bicycles and motor vehicles through separation of space for bicycles versus through and right-turning motor vehicles (creation of space for each purpose/user).
- Eastbound bus and bicycle conflicts were eliminated through relocation of bus traffic to the parallel Johnson Street arterial.
- Reduction in travel delay and intersection cross-traffic conflicts through progressive signal timing for both westbound traffic and eastbound bicycle traffic.
- Traffic signals were removed from one low-volume intersection in the corridor, resulting in improved signal progression for westbound traffic.

As they approach the 20-year design life of the University Avenue reconstruction project, local officials look back on the project as a major success, especially in view of the large volume of multi-modal uses and the larger-than-expected increases in traffic volume in the corridor, which still has few problems. There have been few complaints or irresolvable problems, and the safety record is very good with no remarkable issues. The primary conflicts or concerns have to do with turning traffic, both left- and right-turning traffic conflicts as well as conflicts with pedestrians at intersections. The limited number of private driveways and the relatively low volume of turning traffic at most intersections along the corridor have contributed to the good safety record.

CONCLUSIONS AND RECOMMENDATIONS

Local officials conclude that improvements were successful. It's likely that if the corridor were reconstructed today, the existing cross-section would not be changed significantly.

COST AND FUNDING

Construction costs in 1983–1984 were approximately \$1 million and were funded by the Federal Aid Urban System Program (predecessor to the Surface Transportation Program–Urban (STP-U)). Cost sharing was 70 percent Federal, 30 percent local cost match.

REFERENCES

ITE Journal, February 1986 article entitled “Unique Roadway Design Reduces Bus-Bike Conflicts.” Also City of Madison Traffic Engineering project and location files.

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Contraflow Bicycle Lanes on Urban Streets

BACKGROUND

Cities that have extensive one-way street systems can be very frustrating for cyclists to maneuver, especially because they often are more affected by major detours or out-of-the-way travel than motorists, both because the time difference is greater and because the alternative routes are often more stressful or less safe. In addition, because of the inherent greater flexibility of the bicycle, many cyclists will simply ignore the one-way restrictions and travel against traffic, particularly when traffic volumes and speeds on the preferred route do not present a deterrent.

There are some options available in looking at ways to accommodate cyclists on one-way street systems. Many cities and towns in Europe explicitly allow cyclists to travel in both directions on a one-way street. This usually occurs on very narrow streets with very slow traffic, typically in the core areas of older cities and towns. Another option is that specific designated facilities be created to permit travel in the opposite direction. The contraflow bike lane is a designated facility marked to allow bicyclists to travel against the flow of traffic on a one-way street.

There are, of course, safety concerns associated with contraflow bike lanes. Motorists and pedestrians do not expect bicyclists to be traveling in the opposite direction of traffic on one-way streets. However, contraflow bike lanes have been used successfully in some cities in the United States (Boulder, CO; Eugene, OR; Portland, OR; Madison, WI). Building on evaluation criteria developed for Eugene, OR, the city of Cambridge looks at the following conditions when evaluating a potential contraflow lane location:

Cara Seiderman, Transportation Program Manager, Cambridge, MA



Sign indicating contraflow bike lanes on Scott Street. Bike lane is highlighted with blue pavement.

- Safety is improved because of reduced conflicts;
- Bicyclists can safely and conveniently re-enter the traffic stream at either end of the section;
- The contraflow bike lane is short and provides direct access to a high-use destination point;
- There are no or few intersecting driveways, alleys or streets on the side of the proposed contraflow lane;
- A substantial number of cyclists are already using the street;
- There is sufficient street width to accommodate a full-dimension bike lane;
- The contraflow bike lane provides a substantial savings in out-of-direction travel compared to the route motor vehicles must follow;
- The contraflow bike lane provides a significantly improved travel experience for the cyclist (e.g., allows cyclists to avoid a high-volume, high-speed alternative route);
- Traffic volumes on the street are low.

In addition, the following features should be incorporated into the design of the street with the contraflow lane:

- The contraflow lane must be placed on the correct side of the street, to the motorists' left.
- Any intersecting alleys, major driveways and streets must have signs indicating to motorists that they should expect two-way bicycle traffic.
- Existing traffic signals should be modified for bicyclists, with loop detectors or push-buttons. The push-buttons must be placed so they can be easily reached by bicyclists.

It is preferable also to have a separate bike lane in the direction of motor vehicle traffic, striped as a normal bike lane. Where the roadway width does not allow this, bicyclists will have to share the road with traffic.

COUNTERMEASURES

There now are four contraflow bicycle lanes in Cambridge: on Concord Avenue between Follen Street and Waterhouse Street (often referred to as “Little Concord Avenue”); on a portion of Waterhouse Street off of Mass. Ave (it is a very short stretch without much evaluation information so this will not be discussed here); on Scott Street between Beacon Street and Bryant Street; and on Norfolk Street south of Broadway. These contraflow lanes meet the criteria detailed above, although Norfolk Street was somewhat of an exception in that not many cyclists were riding against traffic on this street.

1. CONCORD AVENUE

In 1994, a major street renovation project created changes in the street pattern in the area of Arsenal Square. This route is a direct connection for east-west travel in the city as well as a main route from one part of the Harvard University campus to the main campus. Concord Avenue not only provides the most direct connection, but also allows cyclists to avoid riding on a street with major traffic and no space between the travel lanes and the parking lanes. It also allows cyclists to avoid riding in an underpass where cars reach speeds of up to 50 mph (the city speed limit is 30 mph).

Larger numbers of cyclists already were traveling in both directions on this one short block of a residential street to make the direct connection. There are only two driveways for single-family residences along the street.

A 1.5 m (5 ft) contraflow bicycle lane was created with two solid white lines, bicycle symbols and arrows at very frequent intervals. The reason for using white rather than yellow, which one normally would use to separate the directions of traffic, is because there is parking between the



Concord Avenue contraflow bike lane.

contraflow bike lane and the curb, so motorists needed to be permitted to pull over and park in the direction of travel. A stop sign for cyclists was put up at the end of the block so that cyclists would look for traffic before proceeding across the street.

Signs were installed on the approach to the intersection. The intersection is a non-conventional situation, more of a bend in the road than a real intersection. Motorists must proceed slowly. The street is a U-shaped one, only serving residents along the street, and has very low traffic volumes (under 1000 VPD).

2. SCOTT STREET

Sewer construction and roadway paving on this street offered the possibility of implementing traffic calming and other changes. Scott Street offers a direct connection between a minor arterial that is one of the area's most used bicycle travel corridors and Harvard University, Harvard Square, and other destinations. It is a wide one-way street



Sign indicating contraflow bike lane on Norfolk Street.

with little-used parking on both sides. A contraflow bike lane was marked and blue thermoplastic included to remind motorists to look for cyclists and not to drive in the bicycle lane. A sign was included, stating “Do Not Enter Except for Bicycles.” Traffic volumes are less than 2,000 vehicles per day.

3. NORFOLK STREET

One block of this one-way street was striped as a contra-flow lane to allow cyclists to avoid an arterial street without shoulders or bike lanes and with large traffic volumes, including trucks. A sign with a graphic representation of the contraflow lane was installed at the intersection entering the street. Blue thermoplastic was added to each end of the lane to call attention to its presence. Traffic volumes are below 2,000 vehicles per day.

EVALUATION AND RESULTS

No formal evaluations have been done for these streets. City staff have observed the locations, Cambridge Bicycle Committee members, and members of the traveling public have offered comments, and we have performed before and after bicyclist counts for two of the streets. Cyclists are continuing to use the streets in both directions and are using the designated contraflow lanes.

On Concord Avenue, some cyclists have been observed riding in the contra-flow lane but in the direction of traffic, despite the extremely frequent occurrence of arrows. Anecdotal comments are that the lane has bike symbols, so it seemed to those traveling the wrong way that they were supposed to be in that lane.

On Concord Avenue, there is also a sight-line issue created by a combination of the angle of the street and a private property fence. Concerns were reported by regular users of the street and additional signs were put up to remind motorists to watch for bicyclists.

SCOTT STREET COUNTS

Before and after counts were performed for cyclists riding on Scott Street. These showed an increase of cyclists riding against traffic (using the contraflow lane in the after counts). Given origins and destinations in the area, it would be expected that more people would be using the contraflow lane in the morning peak period, and this was affirmed in the data (see following table).

Before and After Scott Street Contraflow Lane Bike Counts

AM Peak Hour	
Before	20 peak, 16 traveling southbound (against traffic), 4 northbound (with traffic)
After	34 peak, 30 traveling southbound (in contra-flow lane), 4 northbound (with traffic)
PM Peak Hour	
Before	17 peak, 4 traveling southbound (against traffic), 13 northbound (with traffic)
After	19 peak, 7 traveling southbound (in contra-flow lane), 11 northbound (with traffic)

CONCORD AVENUE COUNTS

Before and after counts are not exactly comparable because they were performed at different times of the year. However, the counts consistently showed that there were about the same number of cyclists in both directions of travel, before and after. Peak hour counts were about 62 cyclists (occurring at midday rather than morning or night, presumably because of the student population).

CONCLUSIONS AND RECOMMENDATIONS

Contraflow bike lanes can be used successfully in circumstances similar to the ones described here if they meet the criteria outlined. There may be additional designs or circumstances that would merit testing as well.

Pavement markings and signs should be thought through carefully in the design. It is preferable to implement the lane when longer-lasting pavement marking materials can be installed (thermoplastic or in-lay tape). Otherwise, a strict maintenance program to keep paint highly visible will be required. Bicycle symbols and arrows should be created at frequent intervals (far more frequently than standard AASHTO recommendations). Consideration should be given to adding color (blue is most visible) in the lane. Signs should be installed wherever motorists would be approaching the street (at the beginning of the intersection and at any intersecting roads or major driveways).

Where there is room for bike lanes on both sides of the street, they should be included to clarify where cyclists should travel. If there is no room for a full bike lane, other pavement markings or signs should be considered to clarify direction.

COSTS AND FUNDING

In general, the costs for implementing a contraflow lane are fairly straightforward and easy to calculate when they involve standard pavement markings and signs. The costs would increase somewhat from a standard bicycle lane because it is preferable to use more frequent bicycle symbols and arrows as well as more signs. Additionally, some signs might be custom-made rather than standard. Costs would increase if blue thermoplastic paint is used.

Sample costs for Cambridge in 2002:

Thermoplastic Bike Symbols	\$80 each
Thermoplastic Bike Arrows	\$60 each
Inlay Tape Bike Symbols	\$200 each
Inlay Tape Bike Arrows	\$150 each
Blue Preformed Thermoplastic*	\$10.00/square foot
*Not including installation—All others include installation	

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Left Side Bike Lanes on One-Way Streets

BACKGROUND

More than 50,000 people (35 percent of commuters) travel to downtown Minneapolis each weekday by bus. Practically every street within the downtown grid is a bus route. Most of these buses stop at each block on the right side of the roadway, creating a potential hazard for bicyclists who tend to ride on the right side.

According to Census 2000 data, Minneapolis has one of the highest commuter and bicycle mode shares in the nation for a city of its size. Much of this success is attributed to more than 80 miles of on-street and off-street bikeways. During the mid 1990s, the City of Minneapolis decided to install a grid of east/west and north/south bicycle lanes in downtown Minneapolis to encourage bicycle commuting. Most of these facilities were proposed along one-way streets with high volumes of right-turn movements. Possible bicycle and bus conflicts along these routes greatly concerned city engineers and transit providers, especially after a bicycle fatality involving a bus occurred downtown.



Downtown Minneapolis bicycle lane routes.

COUNTERMEASURES

In an effort to reduce potential bicycle and bus conflicts it was decided that bicycle lanes on one-way streets in downtown Minneapolis would be installed along the left side of the roadway for the following reasons:

- Better visibility—Drivers are better able to see bicyclists in the driver's side mirror than on the passenger side. There is also a large blind spot on the passenger side of most vehicles.
- Fewer rush hour parking restrictions—Rush hour parking restrictions create right-turn lanes and add capacity during peak periods. Having the bicycle lane on the left side ensures a consistent facility during all times of the day.
- Fewer truck conflicts—Since most loading zones are on the right side of the roadway, there are fewer delivery trucks crossing the bike lane on the left side of the roadway.
- Fewer door incidents—Since most commuters drive alone there are relatively few passenger doors swinging open. Having the bike lane on the left side considerably reduces a bicyclist's chance of being hit by a door.

Donald C. Pflaum, City of Minneapolis Public Works
Thomas Becker, P.E., City of Minneapolis Public Works



Left side bicycle lane on Portland Avenue.



Left side bicycle lane on Park Avenue.

- Fewer left-turn movements—There tend to be fewer left-turn movements on one-way streets than right-turn movements. Having the bike lane on the left side of the roadway reduces the number of a turn-related bicycle crashes.

Typical left side bicycle lanes along one-way streets in downtown Minneapolis can be found on 9th Street South, 10th Street South, 12th Street South, Park Avenue and Portland Avenue.

To facilitate the efficient movement of buses during peak periods and to improve air quality, reverse flow bus lanes were implemented along three north/south downtown one-way streets in the mid-1990s. An additional east/west one-way street was converted in 2000 to include a contraflow bus lane and bicycle lane on 4th Street South to accommodate buses and bicycles displaced from 5th Street South, which is the corridor in which Hiawatha Line Light Rail Transit vehicles was to begin operation in 2004. Reconfiguring these streets by removing a 3 m (10 ft) parking lane and an 3.4 m (11 ft) driving lane allowed

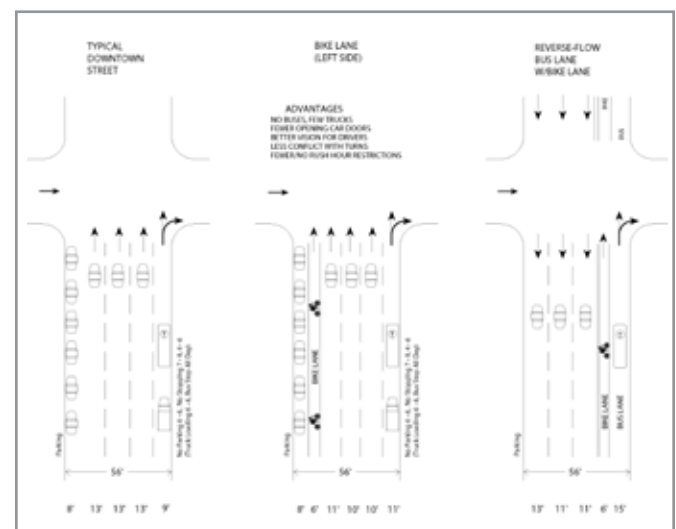
for a new 4.6 m (15 ft)—wide reverse flow bus lane and a parallel 1.8 m (6 ft)—wide bike lane to be constructed. To increase visibility of the bicycle lane, a red seal coat treatment was applied to the bike lane in all of these corridors.

Perhaps one of the most controversial discussions when the 2nd and Marquette corridors were redesigned was deciding which direction to place the bike lanes. Although there is technical merit for either option, the decision ultimately was made by bicyclists. After considerable debate by the Minneapolis Bicycle Advisory Committee, the majority felt that it was better to ride in the same direction as buses since bus drivers are professional drivers and are less likely to hit a bicyclist from behind.

EVALUATION AND RESULTS

The success of the left side bicycle lanes in downtown Minneapolis can best be gauged by observing how much the facilities are used, by examining bicycle crash trends, and by asking bicyclists their opinions. These outcomes were measured by examining accident records, performing a thorough downtown Minneapolis bicycle count, and by performing a survey with a reasonable sample size.

On September 10, 2003, the City of Minneapolis conducted a 12-hour cordon count, counting all people via all modes of transportation entering and existing downtown Minneapolis at 35 perimeter stations. There were 2,311 inbound bicyclists and 2,368 outbound bicyclists counted that day. In addition to the cordon count, over 30 volunteers took turns counting bicycles at four locations from 6 a.m. to 6 p.m. that day. These mid-block stations



Typical downtown cross-sections.



2nd Avenue looking north. Bicycles travel northbound in the same direction as buses. Buses are allowed to use the bike lane to pass other buses only in the event of a bus breakdown. Bicyclists making right turns may share the bus lane with buses. Marquette Avenue one block to the west is the mirror image of 2nd Avenue except that bicycles and buses travel southbound and general traffic travels northbound.



Eastbound bicycle lane along 4th Street South. Note that bicycles travel in the same direction of traffic. A bicycle lane will be installed along 3rd Street South to replace the westbound bicycle lane lost due to Light Rail Transit along 5th Street South. Since 3rd Street is a typical one-way westbound street with a proposed westbound bicycle lane, an eastbound bicycle lane on 4th Street was the most logical application.



Typical signs along 4th Street South.



Modified MUTCD approved sign along 4th Street South.

were set up between 6th Street and 7th Street along Hennepin Avenue, the Nicollet Mall, Marquette Avenue, and 2nd Avenue South. A total of about 1,475 bicycles were counted in these four corridors. About 350 bicyclists were observed using Marquette Avenue, 325 used 2nd Avenue South, 200 used the Nicollet Mall, and over 600 used Hennepin Avenue. In Minnesota it is legal for a bicyclist to ride with vehicular traffic, even if there is a bicycle lane present. It is also important to note that bicycles are prohibited on the Nicollet Mall weekdays from 6 a.m. to 6 p.m. by city ordinance.

About 75 percent of bicyclists who chose to ride in the Hennepin Avenue, Marquette Avenue, and 2nd Avenue corridors used the bicycle lane. Unfortunately, improper

use of the bicycle lanes was common. About 35 percent of those who chose to use the bicycle lanes on Marquette Avenue and 2nd Avenue that day were wrong-way riders. Wrong-way use was considerably less on Hennepin Avenue since there are dedicated bicycle lanes in each direction. One phenomenon that was observed was that wrong-way riding was worse along Marquette Avenue in the morning peak hours and worse along 2nd Avenue in the afternoon peak hours. One theory is that South Minneapolis has more bicycle commuters than other regions of the city and that bicyclists will take the quickest, most direct route possible from their origin to their destination. Clearly some bicyclists do not want to go a block out of their way to get to their destination, even if their behavior is illegal. At the easterly cordon boundary it was also observed that one-third of all bicyclists either used the sidewalk or chose to ride against traffic on one-way streets, both of which are prohibited by law. Bicycles are not permitted on sidewalks in downtown Minneapolis to avoid conflicts with pedestrians.



Looking south along Hennepin Avenue at 7th Street.



Looking north at the same location. Approximately 50 percent of the crashes that have occurred at this intersection (and also at the intersections of 7th Street and 3rd Street) between 1998 and 2003 have involved a left-turning car and a bicyclist going straight ahead. To mitigate this problem, bollards with warning signs have been placed where left turns are permitted. Although the bollards have improved safety, they must be removed in winter to allow for easier snowplowing. The bollards also help keep vehicles from cutting into the bike lane. Over one-third of all bicyclists in Minneapolis bike year-round.

Bicycle crashes in Minneapolis tend to be directionally proportional to the volumes of bicycles in a corridor, vehicular speed, vehicular traffic volumes, and the number of turning movements in a given corridor. After evaluating types of crashes and crash locations from 1999 to 2003, it was found that the above statement is accurate throughout most corridors in downtown Minneapolis. Bicycle crash rates on 2nd Avenue and Marquette Avenue appear to be typical for a corridor of its functional classification and characteristics. Hennepin Avenue crash rates also appeared to be typical, but crash rates were higher at intersections where left turns were permitted. This problem was mitigated with additional signs to warn turning vehicles to yield to bicyclists traveling across an intersection. Many of the crashes that occurred on Hennepin Avenue, Marquette Avenue, and 2nd Avenue involved a driver or a

bicyclist who was using the corridor improperly.

Although no scientific bicycle survey has been conducted citywide, more than 600 bicycle surveys were distributed to bicyclists and neighborhood groups throughout the city in November 2001. Of the 188 bicyclists who responded to the survey, more than 28 percent felt that safety concerns and fear of drivers is the most significant barrier in arriving at their destinations. The lack of trails and on-street bikeways ranked second with 17 percent of responses, and ranking third at 8 percent of responses was the poor maintenance of bikeways, roadways, and bridges. A number of those surveyed indicated the importance of the downtown bicycle lane system, but many felt uncomfortable using the left side bike lanes. Novice and even intermediate adult bicyclists found it especially difficult to safely get on and off the bicycle lanes along Hennepin Avenue. Many experienced bicyclists commented that they would rather ride with traffic instead of use the left side bicycle lanes because they felt unnatural and counterintuitive.

There are several gaps and discontinuities that remain in the Minneapolis bicycle lane system. Many of these gaps and discontinuities are programmed for funding within the next five years. In downtown Minneapolis many of these discontinuities and gaps occur at the perimeter. There is need to connect with existing bikeways systems near the University of Minnesota and in residential areas throughout the city. Experimental mid-block and intersection treatments are now being explored to better integrate left-side bicycle systems on one-way streets with right-side bicycle systems on two-way streets.

CONCLUSIONS AND RECOMMENDATION

After evaluating the left-side bicycle lane concept in downtown Minneapolis and along the Park and Portland corridors over the last several years, City of Minneapolis engineers are satisfied with the left side bicycle lane system. No significant changes are planned for any of the corridors discussed in this analysis, however greater enforcement is needed to ensure proper use of the facilities. What is important to note is the left-side bicycle lane system in downtown Minneapolis was created to accommodate specific needs given unique conditions and circumstances. This concept is not a one-size-fits-all treatment and is not appropriate in some situations. Although many bicyclists do not like the left-side bicycle lane concept, left-side bicycle lanes create a safer environment for bicyclists by effectively providing separation from buses.

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SRF Consulting Group. *Downtown Minneapolis Cordon Count*, 2003

COSTS AND FUNDING

Standard bicycle lane striping and counterpart signs cost about \$50,000 per mile to implement in an urban setting. Roadway configurations and seal coat/pavement treatments are extra and project costs widely vary. For example it cost \$100,000 in 1996 to implement the Marquette Avenue/2nd Avenue restriping, signs, and seal coating project (3.2 km (2 mi) long). The 4th Street reverse flow bus lane project was part of a \$900,000 mill/overlay project about 1.6 m (1 mi) in length. Annual bicycle lane maintenance costs in Minneapolis have been estimated at about \$6.50 per linear meter (\$2 per linear foot).

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Curb Radii/Curb Revisions

BACKGROUND

When streets intersect at an obtuse angle or have a large curb radius, motorists can make turns at relatively high speeds. By contrast, 90-degree intersections and corners with tight curb radii tend to slow motorists down. The problem with obtuse angles is particularly bad when a vehicle on an arterial street turns onto a residential street. Motorists turning right at high speed may cut off bicyclists traveling straight on the arterial street. Pedestrians crossing the residential street adjacent to the arterial may not expect high-speed turning traffic, or they may have their backs facing the turning cars.

COUNTERMEASURE

The solution to this problem in Seattle has been to reduce the turning radius. Seattle routinely reduces the curb radii at locations that: a) are on routes used by school children or the elderly; b) are in neighborhood shopping areas with high pedestrian volumes; and c) are at intersections identified by the neighborhood as having a unique safety problem.

The goal is to slow down right turning motor vehicles. This solution works particularly well where motor vehicles are turning right, at an obtuse angle, from an arterial street onto a residential street.

When making curb radii revisions, consideration must be made for truck and bus traffic. A curb radius that is too tight may result in the truck or bus crossing the double yellow line or overriding the curb. This can damage the curb and pose a risk to pedestrians. However, when a truck or bus is turning onto a four-lane roadway (two



Obtuse angle intersection allowed motorists to make high-speed turns.

lanes in each direction), it often is acceptable to turn into the second (inside) lane as long as the center double yellow line is not crossed. Such turns would not be acceptable in cases where truck traffic is very heavy or there is a double right turn.

Seattle has adopted the following guidelines for reducing curb radii:

- A curb radius of 3 to 4.5 m (10 ft to 15 ft) is recommended where residential streets intersect other residential streets and arterial streets.
- A curb radius of 6 m (20 ft) is recommended at intersections of arterial streets that are not bus or truck routes.
- A curb radius of 7.5 to 9 m (25 ft to 30 ft) is recommended at intersections of arterial streets that are bus or truck routes.

EVALUATION AND RESULTS

Reducing the curb radius is expected to reduce turning speeds and increase the comfort of bicyclists traveling straight through past this junction. Seattle has not conducted a formal study to determine if crash rates have been reduced.

Peter Lagerwey, Pedestrian & Bicycle Program
Coordinator, City of Seattle



Curb realignment reduced the turning radius, forcing turning vehicles to slow. Crossing distance was also narrowed.

CONCLUSIONS AND RECOMMENDATIONS

While many transportation agencies have increased curb radii over the years, these changes have had the effect of increasing the turning speed of motor vehicles. This has made bicycling and walking less safe and less inviting. In many cases, turning radii have been unnecessarily increased on neighborhood and arterial streets where there is little or no truck or bus traffic. Seattle has found that reducing curb radii is a relatively cheap, effective and popular way to create a more bicycle- and pedestrian-friendly community.

COSTS AND FUNDING

The costs of changing curb radii can vary considerably, depending on the amount of concrete and landscaping that is required and also on whether drainage grates and other utilities have to be moved or if there are other issues that need to be addressed. For example, it may be necessary to move a conduit for a signal or relocate utility poles and light standards. In Seattle, costs typically range from as low as \$5,000 to as high as \$40,000.

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Combined Bicycle Lane/Right-Turn Lane

BACKGROUND

In many bike lane retrofit projects, there is not enough space to mark a minimum 1.2 m (4 ft) bike lane to the left of a right-turn lane. This case study focuses on a combined bicycle lane/right-turn lane used in Eugene, OR, when right-of-way at an intersection was limited. There are standard options for installing or retrofitting bike lanes onto shared roadways. The American Association of State Highway and Transportation Officials *Guide for the Development of Bicycle Facilities* (1999) shows accepted ways of accommodating bike lanes at intersections. Placement of bike lanes in conjunction with right-turn lane lanes must be done carefully, in that conflicts result between straight-through bicycles and right-turning motor vehicles (Hunter, Stewart, Stutts, Huang, and Pein, 1999). In some cases where insufficient room exists, the bike lane is dropped prior to the intersection. The *Oregon Bicycle and Pedestrian Plan* (Oregon DOT, 1995) recognizes this limitation and states that when this occurs, “a right-turn lane may be marked and signed as a shared-use lane, to encourage through cyclists to occupy the left portion of the turn lane. This is most successful on slow-speed streets.”

COUNTERMEASURES

The City of Eugene, OR, has such a shared, narrow right-turn lane in place on 13th Avenue at its intersection with Patterson Street. The avenue leads directly into the University of Oregon campus and has considerable bicycle traffic (see figure 1—left side diagram). Near campus, 13th Avenue has a speed limit of 48.3 km/h (30 mi/h) and carries 6,000 to 8,000 vehicles per day.

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UNC Highway Safety Research Center

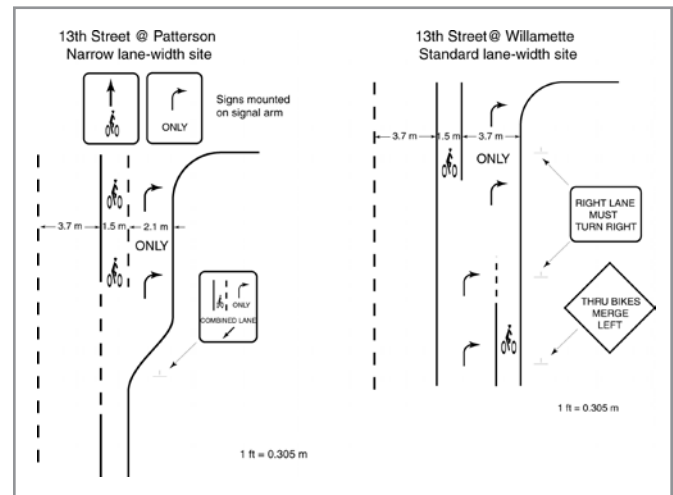


Figure 1. Narrow- and standard-lane views.

The left side of Figure 1 provides details for 13th and Patterson, which will be referred to hereafter as the narrow-width right-turn lane site. At this site, bicyclists usually approach the intersection in a 1.5 m (5 ft) bike lane at the edge of the street. At the intersection proper, the total right-turn lane width is 3.6 m (12 ft), which includes a bike lane (pocket) of 1.5 m (5 ft) and a 2.1 m (7 ft) space to the right of the bike pocket. The right side of Figure 1 provides details for 13th and Willamette, which will be referred to hereafter as the standard-width right-turn lane site. At this location, bicyclists also usually approach the intersection in a 1.5 m (5 ft) bike lane at the edge of the street. At the intersection proper, the total right-turn lane width is 5.2 m (17 ft), which includes a bike lane (pocket) of 1.5 m (5 ft) and a standard 3.7 m (12 ft) lane to the right of the bike pocket. Figure 1 also shows accompanying signs used at both intersections.

EVALUATION AND RESULTS

The narrow right-turn lane described above was evaluated by comparing the behaviors of bicyclists and motor vehicle drivers at 13th and Patterson (an intersection that had the shared, narrow right-turn lane described above in



Figure 2. Videotaped bicyclists at the narrow-lane sites (above) and standard-lane sites (below).

place) with behaviors at 13th and Willamette (an intersection that had a standard-width (3.7 m (12 ft)) right-turn lane and accompanying bike lane (pocket) to the left of the right-turn lane). The intersection of 13th and Willamette is located about 0.8 km (0.5 mi) west of 13th and Patterson. These right-turn treatments had been in place for several years when this evaluation was done, and bicyclists were familiar with the movements.

It is important to note that bicyclists approaching on 13th at Patterson Street proceed straight ahead to the bike pocket at the intersection proper, in that the right-turn lane is “bulbed out.” Bicyclists approaching on 13th at Willamette have to shift to the left to get in the bike pocket adjacent to the right-turn lane at the intersection (i.e., no “bulb out”).

Approximately 600 bicyclists traveling through each intersection were videotaped during a three-week period in May 1998. Videotaping was done for two-hour periods at different times of the day and week to get a cross-section of bicyclists and to avoid recording bicyclists more than once. It is possible that some duplication occurred, but the number would have been quite small. Figure 2 shows the view from a video camera of oncoming bicyclists at both 13th and Patterson (the narrow-width site) and 13th and Willamette (the standard-width site). The videotapes were coded to evaluate operational behaviors and

conflicts with motorists, other bicyclists, and pedestrians. Coded bicyclist variables included sex, age group, helmet use, whether a passenger was being carried, intersection approach position, position at the intersection, proximity of the bicyclist to motor vehicle at a red traffic signal indication, turning movements, traffic signal violations, and whether the bicyclist prevented a right-turn-on-red by following motorist. Coded motor vehicle information included type of motor vehicle beside the bicyclist at a red traffic signal indication, and motor vehicle type and position without a bicyclist present. We also coded whether any conflicts occurred. Conflicts between a bicyclist and a motor vehicle, another bicyclist, or a pedestrian were defined as an interaction such that at least one of the parties had to make a sudden change in speed or direction to avoid the other.

The technique worked well at the intersection locations evaluated in this study. More than 17 percent of the surveyed bicyclists using the narrow-lane intersection felt that it was safer than the comparison location with a standard-width right-turn lane, and another 55 percent felt that the narrow-lane site was no different safety-wise than the standard-width location. This is probably a function not only of relatively slow motor vehicle traffic speeds on 13th Street, but also because of the bike lane proceeding straight through the intersection at the narrow-lane site such that motorists crossing to the right-turn lane tended to have to yield. Bicyclists at the comparison intersection had to shift to the left to be positioned in the bike pocket next to the right-turn lane. It was also relatively easy for bicyclists to time their approach to the narrow-lane intersection and ride through on a green indication.

It was expected that bicyclists going straight through the narrow-lane intersection would position themselves either in front of or behind motorists. However, it was quite easy for bicyclists to ride up to the narrow-lane intersection and position themselves beside passenger cars or light trucks. The issue of the most appropriate position for a bicyclist at an intersection is not necessarily well understood or agreed upon. Positioning certainly can vary as a function of motor vehicle speed, traffic volume, turning movements, and a number of other variables. This evaluation pertains to a single location for this narrow-lane treatment, and it would be beneficial to compare bicyclist positioning choice here to what occurs at other intersection types, such as a shared through/right-turn lane with no bicycle lane or pocket.

Bicyclists at the narrow-lane site chose to position themselves in the adjacent traffic lane on a few occasions, usually the result of a heavy vehicle taking extra space. Some-

times bicyclists would shift to the right-turn portion of the lane if a heavy vehicle were in the through lane. Right turns on red by motor vehicles were rarely prevented when bicyclists were present at the front of the queue at the narrow-lane site. No conflicts between bicyclists and motor vehicles, other bicyclists, or pedestrians took place at either intersection.

The combined bicycle lane/right-turn lane design is shown in the *Oregon Bicycle and Pedestrian Plan* and has been reviewed, but not yet officially adopted, by the Oregon Department of Transportation's Traffic Control Device Committee. However, adoption is expected in the near future. For the present, favorable conditions for implementation appear to be on local streets with speeds of 48.3 km/h (30 mi/h) and traffic volumes of less than 10,000 vehicles per day. Adding a bulb-out to the combined bike lane/right-turn lane so that motorists move to the right and bicyclists continue in a straight line may also be a safer situation for bicyclists.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the design be implemented at other types of intersection locations (i.e., different motor vehicle approach speeds and approach configurations) and evaluated for effectiveness.

There are many intersections where using a minimum-width bike lane is not possible due to limited right-of-way. The use of a shared, narrow right-turn lane in combination with a bike lane in a limited right-of-way situation is a novel approach. This treatment could be applied in initial intersection design, when retrofitting a bike lane to an existing right-of-way, and when adding an auxiliary right-turn lane.

COSTS AND FUNDING

Costs included the removal of paint (regular, not thermoplastic), new thermoplastic paint, a sign placed in the ground and another sign next to the signal head for about \$1,500 in parts and labor. If traffic loops have to be moved, it would cost an additional \$1,000 per lane.

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Blue Bike Lanes at Intersection Weaving Areas

BACKGROUND

Intersection and intersection-related locations account for 50 to 70 percent of bicycle–motor vehicle crashes (Hunter, Stutts, Pein, and Cox, 1996). In Portland, OR, both motorists and bicyclists had expressed concern about a number of locations where bicycles and motor vehicles came into conflict when motor vehicles turned, changed lanes, or merged across bike lanes at or near intersections. Colored pavement, raised crossing paths, and other measures have the potential to alert motorists and cyclists to these intersection conflict zones, thereby increasing yielding behaviors and reducing conflicts and crashes. Such treatments have been found to be effective in several European and Canadian cities (Pronovost and Lusginan, 1996; Jensen, 1977; Leden, 1977; Leden, Gårder, and Pulkkinen, 1998).

The 10 Portland sites selected for treatment and study were all sites with a high level of bicyclist–motorist interaction and a history of complaints. All were in areas with existing bicycle lanes. Prior to treatment, all of the bike lanes were outlined with dashed lines at the conflict areas. All except one of the sites also had in place traditional regulatory signs to alert motorists to “YIELD TO BIKES.” The signs had been in place for some time and were in good repair. At one location, Hawthorne Bridge, where there was no yield sign for motorists, bicycles had been yielding to motor vehicles before the blue pavement and signs were added.

COUNTERMEASURES

Each of the 10 sites were locations where the bicyclist travels through (straight ahead) and the motorist crosses

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Figure 1. Hawthorne bridge conflict area. Motorists exit right to an off-ramp, crossing the through bike lane that weaves left to cross the bridge. Example of a group 1 configuration.

the bicycle lane to: exit a roadway (group 1), move into a right turn lane (group 2), or merge onto the bicyclist's street from a ramp (group 3). (See figures 1–3 for examples.)

At all 10 sites, the conflict areas of the bicycle lanes were marked with light blue paint or with blue thermoplastic intended to highlight the conflict zone. The intent was to increase awareness and safe behaviors by both cyclists and motorists and yielding behaviors by motorists. Light blue was chosen because it doesn't have another meaning to motorists (as do red and green, sometimes used in other countries), can be detected by color-blind individuals, and usually is relatively visible in low-light or wet conditions. Additionally, blue was overwhelmingly favored by participants in a number of public presentations, as well as by bicycling professionals, and prior studies suggested that it would be an effective color.

The first sites were painted blue with glass beads applied to the wet paint at a total cost of \$900. Unfortunately, within two to three months, the paint was worn away at some of the locations with higher traffic volumes. Therefore, at eight of the sites, a more expensive, thermoplastic, skid-resistant material was applied.



Figure 2. Motorists approaching Grand Avenue weave across a bicycle through lane to enter a right-turn- only lane on Madison Street. (Group 2 site)



Figure 3. Bicyclists approaching the Broadway Bridge travel straight, while motorists from Interstate Avenue entering Broadway cross the bike lane conflict area (outlined by the dashed striping). (Group 3 site)

At each location, one of several innovative “YIELD TO BIKES” signs was installed with a design appropriate for the particular motorist maneuver and configuration at that site (Fig. 4).

EVALUATION AND RESULTS

Videotape analysis was used to compare before and after behaviors of both motorists and bicyclists in the conflict areas. Twenty hours of “before” treatment video data (two hours per site) and 30 hours of “after” data (two or four hours per site) were collected. Videotaping was performed at peak-hour ride times on days with good weather. Video data were compared with observations conducted before videotaping, and there was no evidence that the presence of the camera affected rider or motorist behavior. Each bicyclist traveling through a site

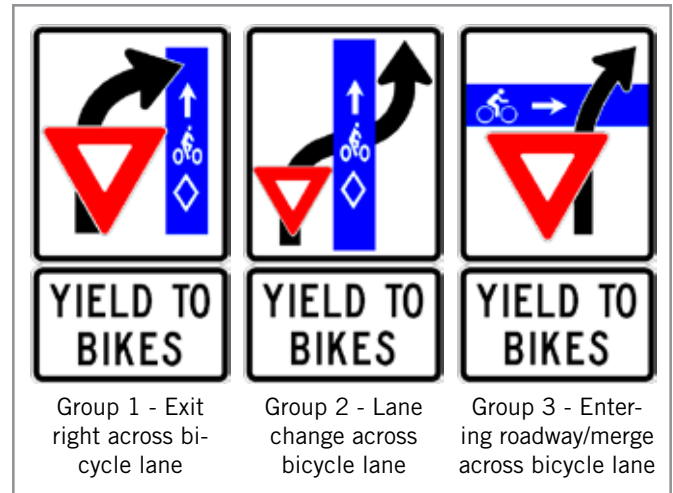


Figure 4. Novel signs (non-MUTCD approved) used in conjunction with blue pavement marking to alert motorists and bicyclists of conflict areas and to warn motorists to yield to bicyclists.

was an observation, while each vehicle traveling through a site in the presence of a bicycle was also an observation. Videotapes were analyzed to code signaling, slowing and stopping, and yielding behaviors for both bicyclists and motorists, as well as head-turning or scanning behavior for bicyclists only.

Videotapes were also analyzed to code conflicts “before” and “after” treatment. Conflicts were defined as an interaction between motorist and bicyclist where at least one of the parties had to make a sudden change in speed or direction to avoid the other (a stringent definition).

Bicyclists’ opinions on the treatment were solicited through an in-the-field, oral survey of 200 riders who had just traveled through one of the sites. A survey was also mailed to about 1,200 owners of vehicles who had been spotted driving through the same site as determined from license plate numbers. Responses were received from 222 of the vehicle owners. Additionally, city staff members performed test rides on wet treated surfaces to evaluate slipperiness. The sites were also informally evaluated for durability and wear of the markings.

As mentioned above, the painted markings did not last more than two months at high traffic locations. Almost a year after the thermoplastic treatments were applied, six of those eight locations showed little wear. One was in fair condition, and one was in poor condition because it may have been installed incorrectly. Thus, the higher cost for thermoplastic application may be offset by greater durability and lower maintenance costs. Neither the paint nor the thermoplastic was slippery, but neither material was as visible at night as had been expected.



MOTORISTS

Motorist behaviors changed significantly in one or more ways at most sites. From the data pooled across sites, significantly more motorists slowed or stopped at the conflict area in the “after” period than in the “before” period (87 percent after compared to 71 percent before). Fewer motorists signaled their intentions after the blue pavement was installed (63 percent after compared with 84 percent before), but this result could partially be because the motorists yielded more frequently.

BICYCLISTS

Most observable bicyclist characteristics (age group, helmet use, passengers carried) remained the same for the before and after periods, with the exception that there were 29 percent females before and 21 percent in the after period over all the sites. The percentage of bicyclists following the marked path through the conflict areas significantly increased over all sites from 85 percent before to 93 percent after the blue markings were added. Bicyclists slowing or stopping on approach to the conflict areas decreased from 11 percent to 4 percent after the treatment. Reduced slowing is interpreted to signify bicyclists’ increased comfort in approaching the conflict areas.

Some desirable bicyclist behaviors decreased, however, after the treatment. Considerably fewer bicyclists turned their heads to check for motor vehicle traffic after the treatment than before (43 percent before, 26 percent after). Additionally, as with motorists, fewer bicyclists (4 percent) used hand signals to indicate their intended movement after the blue pavement was installed, although few bicyclists (11 percent) used hand signals in the before period either. It also should be noted that bicyclists would not be expected to signal at sites where they were riding straight ahead (all but two of the sites).

MOTORIST AND BICYCLIST INTERACTIONS

A significantly higher percentage of motorists over all sites yielded to bicyclists after the blue pavement was installed—92 percent in the after phase compared with 72 percent in the before period. Conflicts, as defined in this study, were infrequent in both periods, with eight coded in the before period and six coded in the after period. Conflict rates were therefore quite small—0.95 per 100 entering bicyclists in the before period. This rate decreased to 0.59 per 100 after the blue pavement was installed.

There were differences by site and by type of site (group) in some of the outcomes noted above (for full report and analyses, see Hunter, et al. 2000). For example, after blue pavement was installed for the group 1 and group 3 sites described above, the percentage of bicyclists using the marked pathway increased significantly and the percentage of bicyclists slowing or stopping decreased significantly. Also, the percentage of motorists yielding to bicyclists increased significantly. Unfortunately, bicyclists turned to check for traffic less frequently at those groups of sites. In the group 2 sites, where motorists were shifting into a right-turn lane across a through bicycle lane (as opposed to entering or exiting the roadway), cyclists actually increased their scanning behavior and motorist signaling also increased significantly. The percentage of bicyclists using the painted area at the group 2 sites decreased after treatment, and motorist yielding did not change significantly at the group 2 sites.

SURVEY RESULTS

The majority of bicyclists indicated the following:

- the pavement markings were no more slippery than before,
- motorists were yielding to bicyclists more than before,
- the treated locations were safer than before, and
- the markings increased motorist awareness of the conflict areas.

A majority of surveyed motorists noticed the blue markings and the signs. More motorists who noticed the signs also correctly interpreted that the blue pavement meant they should yield to cyclists. Nearly 50 percent of the motorists who responded said the treatment helped increase awareness of the conflict areas, while others expressed concern about creating a false sense of security for bicyclists.

CONCLUSIONS AND RECOMMENDATIONS

These results suggest that colored bike lanes and accompanying signs may be one way to heighten both motorist and bicyclist awareness of some types of intersection and merge conflict areas, thereby creating a safer riding environment. Motorist yielding behavior increased overall and at six of 10 individual sites. Slowing by bicyclists approaching the conflict areas also decreased, signaling an increased comfort level among cyclists. Some of the treated areas still are in good condition, even five years after the thermoplastic markings were installed. Some are somewhat worn, but still functional. Others are greatly worn where traffic is heavy. The thermoplastic coloring seems to last two to three years in places with heavy traffic. Five years following installation, Portland's bicycle coordinator still has a high opinion of the value of the blue pavement markings. He has more sites identified for implementing this treatment when funds become available to install and maintain them.

More evaluations are needed of the use of this treatment as well as when and where such applications are appropriate, the effects and use of signs with markings, and the types of materials and colors that should be used. Additionally, bicyclists should be encouraged to continue their vigilance and scanning behavior after colored pavement markings are installed in conflict areas.

COSTS AND FUNDING

Painted sites	materials and labor	\$900/10 sites
Blue thermoplastic sites	materials	9,700
	labor	6,300
Total:		\$16,000/8 sites (1998)

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The modification (blue bike lanes) that is the subject of this case study is not compliant with the *Manual on Uniform Traffic Control Devices*, nor is it currently being considered for inclusion. Accordingly, it is imperative that any jurisdiction wishing to utilize blue bike lanes (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

Crossing an Arterial through an Offset Intersection: Bicycle-Only Center-Turn Lane

BACKGROUND

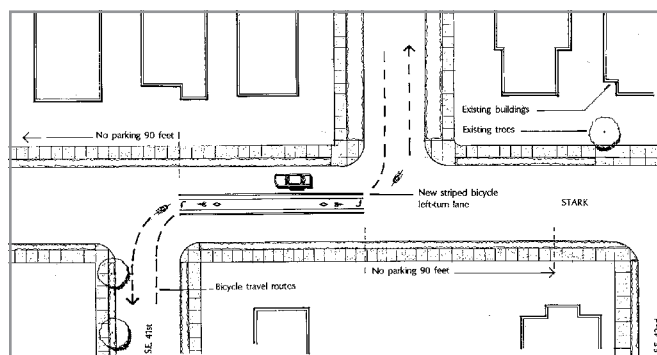
The North-South 40s Bikeway is a 12.2 km (7.6 mi) bicycle corridor about 4 km (2.5 mi) from Portland's downtown core. Developed in 1999, the bikeway runs the entire breadth of Portland from north to south, connecting residential neighborhoods to five commercial districts, six parks and 10 schools and intersecting 10 perpendicular bikeways. It comprises 9 km (5.6 mi) of bicycle boulevards, 2.9 km (1.8 mi) of bicycle lanes and 152.4 m (500 ft) of off-street path¹.

