



Review of Guidelines and Standards for Accommodating Bicycles
&
Getting Bicycles Through Intersections



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Introduction

Rutgers' Voorhees Transportation Policy Institute (VTPI) has been retained by the New Jersey Department of Transportation (NJDOT) to establish a Pedestrian and Bicycle Resource Project. The goal is to provide consistent vision and policy for application throughout the state to address the needs of pedestrians and bicyclists. To accomplish this VTPI is in the process of establishing an Information Clearinghouse as well as gathering technical resources to make available for all levels of government throughout New Jersey. As part of the project VTPI is also providing education and training through organization of workshops and conferences, and assistance in clarifying specific legal and technical issues concerning walking and bicycling.

This discussion paper is presented in two sections:

- Section I: Provides a review and comparison of the goals and objectives of the New Jersey Bicycle Planning and Design Guideline, the New Jersey Roadway Design Manual (RDM), the American Association of State Highway and Transportation Official's (AASHTO) Guide for the Development of Bicycle Facilities and other national and international guidelines for accommodating bicycles. Based upon that analysis, section 1 further outlines recommendations to enhance practices and policies for bicycling in New Jersey.
- Section II: Presents the results of research that was specifically conducted on the issue of getting bicycles through intersections.

Guidance and direction for this research was provided by an Advisory Committee consisting of NJDOT, - county, - local - and consulting engineers. The Committee was appointed at the beginning of the project to review draft work products, provide assistance and contribute ideas from their own experience and expertise.

The need for these discussions arose out of recognition that although bicycle planning has received growing attention in recent years, successful implementation is difficult due to the increasingly complex design of New Jersey's roadways and intersections. Such design continues to focus on providing better and faster motor vehicle passage without recognizing that

it often makes it impossible if not life threatening for cyclists to ride safely. The recommendations made in this paper carefully consider applicability of design and practice for New Jersey based on the different road functions/ classifications, volumes and speeds. This paper also addresses issues that go beyond design such as the need for cultural change, acceptance and informed awareness of the need of bicyclists. The review of current practice reveals that it is not (yet) within the culture of New Jersey to emphasize or prioritize cycling in its roadway design except for maybe recreational purposes. Although recreational cycling cannot and should not be discounted, using the bicycle just for recreation will not result in a significant mode shift and therefore not reduce congestion; improve our air quality; (re-) create more "livable" communities; or give our children the freedom and independence they crave.

This paper begins with a general overview of cycling conditions and facilities used in New Jersey and comparing them with conditions and facilities used in various other places, where cycling is a more common mode for general travel and commuting. The VTPI team believes that some of the problems New Jersey faces in promoting bicycling are missing links and clarifications among its manuals and guidelines. More importantly, the existing guidelines do not recognize the complexity of New Jersey's roadways and traffic conditions and thus do not allow local officials, planners and engineers to choose optimal alternatives for their particular situations. Providing more detailed guidelines for a variety of facilities and prioritizing investments in missing infrastructure will improve cycling conditions throughout the state and create more opportunities to establish bicycling as a viable means of transportation.

Considering that many safety hazards and conflicts occur at intersections where all the different modes converge, the second part of this paper specifically focuses on design issues related to getting bicyclists through intersections based upon previous findings and recommendations within the first section of this paper.

Chapter 1 Review of Guidelines and Standards for Accommodating Bicycles

Review, Comparison and Recommendations

Bicycling in New Jersey

Bicycling's share of urban trips in New Jersey account for less than one percent of all trips, even though New Jersey is the most densely populated state in the country. Interestingly, New Jersey has a population density that is comparable to the Netherlands - the nation which maintains the highest bicycling share in Europe with 27% of all trips made (Pucher and Dijkstra, 2000). Comparison to the European countries is often neglected and dismissed as not applicable due to different land use conditions, history of transportation planning, politics and cultures. However, the fact is that these nations were (and still are) facing similar dilemmas as the US – suburban development and growing popularity of the automobile has increased congestion and air pollution – but countermeasures started much earlier including the systematic encouragement of cycling since the 70's. Interestingly, an estimated 50% of all urban and suburban trips in the US made by car are less than three miles - a comfortable bicycling distance even for children and the elderly. Many of these short trips cause unnecessary congestion and air pollution, require parking spaces and prevent people from getting valuable exercise.

While it is true that the bicycle cannot provide the same mobility for longer trips as cars provide us, many of these shorter trips can be made in similar if not faster time than by car particularly in congested areas. In addition, bicycles take up much less space than automobiles. At least 12 bicycles fit into a single car parking space. Thus, encouraging people to cycle for at least some of their daily (and especially shorter) trips could eventually allow more valuable usage of public space instead of building more parking lots and garages throughout New Jersey's communities and downtowns.

Furthermore, according to a recent report by the Environmental Protection Agency, emissions of nitrogen oxides (NO) continue to increase with the majority of NO emissions coming from

transportation sources and fuel combustionⁱ. For New Jersey where roads experience more vehicle miles traveled annually than in any other state as well as claiming the highest level of congestion, this is an especially important challenge. Air pollution, among other health impediments, results in an increased risk of asthma and costs the state a significant amount of health care costs annually. Encouraging people to ride their bicycle, a zero-polluting and sustainable mode of transportation, can have a significant impact on improving air quality and public health for the citizens of New Jersey.

Finally, the benefits of walking and cycling on a regular basis are increasingly highlighted by national and international health and safety research as measures to prevent the eminent trends for obesity and the related diseases such as diabetes, which have reached an alarming level among adults but also children.

Yet in spite of the obvious benefits, few people ride their bicycle at all. The inability to get out of the car and preventing people from riding bicycles may be attributed to a lack of convenient and comfortable facilities and fear of safety while riding in traffic. People in the European cycling countries but also in some US and other North American cities such as Boston, MA, Davis, CA, Madison, WI, Portland, OR, San Francisco, CA, Seattle, WA, and Montreal, QC and Toronto, ON, enjoy the mobility of the car just as much, however, they have more travel options available to them. Bicycling (and walking) accounts for a much greater share of total trips in those locations, which in itself increases cyclists' safety through increased visibility.

Bicycling Mode Share for Select Cities

	<i>Bicycling Mode Share</i>
<i>Boston, MA (1)</i>	1.5%
<i>Davis, CA (1)</i>	22%
<i>Madison, WI (1)</i>	3.4%
<i>Portland, OR (1)</i>	3.3%
<i>San Francisco, CA (1)</i>	3.7%
<i>Seattle, WA (1)</i>	2.3%
<i>Toronto, ON (1)</i>	4%
<i>Denmark (2)</i>	20%
<i>Germany (2)</i>	12%

ⁱ <http://www.lungusa.org>

The Netherlands (2)	28%
New Jersey (4)	0.5%

Sources: 1) (Pucher, Komanoff, Schimek, 1999); 2) (Pucher, Dijkstra, 2000); 3) www.apbp.or:2000; 4) Census Data.

Safety is in fact a major impediment to cycling. Between 1986 and 1995, a total of 223 bicyclists were killed in motor vehicle crashes in New Jersey (22 per year). About 1,950 are injured each year throughout the state. 55.6% of all bicycle fatalities in New Jersey involved children under the age of 18. About 1,240 children are also injured each year in crashes while riding a bicycle.ⁱⁱ

Yet it would be a mistake to look at this data and come to the conclusion that one should stay off bicycles because of safety concerns. Bicycling is activity that is good for children, our health, and our communities. Making bicycling safer and more accessible will allow greater flexibility and independence especially for young children, teenagers and the elderly, who have become highly dependant on parents or others to drive them everywhere.

The following section provides an overview of the most common bicycle planning and design practices and facilities in New Jersey, which are based upon NJ DOT's Bicycle Compatible Roadways and Bikeways Manual. The purpose is to highlight some of the critical design standards and practices and recommend improvements for future application.

Statewide and National Guidance – State of the Practice

The New Jersey Bicycle Manual is intended to supplement the national AASHTO Guide for the Development of Bicycle Facilities and the NJ DOT Design Manuals for Roadways and Bridges. AASHTO guidelines are reproduced wholly or in part in various sections of the Manual. Additional information has been provided to refine, but not change, the intent of information presented in the AASHTO guideline.

The New Jersey Bicycle Manual provides guidance regarding how roadways should be designed to accommodate shared use by motor vehicles and bicycles. It further provides

ⁱⁱ Environmental Working Group/ Bicycle Federation of America/ Surface Transportation Policy Project, Share the Road, Let's Make New Jersey Bicycle Friendly, May 1997.

guidance for selection and design of designated bicycle facilities that encourage use by bicyclists. Thus, it recognizes the different skill levels of bicycle riders and distinguishes between *compatible* roadways and *designated* roadways.

Compatible Roadways

Shared Lanes (w/ wo parking)

Paved Shoulders

Pavement width recommendations to permit shared use of the roadway are based upon traffic volume, speed, sight distance, number of trucks and larger vehicles, and grade.

The common practice on highways in New Jersey is to provide 14-foot wide outside lanes or a minimum 3-foot wide shoulder (preferably 8-foot shoulders) to accommodate cyclists on state highways.



Picture 1: Wide outside lane with parking. Source: AASHTO.

In many cases existing highways are retrofitted to meet these standards which is accomplished through reduction of center lane width and widening of the outside lane, widening the roadway to pave a shoulder, removing parking (either on one or both sides of the roadway), and reducing the number of lanes and adding center turning lanes. These practices are generally the least expensive and easiest to implement, and are most commonly applied to accommodate cyclists in New Jersey.



Picture 2: Wide paved shoulder accommodating bicycles. NJ. Source: VTPI.



Picture 3: Shared roadway with "Share the Road sign". NJ. Source: VTPI.

In addition the following cycle facilities for separation can be found:

Designated Roadway

- Bicycle Routes (signage)
- Bicycle Lanes (striping and marking)
- Bicycle Paths (separated from vehicular traffic)

A fairly common practice in New Jersey in designating roadways for bicyclists is the provision of bike routes through signage and numbering. The purpose is to encourage bicycle use on a particular road without providing specific facilities. The most important considerations when determining a bicycle route are pavement width and geometrics, traffic conditions and appropriateness for the intended purpose. Routes are selected based upon their function, - directness is important for cyclists traveling for a purpose, scenery is more important for the recreational rider.

Designating roadways for cycling has also been accomplished through the provision of bicycle lanes. In New Jersey bicycle lanes are considered to be more suitable in urban settings on roads with high traffic volumes and speeds. Bicycle lanes are recommended to always be one-way facilities in the same direction as adjacent motor vehicle traffic. Ideal minimum width is 5-feet but depends on edge, - pavement - and parking conditions. In rural settings bicycle lanes are not considered necessary to designate preferential use. On higher volume roadways the manual suggests that wide shoulders offer bicyclists a safe and comfortable riding area. On low

volume roadways, bicyclists seem to prefer the appearance of a narrow, low speed country road.



Picture 4: Bike lane with bike route signage.



Picture 5: Bike lane.

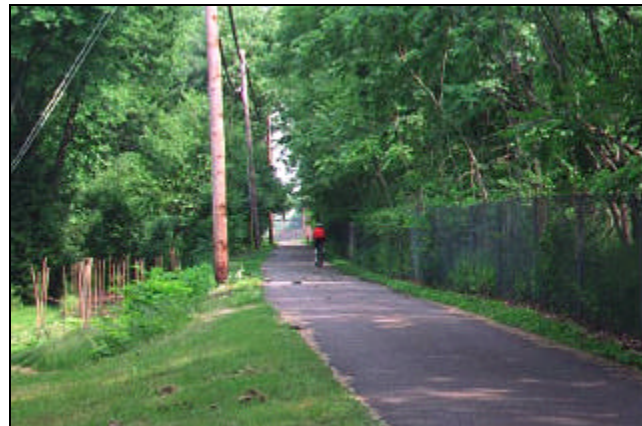
Source: VTPI.

A third rather common practice in New Jersey to designate bicycle facilities is the provision of bicycle paths. Bike paths in New Jersey, referred to as shared use paths in AASHTO, are defined as a bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way, with *minimal cross flow by motor vehicles*.

A bike path can be designed for the exclusive use by bicycles but may also be designated for mixed use with pedestrians, skaters, wheelchair users, joggers, and other non-motorized users such as a shared use path. AASTHO states that these facilities are most commonly designed for two-way travel. New Jersey does not recommend one-directional paths since they will usually be used as two-way facilities and should be designed accordingly (e.g. sufficient width). AASHTO further states that shared use paths should not be used to preclude on-road bicycle facilities, but rather to supplement a system of on-road bike lanes, wide outside lanes, paved shoulders and bike routes.



Picture 6: Separate multi-use path.



Picture 7: Separate multi-use path.

Source: VTPI.

Needs Assessment and LOS

The New Jersey Bicycle Manual also provides a section with respect to land use and location factors to assist in recognizing the potential for non-motorized travel.

- Does the highway serve an activity center, which could generate bicycle trips?
- Is the highway included on a county or municipal bicycle master plan?
- Will the highway provide continuity with or between existing bicycle facilities?
- Is the highway part of a mapped bike route or utilized regularly by local bicycle clubs?
- Does the highway pass within two miles of a transit station?
- Does the highway pass within two miles of a high school or college?
- Does the highway pass within 1/2 mile of an elementary school or middle school?
- Does the highway pass through an employment center? If so, is there a significant residential area within a three-mile radius?
- Does the highway provide access to a recreation area or otherwise serve a recreation purpose?

If any of the listed criteria is yes, the highway facility has the potential of attracting less experienced bicycle riders and/ or large numbers of advanced riders. Designated facilities are then desired. If none of the criteria is met, minimum bicycle compatible roadway design is recommended.

Although needs assessment is considered within the Bicycle Manual, in practice this has yet to become a greater driving force when considering bicycle facility implementation. In reality, many bicycle projects are denied or receive little acceptance from either the community or the implementation agency because ridership is low - if at all existing. Many argue that, spending money on facilities that won't be used, that are perceived as slowing down motor vehicle traffic and creating safety hazards, especially for children, does not make sense. Thus, the first choice is often either implementation of the least costly option to meet minimum standards or none at all. Caution should be exercised when using existing bicycle volumes as a measure of current demand since these numbers can significantly underestimate potential users.

Similarly, arguments that spending money on facilities that will not be used are often misleading. The facilities that truly encourage bicycling, that generate new bicyclists and that make bicycling safe, need to be provided before any decision should be based upon actual volumes. Once a network is established and people have adjusted to the new facilities, then measures can be taken to count people riding and evaluating facilities in much greater detail. Volumes are inherently low when there is a lack of safe and efficient facilities for cyclists. After all, the automobile's popularity did not precede the building of our roadways – the roadways were built first to accommodate and encourage people to travel to and from origins and destinations. A good example offers the West Side Highway (Route 9A) greenway project in New York City: The recently built waterfront path along the Hudson river provides a car-free walkable/ cyclable path currently from Manhattan's southern tip up to 59th Street and will eventually reach beyond the George Washington Bridge. It provides a convenient corridor between some of the City's densely residential areas and Midtown and downtown business and entertainment districts and has significantly boosted Manhattan cycling trips. Just the Manhattan portion is predicted to become the nation's busiest cycling path, something that was hard to imagine prior to its construction.ⁱⁱⁱ

The Transportation planning and engineering community has recently attempted to provide analysis and design methods to help create more "livable" streets and roadway environments. These efforts include the provision of a multidiscipline level of service for bicyclists, pedestrians and transit riders. So far a level of service analysis has only been used to measure road

ⁱⁱⁱ "Key NYC Greenway Link in Place." Mobilizing the Region, Tri-State Transportation Campaign. Issue 313, April 16th, 2001.

performance for motor vehicles, thus design of roadways and streets primarily depends on traffic flow and delay of motor vehicles. Evaluating the performance of roadways for all travel modes is essential, especially in downtown areas, but also in other places where travel by bike and foot can be expected. Such level of service will not focus on the number of bicyclists (pedestrians or transit riders) present, but it is rather an indicator of the number of people that could be bicycling in a given environment, which would be based upon identification of certain bicycling generating factors. Short distances and directness as well as land use (origins and destinations) have a major impact on this indicator. Again, one reason why the needs assessment provided within the New Jersey Bicycle Manual is not extensively used may be the missing link to the Roadway Design Manual. A recommendation made herein is to include a multidiscipline level of service in all of New Jersey roadway design guidelines and standards to ensure implementation in practice.

Most bicycle planning and design standards used throughout the United States are based upon the national guideline published by AASHTO, variations do however occur. Oregon for example has gone beyond New Jersey and AASHTO regarding some of its recommended and implemented designs. Oregon's efforts seem to pay off. Bicycle ridership, despite often unfavorable weather conditions, has increased significantly over the past years compared to other states throughout the nation. In addition, Oregon's bicycle-and pedestrian-friendly cities (e.g. Portland, Eugene)^{iv} rank high in terms of "livability" which is often associated with walkability and bicycling. A few of the more progressive and more innovative design practices from Oregon are outlined below.

Oregon

The Oregon Bicycle and Pedestrian Plan includes the same bikeway types with similar volume and speed considerations as used in New Jersey. However, the Oregon Plan suggests that many urban local streets that carry excessive traffic volumes at higher speeds than they were designed to carry, can function as shared roadways **if traffic speeds and volumes were reduced**. It recommends applying traffic calming techniques to achieve this goal.

^{iv} Portland's bicycle share of trips is about 2%, rising to 3.3% of trips in the inner, more dense areas of town. Compare article by Mia Birk, City of Portland – [A Total Commitment to Bicycling](#) in: Community Focus, City of Portland, Oregon.