A minor arterial with an average daily traffic of about 10,000, SE Stark Street, intersects a segment of the bikeway on SE 41st Avenue. The junction is complicated by a 35 m (115 ft) offset of 41st as it crosses Stark. North and south approaches are stopped with stop signs. The standard set of crossing treatments were considered but posed significant drawbacks for this project. The only effective civil option would have been a median refuge, which would have prohibited some turning movements from Stark to 41st.

COUNTERMEASURES

In the end it was decided to stripe a bicycle-only center-turn lane. This two-way, 3 m (10 ft) lane provides a refuge for cyclists who cross Stark by essentially executing first a right-turn onto Stark and then a left-turn back onto the bikeway².

Roger Geller, Bicycle Coordinator, City of Portland, Oregon



Rendering of bicycle-only center-turn lane.



Photo of bicycle-only center-turn lane as implemented.

EVALUATION AND RESULTS

There has been no formal evaluation, but feedback from cyclists has been positive and the intersection continues to function as intended.

CONCLUSIONS AND RECOMMENDATIONS

This treatment successfully addressed three criteria: it offered a refuge for crossing cyclists and allowed them to cross one direction of traffic at a time; it maintained all automotive turning movements, and it provided an inexpensive solution to this crossing that left more available

funding for conventional civil treatments at other intersections on the bikeway.

COSTS AND FUNDING

Costs for thermoplastic paint to make the bike markings were minimal. The project was implemented as part of a larger plan, so there is no break-out for this treatment.

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¹Portland stripes bicycle lanes on roads with average daily traffic volumes of 3,000 or greater. Bicycle boulevards are low volume streets that generally work well for bicycling. The city typically improves arterial crossings, alters the stop sign pattern, and occasionally diverts automotive traffic to make them work better.

²We considered two options—crossing making first a right turn and then a left turn, or using the next street to cross making first a left turn and then a right turn. Doing the latter would require only striping receiving bicycle lanes on the cross street. We rejected that in favor of the right-turn first scenario because to make the left turn first would necessitate crossing both lanes of cross traffic at once, rather than crossing one lane at a time, as is done when making the right turn first.

Improving Sight Distance between Cyclists and Motorists

BACKGROUND

A shared-use pathway for bicyclists and pedestrians travels east to west along the Panhandle portion of Golden Gate Park, bordered by a couplet of one-way arterials. Fell Street, the west-bound portion of the couplet, is the closest to the path and to the north. The path travels along the park mostly free of intersections with any roadways except at Masonic Avenue where the path crosses the street in the south crosswalk. The intersection is controlled by a two-phase signal where motorists on Fell Street and people in the east-west crosswalk see a green light and WALK signal at the same time (see figure 1).

There are approximately 300 vehicles per hour turning left from Fell Street to Masonic Avenue in the evening peak hour. That same time is also peak usage for the pathway, which serves as a popular commute route for cyclists. In 2002, 100 cyclists per hour were counted on the path. Given city-wide trends and anecdotal observations, there are likely more cyclists than this today. The number of pedestrians and other wheeled path users contributes to the number of people in the crosswalk at any given time.

Given the popularity of the path, the number of left-turning vehicles traveling across the path, and the number of close calls reported, it has been widely recognized that improvements were needed to ease the potential for conflicts in the crosswalk.

Michael Sallaberry, PE, Associate Transportation Engineer, San Francisco Department of Parking and Traffic

Contributions by Dustin White, intern, San Francisco Department of Parking and Traffic



Figure 1. Aerial view of path intersection with Masonic Avenue and Fell Street.

COUNTERMEASURES

About five years ago, some measures were implemented to improve this area. First, an approximately 3 m (10 ft) long red (no parking) zone approaching the intersection on Fell Street was painted to improve sight lines. Three meters in length was chosen as it was feared that a longer red zone would be routinely violated, as parking demand in the area was high and it may not be clear to motorists why a long red zone was needed. Later on, signs were installed stating LEFT TURN YIELD TO BIKES AND PEDS (figure 2).

Since then, the path was widened and repaved to handle increased demand. As the number of path users continued to climb, so did the number of reported collisions and near-collisions. Another round of improvements to the crossing was warranted.

Though many believed it might be time to have a separate phase for path users and for left turning vehicles, it was recognized that this change would require more time and funding for the needed signal upgrade. Some also thought that perhaps a more moderate, shorter term ap-



Figure 2. Signage at path crossing.

proach might suffice. In any case, all recognized the need for improvements in the near term. Thus, the next round of improvements included the following:

- A longer red (no parking) zone on the Fell Street approach to the intersection to improve sightlines
- Striping to encourage wider and thus slower left turn movements
- A ladder-treatment to the crosswalk with advanced stop bar on Masonic Avenue
- A leading pedestrian signal interval (see figure 3)

The proposed red zone improves sightlines between motorists and path users, and is now 18.3 m (60 ft) long, a 15.2 m (50 ft) extension of the existing 3.0 m (10 ft) zone. To improve compliance with this parking restriction, a cross-hatched area was striped in addition to the usual red curb paint and the NO PARKING signs. Speeds on Fell Street are controlled using regularly

spaced signals and are 48kph (30mph) during the evening peak period. With a 15.2 m (50 ft) increase to the existing red zone, motorists are able to see people in the crosswalk 1.1 seconds sooner.

The same cross hatching used to emphasize the NO PARKING restriction also discourages motorists from moving closer to the curb as they turn right. A curved extension of the cross-hatching is intended to encourage wider and slower turn movements. Prior to the restriping, many motorists cut the turn with minimal reduction in their speed. The other striping change was to make the crosswalk a ladder-style crossing with a stop bar for northbound Masonic Avenue motorists. These markings were intended to increase the visibility of the crosswalk, and create some space between northbound motorists and the crosswalk. The additional space was intended to allow some margin of safety between path users entering the crosswalk on a stale green and motorists eager to proceed north at their green.

A leading pedestrian interval (LPI) of 3 seconds was also implemented to allow path users to establish themselves in the crosswalk before the platoon of vehicles on Fell Street arrived at the intersection. The LPI also provides a 3 second all-red for the intersection, a secondary benefit. It should be noted that the pedestrian signal is a countdown signal, which displays the amount of time left during the “flashing hand.”

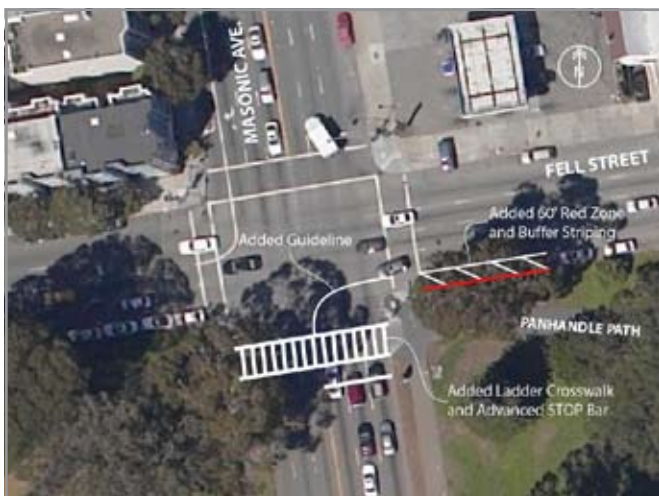


Figure 3. Aerial view of the intersection with the improvements.



Figure 4. Eastbound view of the crosswalk/path and westbound motorists on Fell Street.

EVALUATION AND RESULTS

To determine the effectiveness of the changes, a survey was taken of path users. A more scientific approach would have been to observe the intersection and collect data. However, given limited resources and the difficulty of evaluating various levels of conflict and near-collisions between path users and left turning motorists, it was decided that a survey would have to suffice. The survey was taken at various times of the day, mostly on weekdays but also on a Saturday. An effort was made to pick 100 people randomly so that cyclists, pedestrians, and other path user groups would be represented.

Fifty-six percent of path users surveyed did not notice the changes. The 44 percent who did were asked on a 1 to 5 scale what they thought of the changes, 1 meaning “much more safe”, 2 meaning “more safe”, 3 meaning “no change,” 4 meaning “less safe,” and 5 meaning “much less safe.” The average score from this response was 2.3, somewhere between “more safe” and “no change.” More than half of the 42 who responded (two did not) gave a score of 2 (“more safe”) while three respondents replied they felt either “less safe” or “much less safe.”

Anecdotally, some observations have been made. Many motorists are still cutting the turn short, but a higher percentage than before is taking it wider and slower. North-bound motorists on Masonic Avenue obey the stop bar set back 1.5 m (5 ft) from the crosswalk approximately 80–90 percent of the time. Also, there have been very few incidents of motorists parking in the extended red zone. Based on the much higher incidence of motorists parking in the previous 3 m (10 ft)–long red zone, this indicates the crosshatching along the curb makes a difference.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the survey and anecdotal observations, these changes have improved the crossing. However, as noted in the survey results, 56 percent of the respondents did not notice the improvements. The next steps are to consider additional short term improvements and concurrently consider the costs, benefits, and impacts of a separate phase for crosswalk users and left-turning vehicles. As the intersection is already near a volume/capacity ratio of 1.0, there is not much time during a signal cycle to work with. Splitting the phase would yield a significantly shorter crossing time for path users, up to half what it is today. Still, the proposal will be studied in greater detail so that a more informed decision can be made.

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COSTS AND FUNDING

It cost approximately \$5000 to design and implement the changes and take the survey. The funding was provided by the San Francisco Transportation Authority via Proposition K funds, a fund developed by a half-cent sales tax devoted to transportation improvements within the city and county of San Francisco.

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Grandview Drive Roundabout and Corridor Improvements

BACKGROUND

Because Grandview Drive (an arterial road) lacked adequate shoulders, children bicycling and walking to school were forced to travel along the edge of paved travel lanes, adjacent to 45 mph traffic. In 1996, the University Place Council and staff commenced a public involvement process in the community to determine the improvement options for Grandview Drive. Grandview Drive is a secondary arterial that provides access to a high school, middle school and over 200 residents. It ends at the City's undeveloped 700-acre waterfront. The one-mile stretch of road did not have any pedestrian or bicycle facilities, and although the speed limit on the road was marked as 35 mph (56 kph), the average speed was as high as 42 to 45 mph (73 kph). Therefore, the children were forced to negotiate this commute—adjacent to high speeding vehicles—by walking on the edge of travel lanes, as there was no other place for them to walk (see figure 1).

In addition, the intersection of Grandview Drive and Olympic Drive was controlled by a four-way stop, causing traffic to back up hundreds of feet in every direction during peak hours. Many impatient drivers, waiting to cross the intersection, did not pay attention to the pedestrians and bicyclists who were trying to cross the roadway.

COUNTERMEASURES

After many public meetings, the City Council decided to build Washington State's very first modern roundabout at the intersection of Grandview Drive and Olympic Drive.

Ben Yazici, City Manager, City of Sammamish, WA; Former Assistant City Manager/Director of Public Works for City of University Place, WA
Contributions by Steve Sugg, Current Director of Public Works, University Place, WA



Figure 1. Grandview Drive before roundabouts bike lanes, and other improvements were added.

Initially, there was overwhelming opposition to the roundabout from the community. Many residents were concerned that it would create more safety problems for pedestrian and bicyclists. So, the Council decided to build a temporary roundabout for twelve months. At the end of the twelve-month period, an analysis was to be conducted, including an assessment of the community's acceptance along with technical data to help decide the fate of the roundabout.

The City did extensive research on the roundabout. Fewer and less severe accidents were expected with roundabout-controlled intersections than with signal or stop-controlled intersections. While there are 32 potential conflict points at a conventional (sign or signal controlled) intersection, there are only 12 potential conflict points in a roundabout (figure 2).

After the test period, community acceptance of the roundabout was measured at 75+ percent, so the Council decided to keep it as a permanent traffic control device. Ultimately, the entire roadway was reconstructed with curbs, gutters, sidewalks, bike lanes, planter strips and street lighting (see figure 3). And four additional roundabouts were

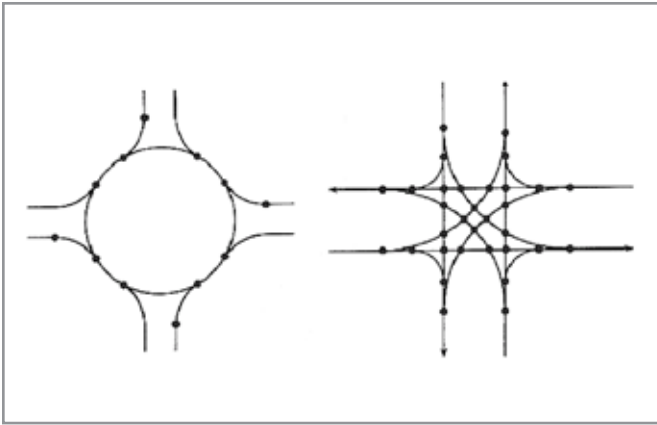


Figure 2. Diagram of conflict points at roundabout and conventional four-way intersections.



Figure 3. Redesigned Grandview drive with roundabout, bike lanes, crosswalks, curb and sidewalk with buffer strips and enhanced lighting.

constructed, along with four mid-block school crosswalks with yellow flashers.

EVALUATION AND RESULTS

Delay and crashes have both decreased for motor vehicle traffic. Residents perceived the roadway's gravel shoulders as unsafe for pedestrians before the project, so pedestrians have a much greater level of comfort with the new design. And bicyclists are more comfortable because of the new bicycle lanes.

Average speed at a mid-block location on Grandview Drive was lowered from over 40 mph (64 kph) to 32 mph (52 kph). Another study of midday speeds found that the design with the roundabout and pedestrian and bicycle enhancements reduced average speeds by 4.1 mph (6.6 kph) without the support of increased enforce-

ment. Average midday speeds on a parallel roadway that was targeted with heavy enforcement, but did not have any design changes, experienced a reduction of only 0.8 mph (1.3 kph).

ADT on Grandview Drive at Olympic Drive was 6932 in 1994, before the improvements, and 6503 in 2001, after the improvements were completed.

CONCLUSIONS AND RECOMMENDATIONS

Because the roadway design is much more aesthetically-pleasing, residents now consider Grandview Drive to be the City's "linear park" as it connects to the undeveloped waterfront.

No official data have been collected, but pedestrian activity has increased along Grandview Drive. According to Steve Sugg of the University Place Public Works Department, "sidewalks brought the people out."

The project was a complete success as the citizens of University Place have overwhelmingly supported the street improvements and the roundabouts. Further, the Washington State Department of Transportation developed roundabout guidelines and many communities in Washington State built roundabouts after the Grandview Drive project was completed.

COSTS AND FUNDING

The first roundabout, at Grandview and Olympic Drives, cost only \$20,000 more than the projected cost of the traditional intersection improvement that was initially planned and designed for the intersection.

The entire project cost \$6.15 million and was funded and built in three phases. It includes five roundabouts and over three miles (4.8 km) of reconstructed roadway. Funding came from a variety of sources, including City general funds (~\$3 million), a low interest loan from a state public works revolving loan fund (\$1.8 million), local bonds (\$1 million), County funds and donated right-of-way (\$320,000), and a contribution from a local gravel business (\$50,000).

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Innovative Application of the Bike Box

BACKGROUND

Bike box is a term that has gained popularity in the United States for a European treatment usually known as the advanced stop bar (figure 1). The box is a right angle extension to a bike lane at the head of the intersection. The box allows bicyclists to get to the head of the traffic queue on a red traffic signal indication and then proceed first when the traffic signal changes to green. Such a movement is beneficial to bicyclists and eliminates conflicts when, for example, there are many right-turning motor vehicles next to a right side bike lane. Being in the box, and thus at the front of the traffic queue, also tends to make bicyclists more visible to motorists.

COUNTERMEASURES

A bike box and accompanying traffic signs, but with no special traffic signals to hold motorists or direct bicyclists to the box, were installed on High Street at 7th Avenue in Eugene, OR, in the summer of 1998. The application of the bike box was innovative in the sense that the intent was to give bicyclists a safer way to change from one side of the street to the other at a busy downtown intersection featuring two one-way streets. Prior to the box, the vast majority of cyclists approached on High Street in the left-side bike lane adjacent to parked motor vehicles. The bike lane was left-side to match with another one-way couplet and to avoid having a right-side bike lane next to intersections with double right-turn lanes. Many of the cyclists approaching in the left-side bike lane preferred to switch to the right-side (through) bike lane on the far side of the intersection because at the next block cyclists in the left-side bike lane must turn left. Moving from left to right side after the intersection entails crossing three lanes

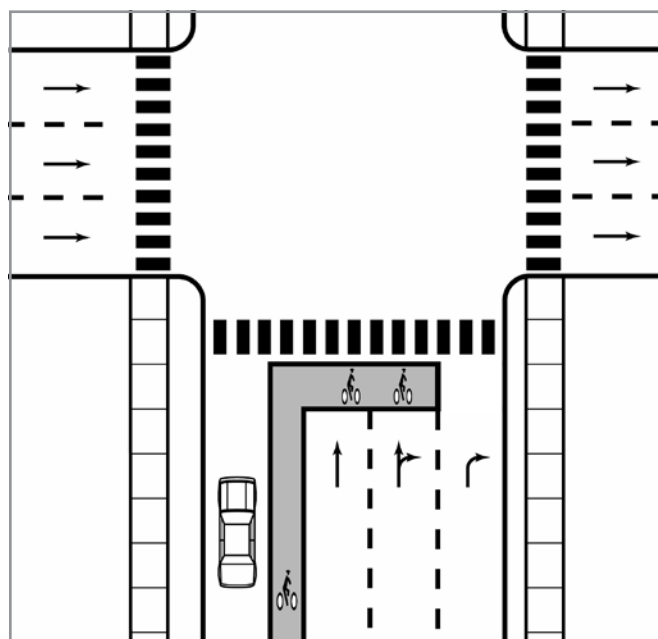


Figure 1. Diagram of a bike box used with left side bike lane.

of traffic. The average annual daily traffic on High Street is about 8,500 vehicles per day, and the peak hour total is about 1,000 motor vehicles. When traffic was busy, bicyclists could have difficulty finding a gap large enough to allow an easy move from left to right. Some bicyclists were aggressive and used hand signals to indicate their movement from left to right. Many, however, simply stopped in the bike lane and waited for a suitable gap.

Besides the crossover from left to right after the intersection identified above, there were a variety of other ways used by bicyclists to negotiate this intersection. Some would shift from the bike lane to the motor vehicle traffic lanes prior to the intersection. Others rode or walked their bicycle through the crosswalks on both High Street and 7th Avenue as pedestrians would, a movement that delays right-turning motorists. Some bicyclists would intentionally disobey the traffic signal at the intersection proper while motorists waited for the signal to change, move into the intersection, and then shift from left to right.

William W. Hunter, Senior Research Scientist,
UNC Highway Safety Research Center

With the bike box in place, bicyclists desiring to change from the left to the right side of High Street can proceed to the head of the traffic queue on a red traffic signal indication and then cross over to the front of the second lane of traffic (figure 2). The second lane is a combination through/right-turn lane. The right-most lane is right turn only. Right turn on red is not permitted; however, some motorists do not comply. The box is not meant to be used on a green traffic signal indication.

Bicyclists have the right of way when in the box. They generally are able to accelerate quickly through the intersection ahead of motor vehicles when the signal changes to green, then safely switch to the through bike lane on the right-hand side of High Street such that motorists are not inconvenienced.

Several other steps were taken to help bicyclists and motorists understand the use of this innovative treatment at this intersection. A press release was prepared and stories run in the local newspaper and the University of Oregon student newspaper. A special sign board with information about how to use the bike box was placed on a construction barricade near the intersection pedestrian crosswalk. The barricade with educational sign also had a flashing light attached. Traffic signs with orange diamond attachments added for conspicuity were placed at the intersection to indicate that traffic, except bikes, should stop prior to the box on a red signal indication (STOP HERE ON RED, with EXCEPT BICYCLES mounted below). A yellow diagrammatic sign with a BICYCLES MERGING message was already in place.

EVALUATION AND RESULTS

Cyclists traveling through the intersection were videotaped before and after placement of the box. The videotapes were coded to evaluate operational behaviors and conflicts with motorists, other bicyclists, and pedestrians. Other data concerning bicyclists' characteristics and experience, as well as their opinion of how the bike box functioned, were obtained through short oral surveys. These surveys were performed on days when videotaping was not occurring.

The use of a bike box to facilitate the movement of bicyclists from a left-side bike lane, through an intersection, and across several lanes of a one-way street to a right-side bike lane was an innovative approach. The data indicated that the use of the box was reasonably good. Usage can be examined several ways.



Figure 2. Three bicyclists using the box correctly.

- For all bicyclists coming through this intersection, 11 percent used the box as intended (i.e., approaching from the left-side bike lane and then moving into the box on a red traffic signal indication).
- Including bicyclists who used the box through other maneuvers, such as crossing from left to right before the intersection and then moving into the box, 16 percent of all bicyclists used the box.
- Narrowing further, of the bicyclists who approached in the left-side bike lane and then crossed to the right side of the street (the bicyclists for whom the box was most intended), 22 percent used the box.
- Many more bicyclists in this target group could have used the box (i.e., they had a red signal indication and enough time to move into the box). Had these bicyclists done so, then some 52 percent would have used the box. This last percentage thus approximates the upper limit of bike box use for this pilot location and left-to-right maneuver during this time period.

A problem with motor vehicle encroachments into the box likely diminished the amount of use. Overall, encroachments occurred in 52 percent of the red traffic signal indications after the box had been in place for five months. While this is not uncommon, even in Europe where the design has been in place for some time, it is troubling, and remedies should be sought. Bicyclists surveyed about the pilot location tended to frequently complain about the encroachment problem.

The bike box had no effect on signal violations. Some 6 to 7 percent of bicyclists violated a red signal indication both before and after placement of the box.

The rate of conflicts between bicycles and motor vehicles changed little in the before and after periods. The

rate was 1.3 conflicts per 100 entering bicyclists before the bike box and 1.5 conflicts per 100 entering bicyclists after. However, the pattern of the conflicts did change. Eight of the 10 conflicts in the before period involved a bicyclist moving from left to right across the travel lanes after the intersection. Two of the 10 conflicts in the after period were of this type. Six of the after conflicts took place within the intersection proper, but three of these involved bicyclists coming off the right sidewalk and conflicting with right turning motor vehicles. No conflicts took place while using the bike box in the normal sense.

CONCLUSIONS AND RECOMMENDATIONS

Use of the bike box to help bicyclists negotiate a difficult maneuver at this intersection was considered to be a rigorous test. All things considered, the innovative treatment worked reasonably well. More evaluations should be conducted in other settings and for other maneuvers to further understand how well this design works in the United States and how it might be improved. For upcoming evaluations, a number of recommendations can be made.

- Education of both bicyclists and drivers as to the proper use of the box is important. This can be accomplished through newspaper stories, radio and television public service announcements, brochures in bike shops, etc. The special education sign posted at the Eugene intersection came about after it was learned in the oral survey of bicyclists that the box was not well understood. One of the bicyclists participating in the oral survey suggested use of a banner across the roadway. This would be an excellent way of drawing attention to the presence of the box and the expected movements, especially for motorists.
- Use of bold demarcation of the box is vital. This could involve wider striping than the norm or perhaps painting the box a bright color.
- Steps should be taken to limit motor vehicle encroachment. Setting stop bars back a short distance from the box might lessen encroachment. Offset (or staggered) stop bars also would be beneficial, not only for encroachment purposes but also to help motorists see bicyclists moving into the box. Some police presence may also be necessary to instruct, warn, or ticket motorists about improper encroachment.

In summary, the bike box is a promising tool to help bicyclists and motorists avoid conflicts in certain kinds of intersection movements. More boxes need to be installed and evaluated to further understand their effectiveness in different settings. Pilot testing the Danish treatment of recessed stop bars for motor vehicles is also recommended.

COSTS AND FUNDING

Costs included paint (regular, not thermoplastic) removal, new thermoplastic, two signs near intersection and informational sign for approximately \$2,500 parts and labor. If traffic loops have to be moved: \$1,000/lane extra.

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The modification (bike box) that is the subject of this case study is not compliant with the *Manual on Uniform Traffic Control Devices*, nor is it currently being considered for inclusion. Accordingly, it is imperative that any jurisdiction wishing to utilize the bike box (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

Comprehensive Maintenance Planning for Bicycle Facilities

BACKGROUND

A comprehensive budget and maintenance plan should be developed before construction of a bicycle facility. The costs involved with maintaining a facility should be considered and budgeted for during the planning process.

The most important concept to keep in mind when considering maintenance costs is the direct relationship between what is built and what is maintained. If you build it, it will have to be maintained. If you don't build it, it won't have to be maintained. For example, if you install automatic sprinkler systems, you will have to follow a sprinkler maintenance schedule supplied by the manufacturer. If you install informational and directional signs, you will have to replace a certain percentage of them each year. Your facility design, therefore, should directly reflect the amount of money you anticipate having available for maintenance.

A second important concept to keep in mind is that it is very difficult to secure maintenance dollars. Foundation and government grants, while available for design and construction of bicycle facilities, are generally not available for maintenance. Additionally, it is difficult to get the public involved in raising funds for routine maintenance. The lesson is that maintenance costs are best addressed through prevention. For example, it is always easier to include the cost of installing a good drainage system in the initial cost of a project than it will be to secure funding for fixing a drainage problem at a later date.

The third and final important point is that developing an accurate maintenance budget is a process, not an exact science. Because of differences in bookkeeping methods, wages, facility design, topography, availability of maintenance

equipment, community expectations and a host of other variables, it is impossible to determine the potential maintenance costs of any one facility, per mile per year. For example, two identical trails in different communities will frequently have radically different per-mile maintenance costs. It is, however, possible to develop an accurate estimate of maintenance costs for a particular facility system if proper procedures are followed.

COUNTERMEASURE

Seattle's solution for developing a maintenance program for bicycle facilities has been to develop and implement a seven-step approach:

1) EXISTING COSTS

When developing a maintenance plan for a new facility, the first step is to check current costs for maintaining an existing facility. The key is to get the costs for maintaining a facility that is similar to the facility you plan to construct. When reviewing cost information, go over the budget with someone who can explain exactly what items are included in the cost figures. For example, you will want to know if they include labor and overhead costs. Do they include one-time costs on major equipment such as sweepers and trucks? Do they include charges for bringing debris to the local landfill? Do volunteers do some of the maintenance?

2) BOOKKEEPING

A second important step is to find out costs that will be assigned for various maintenance activities. In particular, you will want to look at major equipment, labor and overhead costs. For example, if you are going to need a sweeper, the agency may have a separate capital fund to pay for the sweeper, in which case you only pay the labor costs of the operator. On the other hand, the maintenance budget may be charged a per-hour fee that covers the amortized, lifetime costs associated with the purchase and maintenance of the sweeper. Labor and overhead can also

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vary greatly. For example, a maintenance employee who makes \$14 an hour may actually cost the maintenance budget \$28 per hour if all overhead costs are included. Again, every agency keeps its books differently, with some having separate budgets for categories like benefits, office space, and management support, and others having bookkeeping systems that include these items in their per hour labor costs. The bottom line is that the bookkeeping methods used by the agency managing your bicycle facilities will have a major impact on how you develop a maintenance budget.

3) MAINTENANCE CHECKLIST AND COST

The next step in developing a maintenance budget and plan is to create a checklist of all possible maintenance activities. A good way to begin is to list everything included in the facilities design. Once again, the rule of thumb is that you will have to maintain whatever you build. Besides each maintenance activity, list its frequency, its cost per application, and its annual cost. Listing the annual cost, while a lot of work, is doable if you are familiar with the bookkeeping system and with how charges will be assigned.

4) ROUTINE AND MAJOR MAINTENANCE

Once you have completed a draft list of maintenance activities, divide them into “routine” and “major” maintenance categories. In general, maintenance activities such as mowing, that have a frequency of one or more times per year, will fall into the category of routine maintenance. Activities such as repaving a trail surface, that have a frequency of two or more years, will fall into the category of major maintenance. While major maintenance occurs infrequently, it should be budgeted for on an annual basis to avoid the periodic need for a major infusion of cash.

5) MAINTENANCE PRIORITIES

Once you have divided maintenance activities into routine and major maintenance categories, you will want to set maintenance priorities by identifying which activities are critical to the safe operation of the facility, and which ones are critical to other objectives, such as protecting the investment in the infrastructure, protecting the environment, and protecting aesthetics. While some priorities may vary to reflect local community expectations, safe operation of the facility should never be compromised. The American Association of State Highway and Transportation Officials (AASHTO) *Maintenance Manual* recommends that maintenance should seek to maintain conformance with the design guidelines used to build the facility. Where proper guidelines were not used, maintenance should include improvements that will improve the facilities’ safety and operation.

6) TRACKING

The final task is to create a tracking system to insure that all maintenance activities are completed in a timely, systematic way. More than likely, the agency that will manage a facility already has a system in place. Typically, you will want a checklist for field crews that includes instructions and frequency. Once completed, checklists should be reviewed and kept on file for developing future maintenance budgets and plans. There also needs to be a system for requesting specific maintenance improvements such as sign replacement. A standardized work instruction form should be developed and sent to the field crew, then returned to the maintenance supervisor for filing once the work has been completed. Finally, there needs to be a way to track resident complaints and requests for maintenance. This is particularly critical from a liability standpoint. Once an agency has been “put on notice” concerning a particular safety-related maintenance problem, it must be corrected within a reasonable period of time. When residents call or write in, their concern should be put on a standard form that includes the resident’s name and day phone number, the date, and the location and nature of the problem. This should be followed up with a field visit and a call back to the resident explaining what, if anything, will be done about the situation. Again, all complaints should be filed for future reference.

7) MAINTENANCE BUDGET AND PLAN

Once the above steps have been completed, the maintenance budget and plan is ready to be put in final form. It should include a checklist of all maintenance items, the frequency of each activity, the cost for each activity, the annual cost of each activity and an indication of who will perform the activity. Priorities related to safe operation of the facility should be clearly identified and a tracking procedure clearly outlined.

SAFETY

As previously mentioned, maintenance activities related to the safe operation of a facility should always receive top priority. The AASHTO *Maintenance Manual* identifies seven maintenance activities that should be carried out on a routine basis. They include:

Signs and Traffic Markings

Signs warning both the motorist and bicyclist should be inspected regularly and kept in good condition; and striping should be kept prominent.

Sight Distance and Clearance

Sight distances on parallel roadways and trails should not be impaired leading up to crossings and curves. Trees, shrubs and tall grass should be regularly inspected and

either removed or trimmed if they can interfere. Adequate clearances on both sides and overhead should be checked regularly. Tree branches should be trimmed to allow enough room for seasonal growth without encroaching onto the street or trail.

Surface Repair

Streets and trails should be patched or graded on a regular basis. It is important that finished patches be flush with the existing surface. Skid resistance of surface should be the same as the adjoining surface. Ruts should be removed by whatever measures are appropriate to give a satisfactory result and avoid recurrence.

Drainage

Seasonal washout, silt or gravel washes across a street or trail, or sinking should be watched for and appropriate measures taken. Installation of culverts or building small bridges could be considered a maintenance function to achieve an immediate result and avoid the expense of contracting. Drainage grates should not have parallel openings that could catch narrow bicycle tires. Maintenance personnel should be especially instructed to assure that grates are positioned so that openings are at angles to the bicyclist's direction.

Sweeping and Cleaning

The tires of a bicycle can be easily damaged by broken glass and other sharp objects. Bicycle wheels slip easily on leaves or ice. Small solid objects such as loose gravel or a stick on an asphalt surface can cause a serious fall. There also should be concern when mechanically sweeping roadways that material is not thrown onto a bike lane, shoulder or trail. Materials such as bark or gravel may ravel and necessitate frequent sweeping.

Structural Deterioration

Structures should be inspected annually to ensure they are in good condition. Special attention should be given to wood foundations and posts to determine whether rot or termites are present.

Illumination

Lighting improvements should be made at busy arterials. Once installed, the lights should be maintained not only to guarantee reliable operation, but also to ensure that they are kept clean and replaced as required to maintain the desired luminescence.

SAMPLE MAINTENANCE ACTIVITY LIST

The following is a partial list of some of the maintenance activities to consider when developing a main-

tenance budget and plan. It is important to note that this list should be modified to reflect your particular needs and community expectations. This includes identifying priorities and classifying activities as routine or major maintenance. For example, while mowing may be a weekly activity in a wet, warm area, it may never be required in a dry, arid part of the country. When you develop your own plan, you will want to include the frequency, cost per application, cost per year and specific instructions for each item listed as previously described.

- Replace missing and damaged regulatory and directional signs.
- Repaint worn pavement markings.
- Trim trees, shrubs and grass to maintain sight distances.
- Patch holes, fill cracks and feather edges.
- Clean drainage systems, make modifications to eliminate the formation of ponds.
- Sweep to remove mud, gravel and other debris
- Mow bike lane, roadway and trail shoulders (0.8 to 1.5 m (2.5 to 5 ft) back from facility).
- Inspect structures for structural deterioration.
- Spot pruning to maintain view, enhance aesthetics.
- Maintain furniture and other furnishings.
- Mow selectively where groomed look is desired.
- Install and remove snow fences.
- Maintain irrigation lines.
- Pick up trash, empty trash cans.
- Clean rest rooms and drinking fountains, repair as needed.
- Remove graffiti from retaining walls, rocks, etc..
- Prune dense understory growth to improve user safety.
- Spray for weed control.
- Remove snow and ice.
- Maintain emergency telephones.

EVALUATION AND RESULTS

Seattle's Maintenance Program is evaluated by the feedback of residents, the number of claims resulting from poor maintenance and the number of people bicycling.

The program is a success by all measures. The city has been recognized five times as one of the best bicycling cities in North America. Public involvement has been and continues to be high with the Bicycle Program Web site, the location visited most frequently by those accessing the Seattle Department of Transportation site.

CONCLUSIONS AND RECOMMENDATIONS

After more than 30 years of building and maintaining bicycle facilities, Seattle has been very successful in encouraging people to bicycle more often while reducing the number of crashes. Additionally, Seattle residents enthusiastically support the program and have twice voted for million dollar bonds and levies to construct more bicycle facilities.

COSTS AND FUNDING

Multiple funding sources include gas tax funds, general revenue funds, B & O Tax funds, car tab revenues, federal and state grants, etc.

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Road Hazard Identification Pilot Project

BACKGROUND

Road conditions such as potholes, debris, drain grates, cracked or uneven pavement, railroad tracks, and overhanging vegetation can cause bicyclist crashes by disturbing the delicate balance between rider and machine. These hazards may contribute to falls which account for 50 percent or more of bicyclist crashes. Road hazards also may result in crashes with fixed objects, other bicyclists, or motor vehicles if a bicyclist swerves to avoid a hazard. Collisions between bicyclists and motorists are usually the most serious. More than 90 percent of bicyclist fatalities occur in crashes with motor vehicles (Baker, et al, 1993). In 2003, 622 bicyclists were killed and 46,000 injured in reported crashes with motor vehicles in the United States (National Center for Statistics and Analysis, 2003 data). Road hazards increase the chances that a bicyclist will be involved in a crash.

In addition, bicyclists tend to avoid roads and trails that they feel have unsafe or otherwise uncomfortable riding surfaces. Decreased bicycling may result if more acceptable routes are not available.

Bicyclists are often reluctant to report road hazards because they do not know how and they often believe that the necessary repairs will not be made even if reported. It is often difficult for cyclists to identify which jurisdiction has maintenance responsibility for a given section of road such as the city vs. the county.

Road crews seldom are trained to identify and repair bicycle road hazards. They are typically better at dealing with hazards for motorists. However, by the time something is hazardous for motorists, it has long been a danger to bicyclists. For example, a 1.3 cm (0.5 in)–wide crack in the road that runs parallel to the direction of travel is sufficient



Bicycle tire in a drain grate.

to cause a bicyclist to fall, but will not present a problem to motorists (California. Dept. of Transportation, 1995).

The Road Hazard Identification Pilot Project was developed and tested for the Wisconsin Department of Transportation. Local sponsors were the Village of Howard and the Bay Shore Bicycle Club. The project was based on similar “spot improvement” programs in Seattle, WA, Chicago, IL, and Madison, WI. The goal was to develop a system which could be used by public or private entities to easily and inexpensively facilitate the identification and repair of bicycle road hazards. Such a system improves bicyclist safety and enjoyment as well as cooperation between bicyclists, road crews and decision-makers. The greater Green Bay, WI, area consisting of six municipalities within Brown County was chosen to pilot test the project. Before the pilot program there were no organized efforts, either public or private, to identify and repair bicycle-specific road hazards. Municipalities in the pilot project area ranged in population size from 1,400 to 96,000.

COUNTERMEASURES

The pilot project ran from June through September 1995 in the greater Green Bay, WI, area. Road Hazard Identi-

Peter Flucke, President – WE BIKE

fication postcards were distributed to the public through bicycle shops, bicycle clubs, recreation departments, county, city, and village offices. These cards were used by bicyclists to report hazards. After a card was completed it was mailed (at the sender's expense) to a central location where the hazard identification information was entered into a specially designed computer database. The database allowed the hazard to be tracked by the project coordinator from the time it was reported until it was repaired. The database also assisted in identifying which jurisdiction was responsible for repairs, and in creating hazard reports which were sent to affected jurisdictions. Following data entry, the card was given to a trained volunteer who checked the card and hazard for accuracy and validity via a site visit. Two weeks after hazard reports were forwarded to jurisdictions, repair status updates were requested. The project coordinator contacted jurisdictions personally for subsequent status reports.

Prior to the implementation of the pilot project, a computer program was developed for tracking hazards, volunteer inspectors were identified and trained, public works directors and the County Highway Commissioner were consulted, and specialized bicycle road hazard training was offered to each jurisdiction involved.

EVALUATION AND RESULTS

Road Hazard Cards were tabulated to determine the number of hazards reported and the repair status of these hazards. Hazard inspector activity was analyzed, and bicyclists, inspectors and public works supervisors were surveyed about the project.

During the four-month pilot project, 120 hazards were reported. Of these, 23 were repaired or deemed unrepairable. The "unrepairable" designation usually referred to

minor streets that were in overall rough shape but that were not scheduled for resurfacing for several years. The other common situation was where a sheet of concrete road surface had risen up or subsided and because of the excessive cost of repair, the repair would not be made until the situation became much worse or, more likely still, when the entire road was replaced. (Without major road work, 67 were scheduled for repairs and the remaining 30 were working their way through the system at the time the pilot evaluation ended.)

Twenty-four different bicyclists reported hazards during the pilot project. Reporters tended to be experienced bicyclists, often commuters, who reported hazards primarily on busy, narrow collector and arterial streets.

Positive outcomes of the project as reported by the project coordinator, public works supervisors, hazard inspectors and bicyclists were:

For bicyclists:

- Increased awareness of road hazards;
- Increased opportunities to report hazards;
- Increased bicyclist safety;
- A core group of "hazard" educated bicyclists formed;
- Professional contacts by bicyclists developed with street departments;
- Ease of implementation;
- Change in street departments attitudes;
- Hazards often were repaired before they could be reported because of increased awareness among road crews.

For municipalities:

- Safer streets;
- Decreased exposure to liability;
- Decreased maintenance costs;
- Ease of implementation;
- Cost-effective to identify hazards and coordinate repairs;
- Improved traffic flow;
- Good public relations;
- Less critical attitudes of bicyclists toward public works departments.

There still are several areas of concern which need to be further addressed:

For bicyclists:

- Relatively small number of bicyclists reported hazards;
- Project information may not be reaching all bicyclists;

**BAY SHORE BICYCLE CLUB
BICYCLE ROAD HAZARD
IDENTIFICATION PROJECT**

Road conditions such as potholes, unsafe drain grates, railroad tracks, overhanging vegetation, glass, debris, etc. are hazardous to bicyclists. To enable repairs to be made, please fill out the form below and mail it in.

Location: Roadway Name _____

Landmarks: (Address, side of street, cross street, etc.) Be specific! _____

Description of hazard: _____

Reported by: Name _____ Phone _____ Date _____
Address _____ City/State/Zip _____

FOR FURTHER INFORMATION, CALL WE BIKE® (414) 497-3196

FOR OFFICE USE ONLY: Received _____ Checked _____ Repaired _____ Card # _____

- Some reporting bicyclists were discouraged because of slow hazard repairs (perceived or actual);
- Some hazards were difficult for inspectors to locate because of inadequate site descriptions ;
- Continuation of project following pilot test.

For municipalities:

- Slow to make repairs;
- Hazards were sometimes difficult to locate;
- Some hazards are expensive to repair (including sections of entire streets);
- Some jurisdictions communicated poorly with project director;
- No maintenance department accepted the offer of bicycle hazard identification training for their staff;
- Project/effort discontinued following pilot.

CONCLUSIONS AND RECOMMENDATIONS

A formal system for identifying road conditions that are hazardous to bicyclists is important for improving bicyclist safety and enjoyment. Once established, the Road Hazard Identification Project proved to be an inexpensive and effective means of identifying and facilitating the repair of bicycle road hazards. This program, or a similar one that incorporates bicyclist and professional training and input, would be valuable in any community.

COSTS AND FUNDING

The main costs of developing the program are project coordinator training and research (about eight hours), computer database setup (about eight hours), inspector and public works trainings (about three hours) and advertising (about three hours). The project coordinator spent about two hours per week on the project, and public works supervisors spent about the same amount of time.

Funding for the project was provided by the Wisconsin Department of Transportation's Bureau of Transportation Safety using Federal Highway Safety (402) Funds. The total cost of the project, including development and the pilot test, was \$9,615.

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Bikeway Speed Humps

BACKGROUND

Portland's Bike Program enlisted the help of the Traffic Calming section for a speed hump project in spring 1998. Speed humps were identified by local citizens as the most appropriate tool to address traffic problems on Southeast Clinton Street. Though three traffic circles were constructed toward the east end of Clinton in 1990, speeding vehicles continued to be a problem. Clinton had been designated a City Bikeway but did not have adequate curb-to-curb width to mark bike lanes without removal of parking. Reduction of traffic volume on the street was obtained in conjunction with the 1990 project that installed traffic circles, so speed reduction was the primary objective for this project.

The specific goal of the project was to enhance street safety for bicycle riders by reducing the 85th percentile speed of vehicles using Southeast Clinton closer to the legal maximum speed limit of 25 mph. Portland has determined speed humps to be an effective tool to reduce traffic speeding.

Southeast Clinton was divided into three segments for the undertaking of this project. A middle portion of the street, 21st Avenue to 26th Avenue, is part of a transit route that jogs through the neighborhood. This segment of Clinton necessitated a speed table design by City policy.

Southeast Clinton is a local service street and serves a mixed single-family residence and commercial neighborhood. Southeast Clinton is fairly level and straight. The entire length of Southeast Clinton has parking, sidewalks and curbs on both sides of the street.

Scott Batson, PE, Senior Engineering Associate,
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OPEN HOUSE

Residents along Southeast Clinton were invited to an open house on June 3, 1998, to review and comment on the proposed speed hump installation. Forty-five people attended the open house. Most of those who attended expressed approval for the proposed project. Some considered the humps to be excessive or inadequate, while others expressed concern over noise and hump location. A petition was available at the open house for residents along Southeast Clinton to sign, and was circulated after the open house by local residents. Petition results in aggregate for the three segments were as follows:

In favor of speed humps	Number	Percent of Total
Yes	179	77
No	52	23
Total	231	100

COUNTERMEASURES

Five 4.3 m (14 ft) speed humps, at 121.9 to 161.5 m (400 to 530 ft) spacing, were constructed along the 0.7 km



(0.44 mi) length of Southeast Clinton, from 12th to 21st avenues. Two 6.7 m (22 ft) speed tables were constructed along the 0.4 km (0.24 mi) length of Southeast Clinton, from 21st to 26th in the segment used by transit. Nine 4.3 m (14 ft) speed humps, at 97.5 to 182.9 m (320 to 600 ft) spacing, were constructed along the 1.3 km (0.83 mi) length of Southeast Clinton from 26th to 39th avenues. The projects were completed between September 26 and October 18, 1998, by Portland's Bureau of Maintenance.

EVALUATION AND RESULTS

Standard velocity and volume counts, before and after speed hump construction, were used to measure the change in vehicle speed. Measurements taken after speed hump construction were averaged over the length of the street for comparison to speed before construction. The after velocities were weighted based on distance from the center of the nearest speed hump. Manual peak-hour turning movement counts were also conducted to assess the change in usage by cyclists. Counts were taken six months after construction was completed.

TRAFFIC SPEEDS

Table 1 describes the change in speed in the three sections of Southeast Clinton.

The changes in traffic speed associated with this project were typical of speed hump projects elsewhere in Portland.

TRAFFIC VOLUME

Table 2 summarizes the change in traffic volume in the three sections of Southeast Clinton.

Typical daily fluctuations of traffic volume are expected to be 10 percent. The 25 to 30 percent reduction on Southeast Clinton is greater than normal (see table 2). The 1990 traffic circle project was constructed as part of an effort to deter use of Clinton as an alternative to parallel streets of higher classification.

Table 2. Vehicle Volume Changes

Segment	Speed Hump	Average Volume, vpd ¹		Change
		Before	After	
12th to 21st	14 ft	3400	2300	-30%
21st to 26th	22 ft	3300	2450	-25%
26th to 39th	14 ft	2600	1800	-30%
¹ Vehicles Per Day				

Table 3. Cyclist Usage

East-West 7-9 AM			
Intersection	Before	After	Change
Clinton at 26th	40	66	40%
Clinton at 39th	20	35	75%
East-West 4-6 PM			
Intersection	Before	After	Change
Clinton at 26th	37	83	128%
Clinton at 39th	24	36	50%

Traffic volume measurements at over 40 locations adjacent to Southeast Clinton identified four that had volume increases that warranted additional monitoring. Subsequent reevaluation determined the volume increases to be anomalous.