Traffic calming strategies use both, physical design features and traffic regulations to reduce speeds of motor vehicles. Such techniques have proven successful in both urban and suburban areas throughout the nation, but have yet to be applied more extensively. Typical traffic calming devices include narrowed road segments, speed humps or tables, special, textured paving material, curving roadways and landscaping. The main purpose is to reduce speeds on local and residential streets and placing road users on a more equal footing with the remaining traffic.

New Jersey and Oregon have gone beyond the AASHTO bicycle guide by acknowledging the potential benefits of area-wide traffic calming implementation within their bicycle and pedestrian guidelines. However, neither Plan provides detailed prescriptions of how, when and where to apply traffic calming devices and thus give little guidance to communities, engineers or the implementation agency.

The Oregon Plan further outlines practices that should be avoided - among those are two-way bike lanes, rumble strips and extruded curbs. The Plan suggests that extruded curbs may be hit by either the cyclist or the motor vehicle and cause them to lose control, thus creating dangerous situations along a roadway.

Within its "Innovative Design" section, the Plan does suggest consideration of raised (or physically separated) bike lanes within the ROW. Although rarely seen anywhere in the United States, this is a very common facility implemented in many of the European cycling nations. (Further details on European practices are outlined within Appendix I). A raised bike lane (referred to as a certain type of cycle track in the Dutch and Danish guidelines) at minimum reduces perceived risk by bicyclists when riding adjacent to motor vehicle traffic.

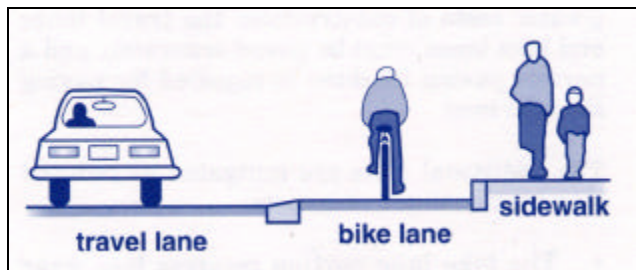
The Oregon Plan lists advantages of raised bike lanes as followed:

- A mountable curb allows cyclists to enter or leave the lane as needed for turning or overtaking;
- Other than with bike lanes, motorists know they are straying from the travel lanes when they feel the slight bump created by the mountable curb;
- Novice cyclists are more likely to ride in the bike lane, leaving the sidewalk for pedestrians.

An effective design provides a gentle slope, with no lip, so a bicycle tire is not caught during crossing maneuvers. The raised bike lane shall be dropped prior to intersections where the roadway surfacing is uniform.

Referring to ODOT, the biggest downside of raised bike lanes is cost:

- The curb itself will be in the roadway and is expected to be driven over by trucks, therefore it has to be set on a substantive basis;
- Paving the roadway and the bike lane separately – the bike lane needs a special attachment to pave 5 feet only;
- Placing and maintaining drainage grates in the travel lanes.



Picture 8: Raised Bike Lane



Picture 9: Raised Bike Lane

Source: Oregon DOT Bicycle and Pedestrian Plan.

However, as further described within Appendix I, a raised bike lane or otherwise physically separated bikeway adjacent to the roadway is a good solution to increase cyclists' comfort and thus encouraging bicycle riding, especially in urban settings, where separated paths (not immediately adjacent to the roadway) are not practical. In fact, since the 70's similar facilities have been promoted by national and local cycling advocates in North America, but with mixed results. Because of an existing potential for conflicts at intersections, AASHTO generally discourages sidewalk bikeways and otherwise separated bikeways along roads such as raised bike lanes. In their place AASHTO favors bicycle lanes separated from the remaining traffic

only by paint. Whereas cycle lanes and cycle tracks each have their advantages and disadvantages, these need to be outlined. This would allow for a much greater range of solutions than are currently provided in our guidelines. Within AASHTO, there is no comprehensive recognition of the complexity and needs of urban and suburban traffic situations and conditions as they relate to cyclists. European cycle planners on the other hand recommend a range of solutions depending on circumstances and these solutions are outlined within governmental guidelines for bicycle facilities (e.g. in Germany and Denmark). Separate bikeways in Europe have helped to encourage high levels of cycling – which in itself increases their safety due to greater visibility. Appendix I in further detail addresses the benefits of- and existing controversies towards physically separated bicycle facilities and emphasizes the importance of such facilities to bring bicycling back into the mainstream of our transportation system.

Another recommendation Oregon makes is the consideration of Bicycle Boulevards. Such a facility is described as a modification of the operation of a local street to function as a through street for cyclists while maintaining local access for automobiles. Traffic calming devices are used to control traffic speeds and discourage through trips by motor vehicles.

Physically separated bicycle lanes as well as some of the other innovative, yet applicable designs and standards recommended in Oregon, have not been addressed in New Jersey, but are worthwhile to consider for future practice.

New Jersey Roadway Design Manual

Additional findings were drawn from a review of the New Jersey Roadway Design Manual (RDM), which provides the roadway design standards for New Jersey state highways. Standards specifically addressing the needs and design for bicycle facilities are minimal, and standards that indirectly affect the implementation of bicycle facilities, such as lane widths, turning radii, design speed, design vehicles, etc., tend to be rather non-cycle friendly or safe. Designing to these standards often prevents the provision of safe and convenient bicycle and pedestrian facilities. And, since bicycle and pedestrian facilities are barely addressed within the Roadway Design Manual, highway engineers often do not consider these modes. Also observed was that while the RDM makes many urban/ rural differentiations, the general

emphasis is to design all “land service” highways equally. The problem here is that minimum shoulder width for all state highways does not change between urban and rural classifications (8' outside and 3' at medians for both - exceeding Green Book values). In practice the same is true – “land service” highways commonly have shoulders, wide clear zones, no curbs and high speed limits, all of which are generally not bicycle and pedestrian friendly design features. In addition, many of the features consume valuable space that could otherwise be used by non-motorized modes.

The New Jersey Bicycle Manual does distinguish between rural and urban concerning bicycle facility implementation, however, the common practice among traffic engineers and local officials is to design to standards outlined within the Roadway Design Manual, thus treating all land service highways equally. This again emphasizes the importance of a greater compatibility of the RDM and the Bicycle Manual.

Note: In terms of shoulder width the New Jersey Bicycle Manual recommends that highways having an AADT greater than 20,000 vehicles per day, or on which more than 5% trucks operate, every effort should be made to provide an eight-foot shoulder to accommodate the cyclist. By comparison, in Denmark it is recommended that under no circumstances should the roadway be widened to accommodate the bicyclist, but rather a raised/ physically separated bike lane be provided which would be equal in cost but enhance safety for cyclists.

When planning and designing for bicycles, among other things a clear distinction between urban and rural and the consideration of adjacent land-use (origin and destination) is necessary to ensure safe, comfortable and convenient facility provision. New Jersey's common practice to provide 14-foot shared use lanes (or cycle lanes) to accommodate cyclists often conflicts with narrow streets desirable in many towns, centers, etc., and encourages higher motor vehicle speeds due to the greater (apparent in the case of lanes) roadway width. One possible way to address this is by asking, "what is the speed/ volume at which cyclists can safely take a lane and where/ under which circumstances (traffic configuration/ parking/ child cyclists (schools)^y/ space...) can this be justified?" Generally not in rural/ high-speed settings, however, it might be a much better alternative within urban/ low-speed settings and possibly rural town centers,

^y Note: Especially in residential areas with low pedestrian volumes it is generally accepted for very young children to ride on the sidewalk.

rather than providing wider lanes or shoulders for which there may not be enough space, and secondly, that might not be in the interest of a community.



Picture 10: Limited space to provide bike lane, wide outside lane or shoulder leaves the options to either eliminate parking or to introduce a speed limit of 20mph or less to allow cyclists to safely take the lane. (MK)

This is just one reason why it is important to carefully differentiate among given environments and land uses to be able to provide efficient and safe travel options for all modes.

Note: NJDOT has recently hired a planning consultant firm to review their Roadway Design Manual. Preliminary outlines indicate a separate traffic calming chapter to be added to the RDM as well as separate chapters providing standards for bicycle and pedestrian planning and design. The revisions should consider more specific differentiation between the various road functions and classifications; design should be considered accordingly.

Chapter 2 Bicycles Through Intersections – State of the Practice

The need to accommodate numerous turning movements by both, motor vehicles and bicyclists, has made the design of intersections very complicated. Intersections are also the locations where most conflicts occur between the various road users. The following section provides a review and comparison of various guidelines and practices on the issue of getting bicycles through intersections. It includes examples of state, national and international practices.

Background

In New Jersey bicycle planning and design standards for intersections are not very specific and only briefly touched upon within the state's bicycle guidelines. In addition, provided guidance lacks careful distinction between the many different intersection conditions and designs one finds in New Jersey's urban, rural and downtown areas. Finally, the New Jersey Roadway Design Manual and Bicycle Manual do not comply with each other, - the RDM actually does not provide any guidance on accommodating bicycles at intersections. Some of the general roadway design standards within the RDM on the other hand negatively affect accommodation of cyclists in New Jersey. For example turning movement standards cause rather undesirable roadway conditions for cycling. Encouragement to use the WB-19 (WB-62 in English Units) turning template as the design vehicle when designing new intersections or upgrading existing intersections often results in wide corner radii, higher turning speeds and thus, safety hazards for cyclists (and pedestrians) trying to cross. In any future revisions of the RDM it will be important to 1) incorporate comprehensive design and implementation instructions for bicycle (and pedestrian) facilities, and 2) emphasize the negative and positive effects of various roadway designs on all road users.

Recommended intersection designs are generally based upon the assumption that:

- Motorists making right turns should make their turn from as close to the right-hand curb as practicable;
- Bicyclists going straight ahead should be to the left of right turning traffic;

- ❑ Bicyclists turning left should turn from a left turn lane or left side lane.^{vi}

The existing guidance in the New Jersey bicycle manual is primarily based on the AASHTO guide, but again, is not very detailed.

Comparative Analysis - New Jersey, AASHTO, Oregon and European Practice

General

Common practice in New Jersey to channel bicyclists through intersections is to try and provide standard lane widths (as used for shared lanes) and to allow cyclists to merge with traffic. It is also common to provide the approach shoulder width at intersections, where feasible, to accommodate right-turning bicyclists or bicyclists who prefer to use crosswalks to negotiate the intersection. Whether this is always desirable for safe cycling conditions is debatable. Greater pavement width primarily results in smoother turning movements for motor vehicles and thus higher speeds, which does not necessarily comfort bicyclists. Bicyclists do need the space, and many prefer either speed reduction measures or clear designation of space for cyclists. Such measures are especially critical for child cyclists.

Motorists Turning Right

The bicycle guideline also suggests that bicycle lanes tend to complicate both bicycle and motor vehicle turning movements at intersections. Because they encourage bicyclists to keep to the right and motorists to keep to the left, both operators are somewhat discouraged from merging in advance of turns. Therefore at signalized stop-controlled intersections with right-turning motor vehicles and approach bike lane, the solid striping - which is generally provided between the straight and turn lane based on roadway configuration - is replaced with a broken/ dashed line approximately 50-200 feet before the intersection. The purpose is to allow cyclists to weave into traffic and to proceed as motor vehicles do. Sometimes it is recommended to continue the line as a dotted line through complex intersections or multi-lane roundabouts.

Where only small volumes of right-turning motor vehicles exist (primarily at non-signalized/

^{vi} www.bicyclinginfo.org/elements/intersections/
Final Draft
Pedestrian and Bicycle Resource Project
Rutgers' Voorhees Transportation Policy Institute

minor intersections), the solid striping is usually continued all the way up to the crosswalk at the near side (but dashed at bus stops).

Multi-Lane Intersections

The common design treatment at multi-lane intersections is more complex. New Jersey and AASHTO provide the following guidance:

- ❑ At multi-lane intersections with right-turn-only lane, discontinue bike lane in advance (continuation as dashed line optional) and have motorists cross the (imaginary) bike lane to proceed into the right-turn-only lane;
- ❑ At multi-lane intersections with parking lane that becomes right-turn-only lane, discontinue bike lane in advance, let bicyclists weave into narrower adjacent straight-through lane and if space available, provide short bike lane just before the intersection;
- ❑ At optional double-right-turn lane, let cyclists weave into middle of second right-turn lane (combined through lane);
- ❑ When a right lane becomes a right-turn-only lane, drop the bike lane stripe where the right-turn-only is designated and create a weave. Cyclists will position to the left of the right-turn-only lane (optional bike lane striping just before the intersection).

At wide radius curb return intersections in New Jersey dashed through bicycle lanes are generally considered with "share the road" signs in advance and "yield to bicyclists" signs on the approach.

Oregon specifically cautions right-turn lanes for motor vehicles and suggests they shall only be used where warranted by a traffic study (as done in New Jersey). If they exist, the bike lane, as in New Jersey and AASHTO, is placed between the straight and turn lane and a weave between bicyclists and right-turning vehicles is created prior to the intersection. Oregon makes the exception for situations where major traffic movement is to the right, and the straight through move leads to a minor side street. In such cases the bike lane is normally placed on the right and wrapped around the curve, assuming the majority of cyclists will desire to turn right too. The graphics below show additional guidance from Oregon.

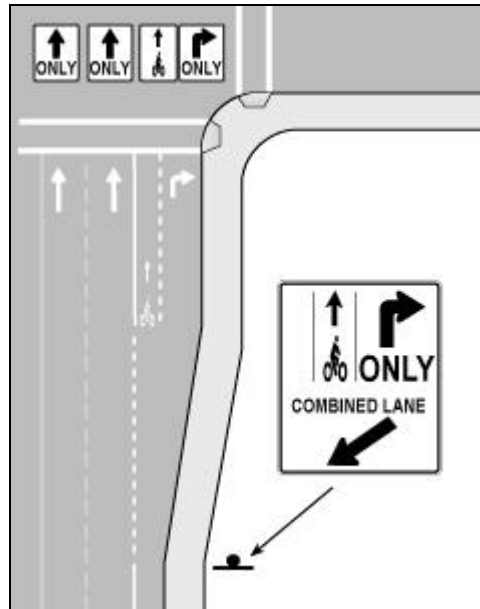


Figure 2: Joint use of a right-turn lane for through bicyclists.

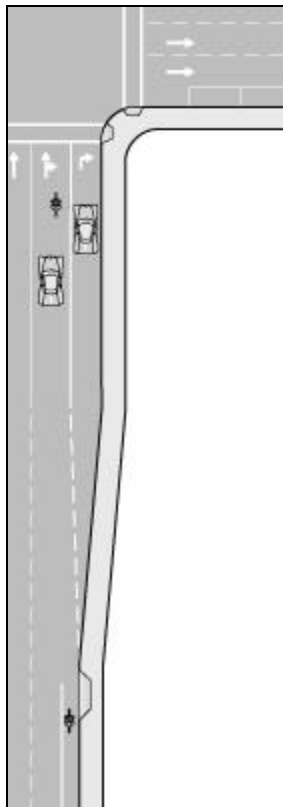


Figure 3: Design encourages cyclists to share the optional through/ right-turn lane with motorists.

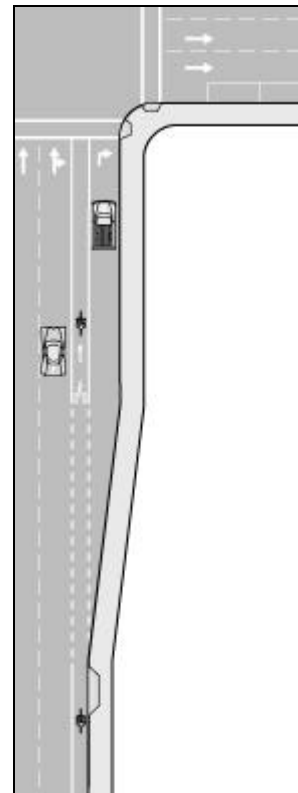


Figure 4: Design guides cyclists up to the intersection in a dedicated bike lane.

Source: Oregon DOT Bicycle and Pedestrian Plan

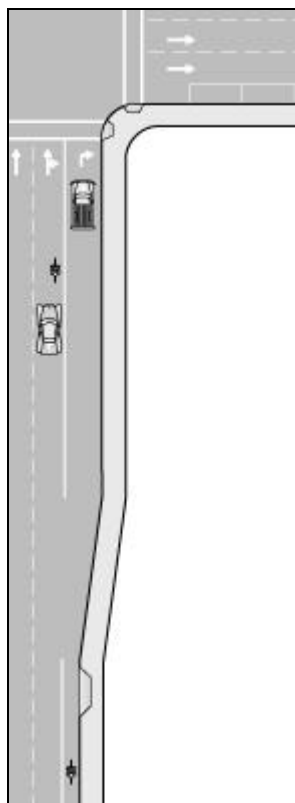


Figure 5: Design makes cyclists choose a path themselves by dropping the bike lane prior to the intersection (AASHTO recommendation).

Source: Oregon DOT Bicycle and Pedestrian Plan



Figure 6: Bike lane through dual right-turn lanes with island.

European Guidelines consider free right-turn lanes for motor vehicles with safety islands and no signal, particularly dangerous for cyclists (and pedestrians) who are proceeding straight. Such practice should be avoided.

Left-Turning Cyclists

At intersections with numerous left-turning cyclists, a separate turning lane for cyclists is sometimes considered. The guidelines also recommend implementation of advanced stop lines to provide a stopping area for cyclists in front of motor vehicles at signalized intersections and recessed stop lines for motor vehicles where priority needs to be given to cyclists. Both practices are considered very beneficial in that they allow cyclists to proceed in front of traffic, thus getting a head start when the signal changes, increasing their visibility by motorists and preventing cyclists from waiting in the exhaust fumes of motor vehicles. Advanced waiting

areas are especially beneficial for left-turning cyclists. Although these provisions are easy to implement since no roadway widening or paving is required, they have hardly been made for cyclists in New Jersey.