The increase in usage by cyclists is another indication of the success of this project (see table 3). Feedback from local residents has been very positive.

CONCLUSIONS AND RECOMMENDATIONS

Traffic calming on Southeast Clinton from 12th to 39th Avenues successfully reduced the average 85th percentile speed

Table 1. Vehicle Velocity Changes

Segment	Speed Hump	Average Speed ¹ , mph		Highest Speed ¹ , mph	Speeders, Over Posted 25 mph		Speeders, Over 35 mph	
		Before	After	After	Before	After	Before	After
12th to 21st	14 ft	33	25	27	80%	12%	10%	0%
21st to 26th	22 ft	26	24	26	15%	8%	0%	0%
26th to 39th	14 ft	31	25	28	58%	8%	15%	0%
¹ 85th Percentile Speed								

closer to the posted speed and produced an unexpected benefit of decreasing the number of cars using the street. The speed reduction associated with the use of speed humps will provide increased safety to cyclists using this bikeway.

Feedback from cyclists regarding a preference for speed humps versus speed tables has been mixed. It is unclear from this project if speed tables would have had as significant an effect on speeding if they were implemented along the entire project length. It is likely that speed tables will produce less discomfort to cyclists than do speed humps. A common theme with traffic calming projects is the tradeoffs such projects involve. The potential discomfort of the cyclist traversing a speed hump or table should be compared to the discomfort associated with the speed of adjacent vehicles.



Southeast Clinton is part of a dense grid of streets (typical 61-m (200-ft) block faces). Monitoring of adjacent streets for unintended diversion is critical. If diversion is identified as a significant issue and possibility, modification of the hump layout or use of the longer table design is recommended.

COSTS AND FUNDING

Item	Cost	Quantity	Subtotal
4.3-m (14-ft) speed hump, including markings	\$1,500	14	\$21,000
6.7-m (22-ft) speed table, including markings	\$1,800	2	\$3,600
Warning Signs and posts	\$160/group	7	\$1,120
Total Construction Costs			\$25,720

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Speed Cushions for the Evergreen Corridor

Bike Lane Project

BACKGROUND

Evergreen Boulevard serves as a popular bike route with great potential as a bike commuter route. It was rated by the *Cycle Clark County Map* as having a low level-of-service for bikes. Its roadway classification is collector with an average daily traffic of 3200 vehicles per day. It connects between downtown and a large residential neighborhood. The width is 9.8 m (32 ft), with parking allowed on one side before the project (figure 1). It has commercial bus service that serves both blind and deaf students in the area.



Figure 1. Evergreen Boulevard before the project in area of speed cushions.

The street was an old state highway before the construction of Washington SR 14 and still provides access to the City's Historic Reserve.

Community goals for the project were to improve bicycle safety and compatibility, pedestrian access for persons

John Manix PE PTOE Neighborhood Traffic Engineer, City of Vancouver, WA

with disabilities, to slow traffic, and to enhance the roadway aesthetics with the hope of spurring redevelopment.

The work on the corridor was broken down into phases. This report focuses on Phase 1 from E. Reserve to Grand Boulevard.

Speeding on Evergreen Boulevard was a common neighborhood complaint with the speed posted at 25 mph. The 85th percentile speed was 34 mph, with about 90 percent of the vehicles traveling over the speed limit.

The phase 1 section of Evergreen Boulevard is 0.65 miles long and had relatively few collisions. In the three years before construction, 20 collisions were reported with the majority (12) at Grand Boulevard. The majority of the collisions at Grand Boulevard were "approach turn" collisions related to Grand Boulevard traffic, not Evergreen Boulevard. Most of the other collisions were at minor intersections and were of the "right angle" type. No bike or pedestrian collisions were reported along Evergreen Boulevard in the phase 1 section.

The surrounding and adjacent neighborhood associations had identified a goal of creating a bicycle path along Evergreen Boulevard in their Neighborhood Action Plan. Installation of a path was infeasible, so the alternatives were to install bike lanes, place signs along a bike route, or improve an alternative route.

The project scope proposed installation of bike lanes on Evergreen Boulevard, but this required removal of all on-street parking. Removal of parking is never popular, particularly on this section with commercial land use. Knowing parking restriction would not be popular, staff proposed installation of bike lanes and "streetscape" improvements to minimize the protests associated with the loss of parking. The streetscaping was supported by the local neighborhood association because it reinforced the goal to beautify the street.

After extensive public involvement, the consensus was to install bike lanes on most of Evergreen Boulevard but to leave 26 on-street parking spaces for three blocks in the commercial district. To enhance bicycle compatibility in this section with shared travel lanes and on-street parking, traffic calming was proposed. Traffic calming also addressed resident concerns with speeding on Evergreen Boulevard.

The traffic-calming tool of choice was then an important consideration. Typical speed humps were ruled out based on the impacts to commercial transit service and fire department response time. The use of certain traffic calming measures was controversial with bicyclists because of safety concerns. A previous traffic-calming project on a popular bike route used curb extensions that generated many bicycle safety complaints associated with bike riders being pinched between moving traffic and the curb extensions.

COUNTERMEASURES

Staff had, for some time, considered the use of “speed cushions” as an alternative to speed humps to provide an effective traffic-calming tool on arterial, collector, or local streets that serve as emergency response routes.

Speed cushions are modified speed humps. The shape resembles a cushion or pillow placed in the roadway, but a speed cushion does not span the entire roadway or traffic lane. The intent is to slow most motor vehicles, similarly to a speed hump, but to allow wide wheel-based vehicles such as buses and fire trucks to drive over them with minimal impact, as cushions are narrower than the wheel base of these vehicles.

In researching the topic, staff found speed cushions in use in the United Kingdom as early as 1993 and learned of American experience in the cities of Sacramento, CA, and Austin, TX. Sacramento’s experience with what they refer to as a “speed lump” was particularly important because these devices are designed for the same size of fire engine and commercial bus as used in Vancouver. Figure 2 illustrates the trial speed lump from Sacramento.

Vancouver tested speed cushions using rubber speed hump components that could be assembled to match the Sacramento speed lump width dimension of 1.8 m (6 ft) (see figure 3).

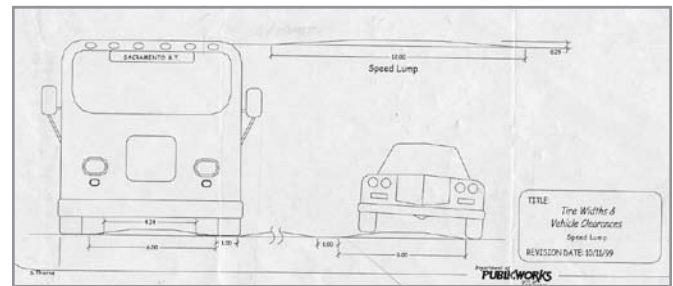


Figure 2. Sacramento speed lump.



Figure 3. Trial rubber speed cushion.

These trials allowed the City to test several configurations related to the position of speed cushion in the street. For example, should one cushion be placed in the center of the roadway like Sacramento’s speed lump, or should they be placed in the center of the travel lane? If in the lane, how far apart should adjacent cushions be?

With the fire department’s endorsement of the rubber speed cushion, the City implemented two other traffic calming projects concurrently with the Evergreen Corridor bike lane project that used speed cushions. These projects were West 33rd Street from Main Street to Columbia Street, and Southeast 155th Avenue from Southeast Mill Plain Road to Southeast 1st Street. They were only intended to slow traffic and were not intended as bike improvements. The before and after speed survey data from the three projects as well as one other is provided in the evaluation.

EVALUATION AND RESULTS

Before and after bike counts were collected, compared and found inconclusive. The pre-project Evergreen Boulevard bike volumes were about 1 percent of the total traffic as measured in the midweek afternoon peak hour. The after volume was about the same but at this small a sample

size, the staff does not feel confident that the results can be attributed to the project.

The Bicycle Compatibility Index: A Level of Service Concept (Bicycle LOS) by FHWA was used to evaluate the projects' effects on bicycling on Evergreen Boulevard. This method is straightforward and matches local experience. In previous work, staff found that this evaluation tool approximately matched the evaluation used by the Clark County Bicycle Advisory Committee's Bike Map (*Cycle Clark County*) that independently rated roadways for bicycle compatibility. The Bicycle LOS evaluation included comparing the shared lane with parking on one side of Evergreen Boulevard section before and after the speed cushions were installed, and also that of the section with bike lanes and no parking allowed.

The secondary performance measures were related to community goals not exclusively linked to bicycling. The neighborhood hoped for a reduction in speeding. This objective was evaluated with a before and after speed survey, a traffic count, and a collision history review. The speed survey and traffic count data were collected via hose counters in the vicinity of the proposed traffic calming before and midway between speed cushions following installation. The traffic data were collected for one midweek day. This report includes the results of three other speed cushion projects to evaluate the effectiveness of this relatively new traffic calming tool.

Staff anticipated a collision reduction associated with the traffic calming. The city's collision database was queried for three years before and one year after the project was implemented.

City staff hoped the speed cushions would demonstrate a bicycle, fire truck, and transit-friendly speed hump design. To evaluate these objectives, staff solicited comments from local bike club members, the local transit agency and the fire department.

The results of installing speed cushions in the section of Evergreen Boulevard with parking improved the Bicycle Level of Service or Compatibility, but not nearly as much as the section with bike lanes and no parking. Table 1 shows the results of the Bicycle LOS evaluation.

Table 1. Bicycle Compatibility Index
Results for Evergreen Boulevard.

Midblock Identifier	BCI	Level of Service	Bicycle Compatibility Level
Evergreen Boulevard—Before Project EB without Parking	3.47	D	Moderately Low
Evergreen Boulevard—Before Project WB with Parking	3.47	D	Moderately Low
Evergreen—After Project with bike lanes & no parking	1.97	B	Very High
Evergreen—After Project WB with Parking	3.24	C	Moderately High
Evergreen—After Project EB without Parking	3.24	C	Moderately High

The LOS changed from a high D to a mid-level C with the addition of speed cushions. This minor change is significant because LOS of C is noted in *The Compatibility Index: A Level of Service Concept, Implementation Manual* as a bench mark for roadways where casual bicyclists are expected. As a popular recreational bikeway, this is a reasonable expectation for Evergreen Boulevard.

The Bicycle LOS of B for the bike lane section confirms staff efforts to keep the shared lane section as short as possible.

The Bicycle LOS evaluation looked at the before and after traffic data, noting changes in traffic volume, speed and parking occupancy of the on-street parking. The Bicycle LOS was calculated for each direction because parking was allowed on one side only. But parking had little impact on the Bicycle LOS because the occupancy rate is low (less than 25 percent) both before and after the project.

In all cases, the speed cushions significantly reduced the speed of vehicles and have likely reduced the number of collisions. Table 2 shows the results of the speed survey and collision history of the four streets with speed cushions. All locations had very consistent results.

Table 2. Traffic Survey Results of Streets with Speed Cushions.

Roadway with Termini	Traffic Collisions per yr	Daily-Traffic Volume	85% Speed	Percentage of Vehicles Over 30 MPH
Evergreen Boulevard; X St to Winchell—Before	1.25	3,900	34 mph	42%
Evergreen Boulevard; X St to Winchell—After	0	3,400	29 mph	8%
W 33rd St; Washington to Columbia—Before	NA*	3,300	33 mph	19%
W 33rd St; Washington to Columbia—After	0	3,000	29 mph	7%
SE 155th Ave; Mill Plain to SE 1st St—Before	0	3,400	34 mph	37%
SE 155th Ave; Mill Plain to SE 1st St—After	0	3,100	28 mph	9%
NE 49th St; NE 26th St to Work St—Before	.33	1,500	35 mph	44%
NE 49th St; NE 26th St to Work St—After	0	1,300	31 mph	17%
* This location had speed humps changed to speed cushions to address fire department concerns with response delays associated with humps.				

The 85 percent speed is at or slightly lower than 30 mph on all streets that have a 25 mph speed limit. More importantly, the percentage of vehicles over 30 mph dropped dramatically (see table 2).

The traffic volume on each of the streets with speed cushions dropped about 10 percent. This traffic diversion could cause complaints on parallel routes, but no complaints have been received.

None of the four sites had a significant number of collisions in the three years before the project. One year after the installation of speed cushions, there are encouraging, but inconclusive results with no collisions since installation (see table 2).

The following information was gained from the trial with rubber humps and permanent installation of four projects:

- The proposed shape of a speed cushion matching the profile of our current speed hump (7.6 cm (3 in) high and a 4.3 m (14 ft) parabolic curve profile), 1.8 m (6 ft) wide with side ramps of 3.7 m (12 ft) (1:4 grade) could be traversed by a fire engine without significant impacts.
- Using a speed cushion less than 1.8 m (6 ft) wide (one trial at 1.7 m (5.5 ft) significantly compromised effectiveness).
- Speed cushions should be spaced approximately 91.4 to 121.9 m (300 to 400 ft) apart along a roadway to keep the 85 percent speed of traffic at or below 30 mph.
- The configuration shown in figure 4 should be used with parking restrictions in the vicinity of the speed cushion if the street is narrower than 11.6 m (38 ft). With our West 33rd Street project, we review conflicts between parked cars and fire trucks. The West 33rd Street is 11.5 m (36 ft) wide. Based on our work, the fire department staff concluded that the distance between the parked car and the fire truck (about 0.6 m (2 ft)) was too close for them to feel comfortable responding to an emergency at normal speed and safely traversing the speed cushion. See figure 5 for a photograph of a fire engine traversing a speed cushion near a parked car. In the case of West 33rd Street, we are modifying the design by restricting parking on one side of the street and adjusting the position on the other side to allow for greater clearance between parked cars and the fire trucks.
- The speed cushion should be positioned in the center of the travel lane so buses and fire engines can align over the center of the cushion and remain within the travel lane.
- The speed cushion should be used on straight sections of roadway for fire trucks to position over the hump. From our trial it appears that speed cushions installed on a horizontal curve will be of little benefit because the rear wheels do not track the same as the front.

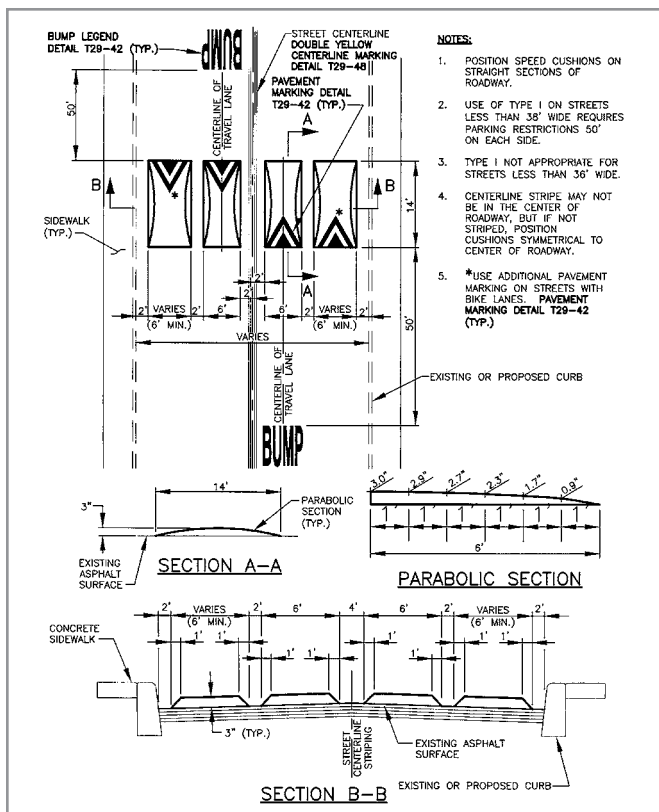


Figure 4. Speed cushion design configuration for 36–38 ft streets—use with parking restrictions.

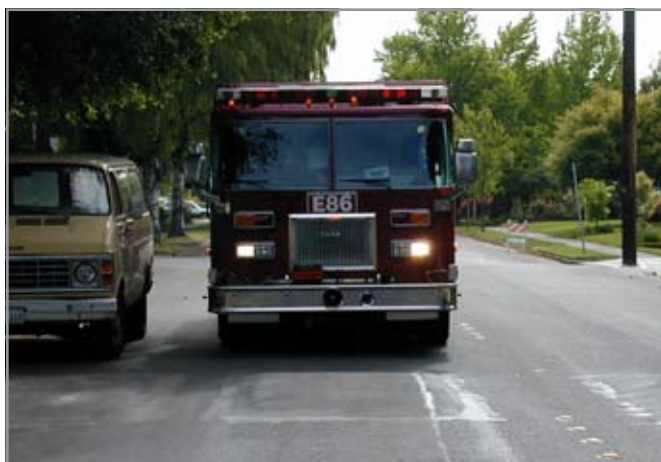


Figure 5. Fire engine over speed cushion—too close to parked vehicle.

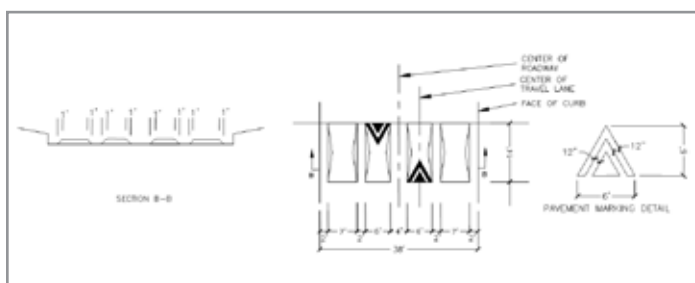


Figure 6. Speed cushion design with pavement marking.

- The gap between the speed cushions should be 0.6 m (2 ft). Our 0.3 m (1 ft) spacing appeared too narrow.
- With the speed cushion centered in the travel lane and the marking centered over the cushion, the marking helps fire engine and bus drivers line up wheels to straddle the cushion. This design also facilitates the use of a marking that is in compliance with the *Manual on Uniform Traffic Control Devices, Millennium Edition*, (U.S. Department of Transportation Federal Highway Administration, 2001).

Figure 6 shows the speed cushion with pavement marking detail that is in compliance with the MUTCD ME.

Our striping crew has added the same pavement marking on the additional hump which spans the shoulder-parking area to the right of the speed cushion. This marking is technically incorrect but conforms with past practice used by many agencies that use an arrowhead-type marking on humps.

The first comments regarding the speed cushions on Evergreen Boulevard from Vancouver Bicycle Club (VBC) members were negative because the speed cushions were initially installed incorrectly, making them uncomfortable to ride over. This was true for both cars and bikes. They also objected to them because of concerns with loss of control and apparent lack of need. After the modifications, the City received the following comment from a member of VBC:

“Bicyclist” stopped in to tell you that you that Evergreen Boulevard is “wonderful.” He was very pleased with the speed bumps being “redone.” We also have received positive comments regarding the bicycle improvements on the corridor.

Comments related to transit have been very positive. The C-Tran representative commented:

Thanks for the information that you provide; it was very helpful. I checked with the current operators driving through Evergreen Boulevard and have not had any negative feedback. In fact, the cushions seem to be allowing them the ability to travel through with limited interference. They appear to be “transit-friendly” with the most recent adjustments.

Another comment from a City Council member to the City Manager:

While on the same bus trip with the Japanese kids I referenced earlier, we took Evergreen eastbound. (It looks absolutely GORGEOUS.) The bumps were no

problem for the driver. In fact, he said that they were so much better than Portland's. That was Evergreen Coach that took us. Big bus, not uncomfortable at all.

Fire department staff gave positive comments on the speed cushions several times. The quality of the ride on Evergreen is relatively poor because of dips at cross streets, so it is not an important response route. The West 33rd Street traffic calming project demonstrated that the fire engine drivers need ample clearance (0.9 m (3 ft) or more) with parked cars to traverse the speed cushion at full speed.

The staff has taken several comments from the public regarding the lack of effectiveness of the speed cushions. The comments are generally related to comparison with speed humps and can be paraphrased as: "I can drive over those humps at a high rate of speed." But the speed data do not support that opinion.

CONCLUSIONS AND RECOMMENDATIONS

Adding speed cushions to Evergreen Boulevard increased the Bike LOS to a level (C) that will accommodate recreational riders expected on this facility, and allowed the city to address the desire of the commercial community to maintain on-street parking. But if parking had significantly increased, the lower speeds and volumes would not have adequately compensated to keep the Bicycle LOS to C. The Bike LOS evaluation methodology is more sensitive to changes in parking than the speed of traffic.

Thus the use of speed cushions is not recommended as a replacement for bike lanes for long sections of roadway, but they are a valuable tool in assuring that the total project was a success in accommodating multiple interests – in this case the businesses that valued parking, bicyclists that needed safe bicycle facilities, and transit and emergency response. Speed cushions are relatively new traffic calming tools that appear to be successful at calming collectors or arterials that serve both as fire response and transit routes and carry moderate levels of bicycle traffic.

Traffic calming remains controversial with some bicycle riders. The main concern with speed cushions relates to loss of control by hitting the tapered side of the speed cushion near the gutter. If the speed cushion design can provide a clear wheel path through the speed cushion, this safety concern would be addressed. On future projects with bike lanes the city plans to modify the design to minimize the risk that bicyclists will traverse the speed cushion on the tapered side. The use of traffic calming on streets classified as "col-

lector" will always be controversial. If time proves speed cushions to be a successful traffic calming tool, we must be wary of overuse. A likely negative outcome of overuse is diversion of traffic onto parallel residential streets. In the past, increases in emergency response time and the high cost of alternative traffic calming tools have limited deployment. Because speed cushions address these issues, adoption of policies to prevent a slippery slide of overuse is recommended. The policy should limit the use on collectors to bracketing important crosswalks, parks, schools or short sections of parking on bike routes.

COSTS AND FUNDING

Speed cushions (material and labor): \$2,000 each

Funded within a larger project included a Federal Transportation Enhancement grant and local matching funds.

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Neighborhood Mini Traffic Circles

BACKGROUND

Seattle's Neighborhood Traffic Control Program (NTCP) started in 1968 when the city began to respond to resident requests to slow motor vehicle traffic and reduce the number of crashes at intersections of residential streets. Of all the treatments used in Seattle, the traffic circle has proven to be the most effective at solving this problem. Since 1973, over 800 circles have been constructed in Seattle and NTCP staff members receive about 700 resident requests for new circles each year.

COUNTERMEASURES

Potential traffic circle locations are identified through community requests or investigation of high accident intersections. Each request is investigated and an initial assessment is performed to determine if a traffic circle is feasible. Residents' requests are responded to with a letter explaining the process for installing a circle and the likelihood of the location competing successfully for full city funding. In order to ensure that the city's traffic safety funding is allocated to intersections demonstrating the greatest need, a priority point system is used to rank the intersections where traffic circles are requested. Ranking criteria include the number of crashes that have occurred at the intersection in the last three years; traffic speed (85th percentile); and traffic volume. To compete for funding, residents are required to submit a petition with signatures representing 60 percent of the households within a one-block radius of the proposed traffic circle. Funding is allocated starting with the intersection with the worst combination of



problems and proceeds as far down the list as funding allows. The cost to construct each circle ranges from \$4,000 to \$7,000.

Each traffic circle is individually designed to fit the intersection without having to modify the street width or corner radii. Most of Seattle's local streets are 7.6 m (25 ft) wide and traffic circles are usually 3.7 to 4.9 m (12 to 16 ft) in diameter. A single unit truck having a 13.7 m (45 ft) turning radius is used as a design vehicle to ensure that fire trucks can pass by the circle without running over the curbs. The fire department reviews all intersections where circles are to be constructed and field tests are conducted where they have a specific concern. While traffic circles are designed to allow fire trucks to pass by them, they are constructed with a 0.6 m (2 ft)–wide mountable curb that allows fire trucks or larger vehicles, such as moving vans, to run over the curb without damaging either the vehicle or the circle.

John Marek, Neighborhood Traffic Control Program Engineer, City of Seattle
Peter Lagerwey, Pedestrian & Bicycle Program Coordinator, City of Seattle

Landscaping is included in all the traffic circles as long as a neighborhood volunteer is identified who will maintain the circle (almost always). The pavement inside the traffic circle is removed during construction to allow for drainage and to accommodate tree roots. The landscaping plays two important roles—it makes the circle more at-



tractive to the neighborhood residents, and changes the character of the street to make it less appealing for high speed driving. The local residents are required to maintain the plantings, which consist of ground cover and one to three trees. Residents are allowed to add their own low-growing plants that will not block pedestrian or driver visibility.

EVALUATION AND RESULTS

Traffic circles are evaluated by comparing the number of crashes occurring in the 12 months before and the 12 months after a traffic circle is installed. Additionally, surveys are mailed to residents following the construction of a traffic circle.

In 1997, a study of 119 traffic circles constructed between 1991 and 1994 showed a 94 percent reduction in all types of crashes. Since the study, subsequent spot checks of other locations have produced similar results. While most of the non-arterial intersections in Seattle have no right-of-way control, 32 of the 119 locations studied had existing two-way stop or yield signs, which were removed when the traffic circles were installed. These locations, which previously had right-of-way control, experienced accident and injury reduction rates similar to those found at uncontrolled intersections.

In addition to reducing accidents, traffic circles have been effective at reducing vehicle speeds but have not significantly reduced traffic volumes. The effect on speed generally carries over to the middle of the block, but to a lesser extent than near the intersection. As might be expected, multiple circles at every intersection are more effective than an isolated circle. The minimal impact on traffic volumes allows circles to be used as a spot or street-long safety device without needing to address the impacts of traffic diverting to other residential streets.

Traffic circles generally have been well-accepted by bicy-

clists. The circles slow down motor vehicle speed, which reduces the speed differential between bicyclists and motor vehicles. Bicyclists have not complained of being “squeezed” by motor vehicles as they go around the circle since the speeds of the motor vehicles are comparable to the bicyclists. A few bicyclists have complained that the circles cause them to slow down (in the same way they slow the motorists).

The success of traffic circles is also measured by its acceptance among residents living near them. By far, the majority of residents are enthusiastic about the traffic circles. For example, nearly 700 requests for new circles are received each year and about 3,000 signatures are received on petitions for new circles each year. Only two circles have been removed out of more than 800 constructed (residents are guaranteed that the city will remove a traffic circle if, after construction, 60 percent of the households within a one block radius have signed a removal petition), and surveys mailed to residents following construction of a traffic circle indicate that 80 percent to 90 percent of residents feel the circles have been effective and want to keep them permanently.

CONCLUSIONS AND RECOMMENDATIONS

After nearly 30 years of experience installing mini traffic circles, Seattle has found them an effective device for controlling neighborhood traffic and improving the safety of residential streets. Additionally, residents feel traffic circles have successfully addressed their safety concerns and make their neighborhoods better places to live. By slowing down motor vehicle speeds, they benefit neighborhood bicyclists. If a residential street has high volumes of bicyclists or is a bicycle boulevard, other treatments, such as diverters for motor vehicles, should be considered before installing a traffic circle.

COSTS AND FUNDING

\$5,000 to \$8,000 including staff time.

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Bicycle Boulevards — Bryant Street Example

BACKGROUND

A three-mile residential street was transformed into a mostly stop-free bicycle arterial that serves cyclists of all levels. This “bicycle boulevard” treatment is straightforward and would be replicable in many cities.

THE BICYCLE BOULEVARD CONCEPT

Bicycle travelways are generally classified as shared roadways, shared roadways with signs, bike lanes and shared-use paths (*Guide for the Development of Bicycle Facilities*, AASHTO 1999). Each type attracts cyclists according to their desire for directness, avoidance of motor traffic and other factors. In the absence of vehicle calming and diversion measures, direct through routes for cyclists often also attract through motor traffic, decreasing their attractiveness for less traffic-tolerant cyclists of all ages.

A bicycle boulevard is a treatment of a low-volume, local street shared roadway that creates a mostly stop-free “arterial” for bicycles while diverting most through motor traffic. Motor vehicle parking and access to all properties is unchanged. Through motor traffic is diverted by bicycle-permeable street closures and mandatory-turn devices spaced every half-mile to a mile. Most stop signs face most cross-streets, creating two-way stops favoring the boulevard. The city of Palo Alto, CA, implemented what is believed to be the nation’s first bicycle boulevard by transforming Bryant Street.

Written by John Ciccarelli, Consultant, Transight LLC / Bicycle Solutions.

Contributions by Gayle Likens, Carl Stoffel, and Ashok Aggarwal (City of Palo Alto Transportation Division), Paul Goldstein (Bicycle Advisory Committee chairperson), and Ellen Fletcher (BAC vice-chair and former City Councilmember).



Bryant at Matadero Creek: Separate bicycle and pedestrian bridges.

COUNTERMEASURES

BICYCLE BOULEVARD HISTORY IN PALO ALTO

Discussion of bicycle-priority streets arose in Palo Alto during the environmental movement of the 1970s, reflecting the community’s desire for bicycle routes with low vehicle traffic to complement busier bike-laned streets. Safety was a secondary goal to be achieved mainly by lowering motor vehicle volume and reducing car-bike conflicts. The city’s first bikeway network plan was adopted in 1972, and its 1976 Comprehensive Plan called for a network of bicycle boulevards and identified several possible streets. The 2000 Draft Bicycle Transportation Plan further develops the proposed bicycle boulevard network.

For its first bicycle boulevard, the city evaluated three parallel streets serving the same north-south travel corridor (Bryant, Waverley, and Cowper). All are residential except for three blocks through downtown, and all have parallel parking for their entire length except for some diagonal parking downtown. All three serve the same destinations, including several schools, and function as nearby multi-lane through streets favored by motorists. At the northern city limit all three streets end near a bicycle and pedestrian bridge across a major creek, enabling extension of

the route into the adjacent city (Menlo Park). Each had a signal at one of the two east-west arterial streets they crossed. One (Waverley) was a bus route.

Bryant was selected because it was not a bus route, it had an existing pedestrian bridge across a creek that diverted through motor traffic—a key bike boulevard feature, and it already had a signal at the southern arterial street that would be crossed. The bicycle boulevard conversion was implemented in two segments each 11 years apart, in part because of the anticipated expense of placing a signal at the crossing of the northern arterial street.

The southern segment, extending 3 km (1.9 mi) from East Meadow Drive to Churchill Avenue, was implemented in 1981 and involved four major elements. The first was a bicycle- and pedestrian-only crossing of a creek that had a wooden pedestrian bridge that was scheduled for replacement. Because of the anticipated increase in bicycle travel due to the boulevard transformation, the old bridge, just one block from an elementary school, was replaced with a bicycle-only bridge aligned with the street centerline and a separate pedestrian-only bridge aligned with one of the sidewalks. These were actually constructed after the boulevard segment opened. The other elements were two bicycle-permeable street closures, and the changing of all stop-controlled intersections to two-way stops on the cross streets except at two intersections that remained four-way stops. The latter change enables uninterrupted pedaling for a mile or more between four-way stops and signals.

The northern segment, extending 1.9 km (1.2 mi) from Churchill Avenue to the northern city limit, was implemented in 1992 and involved three major elements. The first, constituting most of the cost, was a new signal at Embarcadero Road, a four-lane residential arterial street carrying 25,000 vehicles daily, combined with islands that force right-turn-only movements for motor vehicles on Bryant. The cost of the proposed signal attracted a great deal of non-cyclist opposition because of an existing signal one block away. Cyclists responded that a two-block detour added turning movements and compromised navigability, and that interaction with buses on the parallel street was undesirable. The city added the signal and coordinated it with the adjacent signal to minimize delays on the arterial street. The second element was a bicycle-permeable street closure just south of Channing Avenue, which also attracted opposition due to resident concerns over traffic diversion and impacts on an urgent-care medical facility. After a six-month trial, the closure was replaced with a neighborhood traffic circle one block south at Addison. The third element was stop sign changes similar to those implemented on the first segment.



Bryant at Lowell: Typical street closure.



Bryant approaching Embarcadero: Turn restriction sign.

EVALUATION AND RESULTS

FIRST (SOUTHERN) SEGMENT

Bryant's first bicycle boulevard segment was evaluated during a demonstration period from May through October 1982, just after its implementation. Results are reported in the staff's *Bicycle Boulevard Demonstration Study* – Evaluation report of December 9, 1982, which states:

Comparative bicycle counts were taken at three locations on Bryant and at three other locations prior to and during the bike boulevard study. Counts were taken during a twelve hour period (7:00 a.m. – 7:00 p.m.) on mid week days. Base counts were taken in May 1981 and April 1982; counts at these locations were taken again in October 1982.

Twenty-four vehicular traffic counts were taken at eighteen locations along the bike boulevard corridor. These counts included locations along Bryant as well as parallel and cross streets where changes in traffic patterns were anticipated. Base counts were taken in May 1981 and 1982; counts were taken again in October 1982.

The results showed that bicycle traffic on Bryant increased dramatically – 85 percent and 97 percent for two key locations – and that Bryant’s rate of increase in bicycle traffic exceeded that of other streets. Bryant was found to carry 475 to 725 bicycles per day depending on location. Bike traffic decreased substantially on two nearby parallel multilane streets favored by motorists (–35 percent and –54 percent for two key locations).

Motor vehicle volumes within the overall corridor, encompassing Bryant and several parallel streets, remained fairly constant. All but three of the streets in the corridor carried considerably less than 1,000 vehicles per day, quite acceptable for local residential streets. Motor traffic on Bryant near the two street closures declined by 52 percent (953 to 457 vehicles) and 65 percent (481 to 170), respectively. Motor traffic diverted by the closures split about evenly to the two closest parallel streets.

The Palo Alto Police Department reported that collisions remained at a low level on the southern segment. No collisions occurred near the street closures.

Staff sent a letter to all residents within one block of Bryant along the corridor, and 18 individuals responded. Before implementation, neighborhood residents raised several kinds of concerns—increased speeding, motorcycle and moped violations of the street closures, and residence access issues. Speeding complaints were received soon after implementation but dropped off. Twelve-hour motorcycle and moped counts at the two street closures noted 79 moped violations and 4 motorcycle violations. (Mopeds fell out of fashion after the 1970s, and few if any motorcyclists currently use Bryant for through travel because nearby parallel multi-lane streets serve their needs.) One complaint related to driving schools using the streets and

their new cul de sacs as practice areas, but after being contacted the schools agreed to use other routes. The police and the fire department reported no serious impairment of emergency response (Palo Alto has a fully connected street grid that offers many route options).

There was some concern about changes to cyclist behavior at intersections on a route with most stop signs removed in the bicycle travel direction. On a weekday in October 1982, a member of the city’s Bicycle Advisory Committee observed cyclist behavior at one of the remaining four-way stops on Bryant’s first segment. Three hundred to 400 cyclists were observed during each of the morning and afternoon commute periods. Most scanned for cross traffic, some scanned and slowed, and a few made a complete stop. This is typical of cyclist behavior at other stop-controlled intersections in the city.

SECOND (NORTHERN) SEGMENT

Bryant’s second bike boulevard segment was implemented in 1992. Unlike the first segment, whose full length underwent a six-month demonstration, the only trial element was the street closure four blocks north of the new signal. One reason for testing this element was its location next to an emergency medical care building, though that facility subsequently relocated out of the corridor. The trial’s results appeared in the staff report of July 15, 1993 titled *Evaluation of Six-Month Trial of Bryant Street Temporary Street Closure for the Bicycle Boulevard Extension*. Only one parallel street block experienced traffic increases predicted to be “noticeable” by the “Traffic Infusion on Residential Streets” methodology used by neighborhood traffic management researchers. Staff recommended that the closure be made permanent, but residents persuaded the city council to replace it with a neighborhood traffic circle at the nearest intersection to the south. That circle went through its own trial period and is now permanent.

Because of the lack of a street closure on the segment from the northern arterial to downtown, this segment still attracts considerable short-distance through motor traffic. Motor vehicle volumes there are higher and car-bike interactions more frequent than on the boulevard’s purely residential southern segment.

OTHER FEEDBACK

Some cyclists on Bryant have remarked that motorists approaching on stop-controlled cross streets sometimes fail to yield to non-stop through cyclists on Bryant. When each boulevard segment was first installed, the city temporarily added yellow “Cross Traffic Does Not Stop” warning plates below cross-street stop signs to educate drivers about the traffic control change. In both phases



Bryant at Addison: Neighborhood traffic circle.

these were removed after several months because they are nonstandard traffic control devices and because their size impacts sightlines.

As was the existing practice for bicycle-permeable street closures in Palo Alto, the two closures on the boulevard's southern segment were both placed just behind the corner curb returns at intersections, forming an apparent three-way junction that was actually four-way for bicycles. It was found that motorists approaching such intersections do not always scan for and yield to bicyclists traversing the street closures. Palo Alto now installs new street closures several car lengths back so intersections appear as four-way for all parties.

SUBSEQUENT EVALUATION

The city has conducted occasional counts of bicyclists at various locations since the completion of the Bryant bicycle boulevard in 1992. Eight-hour intersection counts conducted in May 1997 tallied 385 bicycles at one location on Bryant. Staff attributes the substantial reduction from 1982 levels to cultural changes—the bicycle's share of commute and utility trips has dropped since the first energy crisis, and a greater fraction of students are driven to school as compared to 20 years ago. The city recently hired a full-time transportation systems management coordinator devoted to facilitating adult and student commute alternatives including bicycling.

CONCLUSIONS AND RECOMMENDATIONS

The bicycle boulevard treatment successfully transformed a local street into a bicycle thoroughway while retaining motor vehicle access to all properties. Bicycle volumes increased substantially, and bicycle trip times compare favorably with parallel route options. Bryant Street has become a widely known and well-used through route on the San Francisco Peninsula, both for inter-city commutes and intra-city trips, including student commutes to elementary, middle, and high schools. In honor of her multi-decade role in the street's transformation, the city recently designated the street to be the Ellen Fletcher Bryant Street Bicycle Boulevard.

The process of identifying potential bicycle boulevards is straightforward, and implementation is relatively simple compared to full-on traffic calming. Other cities throughout the country have implemented bicycle boulevards or are considering them. One Bay Area example is Berkeley. There is a future example in nearby

Sunnyvale, where Borregas Avenue, a local street currently severed by two freeways, will become a bicycle boulevard when those gaps are closed by new bicycle-pedestrian bridges.

COSTS AND FUNDING

California's Transportation Development Act, Article 3 (TDA-3) program dedicates a small fraction of the state sales tax on gasoline for bicycle and pedestrian transportation projects throughout the state. TDA-3 is allocated by city population so it is a fairly predictable—albeit variable—funding source.

For the first (southern) segment of the Bryant bicycle boulevard, Palo Alto obtained \$35,000 of FY 1983-84 TDA-3 funds for a new bicycle bridge across a creek. The remainder of the funding for this segment came from city Street Improvement funds.

The second (northern) segment cost \$243,000 in 1992, including the traffic signal. The signal—including interconnection to the city's control system and the adjacent signal—was paid for with \$75,000 of FY 1992-93 TDA-3 funds and \$99,000 of city Traffic Signal Capital Improvement Project funds. The balance of \$69,000 came from the city's Street Improvement Program.

Cost estimates for bicycle boulevards in other locations will largely depend on the capital improvements needed to divert through motor traffic (such as bike and pedestrian-only waterway bridges and bicycle-permeable street closures), calm remaining motor traffic (such as traffic circles), and create bike route continuity across major streets (new signals, bridges or underpasses).

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Planning, Designing and Implementing a Shared-Use Path

BACKGROUND

There are millions of bicyclists that enjoy and prefer riding on off-road trails rather than sharing the road with trucks and cars. Off-road trails present a different set of design challenges for planners, designers and bicycle advocates. This paper offers a summary of elements that constitute good trail design and defines how such trails can be created within a given community.

Successful, functional, and shared-use (those that accommodate a variety of trail users) trails are, for the most part, the result of good planning and design. Properly planned and designed trails take into account how an individual trail fits into a comprehensive trail network, offering transportation as well as health and recreational benefits to a community. Most importantly, well-designed trails serve the needs of trail users, limit conflicts among user groups, link popular destinations, are successfully integrated into the existing built environment of a community, and are sensitive to the surrounding native landscapes and environment.

COUNTERMEASURES

ELEMENTS OF GOOD TRAIL DESIGN

There are many factors that go into the development of a functional and successful shared-use trail. This paper does not make an attempt to address all factors. The most important factors have been selected and described herein.

Accommodating the User

The most important consideration for the design of a trail is the accommodation of the trail user. Most shared-use trails will need to serve the interests of a wide range of



users, including people who want to walk, jog, bike, and in-line skate. Most shared-use trails will be developed at a minimum width of 3 m (10 ft). This is done to accommodate two-way traffic on the prepared trail tread surface. It may be necessary to increase the width to 3.7 or 4.3 m (12 or 14 ft) in order to accommodate heavy traffic on a given trail. It would also be advisable to divide the trail into “wheeled” and “non-wheeled” treads if the right-of-way and landscape can support two trail treads. The wheeled tread should be 3 m (10 ft) wide. The non-wheeled tread can be 1.8 or 2.4 m (6 or 8 ft) in width.

All trails must be designed and constructed to be accessible to all persons regardless of their abilities. There are very few reasons why a given trail cannot be built to be fully accessible. The best guidebook on this subject is *Designing Sidewalks and Trails for Access: Part 2, Best Practices Design Guide*. Every trail designer and manager should have this reference book on hand to ensure that trail projects are accessible.

Connectivity

The best trails are those that link people to popular destinations. Each trail segment should have logical and functional endpoints. Trails that serve as links throughout a community are the most popular for trail users. While this seems obvious, sometimes off-road trails will end abruptly,

Charles A. Flink, FASLA, President, Greenways Incorporated

especially in urban areas. It is very important that trails be linked to other trails, to parks, and to an on-road network of bicycle facilities and sidewalks.

Reduce Multi-User Conflict

Multi-user conflict is regarded as the most serious safety concern for off-road trails. Conflicts between cyclists and pedestrians are the most prevalent and are usually caused by reckless and unsafe behavior, incompatible use values or by overcrowding. The most effective remedies for this conflict begin with design and management. Trails can and should be designed to reduce conflict by widening the trail tread or by separating the trail tread for different users. Single tread, multi-use trails can also be managed to reduce conflicts, sometimes by separating users under a time of use policy. Involving user groups in the design of a trail is the best way to both understand local needs and resolve the potential for shared-use conflict. Posting trails with a trail use ordinance and providing educational materials on how to use the trail is also important.



Fitting Trails to the Environment

The most enjoyable trails to use are those that celebrate the natural landscapes and native environments traversed by the off-road trail. This is one of the most popular reasons outdoor advocates choose to use off-road, shared-use trails. Trails should have rhythm and syncopation, and flow within their surroundings so that they captivate users. Trails should follow the natural contours of the land and take advantage of native landscape features such as water, groupings of vegetation, scenic views, and interestingly built features.

Integrating Trails into the Built Environment

Trails should also celebrate the built landscapes they traverse. Often we try to hide viewsheds deemed unpleasant. This may not always be a good idea. Since trails are designed to be used by people, it is much better to keep viewsheds open. Trails through urban landscapes provide an opportunity to interpret the surrounding environment. Great care



must also be taken to successfully fit a new trail into the urban fabric. For example, the conversion of abandoned railroad corridors has been the greatest resource for new urban trails in the past 20 years. It presents challenges for trail designers because these corridors supported a different type of transportation activity. Creating new intersections between roads and converted rail-trails is the greatest challenge for these urban trails. It is important that intersections be designed to clearly determine who has the right-of-way. Intersections should also be very clearly marked for all groups to delineate crossing zones for trail users. Pavement markings, signs, lighting, and textured pavement can all be used to make intersections safer.



THE IMPORTANCE OF PUBLIC INPUT

Incorporating public input into the design of a trail is one of the most important steps in the process. Land-owners who are adjacent to trail corridors should always be included in the design process. Finding the most appropriate method for involving the public in the design of a trail is important. A list of involvement techniques is provided below:

Meet with individuals

One-on-one meetings are the best way to approach people who might have opposition to a proposed trail. These meetings offer opportunity to calmly discuss alternatives, as well as specific needs.

Citizen advisory committees

It may be advantageous to convene a group of citizens to help decide elements of the trail design. This can create community buy-in and advocacy for the project. Be certain to have balance on this committee among user groups, as well as advocates and possible opponents.

Public workshops

Perhaps the best method for soliciting input is to invite the public to attend an open house or trail workshop. These meetings can be held during the week or on a Saturday. Provide opportunities for attendees to write on trail design maps and participate in other elements of the design process.

Public hearings

Some local governments may require a formal public hearing or presentation to an elected council or board. These official meetings are important to providing legal foundation for future trail development.

Public survey

It is also advisable to conduct a public survey, either an opinion poll or a statistically valid survey, to better understand interest and level of support for the trail project.

All public input should be recorded and made part of a permanent record with respect to the final design for the trail.

CONCLUSION AND RECOMMENDATIONS

Good trail design is influenced by many factors. This paper has defined the most important components of good design. Within the context of our modern world, trail development is actually a fairly complex undertaking. It requires that we understand the opportunities and constraints of the natural and human-made environments and that we account for the diverse interests of trail users. Defining a logical process for planning and designing every trail is one way to ensure that all factors influencing trail development, function, and safe shared use, have been appropriately addressed and resolved.

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Path and Roadway Intersections

BACKGROUND

The Springwater Corridor is a 25.7 km (16 mi) paved shared-use path from Portland's inner eastside heading east to the adjacent suburbs of Gresham and Boring. A rail-to-trail conversion, it follows power lines and is part of a larger trail system known as the 40-Mile Loop extending throughout the Portland metropolitan area.

Currently experiencing over half a million annual users, the trail crosses 28 roadways along the way, offering an interesting case study of trail-roadway crossings. Almost all are at locations away from existing roadway intersections, thus few before and after safety or functionality comparisons can be made. However, we offer qualitative observations where appropriate.