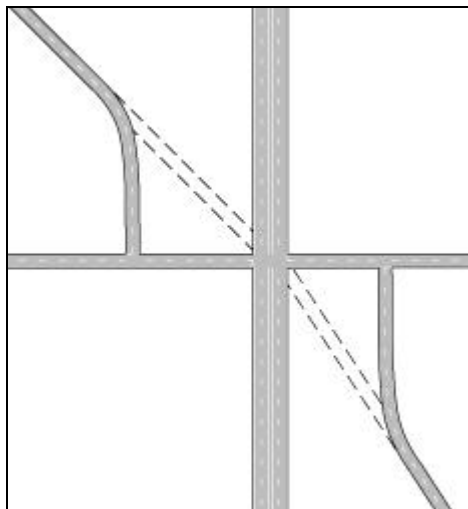
Specifics form Oregon

Oregon's Plan offers additional guidance and recommendations on the issue of getting bicycles through intersections especially for the more critical crossing- and turning maneuvers.

Difficult Situations

The Oregon Plan recommends designing existing skewed intersections closer to a right angle. And, although Oregon does not specifically distinguish intersection treatments based upon road function, speed, and volumes, it does include recommendations specifically for interchanges. For rural area interchanges it suggests providing adequate shoulder width to accommodate bicyclists. In urban and suburban areas non-interchange crossings of freeways are recommended if minimal out-of-direction travel and grade changes can be ensured.

Oregon further suggests that multiple intersections are undesirable for all roadway users and every effort should be made to have only two roads cross at a given point.



**Figure 7: Multiple intersections reconfigured to right-angle.
Source: Oregon DOT Bicycle and Pedestrian Plan.**

Dashed bike lanes are sometimes considered to guide bicyclists through long undefined areas. Configuration of multiple intersections into roundabouts is also suggested in Oregon.

On urban parkways with merging lanes on the right, Oregon suggests leading cyclists over at close to a right angle to create a much shorter crossing across the ramp.

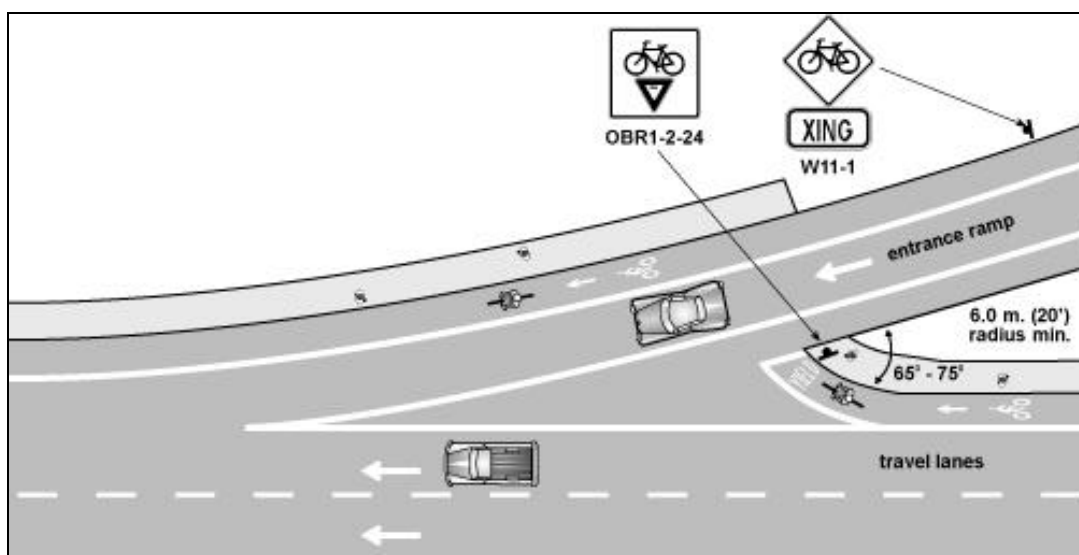
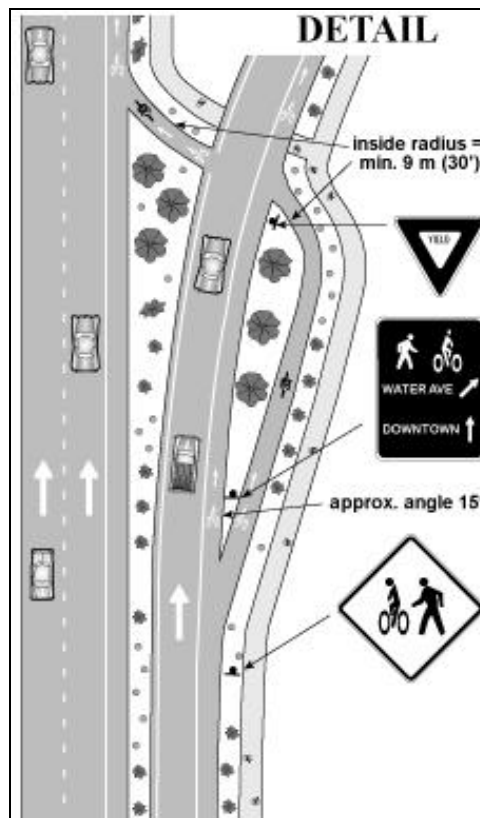
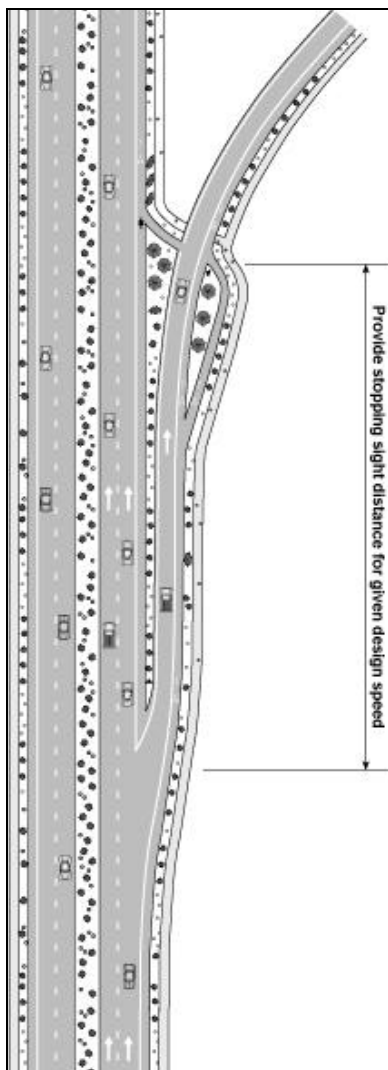


Figure 8: Right-lane merge – bike lane and sidewalk configuration (urban design, not for use on limited access freeways). Source: Oregon DOT Bicycle and Pedestrian Plan.

This also allows crossing in an area where the driver's attention is not entirely focused on merging with traffic. At exit ramps leading the cyclist over at close to a right angle is recommended.

Grade separated crossings are only considered if there are no other options to provide a safe at-grade crossing; and, it can be ensured they will be used by the vulnerable road users such as cyclists and pedestrians.

The New Jersey guide does not address interchanges and AASHTO only provides a brief paragraph that recommends either a close to right angle crossing or no provisions at all to simply let the cyclists choose for themselves.



Figures 9 & 10: Ramp configuration for bike lanes and sidewalks (urban design, not for use on limited access freeways).

Source: Oregon DOT Bicycle and Pedestrian Plan.

In Oregon at T-intersections a bike lane is generally dropped prior to the lane split of motor vehicle traffic to allow cyclists to position themselves in the correct lane; where traffic volumes are very high, a left- and right-turn bike lane is considered.

Colored Bicycle Lanes

Interestingly, in 1997 the City of Portland, Oregon was the first American city to use the technique of colored markings at bicycle-motor vehicle crossings in an attempt to reduce conflicts through increased visibility/ awareness. Although the provisions in Portland have improved safety and enhanced visibility of cyclists, they have yet to become common practice

throughout the U.S. This is not necessarily surprising since the general advice is simply to merge motor vehicles and cyclists at intersections and thus not provide any designated crossing facility. Colored cycle crossings are however very common practice in many European cities, which has resulted in increased safety of cyclists at intersections. The Danish guide reports on an accident study of cycle crossings at signalized intersections. The study shows that the marking of cycle crossings has led to a 36% reduction in the number of bicycle accidents and as much as 57% in the number of severely injured cyclists.^{vii}

Some of the more detailed guidance and recommendations as outlined in Oregon's Plan, especially on the issue of getting bicycles through the more difficult intersections, can be very helpful for future application and consideration in New Jersey. In addition the following section provides a review of European practice, guidance and standards on getting bicycles through intersections. It should be noted that these guidelines are much more specific in that they consider and distinguish between speed and volumes in addition to number of lanes and turning movements.

Additional Guidance from Europe

In Europe it is common and usually recommended to continue facilities for cyclists through intersections. Providing colored crossings, the bending out of cycle facilities at intersections, and preferential signal timing and detection are all very common provisions. The following section provides a summary of findings and recommendations based upon review of intersection treatments to accommodate bicyclists in The Netherlands, Germany and Denmark. Prior to this discussion it is important to note that one of the most common cycle facility implemented in these European countries is the cycle track. Cycle tracks are often located immediately adjacent to the roadway where there is considerable amount of traffic and speeds, and the cyclists and motor vehicles are at minimum separated from each other by a curb. Although, as mentioned earlier in this report, controversial research exists concerning such facilities, it is safe to say that cycle tracks at minimum lower perceived risk, thus reduce cyclists stress levels and therefore encourage bicycling. If well designed and located on appropriate roadways, cycle tracks enhance cycling conditions much more than bicycle lanes, wide outside

^{vii} Collection of Cycle Concepts, Road Directorate, Denmark, 2000.

lanes or shoulders. Although working with the same right-of-way width, implementation of cycle tracks can have a traffic calming effect by making the road appear narrower. Whereas not crucial for the regular and more advanced riders, cycle tracks seem essential to encourage the young and less advanced people to ride. Finally cycle tracks can also simply add to the aesthetics of a roadway's streetscape as they tend to make the roadway appear much narrower compared to a painted stripe on a road. More details on cycle tracks and other European practice and standards are provided in Appendix I.

In Denmark, The Netherlands and Germany, cycle facilities are generally continued across an intersection, for example as a blue cycle crossing, or on a separated track/ path designated for cyclists.



Picture 11: Blue bike lane crossings marked through intersection. Note: Cyclists get a head start due to recessed stop line for motor vehicles in right-turn lane. (DK)



Picture 12: Blue bike lane crossing marked through intersection. (DK)

The German guidelines specifically suggest marked cycle lanes through an intersection:

- on two-lane roadways with vehicular volumes of 18,000 vpd or less; and
- on four-lane roadways with vehicular volumes of 25,000 vpd or less.

Beyond these volumes through bicycle lanes are not considered safe enough for cyclists at intersections and ***other treatments become necessary, such as a separated, designated and signaled paths through the intersection.***



Picture 13: Separate cycle facility at signalized intersection, The Netherlands. (PS)



Picture 14: Separate cycle facility at signalized intersection, Germany. (MK)

In very low speed zones (approximately 20mph), generally no special treatments at intersections are provided, however, if a bicycle facility exists on the approach, it is recommended to continue it through the intersection, even in low-speed zones and minor side roads, with a moderate amount of traffic.



Picture 15: Cycle track continued as colored lane through intersection. (MK)

For priority intersections on primarily 4-lane roads, the Danish guide recommends leading the cycle track away from the main road (bending out) over a side road and sometimes over a raised surface.

Common practice is also to provide a short cycle lane over the last approximately 65-165 feet prior to a signalized intersection on a mixed traffic roadway. Thus, cyclists are given their own area, which results in lower perceived risk and greater ease of passage. This also makes it possible to mark a cycle crossing through the intersection.

As previously mentioned, cycle tracks are sometimes led some distance (approximately 16-26 feet) away from the road and then lead over the side road sometimes on a raised surface. This provides a streaming space between the main carriageway and the bicycle crossing. Such outward displacement of a bike path at an intersection has the benefit that turning cars encounter cyclists after, not during their turning maneuver, thus ensuring greater visibility. The Dutch guide suggests that the widely bending out of cycle tracks (\Rightarrow 50 feet) in combination with the removal of right-of-way must be avoided from the point of view of cyclists' comfort. A bicycle crossing at more than 50 feet from the intersection is only considered acceptable in situations where the cycle track lies far from the parallel running main roadway and is no longer regarded as a component of the same road.



**Picture 16: Bend-out cycle track and sidewalk
(urban setting). (DK)**



**Picture 17: Bend-out cycle track
(suburb of Amsterdam). (PS)**

If bicycle facilities are provided on the approach and if bending out is undesirable or impractical it is common to bring bicycle travel as close to the motor vehicle lanes as possible to increase visibility at intersections, thus, cycle tracks especially at priority intersections are interrupted (except where many child cyclists are expected, in which case greater safety measures are taken). In this scenario lanes or crossings are still provided through the intersection except if the provision of such facilities is not possible in which case motor vehicle speeds are reduced, if possible.



Picture 18: Interrupted cycle track.



Picture 19: Merge with right-turning vehicles long before the intersection.



Picture 20: Cycle track becomes broken bike lane before intersection with right-turn motor vehicle lane.



Picture 21: Blue Crossing.

Sources: (DK)

To allow safe turning movements by cars and bicyclists at intersections, weaving is generally encouraged far in advance of an intersection. However, the Dutch guide specifies:

"For a safe weaving movement between cars and bicycles, the speed difference should not be more than about 6mph. Taking the average speed of cyclists to be 12mph, this means that the average speed of motorized traffic in the area of weaving should not be higher than about 20mph."

To ensure a safe weaving movement, cyclists are generally not allowed to cross more than one traffic lane. In addition cyclists turning left by crossing the path of motor vehicles proceeding straight is not applied at major road intersections with speeds greater than 30mph. At intersections with traffic lights cyclists turning left generally have the opportunity of crossing in two stages (as a pedestrian) besides the possibility of weaving (for children and the elderly).

The weaving length depends on the speed and volumes of motorized traffic and usually varies from 100 -197 feet on controlled and un-controlled intersections in Europe. If the approach cycle facility has a buffer, such as trees or a planting strip, such buffer is also interrupted in advance of the intersection to increase visibility. On roads with many junctions - basically all roads with a desired speed below 35mph - such buffers/ dividing verges are usually not implemented. Additionally to ensure visibility of bicyclists by traffic on the side roads and turning motorists on the major road, stopped buses and parked cars generally are not permitted closer than about 65 feet before or after an intersection. Downhill, the distance increases up to about 100 feet, depending on grade.

In Germany straight-through motor vehicle lanes that become right-turn lanes at intersections are avoided to prevent dangerous lane shifts by cyclists. Another option that is common at intersections is a left-turn cycle lane provided next to a left-turning motor vehicle lane (compare pictures 22 and 23).



Picture 22: Cycle lane for left-turning and right-turning cyclists. (DK)



Picture 23: Broken cycle lane through intersection, Germany. (MK)

European practice includes the following treatments and recommendations for right-turning cyclists at intersections:

- ❑ Cyclists turning right at uncontrolled intersections are hardly ever involved in accidents. No separate facilities are necessary.
- ❑ Priority treatments are provided at signalized intersections to ensure expediency and comfort. Where there is enough room, such treatment includes designated turn lanes established for cyclists before the signal, so they can avoid the light, and / or separate signals.



Picture 24: Pre-right-turn for cyclists to avoid signal, but not pedestrians. (DK)

- ❑ If the cycle route carries on straight ahead, additional facilities for cyclists turning right are less crucial; cyclists turning right then benefit from the priority ruling of the cyclists proceeding straight ahead.

In Europe cyclists' safety is also commonly increased through the establishment of advanced stop boxes, generally marked with bicycle symbols, in front of the stop line for motor vehicles. As mentioned previously, such stopping areas especially benefit left-turning cyclists, and, in Europe, they are generally recommended at intersections that have two- or less approach lanes. This is often accompanied with an advanced cycle green phase prior to motor vehicle green phase so cyclists can clear the intersection first and avoid conflicts.



Picture 25: Advanced Stop Box, Koeln, Germany. (MK)



Picture 26: Advanced Stop Box. (DK)

In addition, staggered stop lines (recessing the stop line for motor vehicles while bringing the stop line for bicyclists up to the crosswalk) is also a very common practice to enhance cyclists safety at intersections due to increased visibility of cyclists by motorists. Both practices are used in mixed traffic situations as well.



**Picture 27: Staggered Stop Lines, Munich, Germany.
(MK)**



**Picture 28: Staggered Stop Lines, Cologne, Germany.
(MK)**

A refuge island is sometimes provided where cyclists may not be able to cross or turn left during one signal phase. Such situations are, however, avoided whenever possible. A minimum width/ length of a safety island should be 6 feet, 8 feet desirable.^{viii}



Picture 29: Refuge Island/ Median) at unsignalized crossing. (MK)

^{viii} The average bicycle length is about 6 feet, therefore a minimum refuge island width of 6 feet is recommended herein.