COUNTERMEASURES

TYPES OF INTERSECTIONS

Evaluation of trail-roadway crossings involves analysis of traffic patterns of vehicles as well as trail users. This includes traffic speeds, street width, traffic volumes (average daily traffic and peak hour), line of sight, and trail user profile (age distribution, destinations). Although many trails or paths use grade-separated crossings of major roadways whenever possible, these are expensive and must be well-designed, or they are not used. On the Springwater Corridor Trail, there are five grade-separated crossings of roadways, three of which existed before development of the trail, and the last two were installed as a new roadway improvements project after the trail was completed. Essentially, the creation of the five grade-separated crossings were therefore funded by sources other than trail construction dollars.

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The existing crossings fall into the following categories:

1. Unprotected, marked crossings—Unprotected crossings include midblock crossings of residential, collector, and sometimes major arterial streets.
2. Routed to existing intersection—In certain locations, the trail emerged quite close (within a few hundred feet) to existing intersections and was routed to use the existing signal.
3. New signalized crossings—In four locations, new signalized crossings were installed at major roadways due to the traffic volumes, speeds, and projected trail usage.
4. Grade-separated crossings—Three grade-separated crossings were in place at the time of acquisition of the corridor. Two additional grade-separated crossings were constructed after the trail was installed. The trail takes advantage of the presence of these grade-separated crossings.

TYPE 1: UNPROTECTED/MARKED CROSSING

Most of the minor public roadway crossings along the Springwater Corridor are serviced by unprotected crossings consisting of crosswalk markings and signs. Where the crossing is of a public roadway, trail users are required to stop for roadway traffic. In addition, there are several private driveway crossings of the trail. At these private driveway crossings, motorists are required to stop for trail users. These crossings have a low volume of traffic and are not public street right-of-ways. As a general policy on the Springwater Corridor Trail, private driveway users are required to stop for trail users as indicated by stop signs and marked crosswalks.

In each case, the crossing design took into consideration vehicular traffic, line of sight, trail traffic, use patterns, road type and width, and other safety issues such as nearby schools.



Unprotected, marked crossing of local street.

These crossings have the following characteristics:

- Crosswalks
- Maximum traffic volumes of approximately 5,000 average daily traffic (ADT) (1,000–1,500 peak hour)
- Maximum 85th percentile speeds—35–45 mph
- Maximum street width—18.3 m (60 ft) (no median)
- Minimum line of sight—25 mph zone: 31.5 m (100 ft), 35 mph zone: 61 m (200 ft), 45 mph zone: 91.4 m (300 ft)
- Warning signs provided for motorists, and stop signs and slowing techniques (bollards/geometry) used on the trail approach. Bollards also serve to minimize motorized vehicle access onto the trail.
- Vegetation and other obstacles cleared from motorists and trail-user sight lines
- Three of the unprotected intersections (Johnson Creek Boulevard, Southeast Flavel, and Southeast 92nd Avenue) have median islands that provide a pedestrian refuge area and were added in anticipation of increases in traffic volumes on these streets

Evaluation and Results

No trail user and motorized vehicle conflicts have been reported. The private driveway crossings typically serve large industrial complexes, and their access across the trail is permitted by the trail managing agency (the city of Portland). There have been no issues at these private driveway crossings, and motorists do stop when crossing the trail.

Two of the three median refuge islands have landscaping. The landscaping has been subject to damage from automobiles.

TYPE 2: ROUTE USERS TO EXISTING SIGNALIZED INTERSECTION

The trail leads users very close to a major intersection at Southeast Linnwood and Johnson Creek Boulevard. This

intersection went through a major redesign shortly after the Springwater Trail was built. New improvements included signalization of this intersection. Trail designers recognized the potential of increased safety by diverting trail users to the new signalized crossing.

In addition, the former rail line crossed an existing intersection at Southeast Bell and Johnson Creek Boulevard at a diagonal through this intersection. The intersection was signalized prior to the construction of the trail. Trail users now utilize the existing signal, crossing each street one at a time.

The crossings have the following characteristics:

- Crosswalks
- Traffic signals and pedestrian activated signal button
- Traffic volumes greater than 15,000 average daily traffic (ADT)
- 85th percentile speeds greater than 45 mph
- Street widths greater than 18.3 m (60 ft)
- Minimum line of sight—25 mph zone: 31.5 m (100 ft), 35 mph zone: 61 m (200 ft), 45 mph zone: 91.4 m (300 ft)
- Warning signs provided for motorists, STOP signs and slowing techniques (bollards/geometry) used on the trail approach, and bollards that serve to minimize motorized vehicle access onto the trail
- Vegetation and other obstacles cleared from motorists and trail user sight lines
- ADA compliant curb ramps
- Distance of trail to signalized intersection less than 106.7 m (350 ft)

Evaluation and Results

No collisions have been reported. Trail users complain of having to cross two crosswalks at Bell and Johnson Creek, thus requiring them to wait for two signal cycles.





Trail routed to Johnson Creek/Linwood signalized intersection. Trail users cross using crosswalks.



Signalized crossing at 82nd Ave and 122nd Ave includes: flat grade with two marked crosswalks (one for each movement) and landscaped median; pedestrian and equestrian push button activation; bicyclist loop detector signal activation; flat grade on approaches with good sight lines; advance warning signs for motorists.

TYPE 3: NEW SIGNALIZED CROSSINGS

There are four locations—Southeast 82nd Ave, Southeast Foster Road, Southeast 122nd Ave and Eastman Parkway—along the Springwater Corridor where the trail crosses a major roadway of above 15,000 ADT. In all four cases, the crossing width was greater than 18.3 m (60 ft), the nearest intersection more than 106.7 m (350 ft) away, and all had anticipated trail user volumes of greater than 100 per hour. Trail designers felt that new signalized crossings would be necessary to facilitate safe travel, and thus developed a signal warrant analysis that projected use through trail user numbers from the Burke Gilman Trail in Seattle, and user counts on a 1.6-km (1-mi) built portion of the Springwater Corridor in Gresham. Each location was also analyzed for sight lines, impacts on traffic progression, timing with adjacent signals, capacity, and safety.

Trail users activate the signal as follows:

- Pedestrians: push button
- Cyclists: loop detector in pavement
- Equestrians: push button mounted on pole at 2.4 m (8 ft) height

At Southeast 82nd, Southeast Foster Road and Southeast 122nd Avenue, the crossing includes a median island to reduce the crossing distance, signal activation in the median for those unable to cross the entire roadway in one movement, and advance warning signs for motorists. Other crossing features follow the guidelines provided for diverting users to an existing signal as described earlier.

Evaluation and Results

The signalized crossings have been effective, safe, and functional. Since their installation in 1995, there have been no reported collisions, with an estimated 500,000 annual us-

ers. Trail users note that although they must activate the signal and wait for a green light, motorists have gotten used to the signal and frequently stop before they get the red light. Traffic engineers report minimal interference with nearby signals, given the relatively distant spacing from the nearest signalized intersections. They also report no problems.

TYPE 4: GRADE-SEPARATED CROSSINGS

There are five grade-separated crossings on the Springwater Corridor. These crossings consist of both over and undercrossings of roadways. Interstate 205, Highland Road/181st, and Telford Road were existing grade-separated crossings developed in response to the presence of the railroad. As such, these crossings are well integrated into the trail layout and easily used by trail users.

Hogan Road and the 7th Street Bridge, both in the City of Gresham, are roadway improvement projects built after the trail was constructed. At both these roadway crossings, the roadway goes over the trail, and Johnson Creek is immediately adjacent to the trail. The Hogan Road crossing was implemented in 1995, while the 7th Street Bridge project followed a few years later. Both grade-separated crossings were built in anticipation of high projected vehicle volumes and speed.

Key characteristics of these undercrossings include:

- A minimum vertical clearance of 2.4 m (8 ft)
- Placement of the trail at an elevation higher than the one year flood plain elevation of the creek
- Maximum trail grade approaching the undercrossing of 5 percent
- Alternative trail route leading up and over the bridge in the event the creek is in flooding stages
- Lighting under the bridge
- Rip-rap reinforced edge to the creek
- Limited vertical clearance warning signs for trail users

Evaluation and Results

Hogan Road, having been the first of the two undercrossings to be implemented, had several shortcomings. Placement of the trail at the two-year flood plain elevation resulted in regular flooding and closure of the trail. With each flooding event, sediments from the creek were deposited on the trail, requiring regular clean-up. The approach to the undercrossing did not facilitate complete visibility through the undercrossing area, resulting in unsafe feelings among users along the approach. Lighting installed in the underpass area was vandalized, requiring retrofitting of the lights with metal cages. In order to meet ADA grades on the trail approach, a switch back ramp was

incorporated on the eastern side of the undercrossing approach. Turning radii used on this approach tend to be a bit tight for bicyclists' comfort. Today, about half the trail users opt to use the alternative, at grade crossing route in lieu of the Hogan Road undercrossing, regardless of creek conditions.

These lessons learned were taken to heart when the 7th Street Bridge project was proposed. Key characteristics of this undercrossing include:

- Placement of the trail at the 25 year flood plain elevation
- Alignment of the trail approach to facilitate complete visibility of the undercrossing area
- Installation of hose bib water connections to facilitate trail clean up in the event of a flood
- 2.7 m (8 ft, 9 in) of vertical clearance instead of the minimum of 2.4 m (8 ft)
- Use of vandal-resistant light fixtures
- Setback of the bridge foundation abutment from the trail, resulting in a greater sense of openness under the bridge

These improvements resulted in an undercrossing that has been well-received and equally well-used by the public. Flooding and maintenance problems are few. Most trail users are surprised to learn the bridge came in after the trail.

CONCLUSIONS AND RECOMMENDATIONS

Trail crossing designs tailored to the site characteristics (type of cross-street, traffic volumes, street width, traffic speeds, proximity to existing intersections, etc.) have resulted in well-functioning trail-roadway intersections with no reported safety problems to date. Experience with some under-crossings highlighted the importance of good design, including open approaches with good visibility and consideration of site environmental conditions.

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Grade-Separated Crossing Treatments

BACKGROUND

For over a century, Boulderites have been getting around by bicycle. The city did not, however, emphasize bicyclists and pedestrians in the design of transportation facilities until the 1980s. The 1989 Transportation Master Plan (TMP) brought with it some major changes in how the city viewed transportation. Transportation's emphasis was moved away from primarily focusing on the automobile, and shifted toward a balanced view of transportation that fully included options like walking, biking, and taking the bus.

Since 1989, the city has seen many changes in transportation facilities, particularly for bicyclists. The planned network of primary and secondary bicycle corridors is largely complete, minus a few key connections that remain to be built. A network of continuous paths along Boulder Creek and its tributaries is 70 percent built. Today, Boulder's bike and pedestrian facilities are among the best in the country.

The city recognizes the importance of providing a variety of transportation options that allow citizens to travel safely and efficiently. All of Boulder's transportation facilities include several elements that have been embraced by the community. Bike and pedestrian underpasses have been such a success that they are now used throughout the city. In explaining how the city has come to provide over 55 underpasses, it is important to consider the history leading to their construction.

Cris Jones, Transportation Planner, Boulder, CO
Contributions by Bill Covern (Traffic Operations Engineer), Annie Noble (Greenways Coordinator) Marni Ratzel (Bike and Pedestrian Planner) and Randall Rutsch (Senior Transportation Planner).

In 1910, Frederick Law Olmsted, Jr. warned the city of Boulder of the dangers of allowing development to encroach upon the floodplain of Boulder Creek. He recommended against the construction of a deep, artificial flood channel to facilitate development in the floodplain. Instead he suggested that Boulder Creek be allowed to remain in a small shallow channel for the ordinary stages of the stream, while including a much broader floodplain as a channel during larger storms. Recognizing the need to dedicate this floodplain land to a useful purpose, he suggested creating a space for public use.

In 1969, a moderate flood affected the city of Boulder. The following decade marked the city's first serious flood control efforts. Initial investigations focused on traditional flood mitigation techniques, such as hard-lining stream channels and using concrete structural facilities to channelize stream flow. These plans, however, conflicted with the city's commitment to improve both quality of life and the urban environment, and evoked considerable public opposition.

With the goal of maintaining and enhancing the aesthetic and environmental integrity of Boulder Creek and its tributaries, the city decided to pursue alternative solutions to flood control. In 1978, the city adopted a "non-containment" policy for Boulder Creek as part of the Boulder Valley Comprehensive Plan. This policy promoted ongoing city efforts to protect public safety by restricting development within the floodplain of Boulder Creek and its tributaries.

In 1984, the city adopted the Boulder Creek Corridor Plan that recommended development of a continuous path along the entire length of Boulder Creek. This corridor would serve both as a flood hazard mitigation measure and as a continuous urban park for recreational and transportation use. It would also serve to restore and enhance wetlands along with fish and wildlife habitats.

The construction of a continuous shared-use facility required separated grade crossings at each intersection throughout the corridor. Existing creek underpasses were converted to include shared-use path underpasses through fairly simple modifications. Upon its completion, the Boulder Creek Path was instantly popular and quickly became a much loved community amenity (figures 1 and 2).



Figure 1. Construction of the Boulder Creek Path underpass at Broadway.



Figure 2. The completed Boulder Creek Path underpass at Broadway.

The public acclaim of the Boulder Creek project led to an increase in public discussion about the desirability of extending and continuing the concept of the Boulder Creek project along Boulder Creek's tributaries within the city. As a result, the city designated over 32.2 km (20 mi) of stream corridors along six tributaries of Boulder Creek for inclusion in the Greenways Program.

COUNTERMEASURES

Today, the city of Boulder is home to more than 55 underpasses built to serve bicyclists and pedestrians. While most new underpass projects are driven by the transportation department, underpasses often have benefits beyond transportation. New underpasses along Boulder's greenways have increased flood carrying capacity and improved the natural environmental systems along Boulder Creek and its tributaries.

Although most underpasses have been built as a part of Boulder's greenway system, a number of underpasses have been constructed at locations not along a waterway. These underpasses serve to eliminate pedestrian barriers and increase safety at dangerous intersections. The College and Broadway underpass, for instance, was designed with the sole purpose of increasing pedestrian safety.

Before construction of the College and Broadway underpass, thousands of students a day were forced to cross Broadway (U.S. Highway 92) at grade, in order to get between campus and the University Hill commercial district. Students often crossed (midblock) and would stand in the median before crossing entirely. Unlike most of the underpasses within the city, the Broadway and College underpass required a lengthy public process before construction. This was largely because of concerns from the merchants in the Hill commercial district. Merchants worried that an unattractive or poorly designed underpass would be perceived as unsafe and discourage pedestrian traffic to their businesses. The city went through an extensive design process, including obtaining public input, and creating photo simulations of the proposed design to gain community acceptance (see figure 3).



Figure 3. Pedestrian underpass at College and Broadway.

EVALUATION AND RESULTS

The success and support of Boulder's underpasses is measured by several elements benefiting the community. These include increasing the safety and convenience of bicycle and pedestrian travel, promoting their use, and in the case of the Greenways system, providing a continuous grade-separated system appropriate for users who are not comfortable using the on-street system. The city currently employs several methods to assess the value of its underpasses relative to its transportation goals. These methods include automated pedestrian and bike counts and periodic surveys used to calculate bicycle and pedestrian mode share.

In addition to routine evaluation methods, the city updates its Transportation Master Plan (TMP) approximately every six to seven years in order to ensure the city is working toward the current needs of the community. The 1989 TMP created a vision of a grade-separated system along Boulder's greenways. This vision was refined in the 1996 TMP update with its recognition of different types of users from the novice to the experienced commuter and goal of providing facilities for all types of users. Underpass construction continues to be strongly supported by Boulder citizens and evaluation of TMP policies will determine the extent of future construction.

The planning and design efforts resulted in an award-winning project widely hailed as a complete success. Today, the College and Broadway underpass allows thousands of bicyclists, pedestrians, and motor vehicles to travel freely and safely through the intersection every day.

As mentioned above, several methods are employed to evaluate underpass use and benefit. User counts are performed at several locations throughout the city including the Broadway and College underpass. Although counts are not available for dates prior to construction, current

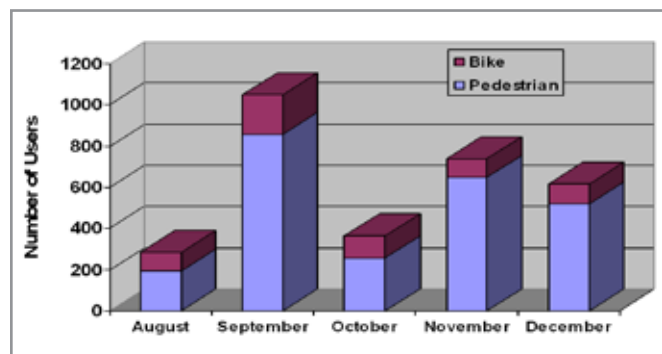


Figure 4. College and Broadway fall 2002 users.

counts indicate a high number of users. If the underpass did not exist, current users would be forced to cross Broadway at grade (figure 4). Counts at Broadway and College are taken once a month from 4:45pm to 5:30pm.

In addition to performing manual counts, the city operates several automated bike counters along several shared-use pathways. These counters monitor use 24 hours a day, 365 days a year. Counts have revealed fairly stable use of about 600 to 800 cyclists per day year-round, excluding days of extreme cold, precipitation, and high winds.

CONCLUSIONS AND RECOMMENDATIONS

As the city of Boulder continues to move toward completing its greenway corridors, it is important to consider the factors that have lead to the city's success (for other communities interested in building a similar system). As mentioned above, much of the success of the greenways system and its underpasses can be attributed to a community that views such a system as beneficial. It also is important to remember that the system has not been built entirely on city dollars. About 50 percent of funding has come from federal resources.

COSTS AND FUNDING

The cost of constructing a grade-separated transportation system is a discouraging factor for many communities. It often is purported that high sales tax revenues have afforded the city's desire to construct such an extensive multi-modal transportation system. In actuality, Boulder's sales tax revenues are average among cities of similar size. It is the community's vision of responsible growth and commitment to a multi-modal network that has driven transportation efforts in the city. In addition to commitment, the rapid and extensive construction of underpasses throughout the city has depended on funding leverage. Many underpass projects have received federal funding based on flood mitigation elements. Please see the table listing of some recent underpass projects and their funding sources.

Underpass Projects and Funding Sources

GREENWAY	PROJECT	DESCRIPTION/GOALS	FUNDING
South Boulder Creek	Central to Stazio	Trail construction including low water crossing and railroad underpass.	\$ 67,000 (Lottery) \$ 70,000 (Flood Control)
Bear Creek	Baseline to US 36 though CU property	One underpass and trail connections to CU Main campus, Apache Trail and Williams Village.	\$ 8,700 (Transportation) \$ 58,000 (Flood Control) (FAUS)
1992			
Wonderland Creek	Broadway Underpass	Flood capacity increase, channel restoration, riparian vegetation restoration, wetland and pond creation.	\$ 45,000 (Transportation)
Wonderland Creek	Valmont Underpass	Flood capacity increase, trail underpass.	\$ 30,000 (Transportation) \$ 45,000 (Flood Control) (FAUS)
South Boulder Creek	Stazio to Arapahoe	Paved trail construction, railroad underpass, wetland creation.	\$ 57,000 (Lottery) \$ 6,000 (Transportation) \$ 55,000 (Flood Control)
1993			
Bear Canyon Creek	Mohawk to Gilpin	Riparian habitat widening and restoration, wetland creation, landscaping and two underpasses, trail construction.	\$ 28,000 (Lottery) \$ 55,000 (Transportation) \$ 84,000 (Flood Control)
South Boulder Creek	Arapahoe Underpass	Trail underpass.	\$ 93,000 (Lottery) \$ 55,000 (Transportation) \$ 45,000 (Flood Control)
South Boulder Creek	EBCC Pedestrian Bridge	New trail bridge and soft-surface trail approaches.	\$ 18,000 (Lottery) \$ 2,000 (Flood Control)
1994			
Bear Canyon Creek	Martin to Moorhead	Food improvements, two underpasses, trail connections.	\$148,000 (Lottery) \$335,000 (Transportation) \$599,000 (Flood Control)
1995			
Fourmile	Broadway Underpass	Trail underpass and flood capacity improvements.	\$ 4,000 (Lottery) \$ 75,500 (Transportation) \$ 10,000 (Flood Control)
Goose Creek	Trail Connection at 30 th Street	Trail through new 30 th Street underpass to Mapleton.	\$ 9,000 (Transportation) \$ 1,000 (Flood Control)
Bear Creek	Mohawk Underpass	Trail underpass and flood capacity improvements.	\$ 93,000 (Transportation) \$ 75,000 (Flood Control) \$200,000 (Urban Drainage)
1997			
South Boulder Creek	Baseline to EBCC	Underpass, habitat restoration and trail connection.	\$ 61,000 (Transportation) \$ 82,000 (Lottery) \$ 52,000 (Flood Control)
Bear Creek	Gilpin Underpass	Flood control, pedestrian and bicycle underpass.	\$ 6,500 (Lottery) \$ 63,000 (Flood Control) \$211,000 (Transportation) \$ 97,000 (Urban Drainage)

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Share the Trail: Minimizing User Conflicts on Non-Motorized Facilities

BACKGROUND

A major portion of bicycle crashes involves falls or collisions with pedestrians and other cyclists. Non-motorized facilities (sidewalks, paths, bike lanes and trails) tend to be particularly hazardous. There are a number of reasons for this:

- These facilities are sometimes crowded, particularly during busy periods.
- These facilities often have a diverse range of users, including cyclists, joggers, skaters, scooter users, pedestrians, pedestrians with pets on leashes, pedestrians with carts or packages, people using wheelchairs and other mobility aids, and even equestrians. There are a wide range of user behaviors, including fast and slow cyclists, users alone and in groups, pedestrians who stop to view, talk or play, and sometimes vendors.
- Users often include young children and pets who cannot be expected to understand traffic rules or take safety precautions.
- Facilities are often built and maintained with limited resources. Designers sometimes accept inadequate standards with the argument that, “It’s better than nothing.” For example, paths and sidewalks often are too narrow for their intended uses. Path intersections are often confusing to use as well.
- There is sometimes little education or enforcement of appropriate user behavior.

These conflicts are likely to increase in the future as user diversity grows. For example, in recent years public paths and sidewalks have experienced increased use by motor-

ized wheelchairs, inline skates, push scooters and electric-powered bicycles. New devices such as Segway may become more common. Effective management of non-motorized facilities is increasingly important to avoid problems, to accommodate diverse users, and to manage resources efficiently.

This case study reports on best practices for managing non-motorized facilities. The goals and objectives of such management are to:

- Increase the safety and comfort of non-motorized facility users;
- Accommodate a diverse range of non-motorized facility users and avoid conflicts; and
- Encourage non-motorized modes for transportation and recreation.

Relying only on separation to solve user conflicts may effectively prohibit some forms of transport. For example, many communities have laws that prohibit cycling on sidewalks, yet many cyclists do not feel safe riding on busy streets. As a result, cycling becomes infeasible for many users (particularly for children and inexperienced adults along busy arterials), or the regulations are ignored by users and seldom enforced by police. Similar patterns occur with other modes, including skates, skateboards, push scooters, and Segway.

An alternative approach to constructing separate facilities is to address potential user conflicts by establishing clear rules that define how each user of a non-motorized facility should behave, supported by adequate education and enforcement efforts. Regulations concerning when and where specific activities are allowed or prohibited, maximum travel speed, and who must yield to whom can help reduce user conflicts. For example, rather than prohibiting all sidewalk cycling (including along suburban arterials where there may be few practical alternatives), it may be better to establish rules that prohibit cycling on sidewalks in commercial areas and other crowded areas, limit

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maximum travel speed to 10 mph on sidewalks, and require cyclists to yield to pedestrians and other sidewalk users.

In other words, good management focuses on user *behavior* more than user *type*, since it is the behavior that tends to create conflicts. For example, there may be less conflict between a walker and a slow, courteous cyclist than between a pedestrian and an inconsiderate jogger, although both of the latter would be classified as pedestrians. Focusing on user behavior can accommodate a broader range of users and address a broader range of conflicts.

COUNTERMEASURES

DEVELOPMENT OF PLANNING PRINCIPLES AND GUIDELINES

Many communities have adopted programs to manage non-motorized facilities, including sidewalks, paths, bike lanes and trails. Such programs are particularly important on heavily-used urban trails, but virtually any non-motorized facility requires some degree of management involving a combination of education and enforcement regarding the safe and considerate sharing between different types of users.

Good management requires the establishment of the basic principles and priorities to guide individual policies and practices. Decision-makers (which may include agency staff, policy makers, citizen advisory groups, etc.) should identify the factors they want to consider when setting priorities for different non-motorized facility users, such as the relative importance and impacts of different types of activities, and the needs and abilities of different types of users. For example, transportation activities may be

given priority over other uses of sidewalks and paths, such as paths (signs, vendors, games), and more vulnerable users (wheelchair users and children) and modes that impose fewer impacts on others (pedestrians) can generally be given priority over less vulnerable and higher impact activities (cyclists, skaters and users of motorized mobility devices).

The table below provides an example comparison of non-motorized modes that has been applied to the management of the Galloping Goose Regional Trail in British Columbia. While some of the listed modes, such as motorized wheelchairs, are not strictly “non-motorized” modes, they frequently use non-motorized facilities such as sidewalks, paths and trails. Of course, these factors, such as speed, maneuverability, and priority are somewhat subjective and may need to be modified to address the needs of a particular situation.

This type of information can help decision-makers develop appropriate guidelines and regulations to manage the use of non-motorized facilities based on the performance and value of each mode. For example:

- Higher-priority modes should have priority to lower-priority modes. For example, recreational modes (such as skateboards) should yield to modes that provide basic mobility (such as walking and wheelchair users) if conflicts exist.
- Lower-speed, smaller modes should have priority over higher-speed, larger modes. For example, bicycles should yield to scooters, and scooters should yield to walkers.

Example Comparison of Non-Motorized Facility Users on British Columbia’s Galloping Goose Trail (VTPI, 2002)

Mode	Speed	Size (Width)	Maneuverability	Priority
Walkers	Low	Narrow	High	High
Walkers with children	Low	Medium to large	Medium to low	High
Walkers with pets	Low	Medium to large	Medium to low	Medium
Human powered wheelchairs	Low	Medium	Low to Medium	High
Motor powered wheelchairs	Medium	Medium	Medium	High
Joggers and runners	Medium to high	Narrow	Medium	Medium
Skates, skateboards and push-scooters	Medium	Narrow to medium	Medium	Low
Powered scooters and electric human transporters (Segway)	Medium	Narrow to medium	Medium	Medium
Handcarts, wagons and pushcarts	Low	Medium to large	Medium	Medium
Human powered bicycle	Medium to high	Medium to large	Low to medium	Medium
Motorized bicycle	High	Medium to large	Low to medium	Low
Equestrians	Medium to high	Large	Low	Low

- Special efforts should be made to accommodate a wide range of users (including cyclists, skaters and runners) where there are no suitable alternative routes (for example, adjacent roadways are unsuitable for such modes).
- Cyclists, skaters and motorized modes should reduce their speed when using mixed use paths (6 to 12 mph maximum, depending on conditions) and yield to non-motorized modes. People who want to go faster should use roadways.
- Posted regulations should clearly indicate when and where pets are forbidden, when and where they are allowed if leashed, and when and where they may run free.

The report, *Conflicts on Multiple-Use Trails: Synthesis of the Literature and State of the Practice* (Moore, 1994), provides further guidelines for developing programs to manage trails. Although this report is primarily concerned with recreational, off-road trails, the guidelines are generally appropriate for managing any non-motorized facilities, including sidewalks and bicycle paths. The report is available at no cost from FHWA. The report identified the following 12 principles for minimizing conflicts on multiple-use trails:

- Recognize Conflict as Goal Interference
- Provide Adequate Trail Opportunities
- Minimize Number of Contacts in Problem Areas
- Involve Users as Early as Possible
- Understand User Needs
- Identify the Actual Sources of Conflict
- Work with Affected Users
- Promote Trail Etiquette
- Encourage Positive Interaction Among Different Users
- Favor “Light-Handed” Management
- Plan and Act Locally
- Monitor Progress

TRAIL USER EDUCATION AND ENFORCEMENT

User guidelines and regulations for sharing non-motorized facilities are only as effective as their education and enforcement. Such programs require special efforts, since there are no testing and licensing requirements for using non-motorized modes as there are for motor vehicles.

Once guidelines and regulations are established, it is important to promote them using signs and brochures, by enlisting the help of public organizations (such as walking and cycling clubs) and schools and by promoting responsible behavior at events such as fairs. Some communities use staff or volunteers to talk with users and distribute brochures and other information materials on public trails during particularly busy times.

Special outreach efforts may be warranted for particular groups, such as wheelchair users, pet owners, skaters and mountain bikers.

Educational information should be presented frequently. For example, in dense urban areas, signs with trail use guidelines can be located at every intersection or every few hundred meters. In less dense areas they may be located every kilometer or so. In general, the more frequent the better to ensure broad distribution of this information.

Messages should be simple, easy to understand, and presented in a friendly way. They should clearly state what behavior is expected from trail users. It generally is better to communicate the intent of the law than to present the actual wording of a law (laws are often difficult to understand). The boxes below illustrate examples of such guidelines.

An example of an education program designed to minimize conflicts among user groups is the Galloping Goose Regional Trail in British Columbia (see figure). *The Official Guide: The Galloping Goose Regional Trail* brochure (Mulchinock, 1996) promotes the following about shared-use trail etiquette:

The key word is multi-use. Share the trail. Keep right except to pass. Motorized vehicles are prohibited (except for motorized wheelchairs). Respect private property adjacent to the trail.

- If you’re on foot or on wheels, pass horseback riders with caution—horses can be spooked by startling noises or motions.



Figure 1. An example of “Share the Trail” signs along the Galloping Goose Trail in Victoria, British Columbia.

- If you're on horseback, let other trail users know when your horse is safe to pass.
- If you're cycling, yield to pedestrians, control your speed and warn—call out or use a bell—other trail users before passing.
- If you're walking your dog, keep it under control or on a leash, and please pick up its droppings.

Additional guidelines directed at cyclists on how to share public trails are available in the League of American Bicyclists' Fact Sheet titled "Sharing the Path" (see <http://www.bikeleague.org/educenter/factsheets/sharingthepath.htm>). They include showing courtesy and respect for other users, announcing yourself when passing, yielding to other users when entering or crossing, keeping to the right, passing on the left, being predictable, using lights at night, not blocking the trail, cleaning up litter and using roadways rather than paths for higher speed travel. A similar set of guidelines for shared-use trails is also available from the International Bicycle Fund (<http://www.ibike.org/education/trail-sharing.htm>).

It may also be important to develop special enforcement procedures for non-motorized traffic violations. Existing traffic enforcement practices often are ineffective for non-motorized modes, because such modes do not generally require a license or vehicle registration, and many non-motorized trail users are children. It is unrealistic to impose a standard traffic citation on non-motorized violations, in part because the fines will seem too large to many residents and in part because there often is no effective mechanism to process a citation if the violator is a minor or does not have a driver's license.

An alternative approach, recommended by the International Bicycle Fund, relies as much on education as on enforcement and creates a friendlier, positive relationship between non-motorized facility users (and their parents) and public officials. The text of a model ordinance is available on the IBF Website (<http://www.ibike.org/education/trail-ordinance.htm>). Non-motorized facility enforcement is also an ideal application for bicycle police (see IPBMA Website, <http://www.ipmba.org>) and for bicyclist diversion programs.

EVALUATION

Most non-motorized facility management programs appear to be successful. However, we have not found any

evaluation studies that measure before-and-after or with-and-without effects, so it is not possible to say with any confidence to what degree such programs reduce crashes, reduce user conflicts, improve user experiences or increase non-motorized travel.

Different communities have had different experiences with programs designed to encourage responsible sharing of non-motorized facilities, virtually all of which are positive. If trails are functioning well with a minimum of conflicts among users, this could be taken as evidence of good trail design and/or management programs.

CONCLUSIONS AND RECOMMENDATIONS

Management programs that address potential conflicts are important for the safety and comfort of non-motorized facility users. This applies to sidewalks, paths, bike lanes and trails.

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COSTS AND FUNDING

Costs vary depending on the type of program and its activities. Most non-motorized facility management programs require staff time for planning, plus resources to produce signs, brochures and other outreach materials, which are usually funded from local transportation or parks budgets. Most other activities, such as traffic law enforcement on non-motorized facilities, are included within existing agency budgets.

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Shared Lane Markings

BACKGROUND

Shared roadways make up the majority of most bike route networks. These shared roadways are often composed of curb lanes too narrow for motorists and bicyclists to safely share side by side (defined here as “substandard width”). On these roadways, the following problems often occur:

- Cyclists are pressured into hazards on the edge of the road or lane, such as the “door zone” where motorists leaving parked cars may suddenly open their door in a cyclist’s path.
- Motorists attempt to pass cyclists too closely or intimidate cyclists legally in the lane.
- Cyclists decide to ride on the sidewalk illegally.
- Cyclists ride the wrong way on the road.

Though these problems are faced regularly by municipalities, there is no accepted pavement marking standard for shared roadways. Denver attempted to address this issue by developing an arrow with cyclist symbol inside to be placed in shared lanes. San Francisco used this marking on some streets but determined that the marking could be more visible.

COUNTERMEASURES

After obtaining permission from the California Traffic Control Device Committee (CTCDC) to experiment, San Francisco hired a consultant to review a number of marking designs and study the best two in the field. The two marking designs (see figures 1 and 2) were placed on six city streets with substandard curb lane widths (5.1 m (16 ft, 10 in) to 6.7 m (22 ft) wide, with parking).

Michael Sallaberry, PE, Associate Transportation Engineer, San Francisco Department of Parking and Traffic



Figure 1. “Bike and Chevron”



Figure 2. “Bike-in-House”

Based on previously recorded observations which showed that car doors open to about 2.9 m (9 ft, 6 in) from the curb face, the markings were placed 11 feet from the curb, giving cyclists with 0.6 m (2 ft) wide handlebars approximately 15.2 cm (6 in) of clearance from opened doors.

EVALUATION AND RESULTS

“Before” and “after” video was taken at each marking location, and a limited number of surveys were distributed to cyclists and motorists to determine their understanding of the marking designs. Recorded behaviors taken with video included:

- Cyclists’ positions on roadway (e.g. distance from parked cars).
- Motorists’ positions (e.g. distance from cyclists when passing).
- Cyclist direction (with or against traffic).
- Cyclist location (street or sidewalk).
- Conflicts between cyclists and motorists.

After reviewing videotape of 2400 cyclists and 2400 motorists, the most effective pavement marking design, the “bike and chevron” (figure 1), was shown to:

- Encourage cyclists to ride 20.3 cm (8 in) further away from the door zone.



- Encourage motorists to give 68.6 cm (2 ft, 3 in) more space when passing cyclists.
- Reduce the incidence of wrong way riding by 80 percent.
- Reduce the incidence of sidewalk riding by 35 percent.

There was no statistically significant change in hostile or aggressive behavior by motorists, but this may be attributed to the very small number of observed conflicts in both the “before” and “after” videotapes.

Through the motorist and cyclist surveys, it was determined that the meaning of the markings was not always clearly understood.

CONCLUSIONS AND RECOMMENDATIONS

As a result of this study, the bike and chevron design (figure 1) was recommended by the California Traffic Control Device Committee as a pavement marking to be included in the MUTCD 2003 California Supplement. As of October 2004, the CTCDC and Caltrans had developed draft language for inclusion of the marking in the manual. The language discusses the optional use of this marking on roadways used by bicyclists, and gives placement guidance.

San Francisco is developing a set of local warrants to help determine on what streets the markings will be placed. Thus far, the following list of factors to consider has been developed:

- Curb lane width
- Parking turnover
- ADTs
- Dooring, overtaking, midblock bicycle collision history
- Gap in otherwise continuous Class I/II bikeway



- Current demand by cyclists
- Prevailing speeds by motor vehicles and cyclists
- Prevalence of cyclists riding on sidewalk or in wrong direction
- Anticipated addition of Class II bikeway to street

Based on the results of the surveys taken as part of the study, outreach campaigns explaining this new marking are recommended. San Francisco plans to launch a campaign, using bus tail cards for example, and other advertising, to explain the shared lane marking. This will likely be an ongoing effort for the first year or so of implementation as people grow accustomed to the new marking.

COSTS AND FUNDING

The \$73,000 study was funded by grants generated by local and state initiatives (San Francisco and California) which earmark portions of sales taxes for transportation projects.

A rough cost estimate of labor and materials for markings applied using methyl methacrylate is \$100 each.

REFERENCES

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The modification (shared lane markings) that is the subject of this case study is not currently compliant with the *Manual on Uniform Traffic Control Devices*, but it is being considered for inclusion (the “Bike-in-House” marking in Figure 2 is not being endorsed by the Bicycle Technical Committee of the National Committee on Uniform Traffic Control Devices, however). Accordingly, it is imperative that any jurisdiction wishing to utilize the shared lane markings (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

Bicycle Detection Program

BACKGROUND

Bicyclists' inability to "get a green light" has been the cause of many a call to the Traffic Engineering office. The callers typically display frustration, confusion, and a sense of modal discrimination. The Bicycle Detection Program was developed as a two-phase strategy to address these complaints. Phase 1 involved correcting actual detection problems at each traffic signal. Phase 2 involved educating the public about how and where to be detected at traffic signals.

The City of Santa Cruz has 40 signalized intersections. Thirty intersections use inductive loop detection and 10 intersections use video detection. Typical loop layout is three "A" loops and a stop bar "Q" or "D" loop for each motor lane. Bicycle lanes typically have a bike "Q" loop at the stop bar for the minor legs. Bicycle detection is not always provided for the major legs if the signal rests in green on the major legs. Video detection intersections use Peek Video cameras. Four arterial corridors are interconnected using Traconet with Traconex controllers.



COUNTERMEASURES

PHASE 1: ENGINEERING

1. Citizen requests and work orders regarding bicycle detection were compiled to determine signals with a history of complaints.
2. A work list was created prioritizing locations and the stated complaints, with proposed short-term and/or long-term solutions and cost estimates.

3. The locations were tested by the Bicycle/Pedestrian Coordinator and the Traffic Signal Technician in the field. The Coordinator rode an aluminum frame bicycle over each lane and the Technician recorded the level of detection at the signal cabinet. Detection levels were adjusted and re-tested as necessary to detect the bicycle (short term solution).
4. Long-term solutions include cutting new loops, adjusting cameras, and installing bike push buttons where necessary. These repairs are funded from an annual Minor Traffic Signal Maintenance budget.

Cheryl Schmitt, Bicycle/Pedestrian Coordinator,
Santa Cruz, CA



PHASE 2: EDUCATION

1. The lead loop in left-turn lanes, curbside lanes without bike lanes, and bike lanes were marked with the *Manual of Uniform Traffic Control Devices* bike detector marking if sawcut lines were not visible.
2. A brochure was developed to describe how traffic signals work and to explain where bicyclists should position themselves on sawcut lines in order to be detected. This brochure is available on-line on the City's Web site at <http://www.ci.santa-cruz.ca.us/pw/trafeng/bikedet.pdf>
3. Signal detection is discussed at the 2-hour bicycle safety class required of all applicants to the regional bike loan and e-bike rebate programs. Over 500 participants have received the Bicycle Detection brochure through this program.



4. Bicyclists on the local e-mail bike list were kept abreast of the program and encouraged to contact the Bike/Pedestrian Coordinator with comments.

EVALUATION AND RESULTS.

Complaint calls to the Traffic Engineering office have decreased dramatically. Bicyclists on the local e-mail bike list and bicyclists' newsletter describe a greater level of confidence in being detected and willingness to wait through the red.

CONCLUSIONS AND RECOMMENDATIONS

Some of the technical problems are difficult to solve. Turning up the sensitivity on the detector amplifier to detect bikes will sometimes work for a period of time, but it usually ends up "locking on," causing a maximum recall condition. Rapidly decaying street infrastructure is resulting in more loop failures, with no funding in sight for repairs.

Video detection is much more reliable overall, but there was a learning curve for the field crew to become proficient with it. Nevertheless, the Bicycle Detection Program has been and continues to be a success.

COSTS

Loops are approximately \$500 each; for bike detection, there are typically two loops per direction of travel. Video detection is approximately \$35,000 for a complete intersection installation. Pedestrian/bicyclist push buttons with the conduit and conductor to the controller cabinet is approximately \$1500; each pole with push button is about \$300.

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The modification (bicycle detector markings) that is the subject of this case study is allowed by the *Manual on Uniform Traffic Control Devices* (MUTCD), but if used, one specific design is required. The specific markings used by Santa Cruz and shown in the article are not in conformance with the technical provisions of the marking shown in Figure 9C-7 of the MUTCD.

Bicycle Signal Heads

BACKGROUND

The city of Davis, CA, has been a mecca for cycling since the mid 1960's. Bicycling accounts for about 17 percent of the mode share in Davis, whereas nationally, two to three percent is considered high. Whenever possible, grade separations have been built to minimize conflicts between cyclists and motorists. These include undercrossings and overcrossings of mostly collector and arterial streets. Where grade separations have not been possible, specially designed traffic control devices have been added at selected intersections.

To help manage the large number of bicyclists utilizing the city's transportation network, there has been a continually increasing need to explore new engineering techniques that would benefit cyclists and enhance safety for all road users. The use of bicycle signal heads was chosen as one such approach. The goal was to enhance safety for cyclists while maintaining adequate levels of service for motor vehicles at each of the intersections where these signals have been installed.

However, bicycle signal heads never had been approved for use by the California Department of Transportation (Caltrans), so the city was required to go through an approval process that included an experimental, conditional-use phase of the bicycle signal heads. Final approval would ultimately be subject to review and acceptance by the California Traffic Control Devices Committee (CTCDC) under the purview of Caltrans.

Timothy Bustos, Bicycle and Pedestrian Coordinator, City of Davis, California
Contributions by Dave Pelz, former Public Works Director, City of Davis, California (retired),
Jonathon Flecker, former Traffic Engineer, City of Davis (now in private practice)



Although the use of bicycle signals had not previously been formally used in California, they have been widely used for many years in countries such as China, England, and the Netherlands. A former Public Works Director for the city of Davis had at one point visited the Netherlands, and brought the concept of the bike signal heads back with him.

Potential intersections that were evaluated for retrofitting with bicycle signal heads were selected based on three primary criteria:

1. Volumes of bicyclists at peak hour(s)
2. Bicycle and motor vehicle crash data
3. Proximity to schools (primary, secondary, and university levels)

Other locations considered for placement were those where separated bike paths connected with intersections in such a way that conventional traffic light configurations could not be seen by cyclists. These were typically locations where there was a three-way intersection for motorists (i.e. "T" intersections) that became four-way intersections for bicyclists.

COUNTERMEASURES

Bicycle signal heads actually are similar to conventional traffic signals. However, rather than red, yellow and green “balls,” the new signal heads use red, yellow, and green bike icons. Initially, the city had to have these custom-made by blacking out conventional colored lens covers to hide everything but the bike shape. The newer signals now use red, yellow, and green LED’s in the shape of a bike that are much brighter, yet more energy-efficient. These lights are also actuated in the same way as traditional traffic lights: through the use of bicycle sensitive loop detectors and, where appropriate, bike push buttons. As technology has advanced, newer intersections utilizing conventional or bicycle signal heads now use camera detection.

Although several locations throughout the city met the criteria listed previously, the location that would ultimately prove the viability of bicycle signal heads was the intersection of Sycamore Lane and Russell Boulevard. This location is a “T” intersection for motor vehicles, yet it is a “five-way” intersection for bicyclists due to the presence of bike lanes and bike paths that converge at this location. It is also a primary access point to the University of California for many of the students in the northwest quadrant of the city. Manual traffic counts at this location indicated that approximately 1,100 cyclists and 2,300 motor vehicles passed through this intersection during peak hours. Additionally, this would be the first location where both motorists and cyclists could see the conventional traffic lights and the bicycle signal heads.

Previously, all bicyclists, pedestrians, and motor vehicles would proceed through this intersection concurrently, with many bicyclists and pedestrians choosing the routes they perceived to be the most direct, not necessarily the



safest. Bicycle signal heads were chosen for this location to help make the respective movements more predictable, and thereby safer. To this end, movements were split, with bicyclists and pedestrians moving through the intersection first and motor vehicles proceeding only after all the bicyclists and pedestrians had cleared the intersection. Additionally, a changeable message sign was added for the motorists, indicating “NO RIGHT TURN ON RED” to prevent through cyclists from being hit by right-turning motorists.

EVALUATION AND RESULTS

In order to objectively assess just how effective the bicycle signal heads were in reducing conflicts, surveys were conducted with both motorists and cyclists before and after the addition of bicycle signal heads. Additionally, video footage was taken of bicycle, pedestrian, and motor vehicle movements before and after intersection modification (both horizontally and vertically). Bicycle and motor vehicle crash reports were also evaluated before and after the installation of the bicycle signal heads.

Both motorists and bicyclists found the new signal heads to be effective in reducing conflicts between the various modes passing through the intersection. Evaluation of crash data seemed to reflect this as well. For the two-year period before the installation of bicycle signal heads at the intersection of Sycamore and Russell, there were about 16 bicycle and motor vehicle collisions. For the two-year period following the installation, there were only two collisions, neither of which involved bicycles.



CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated that:

- Bicycle signals enhance safety by separating large volumes of bicycle and auto traffic.
- There is minimal additional delay to motor vehicles
- Bike signals are easy to comprehend by cyclists and motorists
- Bicycle traffic signals should be considered on a case-by-case basis taking into account intersection geometry and bicycle and motor vehicle volumes

As a result of what the city of Davis was able to demonstrate regarding the effectiveness of bicycle signal heads, CTCDC voted to approve use of this traffic control device in 1998. Subsequently, the California legislature amended the California Vehicle Code to allow its use statewide, and it was signed into law by the governor in 1999.