The Dutch guide also provides very detailed suggestions on the issue of right-of-way. These include:

- ❑ Policies aimed at promoting bicycle-use should give right-of-way to cyclists to minimize waiting times and increase the chance of continuance to enable the cyclist more efficient travel.
- ❑ If a through cycle route runs on or alongside one of the crossing roads, right-of-way should favor cyclists regardless of volume of cyclists.
- ❑ If a distributor cycle route (cyclists will make a turn) runs on or alongside one of the crossing roads, right-of-way should favor cyclists if bicycle volume is higher.
- ❑ On access cycle routes right-of-way for cyclists is not necessary.
- ❑ Within built-up areas, cycle-tracks with their own alignment may be given right-of-way over crossing traffic (without speed-limiting measures), when the road concerned has a limited function and a maximum peak-hour volume of 250mvl/hour at low speeds (85th percentile ≤ 30 km/h (20mph)).
- ❑ In situations where the 85th percentile lies between 30 and 50km/h (20 and 30mph), the speed of motorized traffic can best be reduced by implementing speed control humps positioned at the bicycle crossing. This solution is applicable on roads with a moderate traffic function and a peak hour volume of 400 to 600 mvl/hour. With higher speeds on the road to be crossed, bicycles can no longer force a right-of-way.
- ❑ If a through cycle route crosses an access bus route, bicycle traffic is given right-of-way over bus traffic; If the bus route coincides with a road for motorized traffic, the conditions for a junction of a cycle route and a road for motorized traffic apply.
- ❑ At junctions traffic should yield right-of-way to traffic coming from right. It is desirable that on all roads within built-up areas with a max speed ≥ 50 km/h (30mph) the right of way is regulated by traffic signs and/ or road marking. This means that it is very desirable, from the point of view of promoting bicycle use, to (re-)designate a residential area as an estate area with speeds of ≤ 30 km/h (20mph) and possibly introduce 30km/h (20mph) zones.

Finally, common practice in Europe is to provide special signal timing and detection for cyclists at intersections. The following are common implementations:

- ❑ Junctions with left-turn stage for motorists reduce the number of accidents between left-turning vehicles and oncoming cyclists at large junctions with many traffic lanes.

- ❑ At junctions with tracks or lanes to the stop line, a separate cyclist signal can reduce accidents between both users.
- ❑ The optimal way to detect cyclists is to establish a combination of loop detectors and a separate cyclist push-button placed on a low post at the stop line.
- ❑ By inserting loop detectors in the cycle track/ lane some distance before and closer to the stop line, cyclists can be detected sufficiently early for the signal to change from red to green; or, by extending the green time so that the cyclist does not have to stop.
- ❑ At some junctions, cyclists turning left can be detected only by placing loop detectors in front of the stop line. To prevent crossing cyclists from activating the signal unnecessarily, the loop detector must be activated for at least two seconds.

Conclusion

While there may be no single solution, either in the U.S. or Europe, to accommodate cyclists in general or specifically at intersections, what we find in Europe is a much wider range of measures and facilities as well as more definitive guidance. Bicycle safety concerns and problems are much more systematically approached and solutions are identified based upon places and target groups, to ensure greatest impact of implementations. A greater prevalence of juvenile and elderly cyclists throughout Europe also has a more noticeable impact on the types of facilities provided. A significant difference to current practice in the U.S. is in fact, that children are often the primary target group of bicycle planning efforts in Europe. Although a common goal is to attract car drivers and passengers to cycling, the Danish guide states: "It demands considerable resources to transfer inveterate car drivers to cyclists, so try to forget them as a target group".

The cycle culture is based on a regular accession of new cyclists, thus enhancing safety and comfort for children is one of the most important goals. While sidewalk riding is generally accepted at a very young age, older children often prefer to cycle in groups or at speeds that are undesirable on sidewalks. However, children do not have the same perception of dangers in traffic as adults do and often ride fearless and with less caution. Thus, greater safety and separation than provided through on-road bike lanes, wide shoulders or outside lanes, often becomes essential. The same holds true for other potential riders such as the elderly, the

cyclist that is not interested in developing vehicular cycling skills to maneuver complex traffic situations for the occasional ride to the store downtown, the person riding with a child in the back or front of the bicycle, etc.

Caution however needs to be exercised. Construction of separate bicycle facilities should not reduce the political impetus to make the existing road network more suitable for cycling. In the past the focus on bicycling expenditures on off-highway and recreational facilities seems to have deflected attention from the need to improve roadways for cycling.

What currently exists in New Jersey is a relatively small population of cyclists with a small growth trend. This growth trend could change dramatically by including a wider range of options for municipalities, engineers and implementation agencies to choose from along with comprehensive guidance. In short, safe and accessible cycling facilities will attract more riders and more riders will attract more riders.

Appendix I

European Practice

A major observation made within this report was that although several facilities are similar, the European guidelines are much more comprehensive. They recognize the complexity of roadway conditions and as a result cover a much greater range of situations and options. This is not really surprising given that cycling has for a long time been part of the mainstream of transportation and that there is a greater familiarity with different situations. However, it is important to understand that a lack of detail in bicycle planning can result in poorly developed and underutilized facilities. It should also be remembered that cycling in these European countries was systematically encouraged as countermeasures to growing automobile congestion and pollution and fear of losing livability within communities and cities. Cycling does not just happen by itself – provisions need to be in place first.

The following section provides further review of some of the International standards and practices that could be applied in New Jersey; it is by no means a complete observation of practices used abroad but provides some of the most applicable opportunities for New Jersey.

Cycle facilities used for separation found along roads in Denmark include:

- Cycle Lanes
- Cycle Strips
- Cycle Tracks

Although cycle lanes – separated from motor vehicles by a painted line and at the same level as the roadway - are a common way of designating roadways for cyclists in New Jersey. In Denmark, cycle lanes are applied on streets with only few cyclists and with limited space. It should be noted that the Danish guide considers mixed traffic to be safer than providing narrow bicycle lanes.

Another cycle facility used for separation in Denmark is the cycle strip, which is a marking of the area close to the curb of the roadway. The area is marked with a color, red for example.

The cycle strip can be created as an improvised solution in places with only a few cyclists, with limited space and in cases, which do not allow (according to the regulation) the marking of a cycle lane. The selected color is not a road marking and thus legally it is not a bike lane but a visual signal to car drivers to drive at a suitable distance from the curb, and it is a signal to the cyclist to ride close to the curb.



Picture 30: Cycle (Safety) Strip

Source: ADFC Germany

Probably the most common facility implemented in Denmark and other European cycling nations is the cycle track. Cycle tracks are often located immediately adjacent to the roadway where there is a *considerable amount of traffic*. The cyclists and drivers are at minimum separated from each other by a curb. The curb can be, - but does not necessarily have to be mountable, depending on the width of the bicycle track and bicycle volumes. Such facility design is similar to a sidewalk design but it is not considered part of a sidewalk. Often the sidewalk and raised bicycle facility are also at different levels and/ or consist of different pavement or are separated from each other by a different pavement strip or marking. Another separation used (primarily in rural areas) between the roadway and cycle track and sometimes between the cycle track and sidewalk is a narrow planting strip (dividing verge). Designed as such, this buffer is safer and more attractive than a broad paved shoulder or wide outside lane.

Cycle tracks have been widely used for separation throughout Europe but seem to be missing not just on our streets but also within our guidelines. It is not surprising then that such a facility is not implemented here - although in Denmark and other European countries it is generally considered to be safer than bicycle lanes or wide outside lanes.

One reason for the lack of barrier- or otherwise separated urban bikeways such as cycle tracks goes back to the early 70's, when proposals to designate sidewalks as mandatory-use bikeways provoked a strong counterattack by bicycle club members who had been using the roads. The leader of this movement, John Forester, promotes the principle of "vehicular cycling", which suggests that cyclists should practice and obey traffic laws applicable to drivers of vehicles. It further suggests that cyclists should also be treated by other drivers and by law drivers of vehicles (Forester, 1993). The principle for example demands that cyclists should ride in the roadway with the flow of motor traffic, obey traffic control devices, pass on the left, and make left turns from the left lane. Roads should be designed and maintained with the operating requirements of a bicycle in mind, and motorists should be educated to treat cyclists as lawful users of roadways (Forester, 1993, 1994).

The suggestions of vehicular cyclists are often based upon their belief that most bikeways are unnecessary for bicycle transportation and instead want existing roads improved for cycling through better surface quality, bicycle-detecting sensors, wider lanes on high-speed roads, etc. Vehicular cyclists commonly oppose separated paths or designated bicycle lanes on the grounds that they make cycling slower and more dangerous.

Critics, however, counter that few people are interested in working to develop vehicular cycling skills (Wilkinson et al., 1994; Wilkinson, 1998b). They further argue that most people will not even attempt to cycle unless they have designated facilities available to them, separate from motor vehicle traffic.