COSTS AND FUNDING

Cost will depend on the complexity and size of the intersection, but in general, costs are comparable to the installation of conventional traffic signals (e.g. controller boxes, detection devices, mast arms, etc.)

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The modification (bicycle signal heads) that is the subject of this case study is not currently compliant with the *Manual on Uniform Traffic Control Devices*, but it may be considered for inclusion once research is completed. Accordingly, it is imperative that any jurisdiction wishing to utilize the bicycle signal heads (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

Pedestrian/Bicycle Crosswalk Signals (Half-Signals)

BACKGROUND

Bicyclists using residential streets often have trouble crossing arterial streets at unsignalized intersections. This is especially true for bicyclists trying to cross high-volume, multi-lane arterial streets.

Where streets are laid out in a traditional grid pattern, residential streets become particularly attractive to inexperienced bicyclists. However, if crossing major arterials results in too much delay or makes the crossing too difficult, inexperienced bicyclists who are not comfortable using arterial streets will be discouraged from bicycling.

COUNTERMEASURES

Seattle's solution has been to install pedestrian or bicycle crosswalk signals (formally called half-signals). A crosswalk signal is a pedestrian- or bicyclist-actuated light that stops arterial traffic only, leaving the lower-volume cross-street unsignalized. It allows bicyclists and pedestrians to cross safely upon demand without unnecessarily creating delays for arterial street traffic that a fully signalized intersection might impose. It also can prevent cut-through motor vehicle traffic on the residential street that can happen with the installation of a full signal.

Crosswalk signals also have been successfully installed to facilitate "bicycle boulevards" in various communities around the country. These are bike routes that are designed to encourage fast, through bicycle traffic on residential streets while discouraging through motor vehicle traffic. The crosswalk signals are combined with other treatments such as diverters (for motorists) to create the bicycle boulevard. More often, these signals also have been installed



to facilitate pedestrian crossing near schools, hospitals and in neighborhood shopping districts. To date, more than 80 crosswalk signals have been installed in Seattle.

EVALUATION AND RESULTS

It is relatively easy to evaluate the success of a pedestrian half-signal. If the number of crashes and bicycle and pedestrian complaints goes down, then it's a success. In Seattle, half-signals have consistently had crash rates equal to or lower than full signals. If the arterial has high volumes, traffic impacts such as the frequency of motorist delays should be studied. If frequent red phases cause delays, consider lengthening the green phase a bit. To strike the right balance, observe the intersection throughout the day and, if necessary, vary the timing.

Seattle's crosswalk signals have been well received. In most ways, they operate like the midblock signals that are used in many communities. If installed with the same care that midblock signals are installed, they can be effective and safe. When Seattle's crosswalk signals are reviewed by other communities, their traffic engineers often express concerns about possible driver confusion which in turn could lead to increased crashes. This has not been Seattle's experience—they don't increase crash rates, people like them, and there is constant demand to have them installed at new locations.

Peter Lagerwey, Pedestrian & Bicycle Program
Coordinator, City of Seattle



CONCLUSIONS AND RECOMMENDATIONS

Most jurisdictions use the *Manual on Uniform Traffic Control Devices* (MUTCD) to determine signal warrants, whether the signals are to be installed for vehicular traffic or pedestrians. Crosswalk signals, however, have not yet been incorporated into the MUTCD. Consequently, it is necessary to create more flexible guidelines for installing a crosswalk signal instead of a full signal when there are insufficient gaps for bicyclists and pedestrians. We have two suggestions for installing a crosswalk signal: 1) when traffic volumes on the intersecting street are less than 50 percent of MUTCD recommended benchmarks for a full traffic signal; and 2) when a substantial amount of motor vehicle traffic might be induced to opt for and use a lower volume, residential street if a full signal were installed.

COSTS AND FUNDING:

Cost depends on a lot of factors, including the location of the nearest power source, the type of poles installed and the availability of space for signal equipment. However, in general a crosswalk signal is about half the cost of a full signal. In many cases, they can be installed for less than \$30,000.

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The modification (half signals) that is the subject of this case study is not compliant with the *Manual on Uniform Traffic Control Devices*, nor is it currently being considered for inclusion. Accordingly, it is imperative that any jurisdiction wishing to utilize the half signals (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

Share the Road Sign Initiative

BACKGROUND

The North Carolina Department of Transportation Division of Bicycle and Pedestrian Transportation (DBPT) first installed “Share the Road” signs along designated bicycle routes in 1987. Funding was provided as part of the first annual allocation of Bicycle Transportation Improvement Program (TIP) funds received by the Bicycle Program, as DBPT was known at the time.

The *Manual on Uniform Traffic Control Devices* (MUTCD) specifies what types of signs can be installed along Federal Aid Highways. In 1987, no authorized sign with the “Share the Road” message had been approved. DBPT recognized the need for such a sign and worked within the MUTCD guidelines to develop a state “supplementary” sign. The design chosen utilized an approved black on yellow diamond-shaped bicycle warning sign (designated as W11-1 by the MUTCD) with a supplementary “Share the Road” plaque. In 2000, the Secretary of Transportation decided to use a reflectorized fluorescent yellow-green version of the sign to increase visibility. This design was adopted as a national standard in the most recent MUTCD update.

The sign serves to make motorists aware that bicyclists might be on the road and that they have a legal right to use the roadway. It typically is placed along roadways with high levels of bicycle usage but relatively hazardous conditions for bicyclists. The “Share the Road” sign is especially useful in cities and towns where a significant number of bicyclists use a roadway that by its nature is not suitable to be designated as a bicycle route, but which is an important connection for bicycle transportation. The

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sign should not be used to designate a preferred bicycle route, but may be used along short sections of designated routes where traffic volumes are higher than desirable.

COUNTERMEASURES

The North Carolina “Share the Road” sign has been installed along many miles of roadways since it was created in 1987. It is used along cross-state, regional and local designated bicycle routes on sections of roadway where traffic volumes are higher than desirable. These sections of roadway typically are less than a mile in length and serve to connect the more lightly-traveled roads that comprise the majority of a given route. The signs are placed on the roadway in each direction, just before the bicycle route

joins that particular road, so that motorists will be made aware that cyclists may be on the roadway. If a particular high-volume road must be used for a distance greater than two miles, additional signs are installed. These signs are placed where the greatest number of motorists will see them, based on turning movements off intersecting roads. To elaborate, if there is a choice between placing a sign just before a secondary road with traffic volumes of 1,500 cars versus placing it a short distance farther along the route before a more major road with a traffic count of 5,000, choose the latter. Fieldwork and engineering judgement are necessary to fine-tune the placement of signs.

“Share the Road” signs also have been placed along roads that are not part of a designated bicycle route, both in towns and cities, as well as on rural roadways. Roads and bridges heavily used by cyclists, particularly where on-road improvements cannot be made, are prime locations for such signs. Some examples include a major road near a college or university where many students commute by bike; coastal or mountain roads in tourist areas where no alternate routes exist; or on a bridge approach where no other convenient crossings provide an efficient transportation link.

Installation of “Share the Road” signs is an ongoing process. Each new route system that is developed is assessed for “Share the Road” sign needs. Periodic field inspections of existing routes are conducted not only to check the condition of existing signs, but also to identify areas where changing traffic conditions may warrant additional “Share the Road” signs.

As one example of the extent of sign posting, on a 241-km (150-mi) segment of roadway in Randolph County, NC, a total of 45 “Share the Road” signs were posted (in both directions of travel).



“Share the Road” sign next to a busy roadway.

EVALUATION AND RESULTS

No formal evaluation on the sign’s effectiveness has been conducted, but public feedback has been favorable. Cyclists have noted that motorists seem more courteous in areas where “Share the Road” signs are prominent. One interesting note is that DBPT staff members have received calls from several motorists indicating their willingness to share the road but commenting that cyclists they have encountered do not seem willing to do the same.

CONCLUSIONS AND RECOMMENDATIONS

“Share the Road” sign projects may be a low-cost way to increase the awareness of motorists and enhance the safety of cyclists. The fluorescent yellow-green W11-1 signs are visible from a great distance.

COSTS AND FUNDING

Fabrication and installation of “Share the Road” signs range from \$75 to \$100 each. The fluorescent yellow-green sign costs about twice as much to fabricate as the yellow and black version.

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Placement of 20-mph School Zone Signs

BACKGROUND

Different jurisdictions across the nation do not use the same policies in determining where school speed zones are established. Not all jurisdictions even use the same speed limit in the school zone. Seattle had experienced pressure from parents and schools to place 20-mph school zone signs as a matter of course in the vicinity of any school. No written policies were previously in place, and most decisions were made on a case-by-case basis. However, certain factors remained constant, including the placement of these signs only at elementary schools, and only in direct relation to a marked crosswalk (in contrast to a set area around the school regardless of crossing facilities).

This project looked at defining and updating current placement of the 20-mph school zone signs (as well as all school crosswalk signs) in Seattle. The goal of studying where to place 20-mph school zone signs was to provide consistency of use for better motorist understanding, and better motorist compliance with the speed limit. A secondary goal was to have better internal guidelines on sign placement to improve consistency of responding to public and school requests for 20-mph school zone signs. The underlying project goal was to reduce driver speeds at the locations where elementary school children were most likely to be walking or bicycling to or from school.

One decision about the placement of the 20 mph speed zone signs was already made by the state of Washington. Locations with a School Patrol present, where there is no form of traffic control, are required to have 20-mph speed zone signs. In Seattle, School Patrol is an optional student program run by the individual elementary school. Participating students are typically in 5th grade and have an adult supervisor. School Patrol members help other students cross safely, but must remain

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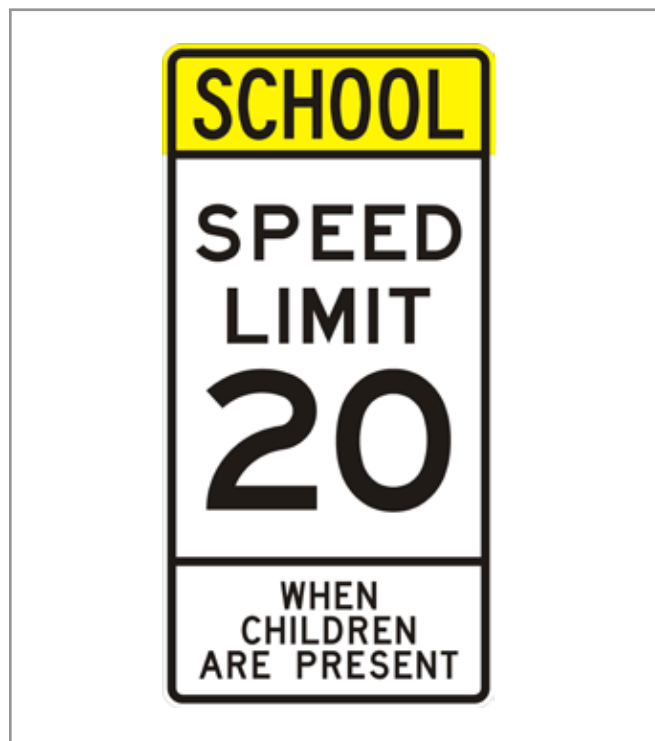


Figure 1. Standard reduced speed school sign.

in sight of the school. By contrast, adult crossing guards are adults employed by the Seattle Police Department.

Combined with this project was an effort to make the 20-mph school zone signs more readily understood as to when the reduced speed limit is in effect and increase motorist compliance. Almost all 20-mph school speed zone signs in Seattle have a qualifying sign attached that reads “WHEN CHILDREN ARE PRESENT” (see fig. 1). This sign is defined through the Washington Administrative Code (WAC) as when:

- 1) School children are occupying or walking within the marked crosswalk.
- 2) School children are waiting at the curb or on the shoulder of the roadway and are about to cross the roadway by way of the marked crosswalk.

(3) Schoolchildren are present or walking along the roadway, either on the adjacent sidewalk or, in the absence of sidewalks, on the shoulder within the posted school speed limit zone which extends 300 feet in either direction from the marked crosswalk.

The general perception in Seattle was that 20 mph school zones are often not obeyed. The Seattle Department of Transportation (SDOT) Pedestrian Program receives a number of complaints from motorists each year asking for clarification of the sign used to qualify 20-mph speed zones. Quite often, the motorist has just received a speeding ticket and is not clear on precisely when the reduced speed limit is in effect. In general, speed zones in Seattle do not receive the respect that parents and school administrators would like to see. The speed at which a motorist travels has a direct effect on the injury sustained by the pedestrian in a collision, and can also increase driver compliance in stopping for pedestrians at crosswalks. A new school zone sign that reads “When Lights are Flashing or When Children are Present” and flashing beacon (figure 2) will replace the sign reading “When Children are Present” and will be set to flash during the times of the day that children are most likely to be traveling to and from school.

The city of Seattle has historically reduced speeds to 20-mph in school zones. The decision of what speed limit to use depends largely on what the normal roadway speed limit is. Almost all arterial streets in Seattle have a speed limit of 30-mph. As the goal of these signs is to reduce motorist speed, the reduced speed should be an achievable change in speed that does not require heavy enforcement. For instance, a reduced speed zone of 15-mph in a section of roadway where the normal speed limit is 40-mph may get very little compliance if it is not enforced. Interestingly enough, however, the city of Tuscon, AZ, has achieved very high compliance in their 15-mph school zones, showing that in the right circumstances this is achievable.

The opportunity for this project occurred as the SDOT upgraded all school crosswalk signs from yellow to fluorescent yellow-green, and changed the school sign at the crosswalk to include an arrow pointing to the crosswalk itself. The field checks necessary to perform the sign replacements presented an opportunity to bring consistency to all school speed zone signs. The pre-existing conditions of each location varied. Fluorescent yellow-green signs were already replaced on principal arterials throughout the city. All other school crosswalks had yellow signs.

COUNTERMEASURES

The project itself was three-fold. First, the existing conditions had to be documented.

- Where were our 20-mph school zone signs presently located?
- What was the traffic control at the crosswalk?
- Was there a School Patrol or an adult crossing guard present?

Second, new School Sign Placement Guidelines were established. Lastly, we implemented the new 20 mph sign policy. During this implementation, a particular location would either:

- keep the signs it originally had (they would just be upgraded).
- gain 20-mph speed zone signs (where currently only advance warning signs were in place).
- lose 20-mph speed zone signs.

Additionally, criteria were developed to prioritize where to use the new signs and flashing beacons. In the program’s first year, new speed zone signs with flashing beacons were installed at 12 locations. An additional 14 locations received beacons in 2004. No funding has been identified for further implementation.



Figure 2. Modified reduced speed zone sign used in conjunction with a flashing beacon.

SURVEY

To find out what the existing conditions were, a sample survey was taken around several schools. First, we defined the different types of locations possible. The following elements were considered:

- type of traffic control (uncontrolled, stop sign, traffic signal, crosswalk signal)
- type of street (arterial street or residential street)
- whether the crosswalk was attended (School Patrol, adult crossing guard, or unattended)

While the number of lanes of traffic a pedestrian must cross is an important factor for SDOT when evaluating uncontrolled marked crosswalks, this factor did not play a big role in this analysis. The main reason for this is that few marked crosswalks across more than two lanes of traffic are established as elementary school crosswalks. The speed limit on the roadway also did not play a major role in the survey as only several arterial streets in the city have a speed limit greater than 30. This was a factor in the final decision of where to install the beacons, however.

It was not feasible to survey the entire city (the city of Seattle has over 300 uncontrolled marked school crosswalks

alone), so the surveyor sought to find a minimum of five examples of each combination (there were a total of 18 combinations).

Once the survey was complete, we had a better understanding of the existing conditions (see table 1).

SPEED ZONE GUIDELINES

When the survey was complete, we drafted guidelines that both met the department's goals of consistency and combined somewhat accurately with existing conditions.

The old 20-mph school zones were inconsistently established. The new guidelines included:

- keeping the zones at all uncontrolled locations with an active School Patrol presence. (required by state law)
- providing 20 mph signs at uncontrolled crosswalk with adult crossing guards.

(Maps showing the locations of School Patrol had been outdated; through this process we were able to update some of the locations.) The second priority guideline established was to begin placing 20 mph zones at any uncontrolled crosswalk location with an adult crossing guard present. The philosophy behind this decision was that

Table 1. School Zone Signs Field Survey Totals

# Crosswalks Sampled	School Signing Scenario		Signs Present At X-Walk	Advance Signs Present	20-mph Sign Present	End Speed Zone	Midblock crossing
29	Arterial: Marked Crosswalk; No Traffic Control	unattended	27	23	5	2	2
17		Adult Guard	16	16	10	3	
8		School Patrol	8	8	6	1	
23	Arterial: Stop Sign	unattended	2	0			
3		Adult Guard	2	2	1		
3		School Patrol		1			
20	Arterial: Full Signal	unattended	2	2	1		
21		Adult Guard	2	6	1		
5		School Patrol		3	2		
18	Arterial: Crosswalk Signal	unattended	4	8	2	1	
8		Adult Guard	6	7	1	1	
3		School Patrol	3	3	3	2	
22	Res: Marked Crosswalk	unattended	20	14	9		
0		Adult Guard					
19		School Patrol	17	14	9		
0	Res: Stop Sign	unattended					
1		Adult Guard					
2		School Patrol		1	1		

the adult crossing guards are typically placed at locations where traffic volumes and intersection characteristics are such that students require extra guidance in crossing safely. The locations where adult guards are typically posted also see the highest number of students crossing. Therefore, reducing driver speeds at the locations likely to see the most student traffic focuses attention on the intersections that benefit the most students.

Revised guidelines were discussed among Seattle Department of Transportation staff from the different traffic management divisions. School zone signs were not used at stop- or signal-controlled locations (including crosswalk signals). (See table 2 for placement guidelines.)

FLASHING BEACONS

In prioritizing the flashing beacon locations, we used the above criteria and also considered average daily traffic (ADT), with higher ADT locations receiving a higher priority. For more consistency with standard engineering practice, and because of the weekday-only nature of the flashing beacon signs, the list of selected locations also includes the most current Average Week Day Traffic (AWDT).

A recent study released by the Federal Highway Administration notes the factors that influence pedestrian safety

at marked crosswalks (Zegeer et al., 2002). These are the number of lanes of motor vehicle traffic, the average daily traffic (ADT) and motor vehicle speeds. To select the final 12 locations, staff at the SDOT evaluated all marked crosswalks qualifying for a 20-mph school speed zone. None of these locations had more than two lanes, and only a few had a speed limit higher than 30 mph. Therefore, the locations were ranked by ADT.

Twelve locations ranked highest on selected criteria for the first year of implementation. All locations had adult crossing guards posted. While almost every marked crosswalk considered for this treatment was an uncontrolled marked crosswalk, there were several locations that had crosswalk signals (also referred to as half-signals). One of these locations had not only very high ADT and high vehicle speeds, but also was a high complaint location. This location also was on a roadway with a speed limit of 35-mph. For that reason, it was included in this list of the top 12 locations. The subsequent year of beacon installations used the next 14 locations on this same list. Two locations on the list were not implemented due to construction and timing issues.

IMPLEMENTATION

With guidelines in place, sign replacement, including the establishment of new 20-mph school zones, was

Table 2. School Sign Placement Guidelines

School Signing Scenario at Marked Crosswalks		Signs Present At Marked X-Walk	Advance Signs Present	R 2M (20mph) Sign Present	End Speed Zone
Arterial: Marked Crosswalk No traffic control	School Patrol	Yes	Yes	Yes	Yes
	Adult Guard	Yes	Yes	Yes	Yes
	unattended	Yes	Yes	No	No
Arterial: Marked Crosswalk Stop Sign	School Patrol	No	No	No	No
	Adult Guard	No	No	No	No
	unattended	No	No	No	No
Arterial: Marked Crosswalk Full Signal	School Patrol	No	No	No	No
	Adult Guard	No	No	No	No
	unattended	No	No	No	No
Arterial: Marked Crosswalk Crosswalk Signal	School Patrol	W-37 overhead sign only	No	No	-
	Adult Guard	W-37 overhead sign only	No	No	-
	unattended	W-37 overhead sign only	No	No	No
Residential Marked Crosswalk No Traffic Control	School Patrol	Yes	Yes	Yes	Yes
	Adult Guard	Yes	Yes	Yes	Yes
	unattended	Yes	Yes	No	No
Residential Marked Crosswalk Stop Sign	School Patrol	No	No	No	No
	Adult Guard	No	No	No	No
	unattended	No	No	No	No

begun. Signs on minor and collector arterials were replaced in 2002. Signs on non-arterial streets were replaced in 2003.

The installation of the flashing beacons required utility poles on which to mount them. All beacons were installed on the side of the road approximately 200 feet in advance of the marked crosswalk. In several cases, it was possible to use an existing pole. However, the majority of locations required the installation of a new pole. Due to restrictions in where a utility pole could be installed, or existed already, some of the school speed zone boundaries were altered. All efforts were made to place the zone limits as close to the MUTCD guidelines as possible.

EVALUATION AND RESULTS

Defining specific evaluation criteria was difficult for this project because we did not know until halfway through which locations would change and which would stay the same. There is also the fact that all locations were being upgraded to the fluorescent yellow-green school signs, which complicated the effect the 20-mph speed zone alone would have.

Therefore, the evaluation could best be examined in terms of public feedback and internal opinion. Positive feedback came from the adult crossing guards themselves because quite a number of them did not have the reduced speed zone signs at their locations. This project also created consistent guidelines for 20 mph zone establishment, and has resulted in clearer communication to the public about where the signs are placed and the reasons for the particular sign placement. There have been some negative comments from citizens, however, who wonder why the school speed zones are being established at the locations *with* an adult crossing guard rather than the ones that lack a guard. This particular complaint requires ongoing explanation of the advantage SDOT sees in focusing attention on the places where the most children cross, and where (through placement of an adult crossing guard) it has been determined that children need more guidance in crossing safely.

Before/after speed assessments were performed for several of the flashing beacon locations to determine if motorist compliance increased. The before measures were taken in spring 2002 for most locations, as project completion was originally scheduled for August 2002 (actual construction occurred in August 2003). The before results showed a clear disregard for the 20-mph school speed zones. 'Before speeds' when children were present ranged from 32 mph to 40 mph.



Speed data were also collected several months after the signs and beacons were installed. In all but one case, vehicle speeds when an adult crossing guard was present were lower following installation of the new signs and beacons. The largest decrease in speed noted was a 22 percent decrease (the 85th percentile speed dropped from 37 mph to 29 mph). Despite the reduction in vehicle speed, the range of speeds measured (29 mph to 34 mph) were still well above the 20 mph speed limit.

CONCLUSIONS AND RECOMMENDATIONS

The SDOT relied directly upon the placement of crossing guards in sign placement. Other jurisdictions may want to consider other criteria in the placement of 20-mph speed zone signs. Criteria that could be considered include the distance from the crosswalk to the school and the number of students using the crosswalk. An important detail to keep in mind is the amount of annual survey work that must be conducted to keep signs current. While the number of students using the crosswalk is important, collecting this information for hundreds of crosswalks could be a large task.

It was very useful to do the survey work and create guidelines for sign placement throughout the city. It is an excellent way to gain internal concurrence on guidelines and to take time to verify that current practices are still useful.

It is not clear whether the consistency of the signs has been noticed or appreciated by the public. In most cases, residents are happy if the change in guidelines allows a school speed zone to be established at a crossing they often use.

While the speed study analysis did not show as large a drop in vehicle speed as we would have liked, it did re-

sult in reduced vehicle speeds within the reduced speed school zones. A notable result of the new beacons has also been more effective enforcement by the SDOT. Officers are given a list of the beacon locations and the times they will be in effect. Targeted enforcement is therefore possible, and the SDOT keeps a log of the times the beacons flash which reduces the number of motorists who can contest a ticket.

COSTS AND FUNDING

The upgrade of the school crosswalk signs was funded through state grant funding. The survey work and background gathering necessary for this project were made possible by help from a graduate school intern and a transportation crew worker on light duty. The first year of flashing beacon installation was funded by a state grant, and the second year was funded by the Seattle Department of Transportation.

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Shared-Use Arrow

BACKGROUND

A bicycle lane stripe provides a lateral positioning reference for both motorists and bicyclists, and the presence of the stripe, as well as signs, informs motorists that bicyclists are typically present upstream. In contrast, the absence of bicycle-specific pavement markings in wide outside lanes (also known as wide curb lanes), another widely acknowledged way to accommodate bicyclists, obviously means that there is no reference for lateral positioning, or a visual cue to the existence of upstream bicyclists.

Another argument put forth is that bicycle lanes are clearly marked spaces for bicyclists that have been shown to draw riders off of adjacent sidewalks and onto the roadway, a desirable outcome given the inherent dangers of sidewalk riding. On the other hand, because there are no bicycle-specific markings in wide outside lanes, they are not recognized as an on-road bicycle “facility” by many bicyclists, resulting in a higher incidence of adjacent sidewalk riding than could otherwise be the case.

COUNTERMEASURES

The shared-use ARROW is a symbol placed on the roadway with a stencil and is used to indicate proper positioning for a bicyclist in a shared travel lane. The shared-use ARROW (figure 1) was developed with the intention of addressing the deficiencies of wide outside lanes mentioned above. Furthermore, for situations at which sufficient pavement width exists to choose between striping a bicycle lane or leaving a wide outside lane, the shared-use ARROW may offer a third option, “bridging the gap” between the two existing treatments. Unlike a bicycle lane stripe, the shared-use ARROW does not restrict bicyclists

and motorists to separate areas of the roadway, thus addressing several potential problems of bicycle lanes. The shared-use ARROW also requires less pavement marking materials than a bicycle lane stripe, and the ARROW reinforces the correct direction of travel, an issue of great importance for bicycling safety.



Figure 1. Shared-use ARROW.

The original shared-use stencil was developed by James Mackay, the Bicycle and Pedestrian Planner for the city and county of Denver, CO. The city of San Francisco, through Manito Velasco, assistant transportation engineer, has also used the stencil. They elongated it from 1.3 m (4.25 ft) to 1.8 m (6 ft) and also altered the placement specifications. The current ARROW builds upon these efforts by establishing a widened opening along its centerline in an effort to channelize and make it more obvious to bicyclists to track down the centerline of the symbol.

Lateral placement was proposed at 0.8 m (2.5 ft) from the curb face, which was based on the local conditions of a 4.6-m (15-ft)-wide lane with no gutter pan and preliminary BEFORE measurements which showed bicy-

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clists riding 0.5 m (1.6 ft) on average from the curb. Furthermore, with this specified spacing, it was expected that motor vehicle tires would be less likely to track over and wear out the marking. However, earlier paving over the old gutter pan had left a seam about 0.6 m (2 ft) from the curb. Thus, instead of at 0.8 m (2.5 ft) from the curb face, the ARROW was placed at 1.1 m (3.5 ft) by Gainesville Public Works (Figure 2).

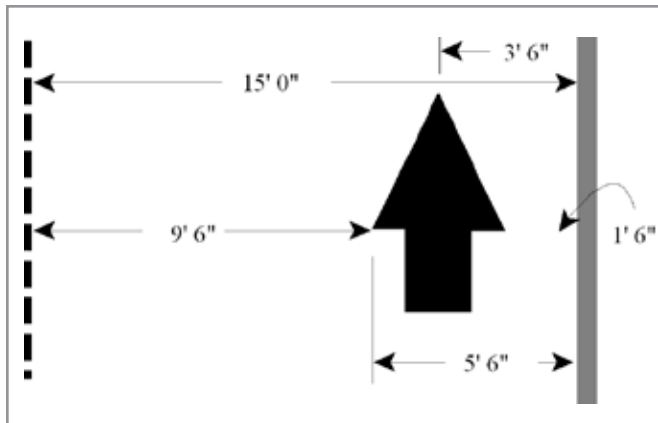


Figure 2. Actual lateral placement.

EVALUATION AND RESULTS

A before and after evaluation was conducted. Four locations along 13th Street (US 441) in Gainesville, FL, were examined using videotaping equipment to record bicycles and motor vehicles. In this study area 13th Street has four lanes with wide outside lanes in both directions. The street has a 30 mph speed limit and carries about 35,000 vehicles per day. Sites 1-3 were acceptable for all data that was to be collected, while one site (Site 4) was not acceptable for spacing measurements.

Seventeen videotaping sessions about two hours long were used to gather data both before and also after the ARROW was installed for a total of 34 sessions. Concurrent with installation of the device, about one week of public awareness was conducted. A press release was prepared, and television crews filmed bicyclists riding along the stenciled street. Information about the stencil was widely disseminated to University of Florida students, faculty, and staff through normal channels. The videotapes were examined by HSRC personnel. Three lateral spacing measurements were made using Jandel Scientific SigmaScan Pro Image Measurement Software on still images of the videotape captured by Snappy Version 3.0. The measurements were bicycle to curb, bicycle to motor vehicle, and motor vehicle to curb.

Before the ARROW was placed, 39.3 percent of bicyclists rode in street, with traffic. After the ARROW was placed, the proportion of bicyclists riding in street, with traffic increased to 45.3 percent. Comparing in street, with traffic with all other positions and directions combined (a 2x2 table, chi-square test) yields a statistically significant increase ($p < .05$) toward riding in the street with traffic after the placement of the ARROW.

Bicycle-to-curb measurements were made to determine if the ARROW was associated with a change in the lateral positioning of bicyclists. The difference between the before measurement of 0.5 m (1.6 ft) and the after of 0.6 m (1.8 ft) (about 76.2 mm (3 in.)) was statistically significant ($p < .01$). However, this small difference was not considered to be practically significant.

Bicycle-to-motor vehicle measurements were made when a motor vehicle with a driver with unobstructed view was directly next to the bicyclist, the front wheels of the motor vehicle and bicycle in line. The mean bicycle-to-motor vehicle measurement in the before period was 1.8 m (6 ft) ($n=92$). The mean bicycle-to-motor vehicle measurement in the after period was 1.9 m (6.1 ft) ($n=83$). The difference was not statistically significant.

The motor vehicle-to-curb distance was measured from the outside edge of the front tire (or in some cases the rear tire) to the curb face when there were no bicyclists nearby to influence the drivers' positioning. The difference between the before mean of 1.9 m (6.3 ft) and the after of 2 m (6.4 ft) was not statistically significant.

There was an interesting difference in the distributions of the measurements that were made, and the difference was associated with the Bicycle-to-Curb distance. There was increased spread in the lower end of the distributions in the after period, such that the proportion of bicyclists riding 0.5 to 0.8 m (1.8 to 2.5 ft) from the curb increased substantially, in effect increasing their safety margin.

CONCLUSIONS AND RECOMMENDATIONS

There were no practical differences in the average lateral spacing measurements of bicycle-to-curb, bicycle-to-motor vehicle, and motor vehicle-to-curb. However, the proportion of bicyclists riding 0.5 to 0.8 m (1.8 to 2.5 ft) from the curb showed a substantial increase, giving them a larger safety margin. There was a statistically significant increase in the proportion of bicyclists riding in the street after placement of the ARROW. This shift from the side-

walk to the street should increase safety by putting cyclists where they are more visible to motorists and out of conflict with vehicles entering or exiting driveways that cross sidewalks, as well as reduce the conflicts with pedestrians.

The 13th Street corridor was chosen because there were enough bicyclists riding on a daily basis to make data collection efficient. In retrospect, however, the number of cyclists may be a factor that mitigates against possible shifts in the distance measures of effectiveness. It is certainly possible that motor vehicle drivers on this route are well attuned to the presence of bicyclists, and thus may already have shifted their traffic lane location away from the curb to account for the space needs of bicyclists before the ARROW was installed. However, the shift in the lower end of the Bicycle-to-Curb measurement which yielded more riding space for bicyclists is compelling enough to “keep the jury out” on this shared lane treatment a bit longer. More trials in other locations are recommended and should result in more conclusive findings.

The modification (shared use arrow) that is the subject of this case study is not compliant with the *Manual on Uniform Traffic Control Devices*, but a version of this marking (bike symbol followed by chevrons, shown on page 279, Figure 2) is being considered for inclusion. Accordingly, it is imperative that any jurisdiction wishing to utilize the shared use arrow (or any other non-approved traffic control device) should seek experimental approval from the Federal Highway Administration. For information on how to do so, please visit this Web site: <http://mutcd.fhwa.dot.gov/kno-amend.htm>.

COSTS AND FUNDING

Approximate costs were the following:

Labor	\$500
Trucks and arrow board	\$216
Paint and stencil	\$118
Total	\$834

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Enforcement for Bicycle Safety

BACKGROUND

The enforcement of laws, both for bicyclists and motorists, is critical to improving bicycle safety and enjoyment. Very little effective enforcement typically occurs, however, in U.S. cities and towns. Wisconsin's Enforcement for Bicycle Safety (EBS) course was designed to help law enforcement agencies and officers correct this situation.

Police officers are the only ones who can enforce laws, yet most officers never receive any bicycle-specific training. Bicycle issues generally are not a police priority. The public and many officers assume that since officers are trained in traffic enforcement, this training includes bicycle safety. Police officers tend not to enforce laws that they do not know or cannot justify enforcing.

In Wisconsin, police recruits receive 400 hours (and soon 520) of basic standards training, of which 10 hours cover traffic law. Laws related to bicycling could be covered during this basic training, but they normally are not discussed. Following recruit school, newly hired officers go through 10+ weeks of field training. This is another bicycle training opportunity, but it is seldom used. All police officers are required to take 24 hours of continuing education each year. This presents a third opportunity for bicycle safety training, but until the creation of EBS in 1995, there was no such training available (this absence of training tends to be true nationwide). Therefore, most police officers have never been taught the leading causes of bicycle crashes, the laws specific to bicycle safety, and how selective enforcement can improve bicycle safety. Without this information, police officers are unlikely to contribute significantly to bicycle safety and enjoyment in their communities.

Enforcement for bicycle safety is part of police culture in only a few communities. EBS is changing the belief

Peter Flucke, President, WE BIKE

of both officers and the public that "Bicycle violations are trivial." Bicycle safety should be a recognized part of every officer's job. In 2001, 728 bicyclists were killed and 45,000 were injured in reported crashes with motor vehicles in the United States (U.S. DOT, 2002).

Law enforcement has a role, along with engineering, education and encouragement, in improving bicycle safety. Well-targeted enforcement (with or without citations) has great potential to positively affect bicycle safety and enjoyment. Officers can also help engineers, educators and others to identify possible problems and solutions.

THE GOALS OF EBS:

Short Range

- 1) Provide police officers with basic training about bicycling and bicycle safety issues.
- 2) Develop awareness among police officers about the significance of bicycling and its related issues.
- 3) Convince officers that they can improve traffic safety by enforcing laws, both for bicyclists and motorists.
- 4) Encourage police departments to adopt a bicycle law enforcement policy.
- 5) Demonstrate the need to develop additional bicycle education curricula and materials for police agencies.

Long Range

- 1) Promote a safer and more enjoyable bicycling environment.
- 2) Reduce deaths and injuries to bicyclists.

COUNTERMEASURES

The Enforcement for Bicycle Safety Course (EBS) was developed in 1995 for the Wisconsin Department of Transportation Bureau of Transportation Safety, in conjunction with the Law Enforcement Training Center at

Lakeshore Technical College (LTC) in Cleveland, WI. LTC was chosen because courses developed with a state-certified law enforcement training center are automatically approved by the Department of Justice for continuing education hours and training dollars.

EBS is a two-day course designed to give police officers the basic bicycle safety information they need to manage traffic and provide a safe bicycling environment in their communities. The course is designed for all police officers who are assigned patrol duties and will encounter bicyclists. Officers patrolling by bicycle and those involved in bicycle education find EBS particularly helpful. Topics covered include bicycle history, bicycle types, why and where people bicycle, engineering, bicycle crashes, enforcement, laws, crash investigation and reporting, education, bicycle theft, bicycle registration, police bicycle patrols, and on-bike training.

Courses initially were offered through the state's law enforcement training centers at vocational-technical colleges, but this approach was quickly abandoned in favor of offering the course through individual police departments.

EVALUATION AND RESULTS

For the first few years of the course, officers were given pre-tests and post-tests designed to measure both their basic bicycle safety knowledge and their attitudes about enforcement for bicycle safety. The bicycle enforcement activities of 10 officers from one department were evaluated for a five-year period before the course and then one year after the course. Feedback is solicited from course participants following every course via a course evaluation form. The number of officers trained is tracked, and the future bicycle safety activities of some of these officers are monitored. Requests for courses and presentations about the course are tracked both within and outside of the state.

Initially, it was difficult to schedule courses and to fill them once scheduled. It seemed logical to offer the course through the vocational-technical colleges because this is where police officers receive their recruit school and continuing education training. But because of a lack of familiarity with the topic and insufficient advertising, few of these courses were successful. Once the courses were transferred to individual departments they became highly successful. The success of department-run courses is primarily because of incentives and marketing. Hosting departments are offered free spots in the course once a minimum number of students is reached. Hosting departments advertise the course heavily to reach this minimum and receive the free spots.

There now are three instructors running regular EBS courses in the state, but reliable course data is available from only one instructor. That instructor, the course developer, has conducted 15 courses over the last eight years. Class sizes average approximately 11 students, and 167 officers have been trained.

During the eight years that the course has been offered, the types of officers participating has changed. For the first few years, most of the attendees were new to the law enforcement field, had little, if any, bicycle experience and were sent by their training officers. Over the years this has changed. More recently the course has attracted officers who have experience in law enforcement (three to five years plus), are already trained as bicycle patrol officers (either by the Law Enforcement Bicycle Association (LEBA) or IPMBA) and have requested the training. Because of their on-bike training and experience, these latter trainees have tended to do better in the course and enjoyed it more.

Based on pre- and post-test results, officers attending EBS significantly improve both their bicycle safety knowledge and their attitudes about enforcement for bicycle safety. Typical comments from officers include, "I wish that I had taken this course years ago," and "It would be a good idea to send every officer through your class." One supervisor commented, "This is the first time that an officer came back from a (class) and shared the information.... Thank you for the presentation."

The bicycle enforcement activities of 10 officers from one department were evaluated for a five-year period before the course and then one year after the course. Before the course, these officers had issued only two citations for bicycle violations. The year following the course, each officer wrote an average of three to five citations. These numbers do not include citations to motorists for bicycle safety-related stops or contacts that did not result in a citation. Those types of enforcement activities are believed to have increased as well.

Following their participation in the EBS course, many students have increased their level of participation in bicycle safety activities. Some make more enforcement contacts, others have sought out additional bicycle safety training and have become instructors for this and other courses. One officer now sits on the board of directors for a state bicycle advocacy organization. All of these activities indicate an increased level of awareness and interest among police officers of bicycling issues.

Developing instructors for the course has been difficult. Police officers, or former police officers, seem to be the most credible when teaching other officers. But, because of their workloads and schedules, most police officers have little free time for other jobs. Also, relatively few officers are interested in teaching bicycle safety to other officers. An instructor course was conducted in 1996 shortly after EBS was developed; however, none of the participants had taken the course before and only two graduates went on to teach courses. Another instructor course was conducted in 2001 using only former EBS graduates. The six instructor candidates still need to co-teach with the lead instructor, but then they will be certified.

EBS has gained national recognition. Courses or presentations about the course have been made in Minnesota, Indiana, Iowa, Pennsylvania, Arizona and Washington. Portions of the course recently were incorporated into a new National Highway Traffic Safety Administration course, "Community Bicycle Safety: For Law Enforcement."

CONCLUSIONS AND RECOMMENDATIONS

The most effective means of introducing bicycle safety knowledge and activities into law enforcement likely is through inclusion of bicycle safety training in police recruit schools and field training for new officers. Until this happens, continuing education training, like EBS, will have to fill the gap. EBS training dramatically improves the knowledge, activity levels, and attitudes of police officers about enforcement for bicycle safety. This type of training should be incorporated into every law enforcement department in the country.

COSTS AND FUNDING

The cost of the EBS course is \$90 to \$100 per officer, but departments that sponsor a course receive a discount, usually free spaces in the course. The course is approved by the Wisconsin Department of Justice and training dollars can be used to pay for attendees.

Funding for the initial development of the course in 1995 was provided by the Wisconsin Department of Transportation-Bureau of Transportation Safety (WisDOT-BOTS) using Federal Highway Safety (402) Funds. The cost was about \$10,000. WisDOT-BOTS paid approximately \$10,000 to revise and update the course materials in 2001.

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Bicycling Ambassadors and Bike Lane Education

BACKGROUND

Mayor Daley's Bicycling Ambassadors spent the summer of 2002 teaching safe cycling in Chicago in several different venues, including Chicago Park District day camps, after school programs, neighborhood festivals, block parties, sporting events and large city festivals like the Taste of Chicago and Jazz Fest. The program, based on a similar program in Toronto, Canada, is part of the Chicago Department of Transportation's Bike Program and was initiated the previous summer to educate Chicagoans about safe cycling, as well as to encourage both children and adults to cycle more. One of the Ambassadors campaigns focused on educating motorists on the proper use of bike lanes on Chicago streets.

Chicago has installed 70 miles of new bike lanes on city streets, a majority of those within the past few years. Because these are new facilities, many cyclists and motorists have misconceptions about how bike lanes will affect the safety, capacity, and access of streets. These misconceptions could lead to community disapproval of new bike lanes.

Many cyclists also complained that they did not feel safe using bike lanes because motorists often drive in them, use them as a passing lane and double-park in them, which forces cyclists to swerve into the travel lane. Since bike lanes are on streets that are highly trafficked by both motorists and cyclists, motorists' practices reduced the feeling of safety the bike lanes were meant to engender.

Dave Glowacz, Director of Education, Chicagoland Bicycle Federation
Christine Ranieri, Bicycle Ambassador, Chicagoland Bicycle Federation



COUNTERMEASURES

The Bicycling Ambassadors canvassed 11 streets where bike lanes had been installed in the last few years. On each stretch, they visited every business and talked to employees about the bike lanes, asking them to encourage their customers not to drive or double-park in the bike lanes at the risk of a \$100 fine. At businesses that agreed, Ambassadors left literature for customers about bike lanes, including "Bike Lanes: Frequently Asked Questions" and a flier titled "This is Not a Parking Spot: Bike Lanes are for Bikes" which explained the \$100 fine and why it is dangerous for cyclists when motorists drive in bike lanes. Several businesses also agreed to tape the flyers in their storefront windows.

EVALUATION AND RESULTS

The Bicycling Ambassadors recorded: 1) each business visited; 2) the opinion expressed by the store's employee(s); 3) whether or not they took the literature; 4) whether or not they agreed to distribute it or post it; and 5) any comments the employees may have made about the bike lanes or literature.



Of the canvassed businesses, 48 percent expressed a favorable opinion towards bike lanes and the task of encouraging their customers not to park or drive in them. Twenty-eight percent had no opinion, eight percent had a negative opinion and 19 percent made no comment. Seventy-five percent of the businesses agreed to take the literature, and of that 75 percent, 71 percent agreed to distribute it by either putting it out near their cash registers, in literature racks or by posting fliers. Several businesses were interested in putting bike racks on the sidewalk in front of their shops (the City of Chicago installs racks on city property free of charge) and obtaining loading zones to help eliminate double parking. Negative comments centered on bicyclists' refusal to follow traffic laws. Positive comments centered around: 1) the hope that bike lanes would reduce the number of people cycling on the sidewalk 2) general enthusiasm for safer cycling in the city and 3) the desire to be regarded as a bicycle-friendly establishment.

CONCLUSIONS AND RECOMMENDATIONS

These results suggest that the business canvassing project should be continued by the Bicycling Ambassadors next summer. It is effective for several reasons. First, the campaign directly educates one or more individuals working in each business. Second, since most bike lanes are on well-trafficked streets with a large number of businesses, customers could see the flyers in every shop they frequent on the block, and realize that respecting bike lanes is a concern for business owners in the area. This impresses cyclists, educates motorists and can only work in the business' favor. Finally, personal contact allows business owners to air concerns and ask important questions about issues such as: loading zone permits, lifts on rush hour parking restrictions, laws concerning cyclists, and

how to get a bike rack installed in front of their business. The campaign might be more effective if literature was regularly replenished in the businesses that were amenable to accepting and displaying it. Finally, the campaign would be most effective if the "Bike Lanes: Frequently Asked Questions" leaflet consistently was placed on cars parked along bike lane streets, reinforcing the information seen in the shops.

An obstacle that often came up in this project was not being able to communicate with non-English speakers. While one of the Bicycling Ambassadors spoke Spanish and the two fliers were printed in Spanish, it still was difficult to communicate if the Spanish-speaking ambassador was not present or if another language was spoken. It would be more effective if those who speak the languages of the particular street or neighborhood were hired to conduct the canvassing, and if literature was printed in several languages commonly spoken in the city.

COSTS AND FUNDING

Funding for the Bicycling Ambassador program predominantly came through a grant from the Illinois Department of Transportation, Division of Traffic Safety and matching funds from the Chicago Department of Transportation, Bureau of Traffic. Office space, training and support came from the Chicagoland Bicycle Federation. Kryptonite Locks, Bob Trailers, American Automobile Association-Chicago Motor Club, and Planet Bike also sponsored the program.

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A Comprehensive Child Bicycle Safety Program

BACKGROUND

BASELINE INJURY INCIDENCE

Preliminary research on bicycle-related injury mortality and morbidity was conducted by the Florida Department of Health's Injury Prevention Program Office (TIPPO) in Duval County during the end of 1994 and the beginning of 1995. Early assessment revealed a disproportionately high incidence of bicycle injuries among the 5- to 14-year-old age population in Duval County. This population group ranked number one with 35 percent of all nonfatal bicycle-related injuries during 1994. Only four of the 115 injured children in the same age group were wearing helmets during the crash event (1). This represents only a 3 percent helmet use rate for the nonfatal injured group and no helmet use among the four fatalities that year.

BASELINE HELMET USE

In 1996 the Florida Department of Transportation approved a grant for Florida State University to conduct a *Florida Bicycle Helmet Use Survey* (2), which included Duval County. The 1996 survey revealed the overall bicycle helmet use rate for all ages in Duval County to be 19 percent (the second lowest rate among the eight counties in the study). The same report revealed a 14 percent observed helmet use rate for the 5- to 14-year-old age group in Duval County—the same population group that experienced the highest injury rate.

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 Carol Conroy, MPH, PhD., Director of Epidemiology Division, Duval County Health Department, FL



COUNTERMEASURES

ACTION PLAN

With the problem clearly defined, Florida Department of Health's Injury Prevention Program Office (TIPPO) in Duval County drew up a project design with the aim of increasing helmet use among 5 to 14 year olds in the county as its primary goal. Our goal was formalized and reads, "To increase use of bike helmets in Duval County Public Elementary Schools' aged children to at least 50 percent by December 1999 as measured by baseline and annual observational surveys." A work plan with scheduled milestones and activities was then drafted to track the implementation progress. Three countermeasures to apply to the at-risk population group were chosen based on efficacy studies found in the literature. The three countermeasures were:

- Institutionalizing a school-based bike safety program with emphasis on knowledge-based education and skills training, including proper helmet use;
- Seeking bicycle helmet legislation and policy support;
- And providing and promoting one of the most effective injury-prevention technologies, bike helmets, at discounted or no cost to school-age children.



ACCESSING HUMAN AND ECONOMIC CAPITAL

To accomplish our objectives, we knew we would need broad community support and a strong coalition of working partners. We were fortunate to gain successful, progressive buy-in from a vast array of disciplines with an interest in mitigating the problem of bicycle-related injuries to children. Both direct financial, and in-kind support, including staff salaries, were and are an important part of this program.

“Show Me the Money!”

Primary underwriting has come from the Florida Department of Transportation State Safety Office with approximately 50 percent of the monetary support over the eight-year history of this project. The second largest cash commitment to the project came from Brooks Health Foundation which is affiliated with Brooks Rehabilitation Hospital. (A cumulative summary of the financiers of the project is listed on the last page.)

In-Kind

The second critical fiscal support element for this project is in-kind donations. The Duval County School Board and the Duval County Health Department carry the lion's share of day-to-day staff allocation by providing project administration staff and teachers for the bicycle safety curriculum at the 103 elementary schools and 26 middle schools in Duval County, Florida, over the past eight years.

A pivotal position to keep the implementation process in the schools going is the school board's bike contact/project coordinator. This person works full time on making sure that the schools are implementing the bike safety curriculum, scheduling the trailers, conducting instructor trainings, and acts as a liaison for communications between all the core partners. In addition, the Fleet Management Division of the school system is invaluable to the project because they store and transport all the equipment the schools need to conduct the project at their individual schools.



Garnering Political Will

A third level of support was sought in the form of coalitions, single organization champions and support groups that would be responsive to the cause of reducing bike injuries in Duval County. At the local level, TIPPO has become an active member in three coalitions that have vested interests in the bicycle-injury problem. These groups are the Jacksonville Pediatric Injury Control System, Duval County Community Traffic Safety, and The Bicycle/Pedestrian Advisory Committee within the mayor's office. These groups provide expertise in the areas of injury prevention among children, traffic-related injury prevention knowledge, and a connection to the local governing body.

Local Champions

The other champions on the local scene are too numerous to mention, but are no less important to the whole mission. They comprise individuals with a passion for the problem, private enterprises that are sensitive to giving back to the community in this form, bike clubs, the housing authority, bike shops, the Jacksonville Jaguars football team's foundation, hospitals, service clubs, the city parks and recreation department, law enforcement agencies, rehabilitation hospitals and clinics, brain injury associations, medical associations, law firms, academia, physical education associations, and public health associations.

State and National Support

Statewide organizations and state and national agencies including The National Highway Traffic Safety Administration, the Federal Highway Administration and the Center for Disease Control & Prevention have also supported this effort.

CURRICULUM

TIPPO selected a bike safety curriculum developed by the University of Florida because of its strong emphasis on skills training, a highly rated peer-reviewed curricu-

lum, its perspective on bicycle safety in the context of all traffic safety (pedestrian to pre-drivers education), its two-day certification requirement for all instructors, and the proximity of the University for technical support. The curriculum, the *Florida Traffic and Bicycle Safety Education Program* is grade-specific and is meant to build on the previous years knowledge and skills base (see <http://www.dcp.ufl.edu/centers/trafficsafetyed/> for more information). The ultimate project vision and mission is that the knowledge and skills learned in the early years will also transfer to safe motor vehicle driving behaviors when the children get older.



INSTRUCTORS

Since 1995, over 175 physical education teachers and school resource officers have been trained and certified with the classroom and the on-bike skills qualifications needed to deliver the curriculum to the children during physical education classes in the 103 schools.

EQUIPMENT

Thirteen custom-designed (by TIPPO) transportable self-contained training modules (trailers) were purchased to house bicycles, helmets, street signs, videos, P.A. systems, curricular manuals, teaching aids, etc. to service and rotate among the 103 elementary schools in the county. The fleet management division of the school system provides transport of the trailers to and from the elementary and middle schools. A school warehouse is used to store equipment between deliveries to the various schools and during school breaks. The school system provides the maintenance of most of the project equipment, but some bicycle repairs are contracted out to local bike shops.

LEGISLATION AND POLICY APPLIED TO THE TARGET POPULATION

In 1996, TIPPO provided statistical data, cost of injuries, and cost benefit analysis of helmets to inform and educate the

state legislators before their vote on bicycle helmet legislation. Florida passed bicycle helmet legislation for children under the age of 16, which took effect in 1997. TIPPO also drafted a Helmet Proclamation, which was adopted and signed by the Duval County School Board President and superintendent of schools. The proclamation then was posted at all elementary schools in 1997. The injury prevention staff worked with the Duval County public school curriculum writers to craft a bicycle safety education standard that served as a countywide mandate to provide the health department's bike safety project in all 103 elementary schools. In 1998 the city of Jacksonville passed a City Council Resolution recognizing the health department's bike safety project.

PROVISION AND ACQUISITION OF HELMETS APPLIED TO THE TARGET POPULATION

Over 20,000 helmets have been sold and distributed with "hands-on" proper fit training throughout the elementary schools of Jacksonville in the last seven years. A unique system of helmet acquisition was designed to be self-contained and modular like the educational trailer component. Twenty-two kits were assembled that contained samples of the helmets, three types of sales procedures, order forms, and measuring instructions. TIPPO then processes the schools' helmet orders and arranges direct shipment from the vendor to the individual schools. Scholarship programs were also designed for each school, and included in the helmet kit. The health department was able to purchase helmets at low cost through its competitive bid process. Rather than give the helmets away free, helmets were sold to the children for \$4 to \$5, about half the price that the health department paid. Subsidizing the helmet cost rather than giving them away, enabled the County to provide low-cost helmets to more of the County's at-risk population, approximately 50 percent instead of 25 percent that would have been possible with free helmets.

Other project reinforcement over this period has included:

- Helmet contracts between dentists, kids, and parents conducted in dental offices
- Implementation of a "safety village" in Jacksonville that in 2001-2002 trained 2000 Pre-K to second-grade children during field trips with proper helmet fit and on-bike riding through a miniature town that includes working traffic lights, railroad crossings, etc.
- Production and airing of two helmet public service announcements reaching a viewing audience of over 180,000 households through the local NBC, ABC, CBS, PBS and FOX affiliate TV stations

- Helmet incentive project with school crossing guards rewarding helmeted kids with age-appropriate prizes
- Weekend bike rodeos conducted with our community education trailer that is specially equipped with tri-cycles, bicycles with training wheels, adult-size bikes and a wide range of age-specific support materials.

All of the above activities and products are specifically planned to raise community awareness of bicycle safety and injury prevention. Therefore, an intensive multifaceted project aimed at the highest risk population combined with a multi-level awareness campaign aimed at creating a community bike safety norm.

EVALUATION AND RESULTS

KIDS TRAINED WITHIN THE ELEMENTARY AND MIDDLE SCHOOLS

There have been 115,000 children (the target population is about 64,000 children in any given year) educated and trained in proper helmet fit and pedestrian and on-bike safety skills. Many of these children have received annual bike safety training throughout their elementary and middle school grades. Program reviews and audits suggest that the number of children educated has actually been underestimated.

About 75 percent of the elementary schools have participated in the project at least once, and some annually, while an estimated 25 percent of the schools have not participated in the bike safety curriculum or helmet distribution. Further study to determine possible barriers to school participation, and to gain higher compliance to reporting protocols, are part of TIPPO's on-going quality improvement goals.

We evaluated data from pre- and post-intervention annual observational surveys (1996–2002) to determine if the intervention (bicycle helmet sales and bicycle safety education) increased the use and proper use of bicycle helmets. We also compared experimental schools (exposed to the intervention) against control schools (not exposed to the intervention). Although data were collected on other bicycle safety behaviors (such as scanning, signaling and wearing bright visible clothing), this case study focuses only on helmet use and proper use.

Data were collected at school locations for approximately 45 minutes before school started or immediately after school ended. To maximize the number of observations, schools were observed during the school year's

warm weather months (April through June). Three Duval County Health Department employees and one Duval County School Board employee collected the data.

PRE-INTERVENTION VS. POST-INTERVENTION

In 1996 there were a total of 735 children observed at school sites. Of those a total of 93 wore a helmet (12.7 percent), an even lower percentage than the results from the statewide observational survey. Over the next six years, the bicycle helmet usage rates ranged from as high as 63.9 percent in 1998 to as low as 43.8 percent in 2001. All of these years have shown a greater helmet use rate than the baseline. The number of bicyclists observed for those same years ranged from 409 to 582, each a smaller sample than the baseline year. The methodology used for the surveys was the same year-to-year except for modification of age groups over different years. Middle school children are included in the yearly results even though they were not exposed to the curriculum until 2001. The observed increases in helmet use might, therefore, be understated, although it remains to be seen if middle school students will show the same degree of increase in helmet use as the elementary-aged children.

There was a significant increasing trend in helmet use across all locations (see figure 1). Only children in elementary and middle schools observed riding to or from school are included in this figure. Figure 1 shows a rapid increase from baseline to the next immediate year then shows the rates start to level off at about 44 percent for 2001 and 2002.

Data on proper use of helmets were available from 1997 to 2002. Because the data were not disaggregated by age group and observation location, proper helmet use was analyzed for the total sample (including children and adults) and not by observation location. Baseline data were from the 1996 observational survey conducted by school board transportation specialists. Proper use as a percent of total use among all ages dropped dramatically from baseline to 1997 and then again from 1997 to 1998, from 87 percent to 47 percent (figure 2). Proper use remained about the same for several years, and then climbed dramatically for 2001 and 2002 to 73 and 77 percent, respectively. Although total use peaked in 1998 and gradually leveled off, proper use showed a somewhat counter-trend. If school-aged children showed similar trends to the all-ages data, then the overall result would be an increase in the proportion of children properly wearing helmets from about 11 percent at baseline to 34 percent in 2002. It is likely, however, that children wear helmets improperly somewhat more often than do all ages. Nevertheless, the results are encouraging that there has been an increasing trend in proper helmet use.

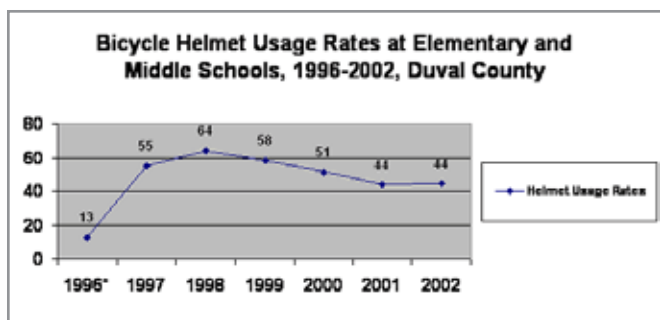


Figure 1. *Note: Bicycle Helmet Use was calculated for both elementary and middle schools over all years even though the first five years of this project targeted only elementary school children. Proper Bicycle Helmet Use, is calculated as percentage of those wearing helmets. 1996 was the baseline year; data from observational survey. Middle school children were not exposed to the intervention until 2001 (2002 survey results).

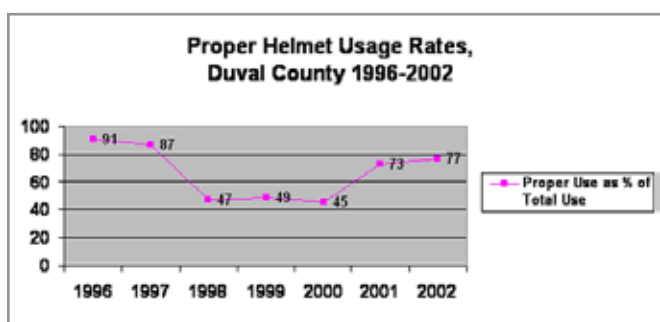


Figure 2. *Note: Proper helmet use is calculated as the percent of those using helmets, for both elementary and middle schools over all years, although the first five years of this project was aimed only at elementary school children. Middle school children were not exposed to the intervention until 2001 (2002 survey results). 1996 is the baseline year.

CONCLUSIONS AND RECOMMENDATIONS

These results suggest that our multi-faceted bicycle safety program has been successful in increasing helmet use among children. Observations indicate substantial increases in helmet use among children riding to and from school, although rates have leveled off since 1998, possibly due to less enforcement of the helmet law in recent years. The evaluation relates to the effect of implementing a safety program in a community (Duval County) and does not address whether there were changes in behavior in the individual children receiving the safety training. Therefore, additional evaluation aimed at comparing individual changes in behavior (e.g., use of helmets, proper use of helmets, safe riding skills) among children receiving the training and those not trained needs to be completed to more precisely measure the success of the safety program.

Additionally, because there were several components to the intervention (distributing low cost helmets, helmet use ed-

ucation, fitting instruction, and riding safety) it is important to evaluate the different components. There may be other factors, including a helmet law that went into effect January 1, 1997, and a school proclamation endorsing helmet use that also contributed to the increase in helmet use. Considering these factors would be an important next step to evaluate the success of this safety program.

The results of the comprehensive community-wide effort are promising and illustrate the need to continue the safety program while conducting a more rigorous evaluation.

From 1995 to the present, the health department's Injury Prevention Office has gained a progressive list of collaborators who are making a difference that likely would not have been achieved by any single agency or entity. All the contributors, great and small, are equally important to the success of this project. Our philosophy is that the smallest contributor could be the difference between life and death with a child that they directly or indirectly affected.

COSTS AND FUNDING

Summary of all financial support, 1995 - 2002	
FDOT Grants (1995-2002)	\$440,000
TIPPO Project Director (DCHD In-kind)	75,000
TIPPO Project Implementation (DCHD In-kind)	43,000
BROOKS Health Foundation Donation	100,000
Helmet Sales Revenue (1995-2002)	93,000
Duval County School Board (in-kind)	140,000
Center for Disease Control Grants	60,000
Port of Jacksonville Pilot Club	5,000
Misc Donations	20,000
Grand Total	\$976,000

Note: Duval County Health Department and Duval County School Board in-kind figures are conservative estimates. Helmet sales revenues are reinvested for continuous helmet procurement. Miscellaneous donations include, but are not limited to, such support materials as surgical caps for prevention of lice transmission, field markers, volunteer service hours, etc.

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Share the Road: Motorist/Bicyclist Traffic Education and Enforcement Programs

BACKGROUND

Most conflicts and collisions between motor vehicles and cyclists result when either a driver or cyclist violates a traffic rule or law, including rules that motorists must observe that reflect cyclists' right to use public roadways. Common violations that can cause these problems include failure to stop or yield when required, following too closely behind another vehicle, illegal turns and passing, and cycling at night without adequate lighting. Traffic rule violations by cyclists reduce respect for cycling as a legitimate form of transportation, and can result in public policies that prohibit or discourage cycling under certain conditions. Traffic rule violations by motorists discourage people from cycling.

This situation suggests that one of the most effective bicycle safety countermeasures, and a way to increase respect for cyclists and encourage cycling, is to implement "Share the Road" programs and materials which provide bicycle traffic safety information and enforcement directed at both motorists and cyclists. The goals and objectives of such programs are to:

- Improve drivers' and cyclists' knowledge and observance of traffic rules as they apply to cycling.
- Reduce conflicts and collisions between motorists and cyclists.
- Increase respect and courtesy between motorists and cyclists.
- Increase understanding of cyclists' right to use public roads.

This case study summarizes some of the best practices in "Share the Road" programs and materials that teach and enforce bicycle-related traffic rules. Many organizations

have developed "Share the Road" traffic education and enforcement programs and materials. These may include:

- Brochures and booklets.
- Cycling route maps that also incorporate "Share the Road" information.
- Training workshops.
- Mass advertising messages (billboards, radio, television, etc.).
- Special police training and bicycle law enforcement programs.

Sponsoring organizations include government agencies, bicycle clubs, transportation advocacy organizations, children's safety programs, and various combinations of these. Since traffic laws are established at the state or provincial level, and sometimes have local variations, such materials are usually implemented at the state, provincial, or local level.

The quality of these programs and materials varies, depending on the perspective, knowledge, and resources of sponsoring organizations. Important factors include:

- Accuracy—materials reflects current rules and laws.
- Clarity—the important concepts are easy to understand and apply.
- Accessibility—programs/materials are attractive and easily available to the intended audience.

As much as possible, information should be presented in a positive manner. For example, rather than conveying the message, "Cycling is dangerous. Watch out!" it is better to emphasize that "Cycling can be easier and safer if you follow the rules when you ride." A "Share the Road" brochure is most effective if it is physically attractive with interesting graphic images and simple but accurate wording that explains key concepts in a friendly, non-threatening manner. Such a brochure must be widely distributed so that the information disseminates through the community.

Todd Litman, Director, Victoria Transport Policy Institute

Materials should target both motorists and cyclists. For example, some “Share the Road” brochures have information for motorists on one side and information for cyclists on the other. Of course, many people will read both sides, because they are interested in both perspectives. Special materials may be necessary to target particular groups, such as children or people who speak a different language.

Occasionally, motorists or public officials assume that cyclists have less right to use public roads than motorists, either because bicycles are smaller and more vulnerable, because they are used by children or because they do not pay fuel taxes and vehicle registration fees. Litman (2000) and Hill (1986) respond to these claims. They point out that:

- The Uniform Vehicle Code (UVC, the basis for most traffic laws) states, “Every person propelling a vehicle by human power or riding a bicycle shall have all the rights and all the duties applicable to the driver of any other vehicle.”
- Most traffic laws do not differentiate between bicycles and other vehicles.
- Because motor vehicles impose significant risks to bicyclists and pedestrians, the UVC gives drivers the responsibility to “avoid colliding with any pedestrian or any person propelling a human-powered vehicle and ...exercise proper precaution upon observing any child or any obviously confused, incapacitated or intoxicated person.”
- Cyclists pay an equal portion of local taxes that are used to fund local roads, which is where the majority of cycling occurs. Since cycling generally takes less road space, causes less wear-and-tear on roads than motor vehicles and imposes relatively small external costs, cyclists tend to pay more than their fair share of roadway costs as calculated by roadway cost allocation methodologies (Litman, 2000).

COUNTERMEASURES

Following are examples of some exemplary brochures and print materials and education and enforcement programs for helping motorists and cyclists better share the road.

BROCHURES

The *Drive Right/Cycle Right* brochure developed by the Insurance Corporation of British Columbia (ICBC, 1999) is a good example of “Share the Road” material that provides information for both drivers and cyclists.

The brochure has “Drive Right” on one side and “Cycle Right” on the other, with simple drawings that illustrate these concepts (<http://www.icbc.com> or <http://www.richmond.ca/services/ttp/cycling/news/driveright.htm>).

Another good example of this type material is the “*Sharing the Road*” tips developed by the League of American Bicyclists, available at <http://www.bikeleague.org/action/sharetheroad.php>.

TRAFFIC LAW ENFORCEMENT — BICYCLE DIVERSION PROGRAMS

Appropriate traffic law enforcement can also help prevent conflicts and collisions between bicyclists and motorists and can instill lifelong traffic safety habits in young people. Children who spend years violating bicycle traffic laws with impunity are being poorly prepared to become responsible car drivers.

Safety experts recommend targeting the following cycle traffic rule violations:

- Motorists failure to yield or stop for pedestrians and cyclists when required by traffic law
- Excessive motor vehicle speed
- Intoxicated drivers and cyclists
- Cyclists failure to yield when required by traffic law
- Cyclists riding in the wrong direction, against traffic
- Cyclists riding at night with inadequate lighting

An effective enforcement program must overcome various barriers. Police officers may be unfamiliar with traffic rules and laws as they apply to bicycles, cyclists’ rights to use the roadway, or how to effectively enforce bicycle traffic laws. Nonmotorized traffic violations, particularly by children, tend to be considered a low priority by officials and the general community. Standard traffic fines may appear excessive or inappropriate for children. Cyclists and pedestrians may ignore citations unless police departments develop a suitable processing system.

A bicycle “diversion” program allows offending cyclists to take a cycling safety workshop as an alternative to paying a traffic fine (i.e., they are “diverted” from the court system). Police departments can run such workshops internally or contract with an outside expert. Such programs are popular because they emphasize safety rather than punishment and help develop cooperation among police, parents, and bicycle safety advocates. Scout troops, school groups and parents often voluntarily attend the safety workshops.

Examples of communities with well-established and ef-

fective bicycle diversion training programs include Tempe, AZ; University of California at Davis through Transportation and Parking Services; and Huntington Beach, CA; as well as Walnut Creek and Brentwood in Contra Costa County, CA. Here is how such programs typically work:

- Cyclist is ticketed for violating a traffic law.
- If the cyclist is a child, police send a standard letter to their parents describing the violation, emphasizing the importance of observing bicycle traffic laws for the sake of safety, asking the parent to bring the child to a bicycle safety workshop (typically offered monthly or semi-monthly) within a specified time period (such as three months), and inviting the parent to contact the program coordinator if they have any questions.
- If the cyclist attends the workshop the traffic ticket is void.
- If the cyclist fails to attend the workshop in the specified period, the ticket is processed.
- Police and courts coordinate to allow efficient processing of cyclist traffic tickets.

CONCLUSIONS AND RECOMMENDATIONS

Many conflicts and collisions between motorists and cyclists result from inadequate understanding and observance of bicycle traffic rules, including rules that cyclists must follow, and rules that motorists must observe that reflect cyclists' right to use public roadways.

"Share the Road" programs have the potential to improve awareness and respect of cyclists' right to use the roads and compliance with rules and laws affecting bicyclist safety by both motorists and cyclists, and may therefore help to reduce conflicts and collisions between cyclists and motorists.

COSTS AND FUNDING

Costs vary depending on the type of program and materials. Most bicycle traffic safety education programs require staff time for planning, plus resources to produce brochures and other outreach materials. Some offer training courses. Most traffic law enforcement activities are included in existing police budgets.

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Hitching Posts for Bicycle Parking

BACKGROUND

BRIEF HISTORY

The 1968 Santa Barbara State Street Plaza project removed on-street parking from the Downtown Commercial area, resulting in a two-way, two-lane road with right-turn pockets and bike lanes for a length of 914 m (3000 ft). Street furniture such as fountains, planters and benches was installed along long reaches of the project. A significant increase in bicycle traffic and insufficient bicycle parking supply were attributed to this project and the later striping of bike lanes. By the early 1980s, 240 bicycle parking spaces of various types, including front wheel racks and hitching posts, were available on sidewalks in the mall to meet the average daily demand of 2000 bicyclists. They were perceived as a nuisance by local business persons, and created a hazard to pedestrians. Furthermore, the imbalance between supply and demand resulted in bicycles regularly blocking the sidewalks.

An additional problem faced was gaining approval from the Historic Landmarks Commission. The Landmarks Commission was formed in May 1960 to ensure that the area within El Pueblo Viejo District would retain its unique early-California Spanish character and atmosphere through careful city planning and development. It is an advisory group to the city Council that approves, disapproves, or approves with conditions plans for exterior alteration, relocation or demolition of locations within the district. Unable to find a balance between aesthetics and functionality, the Historic Landmarks Commission for the area generally disapproved of the installation of bike racks on State Street, finding bicycles inconsistent with the landmarks in the historic district.

Drusilla van Hengel, Ph.D., Mobility Coordinator,
City of Santa Barbara



Figure 1. Bicyclists choose to park against street furniture or trees rather than use substandard parking.

Although this decision was successfully appealed, the conflict lasted several years, with interim designs including the installation of eyebolts into sandstone pillars or planter walls. Finally a hitching post design was approved for the area. In some locations, more aesthetically pleasing solutions that integrate sandstone pillars or ironwork have been required instead of hitching posts. These decisions have resulted in locations where bicycle parking goes unused and bicyclists park against trees or trash receptacles instead of parking in substandard racks, as shown in figure 1.

The practice of providing bicycle racks on the sidewalk is best employed where bicycle and pedestrian volumes are low to moderate and where sidewalk widths are adequate. At the time, neither of these prerequisites applied. The sidewalk bicycle parking was decreasing the available sidewalk width in an area with many pedestrians, and the bicycle volumes were high, with nearly 50 percent of the bicyclists to the downtown responding to a local survey indicating that they parked their bike downtown three to five times per week.

Through public outreach, city staff learned that the removal of bicycle parking from the sidewalk along State Street likely would lead to a large number of bicyclists

parking illegally on the sidewalk. This outreach was conducted by leaving surveys on parked bicycles with self-addressed reply cards. Bicyclists were asked, “If parking your bike on the sidewalk on State Street were made illegal, but bike racks were provided in parking lots, on side streets or along State Street at mid-block locations, what would you do?” Although many indicated that they would continue to park illegally on the sidewalk, the use of racks provided at midblock received the most favorable response.

Fortunately, since that time, several sidewalk improvement projects have been undertaken on State Street, and hitching posts are now a standard street furniture accessory with a goal of providing one hitching post, or two bicycle parking spaces, in front of each business door.

GOALS

The goal of the project is to provide bicycle parking in the public right-of-way where demand warrants. Removing destination barriers is a key element of the city’s 1998 Bicycle Master Plan, and this ongoing project provides convenient parking for downtown customers arriving by bicycle. Additionally, the bike parking solution was needed to prevent bikes from blocking pedestrian traffic or being left in planters or locked to trees.

COUNTERMEASURES

In 1983, a hitching post design was approved for State Street. This design continues to be used with slight modi-



Figure 2. Hitching post.



Figure 3. Bicycles parked at hitching posts adjacent to curb.

fications, such as a protective ultraviolet thermal-resistant sleeve that protects the bicycle frame. The rack provides parking opportunity for two bicycles, with each bicycle having two points of contact with the rack. The design is reflective of the hitching posts historically available to customers arriving downtown on horseback. The success of the State Street hitching post program has been a model for safely providing public bicycle parking spaces city-wide. In addition to periodic inspection of the business area, individual requests for parking trigger a field investigation to evaluate the space available for hitching post-style parking. A traffic technician reviews the proposed location for the racks and marks the acceptable location on the concrete. A minimum of 1.8 m (6 ft) of sidewalk clearance must be maintained for pedestrian access, and placement is made so that passengers exiting parked cars may avoid swinging their doors into the rack or parked bicycles.

The metal post is 1 m (40 in) high, with rings placed at 0.5 m (20.5 in) (figure 2). The ring placement allows for the front wheel and frame to be easily locked to a ring. The post is attached to the sidewalk using four expansion bolts. The posts are set adjacent to the curb line so a bicyclist may park immediately after exiting the street. The goal here is to reduce the distance a cyclist must walk with the bike in order to park and to discourage cyclists from riding on the sidewalk (figure 3).

It is extremely important to orient contractors and staff installing the posts to the subtle difference between orienting the rings parallel or perpendicular to the curb because the bicyclist naturally wants to park the bike perpendicular to the rings, and therefore the ring orientation will affect the footprint of the bicycle on the sidewalk and may even prevent the bicyclist from parking correctly (figure 4).



Figure 4. Properly installed hitching posts create orderly parking areas.

EVALUATION AND RESULTS

The project is evaluated periodically by staff. The bicycle parking count on State Street provides information about the need for more hitching posts, and also confirms what percentage of bicyclists are using the bike parking. Surveys are conducted by counting bicycle usage of available hitching posts during two midweek afternoons. The total number of bicycles parked is also counted.

To date, there are 128 hitching posts in nine blocks of State Street, providing space for 256 bicycles. Thirty percent of the posts are in use at any one time. Although this number shows only a slight increase in bicycle parking availability, census figures over the period between 1980 and 2000 show a general decline in cycling for the journey to work, so the numbers probably represent a real increase relative to the demand. Because there are some locations where the sidewalk is too narrow to permit hitching post installation, we sometimes find bicycles leaned up against buildings or street furniture. However, 82 percent of the bicycles parked in the Plaza are using the hitching posts provided, improving the safety of pedestrians and bicyclists alike.

CONCLUSIONS AND RECOMMENDATIONS

This treatment works extremely well. The hitching posts are easy to store in the Public Works Yard and therefore immediately available for installation. The program accommodates the need to be aesthetically appropriate in this historic area, yet also provides a functional place for short-term bicycle parking. The rack is relatively easy to install, and additional posts are provided whenever the demand warrants and space permits.

Providing appropriate levels of well-sited bicycle parking reduces barriers to bicycling, encourages bicyclists to use the parking and should reduce conflicts between bicyclists and pedestrians or with parked motor vehicles and their occupants.

COSTS AND FUNDING

Hitching post fabrication is completed by our staff welders for an approximate cost of \$100 per post. The project is funded through our ongoing bicycle improvements capital program. Installation is provided by the concrete crew of the street maintenance division of the Public Works Department.

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Bicycle Access on Caltrain

BACKGROUND

Caltrain bicycle accommodation is the San Francisco Bay Area bicycle success story, making it the least restrictive and most accessible rail system in the United States for bicycles.¹ Caltrain runs 124 km (77 mi) southeast from San Francisco through Silicon Valley to San Jose, CA (and Gilroy during peak-hours). It operates 75 bi-level (gallery) car trains each weekday (27,200 riders per day) and provides more limited weekend and holiday service. It is one of the few U.S. rail systems to carry bicycles on all trains.

A September 1997 count showed almost 2,000 bicycles carried (7.5 percent of the total riders), not including cyclists denied boarding due to capacity constraints. Increased ridership because of cyclists repaid the startup costs within six months and is now a revenue source.

COUNTERMEASURES

In 1977 the Southern Pacific Railroad (SP) filed for abandonment of its San Francisco–San Jose commute line. From 1977 to the early '80s, the campaign for bicycle access (other than encased folding bicycles) and continuance of train service, was led by two bicycle advocates, Ellen Fletcher and Darryl Skrabak (of the Silicon Valley and San Francisco Bicycle Coalitions, respectively). By arguing that bicycle access would increase ridership and by submitting petitions with 2,500 signatures, they helped defeat the abandonment. The state and three counties of the San Francisco–San Jose Metropolitan Area began subsidizing the train service.

In 1980, the California Department of Transportation (Caltrans) assumed management of the line, renamed Cal-



train, and contracted operations to the SP. Bicycle access was still denied, but cyclists continued their campaign, resulting in a four-month demonstration program in 1982. Twelve off-peak trains permitted up to five bicycles at the conductors' discretion. SP refused to continue bicycle access without payment for additional liability insurance.² (Later research in 1987 showed that no insurance claims were filed against any U.S. railroad because of bicycle transport.)

Three years after this demonstration's success (up to 100 bicycles per week), Caltrain began a year to a year-and-a-half review of the 1982 demonstration, contacted the 12 North American rail operators with bicycle access, spoke to local bicycle groups, reviewed literature and took bicycles on board out-of-service trains. Caltrans' Roger Hooson completed an in-depth report in 1987 supporting bicycle access and recommending another demonstration, providing groundwork for the current program, while acknowledging a key capacity constraint. Bringing bicycles through the narrow vestibules of commuter rail cars increases train dwell times at stations.

A Metropolitan Transportation Commission study also supported bicycle access, stating that "allowing bicycles on trains could increase the utilization of rail for short trips where bicycle access represents a reasonable alternative to the car."³ To the north and east, bicycle access al-

Peter S. Tannen, Bicycle Program Manager City & County of San Francisco



ready was provided by the Bay Area Rapid Transit District and bay ferries. SP access would add two counties to the five with existing bicycle-on-transit access.

By July 1992, the Peninsula Corridor Joint Powers Board was formed by San Francisco, San Mateo, and Santa Clara counties to purchase Caltrain and contract operations to Amtrak. Caltrans oversaw operations and planning and the San Mateo County Transit District managed the line. Bicycle access still was not provided. After a 1992 meeting of more than 200 people, a Bicycle Advisory Committee was formed.⁴ Cyclists attended hearings, wrote letters, and the Caltrain Citizens Advisory Committee approved resolutions.

At the request of Peninsula Rail 2000 (a Caltrain commuter's advocacy group) and the Citizen Advisory Committee, language was included in Caltrain's Short Range Transit Plan requiring bicycle access. After more lobbying, a second demonstration project began in September 1992. Four bicycles were permitted in the aisle on all but peak hour trains. Free permits were required.

Through the efforts of the Bicycle Advisory Committee and another dedicated bicycle advocate, Lawrence M. "Cap" Thomas, bicycle access was expanded in 1994. Seats were removed to allow installation of four-bicycle racks with securement cords, based upon Cap's design. When he first approached the Joint Powers Board with this idea, they rejected it because of the lack of funds. Cap asked if the project could be implemented if he secured funding and was told yes. He obtained \$30,000 of San Francisco's bicycle and pedestrian funds, and the installation of the racks began. Additional racks were subsequently funded by the city of Menlo Park and the Joint Powers Board. Cap was the recipient of a Metropolitan Transportation Commission Transportation Award and a Caltrain Silver Spike Award for his efforts.

Bicycle areas identified by car-exterior graphics were created in 52 cars. Caltrain decreased the peak-hour bicycle restrictions in steps as experience showed no major problems. By May 1995, when the permit requirement was dropped, more than 9,600 permits were issued and twelve bicycles (four in each of three cars) were allowed on specified trains. Some trains (generally reverse-commute expresses) lacked capacity. Increasing numbers of bicyclists were left to wait for the following local train. In July 1996, timetables were adjusted slightly to account for bicycle loading and unloading at popular stations, evidence of further bicycle accommodation.

EVALUATION AND RESULTS

Racks have been consolidated to fewer cars. All trains now have at least one special bicycle car. Twenty-four bicycles are stored on racks in the front of the bicycle section (four bicycles on each of six racks). Cyclists sit in the rear on remaining seats on the lower or upper levels, in sight of the bicycles. Signs request non-bicyclists sit in other cars. The window information sheets explain bicycle stowage procedures.

Some cyclists have been turned away in past years when trains regularly reached bicycle capacity, especially reverse-commute trains. In response to high demand, an extra bicycle car is sometimes added to some of these trains (used by San Francisco residents with jobs in Silicon Valley), increasing capacity to 48. Caltrain identifies the usual trains that have two bike cars and strives to offer two bike cars on these trains as consistently as possible. Since the main San Francisco station is about a mile from Market Street (the downtown transit corridor), many San Francisco residents would have to take two buses to reach the station. At the work end of the trip, transit service is less fre-



quent with less coverage, since this area is suburban. Therefore, bicycle access for most reverse-commuters is ideal. Without it, many of these reverse-commuters would probably drive cars.

Major rules include: first come, first serve bicycle space for clean, single-rider bicycles; no conductor loading assistance; cyclist at least 16 years old; bicycles secured by bungee cords (provided) and closely attended by rider; boarding and detraining quickly upon arrival at station after passengers exit; conductor's authority is final; and use of destination tags is strongly encouraged. Cyclists never have been charged extra for bicycles.

Thirteen percent of responses to a November 1994 Caltrain passenger survey stated they use the bicycle-on-board program and 43 percent of these reported no problems. Commonly cited bicycle-related problems (decreasing response frequency) included: inadequate capacity, interactions with conductors, adequate seating, inadequate information, bicycles in aisles or vestibules, and "bicycle conditions." Eighteen percent said more bicycle access would enable them to use a bicycle as part of their trip.

Bicycles were counted as part of annual ridership counts since 1994, all conducted during the same period. Although February 1998 shows a drop in bicycles, it was during the height of the area's second rainiest winter. A September 1997 count showed 1,961 bicycles carried on 65 trains (one train omitted) averaging 17 bicycles per train. Five northbound and five southbound trains exceeded capacity.⁵ Cyclists unable to board because of bicycle capacity limitations were not counted.

Besides transportation, cyclists are brought together in one car with an opportunity for conversation, creating a sense of community. Arranging bicycles in first-out in-front order creates a reason to talk and interact. When regular bicycle commuters see first-time bicycle car users, they explain the bicycle stowing procedure. Caltrain facilitates this process by providing bicycle destination tags. Many bicycle commuters are also bicycle activists, so their commute gives them a meeting place for discussions and follow-up e-mails.

CONCLUSION AND RECOMMENDATIONS

The major problem with this program is its success and peak demand. Cyclists are sometimes denied access during peak commute times because of lack of bicycle space.

Caltrain could try to obtain additional funds to secure more bicycle cars or retrofit more cars with racks so more bicycles can be carried per train. Neither is likely in the near future. Caltrain acquired additional cars in 1999 but replaced older cars in need of overhaul. However, more trains will be operated beginning in 2004, resulting in additional bicycle capacity.

The Caltrain Bicycle-on-Board Program shows what can be accomplished by dedicated bicycle activists and a co-operating transit operator. In 1977, at a Public Utilities Commission SP abandonment hearing, a staff attorney said that these trains could become "a national model." He did not have bicycle transportation in mind, but in that realm, Caltrain has become a national model.

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²Caltrans paid SP an extra \$73,200 (or more than \$100/bicycle trip) in insurance costs for the four-month bicycle demonstration. At the time, Caltrans was paying SP \$400,000 annually for general liability insurance.

³Peninsula Route 101 Study, Metropolitan Transportation Commission, Oakland, CA, September, 1984

⁴The Caltrain BAC meets at least quarterly and includes cyclists from each county, JPB staff, Amtrak/Caltrain management, and conductors. It provides bicycle access technical guidance.

⁵Caltrain Bicycle Program Memo, Caltrain, October 1, 1997

Bike and Bus Program

BACKGROUND

The Santa Barbara Metropolitan Transit District (MTD) has promoted bike and bus programs for over 30 years. The goal has always been the same: to help cyclists extend their travel via buses. Over the years, MTD has sought to achieve this through the use of trailers towed behind buses, bicycle lockers, bicycle parking at bus stops, and bicycle racks mounted directly on the bus.

In 1975, MTD acquired a 4.3 m (14 ft) bicycle-capacity trailer from San Diego State University. Towing it behind a 6.1 m (20 ft) bus, MTD targeted the cycling behavior of college students and placed the bus on an eight-mile express service between downtown Santa Barbara and the University of California at Santa Barbara. The regular, one-way bus fare in 1975 was 25 cents, and cyclists paid an additional 15 cents to transport their bicycles. Initially, six percent of all passengers on the route brought their bicycles. This quickly improved to 30 percent.

Within a few months, daily use had fatigued the trailer's springs, causing the axle to bend and the wooden frame to break. The program was temporarily suspended until 1977 when MTD enhanced the trailer design to include a sturdier metal frame, supports that gripped the bicycles' tires, and individual bike ramps for easier loading. The bus and trailer were placed back in service on the express route, the 15-cent bike fare was dropped and the project began to attract national attention.

In 1978, MTD was awarded a \$182,000 Urban Mass Transit Administration grant, which provided for six newly designed, heavy-duty steel trailers, 150 bicycle racks and 12 bicycle lockers.

Lynnette Coverly, Marketing Manager, Passenger Relations



1970s bicycle trailer.

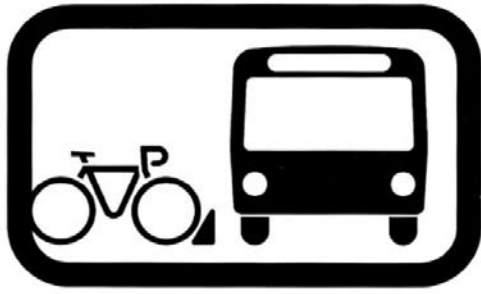
In September 1979, all six bicycle trailers operated on various routes throughout the community. The routes were chosen for their distance between destination points and service to local colleges. MTD carried an average of 105 bicycles on weekdays, 44 on Saturdays and 28 on Sundays on these routes. The service continued to be free.

With the continued growth of the bicycle trailer program and the opening of MTD's new Park & Ride Facility in Goleta, which included new bicycle lockers, MTD embarked upon a large multi-media campaign centered on familiarizing the public with the bike and ride program. The campaign, "Signs of the Times," included print, radio and bus advertising and bus stop signs promoting the Bike 'n Ride and Bus 'n Bike programs.

In 1982, MTD replaced its 6.1 m (20 ft) mini-buses with 12.2 m (40 ft) buses to handle the increasing passenger loads. Consequently, the trailers could not legally be towed behind the new vehicles and the bicycle trailer program was discontinued.

In 1984, MTD mounted bike racks on the rear of its buses. Each rack was capable of holding two bicycles and the buses were available on five routes, including service to local colleges, far-reaching neighborhoods and an outlying community to the south. The bike-bus service continued to be free.

Sign language.



Bike 'n Ride.

Bike riding is more than a Santa Barbara pastime. It's an economical way to get where you're going. And it's great exercise. But a trip all the way downtown just might be overdoing it. So MTD has installed bike lock facilities at 25 bus stops from Goleta to Carpinteria. Complete with theft-resistant cables. All you need is your padlock. Now you can bike to any one of the convenient Bike 'n Ride

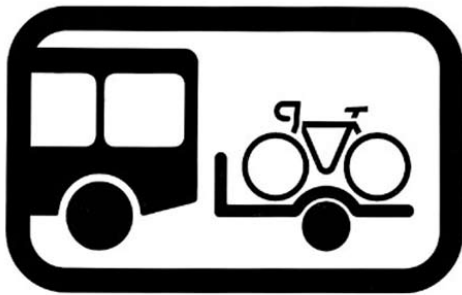
locations. And ride the bus to your final destination. Look for this new symbol. It designates bus stops where the Bike 'n Ride service is available. Bike 'n Ride is just one of three new ways to make riding the bus easier. And more practical. This way you can exercise and end up where you're going without ending up out of breath. **MTD**
Signs of the times.

Call 962-7062 for route and schedule information.



1980s rear-mounted rack.

Sign language.



Bus 'n Bike.

Facing the decision between bus or bike hasn't always been easy. Bikes are a great form of exercise in Santa Barbara's temperate climate. But biking long distances can be taxing. And taking the bus used to mean arriving without the convenience of having a bike at your disposal. MTD has changed all that. Now you can take your bike with you on any one of the six new bike trailers. From Goleta to Summerland. Or from UCSB to

Fairview Shopping Center. And lots of places in between. Look for this new symbol. It designates bus stops where the Bus 'n Bike service is available. Bus 'n Bike is just one of the three new ways to make riding the bus easier. And more practical. If you're faced with choosing bus or bike, choose both. **MTD**
Signs of the times.

Call 962-7062 for route and schedule information.

Promotional materials supporting bike and bus program.

By June 1985, the rear-mounted racks were posing significant problems in the areas of risk management (rear mounting resulted in accidents and theft) and mainte-

nance (the racks had to be removed before each wash because of damage experienced in the bus washer). In 1987 the bike-bus program was terminated.

COUNTERMEASURES

Almost 10 years later in 1995, MTD partnered with the local Air Pollution Control District (APCD) to purchase 20 front-mounted racks capable of holding two bicycles each. The APCD funded the capital cost of the racks up to \$30,000 and MTD installed, maintained and marketed the program. Front-mounted racks were chosen partly because of the driver's ability to easily observe bicycle installation and removal, thus minimizing safety and security issues.

For the next six years, a successful demonstration program ensued. MTD placed the rack-equipped buses on three routes, two serving outlying communities and the other serving the local university. The routes were chosen for their distance between origin and destination points and for the high percentage of college students, many of whom use bicycles to extend their travel once on campus. The buses operating on these three routes carried over 87,000 bicycles from 1995 to 2001 at no additional charge to the passengers. The program was marketed via a brochure distributed to all local bicycle shops as well as

exterior advertisements on the vehicles and display advertising in the university newspaper.

In 2000, MTD and the APCD again cooperated to expand the Bike & Bus Program to MTD’s entire fleet of 12.2 m (40 ft) buses (53 vehicles). The purchase of 35 racks (33 plus 2 spares) at a cost of \$571 per rack (including all brackets, adapters, etc.) came to \$20,000. The APCD again supported the capital expense of purchasing the additional racks—up to \$15,000. MTD paid the difference plus the cost of installation. Additionally, MTD continues to maintain the racks.

EVALUATION AND RESULTS

Bike trailer and rack usage is recorded by the bus driver. In the early years of the bike trailer manual tallies were kept, which was made easier by an express route that had just two stops. In the 1980s, with the rear-mounted racks, data collection became more difficult as drivers frequently were unable to see a passenger loading or unloading their bicycle. Passengers’ current use of the front-mounted racks is tallied via the farebox, which has a code that the driver can easily input for bikes carried per trip. Since the inception of the front-mounted bike rack program, including both the demonstration and expansion, MTD has carried about 153,000 bicycles.

The chart below lists years and corresponding numbers of bicycles carried. Note that between 1984 and 1987 bicycle ridership was much lower than previous years, partly because of the difference in what the racks were capable of carrying—two bikes on the racks compared to 14 bikes on the trailers. Additionally, when the front-mounted racks initially were installed in the latter half of the 1990s, MTD ridership was much greater, reflecting a sharp rise in bike rack use. The fully implemented Bike & Bus Program be-

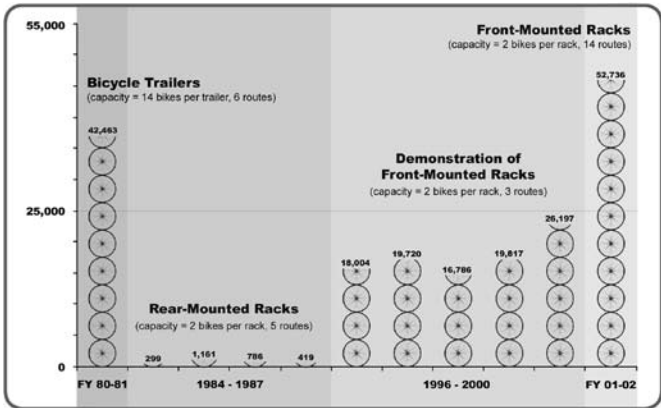
ginning in February 2001 resulted in a sharp increase between fiscal years 2000–2001 and 2001–2002.

The 12.2 m (40 ft) buses are allocated to the routes carrying the largest percentage of passengers and are equipped with bike racks. Thus 14 of MTD’s most populated routes are also guaranteed to provide bike-bus service. The four routes most utilized by cyclists (accounting for 75 percent of bike rack usage) are popular because they travel long distances that may be unattainable by bicycle alone and have destinations that prove useful for bicycles, such as the local university (Lines 6, 11, 12, and 20).

- Line 6: Trunk service traveling along a main business corridor, about 17.7 km (11 mi)
- Lines 11 and 12: Express service to local university, about 12.9 km (8 mi)
- Line 20: Connector service between Carpinteria and Santa Barbara, about 24.1 km (15 mi)

MTD does not have plans to remove the bike racks from buses on lesser performing routes for operational reasons. As stated, 12.2 m (40 ft) buses are allocated to a specific group of routes depending on passenger volume and freeway travel. On any given day, a 12.2 m (40 ft) bus could be assigned to any of the 14 routes. The program is more easily marketed to passengers by ensuring that all 12.2 m (40 ft) buses have racks. Therefore, all routes served by 12.2 m (40 ft) buses are guaranteed the service. The routes are marketed as bike-bus routes via an icon in the bus book, at the bus stop and on the Web site.

Table 1 depicts the percentage of bicycles carried as compared to total ridership of the most utilized bicycle routes: 12, 11, 20, and 6. While the bike-bus program is successful, it does represent a very small percentage of bus passengers overall. MTD gives this serious consideration when reviewing any potential expansion of the bike-bus program.



The following two tables, based on the fully implemented bike-bus program, depict the monthly average of bicycles carried compared to monthly bus ridership, service hours and service miles. Although Lines 11 and 12 carry the most bicycles on average per month (see table 1), Line 13, while not carrying as many bicycles, is the most productive in terms of bicycles carried per hour (see table 2). Line 13 performs well in the bicycles per 100-mile category as well. In fact, 6.6 percent of its ridership is composed of bicycling passengers. It is important to note that both the 13 and the 26 are commuter services with just one morning trip and one afternoon trip daily, thus explaining the low number of bicycles carried overall.

Bike & Bus!



CONCLUSIONS AND RECOMMENDATIONS

With 30 years of experience, it seems that MTD has found a bike-bus pairing that works for passengers, MTD and the community. There are challenges that MTD continues to review, but for the moment, the program is successfully doing its part to help with multimodalism in the greater Santa Barbara community.

MTD's current Bike & Bus program continues to be a popular service with a regular ridership. The trend analysis confirms an increasingly steady usage of the racks among

Table 1. Comparison of Bicycles Carried to Ridership on an Average Month

Route	Avg Monthly Bicycles Carried	Avg Monthly Bus Ridership	Avg Monthly Bicycles Carried per 100 Passengers	% of Cycling Passengers to Non-Cycling Passengers
12	1,112	57,908	1.9	1.92%
11	1,088	80,636	1.3	1.35%
20	601	38,049	1.6	1.58%
6	555	46,138	1.2	1.20%
1	365	112,380	0.3	0.32%
23	250	29,813	0.8	0.84%
8	224	18,358	1.2	1.22%
15	177	12,678	1.4	1.40%
21	176	10,518	1.7	1.67%
13	22	334	6.6	6.59%
18	16	3,181	0.5	0.50%
26	2	408	0.5	0.49%
TOTAL	4,588	410,401	11	1.12%

Table 2. Comparison of Bicycles Carried to Service Hours/Miles on an Average Month

Route	Avg Monthly Passengers Carried per Hour	Avg Monthly Service Hours	Avg Monthly Bicycles Carried per Hour	Avg Monthly Service Miles	Avg Monthly Bicycles Carried per 100 Miles
13x	21.5	20	1.10	592	3.72
12x	53.8	1,203	0.92	27,958	3.98
11	46.8	1,877	0.58	26,014	4.18
6	47.0	1,066	0.52	12,811	4.33
20	37.1	1,192	0.50	20,152	2.98
15x	43.1	382	0.46	10,863	1.63
21x	24.2	433	0.41	8,465	2.08
8	24.1	640	0.35	13,600	1.65
23	42.0	873	0.29	11,291	2.21
1	63.2	1,868	0.20	15,792	2.31
18	27.6	110	0.15	1,890	0.85
26x	25.3	20	0.10	20,152	0.01
TOTAL	42.38	9,684	0.47	169,580	2.71

University of California at Santa Barbara routes as well as with the heavy working trunk and connector routes.

The expansion of the program to include all vehicles has provided for a much more marketable, more reliable program. Passengers are guaranteed bicycle racks on all routes with 12.2 m (40 ft) buses allocated to them, currently 14 lines. Passengers easily know which routes these are simply by looking for the Bike & Bus icon within printed materials and on MTD's Web site.

Bike & Bus is a successful program based on passenger benefit and administrative and safety standpoints. But the popularity of the program also is its drawback. Because each rack can only hold two bicycles, passengers sometimes wait to load their bike at a stop, only to find the approaching bus with a full rack. Proposed solutions include bringing back the trailers, installing rear-mounted racks in addition to the front-mounted racks, providing bicycle racks or lockers at bus stops and allowing bicycles on the bus. All of these solutions have drawbacks. Trailers are outdated now that large 12.2 m (40 ft) buses must maneuver increasingly busy and narrow streets. Rear-mounted racks have proven difficult to maintain with increased liabilities. Bike racks and lockers provide a new set of security issues, and with the high cost of bicycles, passengers are less inclined to leave their bikes at an unattended location such as a bus stop, where the risk of theft is great. Finally, allowing bicycles on board the bus seems unfair and unsafe for the 98 to 99 percent of bus passengers that do not use this service and who must maneuver around a bicycle in the aisle.

A recent technological innovation holds some promise. A popular bike rack manufacturer has developed a prototype of a rack that is capable of holding three bicycles. Concerns over the fully deployed rack extending further than the legal vehicle-length limit appear to be addressed. The manufacturer claims that this new rack does not extend any farther than the two-bicycle rack counterpart that MTD uses. While it may be too early to call, the prototype rack is being tested at a few transit properties in the western United States and has been successful thus far. It seems that another potential solution to carry at least one additional bike per bus is in the works.

It does not appear that all of the answers are available at this time on how best to administer and grow a successful bike-bus program that is beneficial to everyone. The Santa Barbara MTD has, however, shown that with perseverance, support and continued research, bicycles and buses can help extend people's travels while leaving their motor vehicles at home.

COSTS AND FUNDING

The capital costs of the front-mounted bike racks, as mentioned earlier, were covered by a grant from the local APCD. The rest of the program costs are covered by MTD. Initially there were marketing costs to advertise the new program, however all costs now are associated with the maintenance of the racks.

BREAKDOWN OF ANNUAL MAINTENANCE COSTS ASSOCIATED WITH BIKE & BUS PROGRAM

1. Annual parts replacement costs		
Support Arm Grips	\$11.50 x 2/mo x 12 mo	\$276
Bracket Bolts/ Bushings	\$17.00 x 2/mo x 12 mo	\$408
Decals	\$10.00 x 4/mo x 12 mo	\$480
Total		\$1,164

2. Annual preventative maintenance costs (safety inspections)		
Basic Labor	82.4 hr/year x \$35/hr	\$2,884

3. Annual bike rack repairs (straighten damaged bike racks)		
Basic Labor	120 hr/year x \$35/hr	\$4,200

4. Annual rack replacement costs		
There were 9 racks that were in need of replacement due to accidents.		
Cost of racks	\$376/rack x 9 racks	\$3,384
Labor	\$35/hr x 2 hr/rack x 9 racks	\$630
Total		\$4,014

5. Road calls		
In the event of a vehicle requiring towing (about 24 times per year) the front section of the rack must be removed to facilitate maneuverability, adding about five minutes per road call.		
Labor	5 minutes x 24 calls = 2 additional hours per year \$35/hr x 2 hrs	\$70

6. Annual increased bus washing costs		
Bus washing time is increased by 30 seconds per bus or 30 minutes per night because of the necessity of deploying each rack, soaping the front of the bus and stowing the rack before driving through the bus wash. This time is down from two minutes during the pilot program.		
Labor	30 minutes/night x 362 nights = 181 hours 181 hr x \$12/hr	\$2,172

Total annual operational costs:	
Parts Replacement	\$1,164
Preventative Maintenance	\$2,884
Bike Rack Repairs	\$4,200
Bike Rack Replacements	\$4,014
Road Calls	\$70
Bus Washing	\$2,172
Total	\$14,504
* Note that due to the large front window on Nova buses, the bicycle racks were obstructing the driver's view. MTD's maintenance department came up with a way to lower the racks. Therefore, when MTD procured the racks originally, a retrofitting took place to lower the racks at a cost of \$456 per rack (\$176 in parts and \$280 in labor).	

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Mapping for Bicyclists

BACKGROUND

One of the most common questions a bicyclist asks is, “Where can I ride my bike safely?” A good bicycle map will answer this question. Bicycle maps can provide information to guide novice cyclists to less-traveled routes, help an experienced cyclist get around unfamiliar parts of town, or identify suitable routes for touring cyclists. A bicycle map can be a tool to promote alternative transportation, improve cyclists’ safety, or provide a guide to recreational opportunities.

The North Carolina Department of Transportation Division of Bicycle and Pedestrian Transportation (DBPT) has a long history of developing bicycle maps. In mid-1975 the Bicycle Program, as it was then called, initiated a project to design and map a cross-state bicycle route. The map was in response to the Bicycle and Bikeway Act of 1974 that charged the NCDOT with the responsibility of developing a statewide “bikeway” system. The goal of this initial effort was to select and map a route that provided access to the major population centers of the state, linking them to state parks, historic sites, and other points of interest via the more lightly-traveled roads of the extensive secondary road system.

The NCDOT effort was pioneering a new arena. At that time, guidelines for selecting and designating bicycle routes did not exist. Only one other state had produced a bicycle map. Few North Carolina cyclists had long-distance touring experience or knowledge of roads outside their immediate area. No funds had been set aside for such a project. Fortunately, existing resources of the department could be tapped to undertake the tasks. Bicycle program staff, experienced in bicycle touring and mapping,

Mary Paul Meletioui, Program Manager for Planning and Safety, NC Department of Transportation
Division of Bicycle and Pedestrian Transportation



developed route selection criteria, designed and drew the maps, and utilized the DOT print shop to produce the maps (see Yates and Meletioui, 1978).

In the ensuing years, the “Bicycling Highways” system grew to nine discrete routes covering more than 4,023 km (2,500 mi) (See http://www.ncdot.org/transit/bicycle/maps/maps_highways.html). In the 1980s the Division began to produce county and regional bike route system maps as well as urban route and suitability maps. Funds for placing signs on both “Bicycling Highways” routes and local routes became available in 1987. Twenty-two local and regional maps are now available with three additional maps nearing completion. These maps detail approximately 2,000 mi of designated routes. Requests for 20 more maps are being handled as time permits.

COUNTERMEASURES

The 1,126 km (700 mi) Mountains to Sea Route was the first route to be mapped and was completed in June of 1976. A set of sixteen trip-tic maps, each covering 64.3 to 80.5 km (40 to 50 mi) of the route, was developed. The 0.2 m by 0.2 m (8 by 8.5) inch maps were designed to fit in the map pocket of a front handlebar bag when folded, providing easy access for cyclists while riding. All maps were hand-drawn and designed to provide information

of interest to cyclists. Narrative information accompanied each segment and included a general description as well as information on terrain, any hazardous areas, roadway conditions, available services, and points of interest. A separate listing of campgrounds with contact information was provided. The strip maps were packaged in a jacket that provided general information on bicycle touring in North Carolina, a description of the overall route, a guide to using the maps, basic weather information, and a list of resources for obtaining additional information.

As noted above, additional cross-state routes were developed from 1976 to 1985, creating a 4,023 km (2,500 mi) system of “Bicycling Highways.” In 1983, the DBPT completed the first county bicycle map, showing a 241 km (150 mi) system that connected towns and points of interest via low volume scenic roadways. Local cyclists were involved in developing the routes and providing input on map design. In 1987, federal funds became available to place signs along the routes. The 321 km (200 mi) north/south Carolina Connection, which had received American Association of State Highway and Transportation Officials (AASHTO) designation as U.S. Bike Route 1, was the first to receive signs.

In 1991, the DBPT worked with local cyclists, staff, and consultants to create the first two suitability maps. Unlike route selection maps, which recommend a “best route” between two points of interest, bicycle suitability maps provide information on a broader selection of roadways, with the goal of helping cyclists make good choices about where to ride based on their own level of cycling ability and traffic handling skills. Although suitability maps had been created for localities in other parts of the country,

the DBPT refined the process of data collection and application of suitability ratings to reflect conditions in each community. Each North Carolina community is unique, and whether producing a route map or a suitability map, the DBPT strives to reflect these unique characteristics and cycling opportunities.

Over the past 28 years, the route selection, mapping and signing activities of DBPT have continued in response to high local demand for such products. The annual allocation for map and sign projects is now \$200,000, set aside from Transportation Equity Act for the 21st Century (TEA-21) funds. Communities can request a project to develop a route or suitability map for their area through the biannual Transportation Improvement Program. Such requests are generated through local planning departments, parks and recreation departments, chambers of commerce, regional agencies, and advocacy groups. To receive funding authorization, requests must be endorsed and submitted to the NCDOT by a local governing agency such as a city council or county commission.

EVALUATION AND RESULTS

Evaluation of these projects is mostly subjective except for a survey of “Bicycling Highways” map users conducted in 1980. This survey was undertaken to collect demographic information on users and to poll their opinions on the safety and appeal of the routes and usefulness of the maps.

Verbal or written feedback is provided to DBPT staff periodically from requesting agencies noting local response to maps and perceived usage of routes. Individual cyclists, local cycling groups and bicycle shop personnel also provide feedback in the form of praise for the product or constructive suggestions for improvements or revisions to routes.

Although information on the effectiveness of map and sign projects is primarily anecdotal, it is clear that bicycle maps and signs increase bicycle usage and the visibility of bicycling. Following are some examples to support this statement.

- The DBPT distributes more than 25,000 bicycle maps annually and fields thousands of phone calls and e-mails requesting additional information on where to ride.
- An additional 25,000 to 35,000 maps are distributed locally each year by communities for which bicycle maps have been produced.



- The North Carolina ferry system's annual passenger/vehicle counts consistently show significant usage by bicyclists. Several mapped routes make use of this ferry system.
- Informal discussions with proprietors of bed and breakfast accommodations throughout the state show that many guests bring bicycles with them or arrive by bicycle.
- DBPT staff frequently field phone calls or e-mails from visitors to the state noting that they chose to come to North Carolina because of the bicycle mapping program because it provides an abundance of touring information.
- Cycle North Carolina, an annual cross-state event initiated in 1999, is a direct outgrowth of the state's emphasis on mapping for bicycles.
- Each year since 1980 the DBPT has produced a calendar of major bicycle events. The listing has grown from twenty events to more than 200. Many of the ride promoters use the mapped routes for their rides. Local bicycle clubs regularly use the mapped routes in their areas.

Other positive results involve roadway improvements along sections of designated bicycle routes. The route selection process often reveals barriers to bicycling such as bridges with inadequate width or low railings and roadways that need bicycle improvements such as bike lanes, wide curb lanes, or wide paved shoulders to provide a continuous safe corridor of travel. Over the years, by working through ongoing processes of the NCDOT, many significant improvements have been made to roads and bridges identified through these activities.

CONCLUSIONS AND RECOMMENDATIONS

Bicycle map and sign projects provide a low-cost way to improve the safety of cyclists by directing them to roads that are better for bicycling. Bicycle maps are also an excellent tool for promoting cycling. The appointment of a local committee of planning and engineering staff, interested elected officials, and citizens to guide the mapping project creates greater awareness of other bicycling needs and often leads to future planning efforts or facility improvement projects.

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Bicycling and Walking in North Carolina: a Long-Range Transportation Plan, NCDOT Division of Bicycle and Pedestrian Transportation, 1996.

"North Carolina's Bicycling Highways," Curtis B. Yates and Mary Paul Meletiou, Bicycle Program, North Carolina Department of Transportation, *Transportation Research Record* 683, 1978.

http://www.ncdot.org/transit/bicycle/maps/maps_intro.html

COSTS AND FUNDING

Costs of mapping projects vary greatly depending on the format, area covered, number of colors, size of finished product, number of copies printed and whether the work is done in-house or through the services of a consultant. Cost for the trip-tics (strip maps) for the original "Bicycling Highways" maps were minimal – just ink and paper. Recent updates include digitizing the information, undertaken by a consulting cartographer at an average cost of \$1,000 per segment for two-color artwork. The four-color map/brochures for county route systems, produced by outside cartographers and graphic designers, cost \$20,000 for production and about \$.50 for each printed copy. Urban maps produced by outside cartographers and graphic designers have ranged from \$30,000 to \$60,000 for production and \$.34 to \$.78 per copy for printing. These costs do not reflect staff time spent in administering the projects, developing routes, coordinating with local committees, preparing text, or reviewing and proofing the product throughout the production process.

CONTACT

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Commuter Coach: Commuter Bicyclist Recruiting

BACKGROUND

Traffic congestion and air quality are problematic in Fort Collins. With the population projected to increase by 43 percent within the next 20 years, it is imperative that our community make use of alternative sources of transportation and do so safely. Since most commuters live within 4.8 km to 11.2 km (3 to 7 mi) of their workplace, the bicycle is a very viable source of transportation for many. In addition, there may be improved “safety in numbers” in terms of the number of bicyclists that use the road and bicycle facilities. [See case study #54, references (page 346), for studies that document this phenomenon.] Our mild climate, relatively flat terrain, and about 402 km (250 mi) of bike lanes, trails and routes, make commuting by bike an easy option. Additionally, our annual Bike to Work Day research shows that people will commute by bike if given the opportunity and the right incentives.

The goal of Commuter Bicycle Coach was to recruit individuals to ride their bikes one day a week for five months instead of driving alone. In return, they would receive incentives upon reaching specific milestones. By encouraging riding for a period of time, our hope was to change people’s transportation habits.

COUNTERMEASURES

Commuter Bicycle Coach is an intensive bicycle commuter recruiting program that provides support, education and incentives to beginning and existing commuters. Developed and implemented in 2002, Commuter Coach presents cycling as a fun and easy way to commute to work. Bicycle commuting provides the freedom and individuality we enjoy, while easing traffic congestion and improving air quality.

Betsy Jacobsen, Bicycle & Pedestrian Marketing Specialist, City of Fort Collins SmartTrips™



By targeting selected companies that had previously participated in SmartTrips™ programs, we recruited a “Commuter Coach” within their organizations who would become the liaison between our office and theirs. They in turn would recruit individuals for the program as well as assist in tracking mileage and distributing incentives. We would provide the incentives, as well as support their recruitment efforts with graphic and educational materials on safety, clothing, routes (such as bike maps), etc. We also would be available for free presentations and clinics related to commuting.

Prospective coaches (about 30 company representatives who were Bike to Work Day Coordinators) were invited to an informational breakfast where the program was described and incentives were shown. Information also was shared among the group on the best practices of recruiting individuals within the workplace.

From that initial breakfast, we enlisted seven coaches of varying cycling experience. Some were regular commuters; others were infrequent riders. Their companies ranged in size from just a few employees to close to a hundred. Once the program started, word of mouth spread to other companies until we had a total of 15 coaches and 237 participants in the program. Budget limitations required that we stop taking participants at that point.

Our incentives included a cyclometer to provide mileage information, as well as other items that help make commuting safer and easier such as headlights, rear racks and tire pumps. (We learned that many beginning bicycle commuters don't have the equipment to make commuting safe and easy.) Additionally, we selected non-bike incentives that could be enjoyed by anyone, such as free movie passes, ice cream cones, restaurant certificates, etc.

We developed a simple electronic spreadsheet in Excel that the "Coach" posted on his or her company computer network so each participant could easily track the miles and days they rode each month. At the end of the month, the coach would then forward the spreadsheet to me, and I would distribute the milestone incentives.

EVALUATION AND RESULTS

Throughout the program we tracked both mileage and the number of days participants commuted by biking or by walking. This gave us basic information about the frequency and distance participants were commuting.

At the end of the program we distributed a follow-up survey to all Commuter Coaches and asked them to forward the surveys to their participants. Of the 237 enrolled in the program, we received 60 responses—a 25 percent response rate. The survey simply asked if they commuted by bike or walking more, less, or the same amount because of the program.

Our original expectation was to attain 100 bicycle participants the first year, including coaches. We exceeded that goal and achieved 237 participants, including 15 coaches from 15 organizations. Because of budget limitations (the cost of incentives), we stopped taking new participants and created a waiting list for 2003 (when our next budget was to be released).

In addition to bicycle commuters, we also had 15 pedestrian commuters. When the program began, several interested walkers asked to have a program developed for them, so under the same umbrella of Commuter Coach,

we implemented a walking component. Walkers were required to walk at least one day a week for five months and were given pedometers to track their mileage. They also were given different incentives.

Since June, the start of the program, we have tracked 46,414 miles and 6,238 days of commuting as of January 31, 2003. Unfortunately, the vacant position of Bicycle & Pedestrian Marketing Specialist, City of Fort Collins SmartTrips™ could not be filled, and the program was not continued.

Of the 237 participants in the program, more than half (127) finished the program; and another 50 completed at least half the program. Injury, cold weather and darkness were cited as reasons for not completing the program. Additionally, more than half of the participants completing the survey (38) stated the program motivated them to increase the amount they were commuting by biking or walking.

CONCLUSIONS AND RECOMMENDATIONS

Based on the number of participants enrolled in the program and the high number that completed it, this appears to be a successful program that at least introduces bicycle commuting as an alternative transportation choice. However, there certainly are aspects that need to be addressed:

While participants were asked to bike or walk one day a week, bike participation was also tied to distance, meaning that a biker could complete the program in 20 days or 322 km (200 mi). The latter goal caused some of them to do all their riding in a shorter amount of time instead of the anticipated five months. As we moved into 2003, we adjusted the incentive milestones so participants were required to log at least four days a month in order to receive their incentives, and we no longer tied incentives to distance.

Cold weather and lack of daylight were hindrances as we moved into the colder months. While 2002–2003 has still been one of the warmest and driest winters on record, people perceive it to be winter and therefore stop riding. We started the program earlier the second year (March instead of June) in hopes people would form their habit of riding as the weather warms instead of cools.

Clearly, in the companies where the Coaches were more involved (providing hands-on support, internal motivation, prompt distribution of incentives, etc.) the participants did much better. Because of that, we have been more

specific regarding the expectations we have of coaches. Additionally, we're working more closely with them at the onset of the program.

COSTS AND FUNDING:

While we were able to receive discounts on many of the incentives we purchased, the cost per participant is roughly \$100. That includes administration of the program as well as incentives. In 2002, funding was made available through the city. In 2003, it will be combined funding from both the City and Federal CMAQ (Congestion Mitigation and Air Quality) funds.

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Bike to Work Promotion

BACKGROUND

The Capitol Region Council of Governments (CRCOG) based in Hartford, CT, completed its Regional Bicycle Plan in April 2000 with the vision that by the Year 2010, residents and visitors to the region would be able to conveniently and safely bicycle wherever they need or want to go. The Plan included a variety of recommendations to reach this vision, including a mix of facilities, education, enforcement and encouragement. But there were two major findings during the study indicating that it would be unreasonable to expect meaningful implementation of the plan's recommendations:

- A staggering lack of understanding throughout the region that bicycles are to follow the vehicle code and do, in fact, belong on the road.
- A desire on the part of most of the region's towns to accommodate bicyclists, but strictly on separate, multi-use trails.

These issues are not extraordinary, but they do give some indication of where the Hartford, CT, region resides in the spectrum of becoming a bicycle-friendly community and the amount of basic education that needs to be done.

Shortly after the plan was adopted, the CRCOG staff decided to kick off the implementation of the Bike Plan with an all-out effort on National Bike to Work Day in May 2000. A committee was formed, activities and an event were planned for a park in downtown Hartford on the morning of Bike to Work day, gifts for cyclists were obtained and breakfast was ready. Unfortunately, Bike to Work Day 2000 was extremely rainy, and only 12 intrepid souls attended the event. The planning committee

Sandy Fry, Principal Transportation Planner, Capitol Region Council of Governments



felt the momentum created by the event needed to be maintained, and a decision was made to continue Bike to Work Day on the last Friday of each month throughout the summer.

From this start, the region embarked upon a regular Bike to Work promotion, with monthly events through the spring, summer and fall. The events have been designed to:

- Educate bicyclists and others that the bicycle is a sensible and beneficial means of transportation;
- Make basic information on bicycle commuting available to potential riders;
- Encourage people to try bicycle commuting; and
- Increase the general public's awareness of and respect for bicyclists.

COUNTERMEASURES

The Bike to Work program has grown since the first event in May 2000. In 2000 the events were low key and informal—one or two staff members set up a card table in a downtown park and served juice, coffee and donuts to bicycling commuters on the last Friday of the month. A new location was selected in the second year of operation, but the major change in the program was the addition of a raffle. In 2002, the location was changed to a more central downtown spot and the events were expanded to run from April to October. In May, eight towns in the region hosted their own events. The following sections describe the features of the program.

ORGANIZATIONAL STRUCTURE

The Bike to Work Planning Committee, now named Bike to Work—Capitol Region, is chaired by a staff member of the Capitol Region Council of Governments (the area's Metropolitan Planning Organization). Organizations represented on the Committee include state agencies (the Departments of Public Health, Environmental Protection, and Transportation) and advocacy groups (the Connecticut Bicycle Coalition, the Sierra Club, the American Lung Association and All Aboard!, a transit advocacy group.) The MPO provides overall administrative support with other agencies contributing time and funding as they are able.

PROGRAM FEATURES

Bike to Work has evolved to be a once-monthly activity running from April through October. Commuting cyclists are met at a central location where they are provided with free breakfast, a small gift and the opportunity to meet other cyclists. Cyclists fill out a form at the event which makes them eligible for a drawing held at the end of the year. Those commuters who work in locations other than downtown Hartford can still enter the raffle by submitting a raffle form for each event day that they bicycle to work. Other towns in the region are encouraged to sponsor their own events, and their participants are entered into the regional raffle.

PUBLIC/PRIVATE COOPERATION

To date, the events have been strictly low-budget. A small fundraising campaign, targeted at bicyclists, provides \$500 to \$1,000. Agencies on the Bike to Work Planning Committee have contributed to the effort in various ways. In 2002 the Department of Public Health provided funds from a cardiovascular health grant to cover the cost of producing and displaying Bike to Work signs on transit buses



(\$8,500). The Department of Environmental Protection covered the cost of printing and distributing a payroll insert announcing the Bike to Work program, which went to all state employees (at a cost of about \$500) in 2001 and 2002. Gifts for cyclists attending events are donated by bike shops.

In addition, the year-end raffle is for a bicycle that is provided by a manufacturer's representative at wholesale price. A bike shop fits the bike and builds it for the winner. The cost of the breakfasts is covered through donations (primarily from members of the planning committee) and some funding available through the Council of Governments. In 2002, one of the monthly events was sponsored by a large downtown employer, who provided the food and manpower required.

PROMOTIONAL EFFORTS

Promotion of Bike to Work has several aspects:

- Getting the word out
- Helping novices give it a try
- Encouraging bike commuting as a continuing habit

CRCOG maintains a Web site (<http://www.crcog.org/biketowork2005.htm>) that has monthly updates on the program. Each month press releases are distributed widely to create interest in the program, a payroll insert goes to all state employees (one insert each year) and brochures are distributed (including distribution to noontime crowds at a center city park). A large e-mail address list of those who have participated in Bike to Work or who have shown an interest in it is maintained, and they are sent e-mails monthly. The Committee also works with large employers, requesting that they send e-mails to their employees about the event each month. The placement of advertising signs on buses in 2002 significantly boosted the program's visibility.

To encourage those who have never tried bike commuting, a ride coordinator system has been developed. The coordinators are individuals who bike to work regularly and have volunteered to meet cyclists on their trip or to help them plan their commutes. They are listed on the Web site with contact information, trip origin and destination, and frequency.





To encourage bicyclists to continue biking to work, each month we select one individual as our area's Super Bike Commuter with recognition in the monthly press release, on our Web site, and at the monthly event. Selection is based upon dedication to commuting by bike and ability to inspire others to give it a try. This recognition has received significant press attention.

Other features of the program are designed to generate public interest. At each event, cyclists can select a gift (generally related to bike maintenance or safety) and enter a raffle. Monthly raffle prizes are awarded, and the year-end raffle includes a new, high-quality bike with an approximate retail value of \$900. In 2002, a T-shirt was given to the first 50 participants and then made available for sale.

In 2002 the Big Wheel award was created to recognize towns that exhibit a commitment to integrating safe bicycle travel on their roads. (This award was presented only once during the promotion, as only one town, Windsor, CT, exhibited progress warranting the award.)

SAFE CYCLING

Safe cycling has been a continuing theme of the events. A Share the Road brochure was developed for the initial event in May 2000 and has been available at all events. The brochure contains tips for both bicyclists and motorists on how to share the road safely. All cyclists are encouraged to take a copy of the brochure, and since the brochure is targeted to motorists also, passersby are encouraged to pick up a copy.

Cyclists are also given an opportunity to report any hazards they find on their commute. These are reported on a postcard designed for this purpose and returned to CRCOG. CRCOG then forwards the concern to the appropriate road department (state or town) for resolution. Some of the comment cards are returned with specific maintenance issues (debris on the road, potholes)



while others note longer-term issues, like the need for bike lanes or paths.

EVALUATION AND RESULTS

The success of Bike to Work events can be measured in a number of ways:

- How many people attended the events?
- Did the events encourage people to try bike commuting for the first time?

But most importantly for our events:

- Did the events raise community awareness of the role that bikes can play in the transportation system?
- Is there a greater understanding of the fact that bikes do belong on the roads?

A database was developed to measure attendance and characteristics of bike commuters. In the first year (2000), approximately 25 attended the Bike to Work events, but little was known about their commute trip. In 2001 and 2002, a raffle form was designed to provide information on each participant's bike commute and the database was created using this information.

Community awareness has been measured with a surrogate—how many news articles covered the event each year. A survey of the public would provide a more accurate understanding of changes in public perception and

attitudes, but presence of news articles indicates that the information is going out to the public, and that opinion-makers such as the media view the topic as important.

An analysis of the database indicates that the program is having some impact in convincing individuals to try bike commuting. In 2001, 15 percent of the participants were trying bike commuting for the first time (see table). In 2002, the number dropped to just over 10 percent. The diminishing numbers of new bike commuters is somewhat expected. Those who first try biking to work tend to have schedules, work locations and skills most amenable to biking to work. Once the “low-hanging fruit” joins in the program, a greater effort is needed to encourage those who may have more difficult schedules or whose work locations lack suitable facilities to try biking to work. In addition, to continue to attract new commuters, the region’s roads need to feel safe to bicyclists with a wide variety of skill levels. At this point, the Bike to Work program has not been accompanied by widespread introduction of new bike facilities (e.g. bike lanes, parking racks, showers, lockers.)

Record of Participation in Bike to Work Events

	2000	2001	2002
Number of individuals participating throughout promotion	25	201	236
Highest attendance at a single event	20	95	153
Number of first timers (biked to work for the first time on the day of an event)	NA	30	25
Percent of participants who were first timers	NA	15%	11%
Annual bicycle commute miles reported by participants	NA	204,000	225,000
Notes NA = not available 2002 peak attendance includes attendees at one downtown event and 8 regional events.			

Follow-up work is required to determine whether those who tried biking to work as a result of our program have continued to bike to work and if so, how often.

The evaluation has indicated that the program is having some impact in convincing people to try bike commuting, but the numbers are still very small. Feedback from

cyclists and those who have considered biking to work, but have not, indicates that new commuters are discouraged by the lack of bicycle facilities (there are no trails or bike lanes leading into downtown Hartford) and that many of them lack the confidence needed to ride in traffic. The ride coordinator program is designed to help build confidence for novices, but it is not being fully utilized. To date no one has ridden with any of the ride coordinators, but they have been contacted for information regarding preferred routes. In the future the Committee will work to strengthen this program, adding coordinators and improving publicity.

The hazard-spotting program is an effort to improve conditions for bikers, but implementation is still difficult. Some maintenance departments take the complaints seriously and respond immediately. Others are less prompt. The challenge to the Bike to Work Committee is to get the commitment of all the towns and the state to respond promptly to concerns. Other successful bike hazard-spotting programs in the country have been developed from the top down and there is a management directive to implement the program. In this case, the implementation is from the users, and this bottom-up approach will require time before it is fully institutionalized.

The region has not seen a sudden increase in development of bike facilities as a result of the Bike to Work promotion, but there have been some positive signs. The town manager of Windsor, CT, has directed his Public Works Department to examine every street scheduled to be repaved to determine if bike lanes can be designated on the street. The city of Hartford has undertaken a major citywide traffic calming project, and bike lanes are being considered on several major arterials. The town of East Hartford has been working diligently to get funding in place for a piece of bike trail that will link the eastern suburbs with downtown Hartford.

Media coverage has increased each year, and the tone of articles has changed from a focus on trails and paths to a greater emphasis on bicycling as a means of transportation. This indicates a significant change in attitude about the role of biking in the transportation system, at least among the opinion makers of the region.

It does appear that the program has been successful in raising the profile of bicycling as a legitimate part of the transportation system, as evidenced in the increase in media coverage. In addition, the mere presence of a number of bicycle commuters one day each month reinforces the idea that bikes do belong on the street. It

is unclear if the message that bicycles should follow the vehicle code has been conveyed. There is no evidence to indicate that more bicyclists and motorists are properly sharing the road.

CONCLUSIONS AND RECOMMENDATIONS

The Bike to Work promotion has played a role in raising the profile of cycling as a means of transportation in the Hartford region, and it appears that it can play a role in reinforcing the idea that bicycles follow the vehicle code. The program will continue next year with an emphasis on providing support to those who are considering biking to work but are hesitant. This will include expanding the ride coordinator program and providing tips and demonstrations for bike commuters, such as how to dress, how to make a safety check of your bike and how to repair a flat. Further outreach to employers to encourage them to support bike commuting will be undertaken. In addition, more information will be collected from cyclists to better understand how effective the program is and to learn more about the impediments to biking to work.

With the Big Wheel award, the program will continue to recognize towns, to encourage them to consider bike needs on their roadway system. This will dovetail with the MPO's adoption and implementation of the U.S. DOT Policy on Integrating Bicycling and Walking into the Transportation Infrastructure. Also, it is hoped that many of the region's towns will agree to sponsor at least one Bike to Work event next year. Continued dissemination of "Share the Road" information will be an important part of the continuing program.

We consider our program a success in meeting our goals, and expect that by continuing the program we will continue to see benefits. Our advice to others contemplating a similar program is to start simply, add to the program over time and share the responsibilities with partner organizations.

COSTS AND FUNDING

Event	
Food (7 events at \$60 each)	\$420
Publicity	
Banner: 2' X10' (reused year to year)	120
Banner: 3' X 20' (reused year to year)	360
Brochure printing	500
Payroll Insert	500
Signs on Buses	8,550
Gifts/Prizes	
T-shirts (250)	1,530
Bicycle to raffle	500
Total	\$12,480

Notes:

- For several of the events, the food was actually donated by the host.
- The brochure cost covers the cost of printing the Bike to Work brochure.
- The Share the Road brochure printing cost (\$2,200) was covered under another program.
- The cost of the payroll insert was donated by the CT Department of Environmental Protection.
- The cost of the signs on buses was covered by the CT Department of Public Health.
- 85 shirts were given away, the rest were available for sale at \$14.
- The bicycle is provided to the project at close to the manufacturers cost so we pay \$500 for a \$900 to \$1,000 retail value bike.

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Free Cycles Program

BACKGROUND

Free Cycles Missoula was formed in 1996 as a non-profit to address the following issues:

- projections of future increased congestion and air pollution
- lack of community access to affordable bicycles
- broken bicycles being thrown away

Before Free Cycles Missoula began operations, roughly 500 bicycles a year were going to the local recycling center and landfill. These “throw-away” bikes presented an opportunity to increase access to bicycles by all citizens, especially low-income individuals. The act of giving away bicycles also provided increased opportunities to distribute safety information to individual citizens and to the community at large.

The decision to start the project by providing ‘free-roaming’ green bikes was based on the perception that people would gladly donate unused bikes and broken bikes to an organization that would get the bikes back to the community in working order. Another factor to start the project was the knowledge that many short motor vehicle trips could be replaced by bicycle trips (40 percent of local motor vehicle trips are less than two miles) if convenient alternatives existed.

While community awareness existed about these issues, overall there seemed to be a general sense of frustration that motorized traffic was increasing unabated and that cycling conditions were deteriorating. A just-completed Long Range Plan for Missoula County (population



An umbrella advocacy organization helps monitor and advocate for bike facility.

90,000) earmarked several roads to be reconstructed with additional lanes for motorized vehicles as a way to relieve congestion. Yet, it seemed that bicycling was being overlooked as a legitimate mode of transportation that could be planned for and encouraged. No bike lanes existed at the time, which often forced an awkward and dangerous sharing of road space on arterial roadways.

One justification for not spending more resources on bicycle infrastructure was that cycling made up a small portion of the local mode share. To the founders of Free Cycles this seemed to be a “catch-22” situation: without safe facilities bicycling might not grow, but without bicycling growth, the safe facilities may not be supported by decision-makers.

GOALS OF THE PROJECT

At the start of the project, a primary goal of Free Cycles Missoula was “to obtain old, unused bicycles, give them a paint job, fenders, reflectors, and a wire basket, and place them in public places around Missoula” (MIST Web site, 2005). Community involvement in building and main-

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Program Director, Free Cycles Missoula

taining the bikes was also an important goal. By making rebuilt bicycles widely available throughout the city (the bike is ridden, and then parked at any public rack) it was thought that the sheer numbers of bicyclists and bicycle trips would increase.

Longer term, a goal of the project was to embark on a process that would eventually lead to elevated community awareness about, and utilization of, bicycling as a legitimate mode of transportation. By creating a better cycling atmosphere in the city, more facilities and thus more cyclists would eventually exist. Overall, the project aimed to initiate a positive feedback loop that would release and create the latent demand for bicycling.

Several research studies indicate that safety for bicycling increases when more bicyclists are on the street. One paper found an inverse relationship between the number bicyclists on the street and the number of crashes involving bicyclists being hit by motor vehicles (Jacobsen, 2003). Another study similarly found that the risk of a cyclist incurring a severe injury is decreased when numbers of bicyclists increase (Robinson, 2005).

COUNTERMEASURES

In the spring of 1996, 50 green bikes were released to the community. At the end of the riding season, twenty-five had “survived.” While this survival rate peaked at 83 percent in 1999 (MIST Web site, 2005), it became apparent from the middle of the first year of the project that a multi-faceted approach with a variety of community cycling programs would be needed in order to meet the project goals and objectives.

This multi-faceted approach had already been conceived in the Green Bike Proposal that had circulated throughout the city prior to the initial green bike release in April, 1996. This approach reads:

Free Cycles Missoula will be responsible for continually bringing in additional bikes, maintaining the ones in use, conducting seminars on education and safety, working with the city in improving bicycle corridors, and monitoring the success of the program (MIST Web site, 2005).

Years two and three of the project (1997–98) saw an evolution to four more programs:

- the expansion of the green bike release day into a full Festival of Cycles focused on community building and bike building,

- the creation of a second generation of public bicycles (a lending library called Checkout Missoula),
- the spread of an outreach and education program called Pedal Education,
- and the transformation of the green bike repair shop into a formalized gathering place called the Community Bike Shop.

In 2000, in order to address research, design and advocacy for better bicycle systems and, more generally, better transportation systems, an umbrella group, the Missoula Institute for Sustainable Transportation (MIST) was formed. And finally, 2003 saw a 6th program added to Free Cycles—Pedal Technology. The aim of Pedal Technology is to extend the reach of what the bicycle is capable of being used for (i.e. load carrying, protecting the rider from the weather, improving efficiency) and increasing the availability of existing bicycle attachments (i.e. trailers and racks) to more people through inexpensive fabrication (utilizing a stock of 1,000 recovered bikes for parts).

EVALUATION AND RESULTS

One of the outcomes of this project has been the successful recovery of over 5,000 broken and unused bicycles from the community and region. 2,500 of these bicycles



The bike lane was originally striped too narrow and then fixed a few days later. The new line to the left makes for a proper bike lane. The old lane was only 30 in wide, forcing cyclists too close to the gutter pan seam. The city engineer originally wanted to wait a year until the paint wore off to correct the problem but, under direction from city council, fixed the problem within days. MIST was effective at advocating for bicyclist safety.

have been given away to those in need. The recipient of the free bike learns the skills to fix the bicycle at the community shop and learns the skills to ride the bicycle safely either at the shop or at a variety of workshops taught throughout the community. In addition, over 10,000 individuals have interacted with the community bicycle shop in the form of getting information, getting parts, or using tools. Efforts are made by shop personnel and volunteers to ensure that some element of safety is expressed to these shop participants. These efforts take the shape of:

- pointing out safe routes in the community with maps and guides
- encouraging safe riding skills through hands-on demonstrations or through brochures
- ensuring safe mechanical functioning of the bike through one-on-one classes and group discussions

Other outcomes of the project include a successful Festival of Cycles that has run continuously for eight years with average attendance of 1,000 people, approximately 1,000 bicycle checkouts from the bike library (Checkout Missoula program), and several successful bicycle facility improvement projects run by the umbrella organization, MIST. One particular project by MIST improved a bike lane that had been inadvertently narrowed to under three feet by the city of Missoula. The bike lane was restriped at a more proper five foot width within one week of the mistake due solely to the engagement of MIST with the Missoula City Council.

Finally, the original project goal of increasing bike trips by providing free green bikes to citizens was successful in that over 10,000 trips are estimated to have been taken by this method of transportation (primarily in the years 1996–2000). It is unknown how many of these trips replaced an auto trip, a walk trip, or another bike trip. However, there has also been substantial positive feedback from citizens on the effectiveness of the green bikes with respect to 1) providing a fun alternative to driving and 2) spawning a whole range of bicycle and transportation programs aimed at getting more people bicycling as a form of transportation. Further research would need to be conducted to obtain more detailed numbers on the overall effect of all Free Cycles and MIST programs on mode share and bicycle safety.

CONCLUSIONS AND RECOMMENDATIONS

In hindsight, starting with a very simple, highly-visible community-based program with the willingness and inten-

tion to change, grow, and expand, has proved very effective. Recommendations for other communities include:

- Begin a community bicycling program with a community shop. This entails finding space (1000 to 3000 square feet), a coordinator (volunteer or paid) and the support of other local cycling organizations.
- Give away free bicycles, sell some bicycles to cover some expenses, and retain a small fleet for loaning bikes out.
- Get involved in the design and advocacy for better facilities (bike lanes on all arterials, connected multi-use trails, and regaining or maintaining calm neighborhood streets).
- If starting a public bicycle system, compliment a 'free-roaming' program with a 'checkout' program.
- Emphasize safe riding, safe facilities, and safely-tuned bikes in all programs.

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COSTS AND FUNDING

Free Cycles started with \$2,500 in local business donations. The budget has grown approximately \$1,000 a year, mainly through fundraisers, bike sales, fees for services (workshops and classes), and local private donations.

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Bicycle Destination Signing System

BACKGROUND

The city of San Diego began developing a systematic network of bikeway destination signs during the late 1980s. This network went beyond the guidance provided by the *Manual of Uniform Traffic Control Devices* (MUTCD) and the American Association of State Highway and Transportation Officials (AASHTO) section on bikeway design. Using the principles of the California Department of Transportation's Traffic Manual, selected bikeway corridors received consistent and comprehensive destination signs.

Freeways and other major highways define much of the roadway transportation network in San Diego that link neighborhoods and major activity centers within the city and its adjacent neighbors. Many of San Diego's bikeways parallel freeways. In addition numerous arterial, collector and local streets and shared use paths are designated bikeways. Collectively they form a bicycle transportation network.

Disparate roadway and trail segments are used by bicyclists to travel within San Diego. The bikeway destination sign system was established to alert current and potential bicyclists of communities and major activities with bikeway signs that would not necessarily be evident. For example, a resident of the San Diego community of Pacific Beach wishing to travel to downtown San Diego might drive there using Grand Avenue, Interstate 5 and Front Street. If that person wished to cycle to downtown it may not be so evident that they could get there via Grand Avenue, East Mission Bay Drive, and Pacific Highway. Destination bikeway signs make finding the way via bicycle much

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Kathy Keehan, Executive Director, San Diego County Bicycle Coalition.



easier and safer. Anecdotal reports have shown that visitors and residents alike find the destination signs helpful in their cycling travels.

COUNTERMEASURES

Generally at least two different destinations were posted on a sign (one line per destination) as the thinner, one-line signs were more susceptible to being bent. Bikeway destination signs were green with white lettering. The signs are 24 inches wide to match the width of standard 18 x 24 inch BIKE ROUTE signs. Sign height varied according to the amount of information provided. Arrows accompanied each destination line. Arrows indicating straight ahead and left turn destinations were placed to the left of the destination name and destinations requiring right turns had arrows placed on the right side of the destination line.

Destination signs are always accompanied by a BIKE ROUTE or BIKE LANE sign. Destination signs are always placed beneath BIKE ROUTE signs on the premise that people read from left to right and from top to bottom. The "control city" concept was utilized to alert bicyclists to the ultimate destination of a bikeway. For example

northbound travelers on Interstate 5 leaving downtown San Diego are alerted they are going toward Los Angeles. Los Angeles serves as the “control city” and orients travelers to their general direction of travel. Intermediate exits are listed on those freeway guide signs as well to provide supplemental information about the immediate surroundings.

In the case of the bikeway destination signs a major activity center, community or an adjacent city served as the control city and intermediate neighborhoods or major activity centers were also listed. For example a bikeway in South Bay lists Tijuana, Mexico as the “control city” and San Ysidro as the intermediate destination. Another example is the destination signs facing northbound traffic on Pacific Highway out of downtown. Pacific Beach would serve as the “control city” and Mission Bay Park as the intermediate destination.

EVALUATION AND RESULTS

Bikeway destination signing was set up to address the following issues:

- Inform existing bicyclists of how to safely reach major points of interest in San Diego.
- Encourage more bicycle trips by informing would-be bicyclists of destinations that can be reached by bicycle from various locations.
- Provide additional meaningful information to BIKE ROUTE signs.
- Inform all roadway users that the city of San Diego recognizes the legitimacy of bicycling by providing guidance signing.



A small-scale survey of bicyclists in the San Diego area did not elicit sufficient responses to consider them being representative of the collective viewpoints of San Diego’s bicycling community. The majority of responses were, however, generally supportive of the signs. The primary benefits appear to be that the signs confirm direction when one is already on a trip; the signs alerted some bicyclists of potential destinations or routes that are accessible by bicycle that they hadn’t thought of; and some bicyclists felt that the signs could at least alert motorists that bicyclists are legitimate road users, although others felt that motorists might not notice the signs. A few bicyclists also felt that the signs could help to encourage new bicyclists to try a bicycle trip, if the system was well documented.

CONCLUSIONS AND RECOMMENDATIONS

Bikeways destination signing, while not replacing bike route maps and other resources to assist in trip planning, can provide on-the-road assurance of direction (or distance, if provided), if located on routes likely to be used by bicyclists. Bicyclists should therefore be engaged in the process of choosing preferred routes to sign. The signs may help to alert bicyclists to other potential destinations, and alert motorists that bicyclists are expected users of the roadways, which may contribute to a safer bicycling environment as well as a more supportive one. The sign concepts (such as “control city”) and signed routes should be publicized and explained in other publications (such as bike maps) to help bicyclists understand the information provided in the signs.

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Urban Forestry

BACKGROUND

The mission of Seattle's Urban Forestry Program is to administer, maintain, protect and expand the city's urban landscape in street rights-of-way for Seattle's residents and businesses so that environmental, aesthetic, and safety benefits are maximized. Most of Seattle's trees are less than 30 years old and more than 50,000 new trees have been planted in the past 10 years through various city programs. The Urban Forestry Program is part of the city's effort to create a better bicycling and walking environment, to provide a buffer between vehicular and pedestrian traffic, thereby improving comfort and safety, to discourage vehicular parking on planting strips, and to improve air and water quality. When combined with other treatments, street trees also contribute to speed management on residential and arterial streets, creating a better bicycling and walking environment. The posted speeds of most arterial streets in Seattle are 30 or 35 miles per hour.

COUNTERMEASURE

New trees get planted in a variety of ways. They are routinely included in roadway reconstruction projects and sidewalk projects, and are required as part of the development or redevelopment of property. Trees are installed as part of neighborhood tree planting projects, planted by individuals, and the Urban Forestry Program has some funds to plant trees on targeted arterials.

The success of the Urban Forestry Program can be attributed to the successful partnership between the city and



the citizens of Seattle, to maintain, protect and expand the trees in Seattle's street rights-of-way.

STEWARD PROGRAM

Seattle's Steward Program trains residents to help care for street trees. Classes on tree maintenance and planting are provided. Residents are trained to take inventory of the trees, to seek planting opportunities in their neighborhood and to organize neighborhood tree-planting projects.

HERITAGE TREE PROGRAM

Since 1996, Seattle has listed 20 trees with the Heritage Tree program. Heritage trees may be on either City or private property and must have the owner's approval. Trees can be recognized for their size, age, historic association with a place or event, or be a community landmark. Each tree is identified by a plaque and is part of a Heritage tree tour.

CITYWIDE TRAFFIC CIRCLE GARDEN CONTEST

The landscaping on Seattle's traffic circles is maintained by nearby residents. Every year, there is a citywide contest to determine the best-maintained traffic circles. Up to 10 awards are given each year, often with good media coverage.

Shane DeWald, Landscape Architect
Liz Ellis, Program Manager
Peter Lagerwey, Pedestrian and Bicycle Program



Certain tree species are not recommended or are even prohibited due to fruiting characteristics, brittle wood or root growth traits.

More information, including tree selection and planting guidelines, is available at the Seattle Urban Forestry Web site at <http://www.seattle.gov/transportation/treeplanting.htm>.

EVALUATION AND RESULTS

The Urban Forestry Program is evaluated by the health and survival rate of trees, the level of public involvement by the Steward and other programs and the number of new trees planted.

The Urban Forestry Program is a success by all measures. The city has been recognized by the national Arbor Day Foundation as a Tree City USA for 16 years and as a Tree Growth City for nine. Public involvement has been and



Landscape guidelines, such as set back and pruning requirements, help maintain visibility and a safe multi-modal environment while the trees contribute to a healthier, more aesthetically pleasing environment.

continues to be high and over 50,000 new trees have been planted in the last 10 years.

CONCLUSIONS AND RECOMMENDATIONS

After years of focused efforts to maintain, protect and expand the city's urban landscape in street rights-of-way, the program has been successful in making Seattle a more livable, walkable, and bikeable community. The results include improvements in aesthetics, safety and air quality that benefit all road users. Additionally, Seattle residents enthusiastically support the program through their volunteer efforts.

COSTS AND FUNDING

Multiple funding sources acquired through "piggybacking" on other projects and volunteer contributions.

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Raising Funds for Bicycle Safety Programs through Specialty License Plates

BACKGROUND

Florida has one of the highest bicycle injury and fatality rates in the nation. To help reduce the number of bicycle crashes, an ongoing dedicated funding source was needed to help make Florida a safer place to cycle. There had been a variety of short-term state and federal grants and appropriations, but securing sustained financial support was imperative to support quality bicycle safety programs.

Florida is one of the many states that offer motorists an opportunity to purchase a specialty license plate instead of the standard state license plates for their motor vehicle. Each specialty plate in Florida serves as a funding mechanism for a nonprofit organization in the state. The specialty plates cost the consumer an additional fee that is collected by the Department of Highway Safety and Motor Vehicles. The fees are collected every year that the individual possesses the specialty plate and forwarded to the nonprofit organization that sponsors the plate.

Each state has different laws and procedures regarding the specialty license plates and some states do not have any specialty plates for their citizens. Contact your Department of Highway Safety and Motor Vehicles for more information on specialty license plates in your state (see appendix A for information on Florida's statute).

Florida's requirement began with an official application to the Division of Motor Vehicles requesting the establishment of a new specialty license plate. Next, a survey sample of 15,000 registered vehicle owners or registrants stating their intention to purchase the proposed specialty license plate was completed. An application fee of \$60,000 was then submitted to defray the department's cost to review the application and develop the specialty



license plate. The last step in the application process was to submit a marketing strategy outlining short-term and long-term marketing plans for the proposed specialty license plate (see appendix B).

Once the application requirements have been met, Florida law requires that legislation be submitted to the House and Senate Transportation Committees. The proposed legislation would detail the cost of the proposed plates, the purpose in creating the proposed plate and how the funds would be spent (see appendix C).

Upon approval by the legislature, the organization must submit the proposed art design for the specialty license plate. Completion of the design, development, production and distribution of each new specialty license plate shall occur within one year after the legislature's approval of the plate (see appendix D).

COUNTERMEASURES

The process in Florida to create the "Share the Road" specialty license plates began in 1997. A few bicycle advocates were determined to create a new specialty tag in Florida to bring attention to the safe sharing of the Florida roadways following the tragic death of Margaret Raynal. Raynal and a colleague were killed in 1996 while cycling on a rural road in north Florida. Margaret was an avid cyclist and advocate who worked at the Florida

T.J. Juskiewicz, Executive Director of Bike Florida and the Share the Road Campaign, Florida

Bicycle and Traffic Safety Education Program at the University of Florida in Gainesville.

Linda Crider and Jimmy Carnes of Gainesville and Henry Lawrence of Panama City were some of the key individuals involved in the creation of the project. They enlisted the support of the Florida Governor's Council on Physical Fitness and Sports to collect signatures and raise the funds required to create the "Share the Road" specialty license plate. Various bicycle clubs and advocacy groups throughout the state also pitched in by collecting the needed signatures. After two years the required signatures were gathered and the funds were in place to proceed.

The "Share the Road" license plate legislation in Florida was filed and sponsored by Representative Bob Casey (House Bill 601, 1999 Legislative Session) from Gainesville and Senator Donald Sullivan (Senate Bill 280, 1999 Legislative Session) from St. Petersburg. During the 1999 legislative session, both the House (113 to 4) and Senate (38 to 1) approved the "Share the Road" license plate. On June 8, 1999, the governor signed the "Share the Road" specialty license plate bill into law (see appendix E).

During the 1999 legislative session, Senate Bill 1566, Chapter 99-251 provided for the Florida Sports Foundation to absorb many duties currently assigned to the Governor's Council on Physical Fitness and Amateur Sports.

The bill originally distributed the annual user fees of the license plates to the Governor's Council on Physical Fitness and Amateur Sports. A portion was to be used for marketing and promotion of the "Share the Road" concept and license plate. The remaining funds were to be divided equally between Bike Florida, Inc. and the Florida Bicycle Association, Inc. Bike Florida and Florida Bicycle Association, both non-profit organizations founded to promote safe bicycling, had mutually agreed, before passage of the bill, that Bike Florida would administer the marketing and promotion of the specialty license plate and after expenses, split the proceeds. Representative Casey filed a bill to distribute funds directly from the "Share the Road" specialty tags to Bike Florida, Inc., instead of the Governor's Council on Physical Fitness and Sports. After several changes, House Bill 571 and Senate Bill 768 were presented and passed. In July, the Governor signed the bill making it law.

EVALUATION AND RESULTS

Florida's Department of Highway Safety and Motor Vehicles (DHSMV) is the main entity with which Bike

Florida works regarding the "Share the Road" license plates. The DHSMV receives updates on tags sold and funds collected from county tax collectors and tags sold directly through the state office. The DHSMV transfers funds collected through these agencies and mails a paper check to the Bike Florida office. The DHSMV also sends a monthly report of tag funds collected by each county and the state office. The funds typically are distributed by the DHSMV many months after they are collected.

Once Bike Florida receives the funds from DHSMV, Bike Florida calculates 25 percent of each check and deposits that amount into the Share the Road Promotion Account. The remainder is split equally between Bike Florida and the Florida Bicycle Association. The funds are distributed to the Florida Bicycle Association on a quarterly basis.

In 2000, the "Share the Road" specialty license plates generated \$37,245 in revenue. In 2001, \$75,511 was generated. It is projected that well over \$100,000 in revenue will be produced in 2002.

CONCLUSIONS AND RECOMMENDATIONS

The "Share the Road" license plates project has exceeded expectations to date. The goal was to secure an on-going funding mechanism to promote bicycle safety in Florida, which was accomplished. The revenues generated should eclipse the \$100,000 mark for years to come, which will be extremely beneficial to bicycle safety programs throughout Florida.

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APPENDIX A

FLORIDA LAW

Section 320.08053, Florida Statutes outlines the requirements an organization must meet to request that a new specialty license plate be created. Section 320.08056, Florida Statutes provides the responsibilities of the Department of Highway Safety and Motor Vehicles in developing and issuing specialty license plates when legislation authorizes a new specialty license plate to be established.

APPENDIX B

APPLICATION REQUIREMENTS

Initial contact must be made with the Division of Motor Vehicles before an organization can begin the process.

Legislation must be enacted to establish a new specialty license plate design. Proposals for specialty license plates may be considered by the legislature only upon compliance with the following conditions and requirements. An organization that seeks to establish a new specialty license plate, for which an annual use fee is to be charged, must submit to the department:

- 1) A letter of request for the specialty license plate describing the proposed specialty license plate in general terms. The letter must include the purpose for creating the specialty license plate.
- 2) The results of a scientific sample survey of 15,000 or more registered vehicle owners or registrants who state their intent to purchase the proposed specialty license plate. The sample survey must be performed independently of the requestor and be conducted by a organization that does sample surveys as a normal course of business. Additional prerequisites regarding the survey and its content are outlined.
- 3) An application fee of \$60,000, payable to the Division of Motor Vehicles, to defray the department's cost for reviewing the application and developing the specialty license plate. If the specialty license plate requested by the organization is not approved by the legislature, the application fee shall be refunded to the requesting organization.
- 4) A marketing strategy outlining short-term and long-term marketing plans for the proposed specialty license plate. The marketing strategy also must include a financial analysis outlining the anticipated revenues and the planned expenditures of the revenues to be derived from the sale of the proposed specialty license plates.

APPENDIX C

LEGISLATIVE PROCESS

When a proposal has been submitted, the department will notify the House and Senate about whether the application requirements have been met. When the proposed legislation is submitted to the House and Senate Transportation Committees, a copy will be provided to the applicant of the proposed plate. The proposed legislation will be generic to be consistent with all other existing specialty license plates and will:

- 1) Require that the plate be developed, manufactured and distributed within one year.
- 2) Provide for the specialty license plate to be issued to the owner or lessee of any motor vehicle, except for a vehicle registered under the International Registration Plan, a commercial truck required to display two license plates or a truck tractor.
- 3) Specify the amount of the annual use fee for the use and distribution of the fee.
- 4) Describe the basic design specifications of the plate and provide for the plate to be personalized.
- 5) Provide for this department to annually retain, from the first proceeds derived from the annual use fees collected, an amount sufficient to defray the department's costs directly related to issuing the specialty plate.
- 6) Specify audit requirements.
- 7) Provide for de-authorization and discontinuation of the specialty license plate if the license plate does not meet statutory requirements.

APPENDIX D

DESIGN, DEVELOPMENT, MANUFACTURE & DISTRIBUTION

When the new specialty license plate is approved by the legislature, the organization must submit the proposed art design for the specialty license plate to the department within 60 days.

The Division of Motor Vehicles is responsible for coordinating the design and development of the specialty license plate. Completion of the design, development, production and distribution of each new specialty license plate shall occur within one year after the legislature's approval of the specialty license plate.

Specialty license plates must bear the design required by law for the appropriate specialty license plate and the design and colors must be approved by the department. In addition, the produced specialty license plates may bear the imprint of numerals from 1 to 999, inclusive, capital letters “A” through “Z” or a combination thereof. The department shall determine the maximum number of characters including both numbers and letters. All specialty license plates must be of the same material and size as standard license plates.

The organization that requested the specialty license plate may not redesign the specialty license plate before the end of the fifth year, unless the inventory of those plates has been depleted. However, the organization may purchase the remaining inventory of the specialty license plates from the department at cost.

DE-AUTHORIZATION & DISCONTINUATION

The department must discontinue the issuance of an approved specialty license plate if:

- 1) Less than 8,000 plates are issued by the end of the fifth year of sales or any subsequent five-year period.
- 2) The plate’s recipient organization no longer exists, has stopped providing authorized services or has requested discontinuation.

DESIGN SPECIFICATIONS

In addition to the plate design requirements previously mentioned, the following specifications would apply to the design based upon its location on the actual license plate.

CENTER DESIGN

- 1) The plate size must be 30.5 cm by 15.2 cm (12 in by 6 in).
- 2) The center graphic must be no larger than 6.4 cm by 7.6 cm (2.5 in by 3 in).
- 3) The background must be limited to three colors.
- 4) If the lettering of “Florida” which is placed at the bottom or top depending upon the design of the license plate, is to be embossed, it must be the same color as the license plate characters. In addition, a specialty license plate may bear an appropriate slogan.
- 5) The license plate number must have three characters to the left and three to the right of the centered graphic design. The range of license plate numbers assigned will consist of three alpha followed by three numeric or three numeric followed by three alpha characters.

LEFT SIDE DESIGN

- 1) The plate size must be 30.5 cm by 15.2 cm (12 in by 6 in).
- 2) The graphic must be on the left side of the license plate and be no larger than 7.6 cm (3 in) in diameter.
- 3) The background must be limited to three colors.
- 4) If the lettering of “Florida” which is placed at the bottom or top depending upon the design of the license plate is to be embossed, it must be the same color as the license plate characters. In addition, a specialty license plate may bear an appropriate slogan.
- 5) The license plate number is limited to five digits with one alpha character and four numeric characters.

APPENDIX E

2001 FLORIDA STATUTES

Title XXIII – Motor Vehicles

Chapter 320 – Motor Vehicle Licenses

Statute 320.08058 – Specialty License Plates

(31) SHARE THE ROAD LICENSE PLATES

(a) The department shall develop a Share the Road license plate as provided in this section. The word “Florida” must appear at the top of the plate, and the words “Share the Road” must appear at the bottom of the plate.

(b) The annual use fees shall be distributed to Bike Florida, Inc., up to 25 percent of which shall be used for marketing and promotion of the “Share the Road” concept and license plate. The remaining funds shall be divided equally between Bike Florida, Inc., and the Florida Bicycle Association, Inc., to be used for:

1. Education and awareness programs, for bicycle safety and motorist safety, with emphasis on sharing the roadway by all users.
2. Training, workshops, educational materials, and media events.
3. The promotion of safe bicycling.

A Transit Oriented Development Financial Incentive Program—A Tool to Encourage More Bicycling and Walking

BACKGROUND

There are two primary obstacles to using non-motorized transportation for personal, shopping, and commuting trips: lack of facilities and longer than reasonable trip length. People will bicycle and walk more if the proper facilities are provided and their destinations are within a relatively short distance.

The 2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors noted that the average trip length on a bicycle was 6.3 km (3.9 mi) and 38.6 percent were 1.6 km (1 mi) or less. The average trip length for walking was 1.9 km (1.2 mi) and 26.9 percent were shorter than 0.4 km (0.25 mi). Unfortunately, as a result of land uses in San Mateo County, CA, and many communities throughout the United States, distances from residential housing locations to employment and shopping destinations are typically greater than the average trip lengths noted in the 2002 survey.

Use of land and its specific location, as determined by local governments throughout the United States, is traditionally targeted to maximize sales tax revenue. The focus on increasing tax revenue results in a greater tendency for land development projects such as office and retail space, while creating a disincentive to develop residential projects. This often produces an environment where employment, shopping and housing are separated by distances that are much greater than the average bicycling and walking trip distances. In addition to discouraging non-motorized trips, this land use pattern also burdens the motorized transportation infrastructure and reduces air quality.

To further complicate the issue, land use decisions generally are made by local jurisdictions while transportation

Felicia Leonard, Bicycle and Pedestrian Coordinator, City of Clearwater, Florida



PHOTO COURTESY OF C/CAG

Phase 1 of the Franklin Street Project, near completion. The project received \$1.2 million in TOD Incentive Program funds.

decisions are made by regional coalitions. Such regional coalitions might be, for example, Metropolitan Planning Organizations or Congestion Management Agencies (such as the San Mateo City/County Association of Governments (C/CAG).

The goals of this program are not only to promote local land use decisions that reduce the distances between residential units and employment and shopping land uses, but also to provide an alternative source of funding for transportation projects, including non-motorized projects. In addition, efforts to increase the numbers of people or amounts of bicycling and walking may improve individual safety through a phenomenon of improved “safety in numbers.” [See case study #54, references (page 346), for studies that document this phenomenon.] Promoting transit-oriented development may therefore help to improve safety for bicyclists by increasing the numbers of people able to bicycle.

COUNTERMEASURES

In order to influence land use decisions that would create shorter trip lengths and provide funding for adequate facilities, the San Mateo C/CAG has sought to implement a tailored Transit Oriented Development (TOD) Program. In general, TOD programs seek to develop shared-



use, higher-density neighborhoods that take advantage of proximity to transit alternatives. The resulting development encourages more walking and bicycling by offering shorter trip distances between origins and destinations.

Using the TOD concept as a foundation, the San Mateo C/CAG has developed a unique initiative that provides a financial incentive to influence their local jurisdictions (20 cities and the county) when these jurisdictions develop and implement a critical component of Transit Oriented Development: higher density residential uses that are close to transit locations. To fund this financial incentive program, the San Mateo C/CAG allocates up to 10 percent of its State Transportation Improvement Program funds.

Through the program, the San Mateo C/CAG distributes incentive funds to a local jurisdiction for a development that meets the program's basic criteria. To achieve eligibility for the program, the development must include housing that is located within 0.5 km (0.3 mi) of a rail transit station, and density must be at least 40 residential units per acre. Local jurisdictions receive the incentive funding upon the start of construction.

The local jurisdiction typically receives up to \$2,000 per bedroom that is located in the eligible project. Funds are then used to support improvements either on-site or off-site, as determined by the local jurisdiction. In addition to transportation improvements such as non-motorized transportation projects, many general improvements such as landscaping, lighting, plazas and recreational projects are also allowed. The funding or incentive goes to the land use agency to use as they wish on transportation projects. It many times is used on the qualifying project but is not required. It could potentially be used to address a neighborhood concern of the project to help sell it.

EVALUATION AND RESULTS

Since October 1999, the San Mateo City C/CAG has allocated \$5.2 million to the TOD Incentive Program, supporting the development of 3,689 bedrooms in 15 projects. The resulting projects promote more bicycling and walking by providing acceptable trip lengths between origins and destinations. These projects also have provided adequate facilities for bicycling and walking by offering flexibility in the expenditure of the financial incentives.

This innovative TOD Incentive Program, as crafted by the San Mateo C/CAG, has resulted in linking land use and transportation decisions that encourage trip lengths that are suitable for walking and bicycling. In addition to providing an alternative funding source for bicycling and walking facilities, TOD developments reduce traffic congestion and improve air quality.

CONCLUSIONS AND RECOMMENDATIONS

This program truly has provided a link between local land use and transportation decisions. The TOD incentive program has resulted in the creation of shared use, higher-density development in San Mateo County. The higher-density uses in these developments create shorter, acceptable trip lengths for bicyclists and pedestrians. In addition to encouraging more non-motorized trips, the program also provides an alternative funding source that local jurisdictions can use for bicycle and pedestrian improvements.

This program is easily replicated, having already been duplicated in the San Francisco Bay Area through the Metropolitan Transportation Commission's Housing Incentive Program, which has already allocated \$9 million for such uses.

This program was also the recipient of the Environmental Protection Agency's Smart Growth Award in 2002.

REFERENCES

2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors, U.S. DOT and Bureau of Transportation Statistics

COSTS AND FUNDING

The San Mateo C/CAG allocates 10 percent of its State Transportation Improvement Program to fund the TOD

Incentive Program. However, a new program could start with less funding.

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Chapter 7 – Implementation and Resources



Getting Started

Construction Strategies

Funding

Web Sites

Guides, Handbooks and References

Communities are asking that motor vehicle speeds be reduced on their neighborhood streets and that streets be made more accessible and inviting for bicycling (and walking). Some of the most important issues to the public are safety, access, and aesthetics. This chapter discusses some of the issues related to setting priorities and implementing needed bicycling improvements.

GETTING STARTED

Getting started can be daunting—the needs are overwhelming, resources are scarce, and staff time is limited. Every community is faced with the questions of “Where do I start?” and “How do I get going?” While it is not the intent of this guide to provide an exhaustive discussion of implementation strategies, it offers some direction.

PRIORITIES

Since all bicycling needs cannot be addressed immediately, project priorities need to be established. To create priorities requires several program objectives:

- **Safety**—One objective should be to reduce the number and severity of crashes involving bicyclists. Accomplishing this would require: (1) a good understanding of the types of crashes that are occurring in your community, and (2) application of appropriate countermeasures to address these crashes. The information provided in this guide is intended to help select the countermeasures that would be most effective in addressing selected types of crash problems.
- **Access**—A second objective should be to create an accessible community where all bicyclists can reach their desired destinations. Typically, this begins with identifying corridors frequented by bicyclists and how these corridors can be accessed with connecting streets, as well as determining if the main corridor streets need improvements.
- **Aesthetics**—It is not enough to simply have a safe, accessible community—it should also be an aesthetically pleasing place to live and work. Landscaping, lighting, parking, and other facilities help create a “livable community” and should be considered when making bicycling improvements.

ONE STEP AT A TIME

To create a safe community for bicycling, take one step at a time. Along main corridors, check to see that there is adequate space for riding for the speed and volume

of motor vehicle traffic at both midblock and intersection locations. In other words, check block by block and intersection by intersection. Individually, these locations do not create a safe, livable community. Collectively, they create the infrastructure needed for a great place to work, play and conduct business. In other words, the whole bicycling system is greater than the sum of its parts.

COMMUNITY CONCERNS

Be very sensitive to community concerns. Public participation will build community pride and ownership that is essential to long-term success. Some of the problems identified in this guide will not be an issue in your community and some of the tools may be perceived as too expensive (at least initially). There probably will be measures that your community puts on hold for a few years until a community consensus is reached. Conversely, there probably will be measures that your community would like to pursue that are not even mentioned in this planning section.

DELIVERABLES

It is very important to produce immediate deliverables that people can see. For example, the addition of bike lanes and/or the removal of parking along a street are highly visible, while a transportation plan is a paper document that may never be seen or appreciated by the public. To keep its momentum, a program needs some “quick wins.” They create the sense that something is happening and that government is responsive.

ADDITIONAL RESOURCES

The Bikeability Checklist can quickly identify some of the more obvious deficiencies in your neighborhood or community.

http://www.rwjf.org/files/newsroom/interactives/sprawl/bike_app.jsp

<http://www.bicyclinginfo.org/cps/checklist.htm>

The American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities* is a comprehensive document for information about facilities. The AASHTO Web site is:

<http://www.transportation.org/>

The Bicycle Compatibility Index (BCI) is a tool that can be used by bicycle coordinators, transportation planners, traffic engineers, and others to evaluate the capability of specific roadways to accommodate both motorists and bicyclists.

<http://www.hsrc.unc.edu/research/pedbike/98095/index.html>

Information on both Bicycle Level of Service (BLOS) and the Bicycle Compatibility Index (BCI) is contained at a Web site maintained by the League of Illinois Bicyclists.
<http://www.bikelib.org/roads/blos/>

Information on the Intersection Level of Service: The Bicycle Through Movement is contained on a Florida Department of Transportation Web site:
<http://www.dot.state.fl.us/planning/systems/sm/los/pdfs/BLOSTM.pdf>

NCHRP Project 7-14 provides guidelines for the analysis of investments in bicycle facilities. The research was performed by the University of Minnesota, Planners Collaborative Inc, the UNC Highway Safety Research Center, and the UNC Active Living by Design Program. A cost-demands-benefits analysis tool can be found at this Web site:
<http://www.bicyclinginfo.org/bikecost/>

Aesthetics: California's Local Government Commission has some great resources on street design and livability.
<http://www.lgc.org/transportation/street.html>
<http://www.lgc.org/center/index.html>

CONSTRUCTION STRATEGIES

There are many ways to accomplish projects. Be creative; take advantage of opportunities as they present themselves. Here are some suggestions:

REGULATION OF NEW DEVELOPMENT AND REDEVELOPMENT

Issues here tend to pertain more to pedestrian activities. For example, developers can be required to install public infrastructure such as sidewalks, curb ramps, and traffic signals. In addition, zoning requirements can be written to allow for or require narrower streets, shorter blocks, and mixed-use development. However, these infrastructure items benefit bicycling as well. Encouraging developers and community leaders to focus on basic pedestrian and bicycling needs will benefit the community and increase the attractiveness of the developments themselves.

ANNUAL PROGRAMS

Consider expanding or initiating annual programs to make small, visible improvements. Examples include improving space for bicyclists on streets where it is poor, or adding space to a link between two areas to improve connectivity. This creates momentum and community support. Several considerations should be made when developing these programs:

- Identify corridors where bicycling takes place and give priority to these locations.
- Consider giving preference to requests from local bicyclists about spot improvements or addressing a crash problem.
- Evaluate your construction or renovation options. Consider having city crews do work requested by residents to provide fast customer service while bidding out some of the staff-generated projects.

CAPITAL PROJECTS

"Piggybacking" bicycling (and pedestrian) improvements onto capital projects is one of the best ways to make major improvements in a community. For example, when a street is resurfaced, consider whether lanes should be narrowed when the street is re-striped to provide for bike lanes, wide curb lanes, or simply more space for cyclists. Landscaping, lighting, and other amenities can be included in road projects, utility projects and private construction in public rights-of-way (for example, cable television, high-speed fiber optics, etc.). To accomplish this, there are several things that can be done:

- Contact all State and regional agencies, and local public and private utilities that do work in public rights-of-way. Secure their five-year project plans as well as their long-range plans. Then, work with them to make sure that the streets are restored in the way that works for your city.
- Look internally at all capital projects. Make sure that every opportunity to make improvements is taken advantage of at the time of construction.
- Consider combining small projects with larger capital projects as a way of saving money. Generally, bid prices drop as quantities increase.

PUBLIC/PRIVATE PARTNERSHIPS

Increasingly, public improvements are realized through public/private partnerships. These partnerships can take many forms. Examples include Community Development Corporations, neighborhood organizations, grants from foundations, direct industry support and involvement of individual citizens. In fact, many public projects, whether they are traffic-calming improvements, street trees or the restoration of historic buildings, are the result of individual people getting involved and deciding to make a difference. This involvement doesn't just happen; it needs to be encouraged and supported by local governmental authorities.

ADDITIONAL RESOURCES

Cities such as Cambridge, MA, Eugene and Portland, OR, and Seattle, WA have adopted plans and procedures to ensure that bicycle improvements become a routine activity in new development projects, reconstruction work, and retrofits. Charlotte, NC, also has some exciting urban street design guidelines out for public review. These include a chapter on the design of streets for multiple users, as well as an appendix with a tool to calculate bicycle and pedestrian level of service at signalized intersections. Please note that Web site addresses change frequently.

City of Cambridge, MA

<http://www.cambridgema.gov/~CDD/et/bike/>

City of Eugene, OR

http://www.eugene-or.gov/portal/server.pt?space=CommunityPage&cached=true&parentname=CommunityPage&parentid=3&in_hi_userid=2&control=SetCommunity&CommunityID=435&PageID=541

City of Portland, OR

<http://www.portlandonline.com/transportation/index.cfm?c=34772>

City of Seattle, WA

<http://www.ci.seattle.wa.us/transportation/bikeprogram.htm>

City of Charlotte, NC

<http://www.charmeck.org/Departments/Transportation/Urban+Street+Design+Guidelines.htm>

FUNDING

Bicycling (and pedestrian) projects and programs can be funded by federal, State, local, private, or any combination of sources. A summary of federal bicycling (and pedestrian) funding opportunities can be viewed at <http://www.fhwa.dot.gov/environment/bikeped/bp-broch.htm#funding>.

Communities that are most successful at securing funds often have the following ingredients of success:

- **Consensus on Priorities**—Community consensus on what should be accomplished increases the likelihood of successfully funding a project. A divided or uninformed community will find it more difficult to raise funds than a community that gives broad support to bicycle (and pedestrian) improvement programs.

- **Dedication**—Funding a project is hard work, and generally, there are no shortcuts. It takes a great amount of effort by many people using multiple funding sources to complete a project successfully. Be aggressive and apply for many different community grants. While professional grant-writing specialists can help, they are no substitute for community involvement and one-on-one contact (the “people part” of fund raising).
- **Spark Plugs (Change Agents)**—Successful projects typically have one or more “can do” people in the right place at the right time who provide the energy and vision to see a project through. Many successful “can do” politicians get their start as successful neighborhood activists.
- **Leveraging**—Funds, once secured, should always be used to leverage additional funds. For example, a grant from a local foundation could be used as the required match for a Transportation Equity Act for the 21st Century (TEA-21) Enhancement grant.

WEB SITES

There are dozens of Web sites that contain information on bicycle safety and mobility. The Pedestrian and Bicycle Information Center (PBIC) maintains a list at <http://www.bicyclinginfo.org/links> of national and international government agencies, state and local government agencies, professional organizations, advocacy groups and other sites as listed in the following sections.

GOVERNMENT AGENCIES AND OFFICES

Danish Road Directorate

<http://www.vejdirektoratet.dk/roaddirektorat.asp?page=dept&objno=1024>

Federal Highway Administration (FHWA)

<http://www.fhwa.dot.gov>

FHWA Office of Highway Safety

http://safety.fhwa.dot.gov/ped_bike/bike/index.cfm

FHWA/NHTSA National Crash Analysis Center

<http://www.ncac.gwu.edu>

House Committee on Transportation and Infrastructure

<http://www.house.gov/transportation>

International Bicycle Fund

<http://www.ibike.org/>

National Highway Traffic Safety Administration (NHTSA)
<http://www.nhtsa.dot.gov>

Transportation Association of Canada
<http://www.tac-atc.ca>

U.S. Architectural and Transportation Barriers
Compliance Board (Access Board)
<http://www.access-board.gov>

U.S. Department of Transportation (U.S. DOT)
<http://www.dot.gov>

GOVERNMENT PROGRAMS AND INITIATIVES

FHWA Bicycle and Pedestrian Program
<http://www.fhwa.dot.gov/environment/bikeped>

FHWA Office of Safety
<http://safety.fhwa.dot.gov/index.htm>

FHWA Bicycle Safety
http://safety.fhwa.dot.gov/ped_bike/bike/index.htm

FHWA Pedestrian and Bicycle Safety Research Page
<http://www.tfhr.gov/safety/pedbike/pedbike.htm>

FHWA Pedestrian/Bicyclist Crash Analysis Tool
(PBCAT)
<http://www.walkinginfo.org/pc/pbcats.htm>

NHTSA Fatality Analysis Reporting System (FARS)
<http://www-fars.nhtsa.dot.gov/main.cfm>

NHTSA Traffic Safety
[http://www.nhtsa.dot.gov/portal/site/nhtsa/
menuitem.5928da45f99592381601031046108a0c/](http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.5928da45f99592381601031046108a0c/)

For NHTSA Bicycle Safety
[http://www.nhtsa.dot.gov/portal/site/nhtsa/menuite
m.810acaee50c651189ca8e410dba046a0/](http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.810acaee50c651189ca8e410dba046a0/)

For NHTSA Pedestrian Safety
[http://www.nhtsa.dot.gov/portal/site/nhtsa/
menuitem.dfedd570f698cabbf30811060008a0c/](http://www.nhtsa.dot.gov/portal/site/nhtsa/menuitem.dfedd570f698cabbf30811060008a0c/)

Pedestrian and Bicycle Information Center (PBIC) Web Sites
<http://www.pedbikeinfo.org>
<http://www.walkinginfo.org>
<http://www.bicyclinginfo.org>
<http://www.pedbikeimages.org>
<http://www.iwalktoschool.org>
<http://www.walktoschool.org>
<http://www.saferoutesinfo.org>

Safe, Accountable, Flexible, Efficient Transportation Equity
Act: A Legacy for Users (SAFETEA-LU).
August 10, 2005, bill authorizing the Federal surface
transportation programs for highways, highway safety,
and transit for the 5-year period 2005-2009.
<http://www.fhwa.dot.gov/safetealu/>

PROFESSIONAL ORGANIZATIONS

American Association of State Highway and
Transportation Officials (AASHTO)
<http://www.transportation.org>

American Planning Association (APA)
<http://www.planning.org/>

American Public Works Association
<http://www.apwa.net/>

American Society of Landscape Architects
<http://www.asla.org>

American Traffic Safety Services Association
<http://www.atssa.com/>

Association of Pedestrian and Bicycle Professionals
(APBP)
<http://www.apbp.org/>

Bicycle Federation of America/National Center for
Bicycling and Walking
<http://www.bikewalk.org/>

Human-Powered Transportation Committee of the
American Society of Civil Engineers
<http://www.ascehpt.homestead.com/>

Institute of Transportation Engineers
<http://www.ite.org/>

League of American Bicyclists
<http://www.bikeleague.org/>

National Safety Council
<http://www.nsc.org/>

Transportation Research Board
<http://www.trb.org/>

OTHER ORGANIZATIONS (INCLUDING ADVOCACY ORGANIZATIONS)

AAA Foundation for Traffic Safety
<http://www.aaafoundation.org/home/>

America Bikes http://www.americabikes.org/	http://www.thunderheadalliance.org
Bicycle Helmet Safety Institute http://www.bhsi.org	Transportation Alternatives Citizens Group (New York City Area) http://www.transalt.org
Bikes Belong Coalition http://www.bikesbelong.org	Transportation Research Board http://www.trb.org
Better Environmentally Sound Transportation http://www.best.bc.ca	Travis County (Austin, TX) SuperCyclist Project http://www.ci.austin.tx.us/bicycle/super.htm
Brain Injury Association of America (formerly National Head Injury Foundation) http://www.biausa.org/Pages/home.html	Tri-State Transportation Campaign (New York/New Jersey/Connecticut) http://www.tstc.org
Chainguard—Bicycle Advocacy Online http://probicycle.com/	Vermont Bicycle and Pedestrian Coalition http://www.vtbikeped.org
Conservation Law Foundation http://www.clf.org	Victoria Policy Institute http://www.vtpi.org
Harborview Injury Prevention and Research Center http://depts.washington.edu/hiprc/	Walkable Communities, Inc. http://www.walkable.org/
Highway Safety Research Center http://www.hsrrc.unc.edu/	Washington Area Bicyclist Association http://www.waba.org/
International Mountain Bicycling Association http://www.imba.com	LOCAL/STATE SITES
Massachusetts Bicycle Coalition http://www.massbike.org	City of Boulder, CO, Transportation Planning http://www3.ci.boulder.co.us/publicworks/depts/transportation.html
National Center for Bicycling and Walking http://www.bikewalk.org	City of Cambridge, MA, Environmental and Transportation Division http://www.cambridgema.gov/~CDD/et/index.html
National Safety Council http://www.nsc.org/	City of Eugene, OR, Bicycle Information http://www.eugene-or.gov/portal/server.pt?space=CommunityPage&cached=true&parentname=CommunityPage&parentid=3&in_hi_userid=2&control=SetCommunity&CommunityID=435&PageID=541
National Transportation Enhancements Clearinghouse http://www.enhancements.org	City of Portland, OR, Pedestrian Transportation Program http://www.trans.ci.portland.or.us
Rails to Trails Conservancy http://www.railtrails.org	City of Seattle http://www.ci.seattle.wa.us/transportation/bikeprogram.htm
Surface Transportation Policy Project http://www.transact.org	
Texas Bicycle Coalition http://www.biketexas.org	
Thunderhead Alliance	

City of San Francisco (and County)
http://www.bicycle.sfgov.org/site/dptbike_index.asp

City of Tallahassee, FL, Bicycle and Pedestrian Master Plan
<http://www.crtpa.org/>

Florida Department of Transportation Pedestrian and Bicycle Safety Program
http://www.dot.state.fl.us/Safety/ped_bike/ped_bike.htm

Missouri Department of Transportation Bicycle/Pedestrian Program
<http://www.modot.org/othertransportation/bicyclepedestriangeneralinformation.htm>

Montgomery County, MD, Residential Traffic-Calming Program
<http://www.dpwt.com/TraffPkgDiv/triage.htm>

North Carolina Department of Transportation Division of Bicycle and Pedestrian Transportation
<http://www.ncdot.org/transit/bicycle/>
Note: Information from more than 9,000 recent bicycle and pedestrian crashes in North Carolina has been compiled in an interactive database.

Oregon Department of Transportation Bicycle and Pedestrian Program
<http://www.odot.state.or.us/techserv/bikewalk/>

University of California-Davis Bicycle Program
<http://www.taps.ucdavis.edu/bicycle/>

Virginia DOT Traffic Calming Guide
<http://www.virginiadot.org/infoervice/resources/TrafficCalmingGuideOct2002.pdf>

Wisconsin Department of Transportation Bicycle and Pedestrian Information
<http://www.dot.wisconsin.gov/modes/pedestrian.htm>

PEDESTRIAN AND BICYCLE LINK PAGES

Pedestrian and Bicycle Information Center bicycling information sites
<http://www.bicyclinginfo.org>

Bicycle advocacy Web sites provided by Chainguard
<http://probicycle.com/mainnet.html>

Bicycle education and safety sites provided by Chainguard
<http://probicycle.com/mainedu.html>

Pedestrian and bicycle sites provided by TransAct
http://www.transact.org/issues/intro_hss.asp

State bicycle laws provided by Bicycle Coalition of Massachusetts
<http://www.massbike.org/bikelaw>

PEDESTRIAN AND BICYCLE STUDIES AND STATISTICS

Bike Plan Source Hot Topics provided by Tracy-Williams Consulting
<http://www.bikeplan.com/traxq.htm>

BTS National Transportation Library Links to Bike/Pedestrian Transportation Research
http://www.transtats.bts.gov/Databases.asp?Mode_ID=7&Mode_Desc=Bike/Pedestrian&Subject_ID2=0

Bureau of Transportation Statistics
<http://www.bts.gov>

Consumer Product Safety Commission Recreational Safety Publications
http://www.cpsc.gov/cpscpub/pubs/rec_sfy.html

Insurance Institute for Highway Safety – Bicycle Fatality Facts
http://www.iihs.org/research/fatality_facts/bicycles.html

National Bicycling and Walking Study Ten-Year Status Report
<http://www.bicyclinginfo.org/pp/nbws1.htm>

Nationwide Household Travel Survey
<http://www.fhwa.dot.gov/policy/ohpi/nhts/index.htm>

Northwestern University Traffic Institute
<http://server.traffic.northwestern.edu/>

University of Michigan Transportation Research Institute
<http://www.umich.edu/~industry/pedvis.html>

University of North Carolina Highway Safety Research Center
<http://www.hsrc.unc.edu/>

GUIDES, HANDBOOKS AND REFERENCES

There are a significant number of additional resources related to the topic of bicycle (and pedestrian) safety and mobility. A sample of the national and international guides, practitioner handbooks, research reports and other general references are provided in this section. Note that this list is not comprehensive, but it should provide a place to start a search for information.

DOMESTIC GUIDES AND HANDBOOKS

Bike Facility Planning and Design

American Association of State Highway and Transportation Officials, *Guide for the Development of Bicycle Facilities*, Washington, D.C., 1999.

American Planning Association, *Bicycle Facility Planning*, Planning Advisory Service Report 459, Chicago, IL, 1995.

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Bicycle/Pedestrian Safety

Federal Highway Administration. *Good Practices Guide for Bicycle Safety Education*, FHWA-SA-02-001 / HSA-4/30-02(5M)QE, Washington, DC, 2002, available online at <http://www.bicyclinginfo.org/ee/bestguide.cfm>

Federal Highway Administration, *National Bicycling and Walking Study Ten Year Status Report October 2004*, 2004, available online at <http://www.fhwa.dot.gov/environment/bikeped/study/index.htm>

National Highway Traffic Safety Administration /

Federal Highway Administration, *Bicycle Safety Resource Guide* (CD-ROM), see <http://www.bicyclinginfo.org/rd/safety.htm#cd> for ordering information.

National Highway Traffic Safety Administration and the Bureau of Transportation Statistics, *National Survey of Pedestrian and Bicyclist Attitudes and Behaviors, Highlights Report*, n.d., available online at <http://www.walkinginfo.org/survey2002.htm>

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“Rails to Trails: Lessons Learned,” FTA-MA-26-0052-04-1. Available online at <http://www.fhwa.dot.gov/environment/retrails/rwt/>

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Appendix A – Field Investigation Form

The Selection Tool within the BIKESAFE expert system requires a number of inputs describing the geometrics and operations of the location in question. The system uses

these inputs to refine the selection of applicable countermeasures. Included on the following page is a form that may be used in the field to acquire these data elements.

BICYCLE COUNTERMEASURE SELECTION SYSTEM

FIELD INVESTIGATION FORM

Location:	Completed by:
	Date:

Area Type	
Urban CBD	
Urban Other	
Suburban	
Rural	

Roadway Functional Class	
Local	
Collector	
Minor Arterial	
Major Arterial	

Motor Vehicle Speed ^A	
≤ 30 mph	
31-44 mph	
> 45 mph	

Signalization	
Traffic signal present (removal is NOT an option)	
Traffic signal present (removal IS an option)	
No signal present (installation is NOT an option)	
No signal present (installation IS an option)	

Location	
Intersection	
Midblock	

Number of Through Lanes	
≤ 2 lanes	
3-4 lanes	
≥ 5 lanes	

Traffic Volume (Average Daily Traffic)	
< 10,000	
10,000-25,000	
> 25,000	

Bike Facilities	
Bike lane	
Wide curb lane	
Paved shoulder	
None or other	

Comments

Notes ^A Use 85th percentile speed if available. If not available, add 9 mi/h to the posted speed limit as a surrogate measure for the 85th percentile speed. Prior research has shown that 85th percentile speeds for vehicles traveling on many urban and suburban streets (including arterial, collector, and local classifications) generally exceed the posted limit by 6 to 14 mi/h. (D.L. Harkey, H.D. Robertson, and S.E. Davis, "Assessment of Current Speed Zoning Criteria," <i>Transportation Research Record 1281</i> , Transportation Research Board, Washington, DC 1990.)

Appendix B – Case Study Matrix

Included on the following pages is a matrix that shows the specific countermeasures addressed by each of the case studies included in Chapter 6.

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