In Europe, the desirability of barrier-separated urban paths has also become under question but in different dimension. While separate paths have helped to encourage high levels of cycling, concerns have grown over intersection conflicts especially with right-turning motor vehicle traffic as well as the costs to maintain and construct the facilities. Contrary to the US, these concerns have lead to a more comprehensive approach by European cycle planners that now generally recommend a range of solutions depending on the circumstances. For example Danish and

German governmental guidelines for bicycle facilities differentiate according to criteria such as volume of motor vehicle traffic, average vehicle speed, level of truck traffic, volume and mix of bike traffic, roadway width, parking turnover and frequency of intersections (German ministry of Transport, 1995; Danish Road Directorate, 2000). Separate paths are recommended for roads with traffic volumes over 18,000 vehicles per day, or where bus and heavy truck volumes exceed 1000 vehicles per day, or where average speeds exceed 60km/h (37mph). These volume and speed criteria can be overridden by intersection criteria. On stretches of roadway where frequent intersections and private driveways raise the potential for conflicts, bike lanes tend to be preferred to paths. Conversely on streets with high parking turnover and frequent curbside deliveries, bike paths are preferred because vehicles are likely to block bike lanes and cause accidents when pulling in or out. Paths are also recommended where overflows from bike lanes during peak cycling traffic could lead to collisions with fast motor vehicles. And, prevalence of more young and elderly cyclists also turns recommendations towards paths instead of bike lanes.ⁱ

The following provides more detailed information on when and how cycle tracks are being used in Denmark but also Germany.

The table below shows recommended- and recommended minimum width of the different facilities used for separation in Denmark.

	Recommended Width	Recommended Minimum Width
Cycle Track	7.2 feet (2.2m)	5.6 feet (1.7m)
Cycle Lane (incl. 1 ft wide strip)	5 feet (1.5m)	4 feet (1.2m)
Cycle Strip	-	2 feet (0.6m)

Table1: Recommended Width and Minimum Width

ⁱ Pucher, J., Komanoff, C., Schimek, P., Bicycling Renaissance in North America? Recent Trends and Alternative Policies to Promote Bicycling, Transportation Research Part A 33 (1999) 625-654.



Picture 31: Cycle track in Denmark (MK)



Picture 32: Cycle track in Germany (MK)



Picture 33: Cycle track in The Netherlands (PS)



Picture 34: Cycle track in Germany (MK)

In Denmark about 2,200 miles of cycle tracks have been implemented in urban areas compared to about 310 miles of cycle lanes. In rural areas about 994 miles of cycle tracks and 218 miles of cycle lanes have been implemented. (The total length of the road network in Denmark is approximately 47,224 miles, of which 39,768 miles are municipal roads primarily situated in urban areas.) Although cycle tracks are more expensive, in Denmark, The Netherlands and Germany they are preferably implemented in both, urban and rural settings. Cycle tracks have not been implemented in New Jersey most likely because the facility is not defined within the New Jersey guideline and not within the AASHTO guide. The Oregon DOT Bicycle Master Plan comes close to cycle track facilities within its Innovative Design section and refers to them as "raised bike lanes". In Oregon no raised bike lanes have been implemented yet, however, they are currently considered for implementation on two local streets. Oregon DOT refers to both as good uses, as the roads are busy enough to justify bike lanes but the residents do not want a

street that feels and looks too wide. The raised bike lanes will also help deflect fears of encroachment on the inside curves due to curvilinear roadways.

Referring to ODOT, the biggest downside of raised bike lanes is cost:

- ❑ The curb itself will be in the roadway and is expected to be driven over by trucks, therefore it has to be set on a substantive basis;
- ❑ Paving the roadway and the bike lane separately – the paver needs a special attachment to pave only 5 feet for a bike lane;
- ❑ Placing and maintaining drainage grates in the travel lanes.

In Denmark, Germany and The Netherlands a cycle track can also have an extruded curb whereas Oregon does not recommend such separation. (See pictures 35 & 36).



Picture 35: Recommended facility in Denmark (DK)



Picture 36: Not recommended facility in Oregon. Oregon DOT Bicycle and Pedestrian Plan

The closest the AASHTO and New Jersey bike guidelines come in terms of defining an equivalent facility to the European cycle track is a shared use path, bike path or shared use of sidewalks - but cycle tracks as used in Europe are not the same as bike paths or shared use paths. In fact, European practices also provide guidelines on bicycle path design. Thus, a cycle track is a facility between separate paths and bike lanes, providing greater separation than bike lanes, but not intended to lead cyclists along a scenic route away from the roadway. Cycle tracks are used in urban areas, adjacent to the roadway and considered the preferred cycle facility – not a supplement such as a bike path or shared use path. Furthermore cycle tracks are generally one-way when used in Europe, but provided on both sides of the roadway to discourage wrong-way cycling, just like bike lanes. Cycle tracks are designated for cyclists and not considered part of a sidewalk.

Cycle track design is presently not included in the New Jersey guidelines but might be a significant enhancement if it were to be prescribed.



Picture 37: Cycle track in Germany (MK)



Picture 38: Cycle lane in New York (MK)

Comparing images 37 and 38 it is apparent that cycle tracks vs. lanes, at a minimum, reduce the perceived risk a cyclist may feel when riding adjacent to motor vehicles. This is also stated within the Oregon Bicycle and Pedestrian Plan. In addition existence of a low mountable curb alerts motorists when they are straying from the travel lane. The roadway width seems narrower than with striped bike lanes and therefore may reduce speeds. The curb also encourages 1) motorists to travel further to the left, away from the curb (and thus away from the cyclists) due to fear of damaging their tires, and 2) people to ride further to the right, away from

motor vehicle traffic rather than too close to traffic. Finally, novice bicyclists are more likely to ride on the raised bike lane, leaving the sidewalk for pedestrians (Oregon Bicycle and Pedestrian Plan, 1996). Not providing these facilities may be one reason why we do not see many young cyclists as well as occasional adult riders and senior citizens.

The graph below shows an example of separation principles from the Danish guideline. It recommends different facilities based upon various volume and speed conditions.

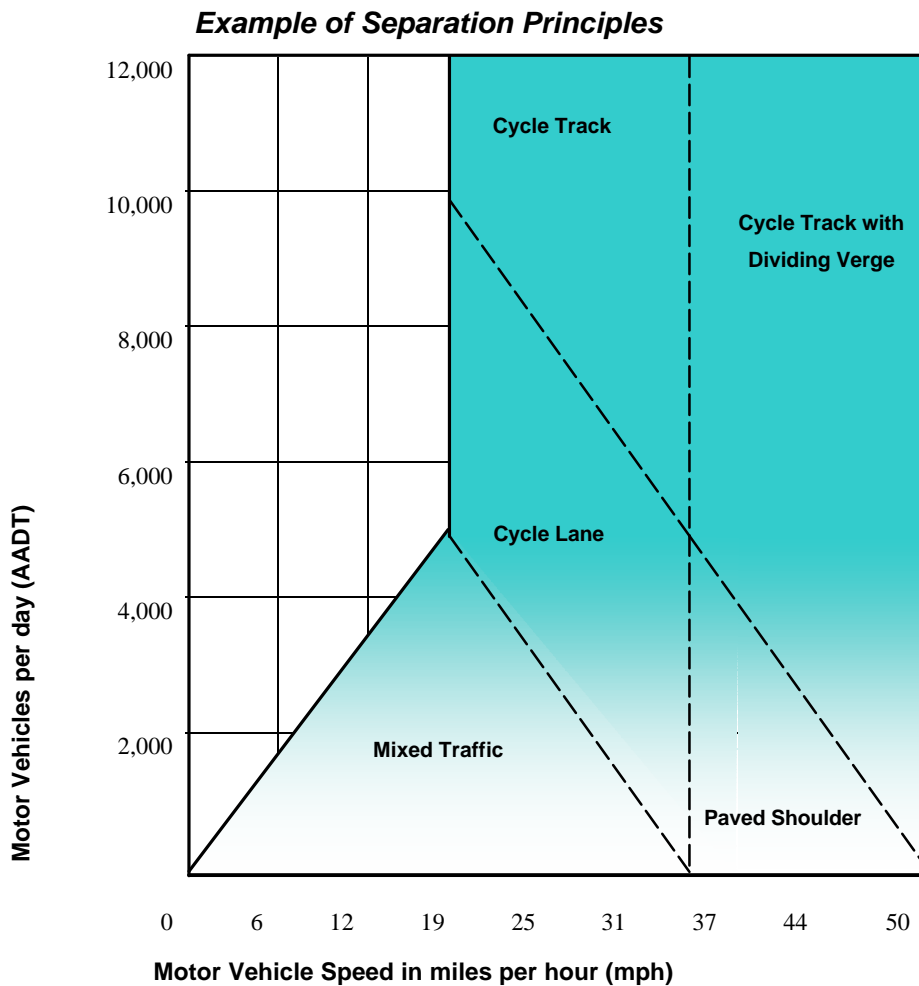


Figure 11: Example of Separation Principles in Denmark (DK)

Appendix II

Summary of Findings and Recommendations

The following is a summary of findings and recommendations for bicycle facilities to consider for implementation in New Jersey. These findings and recommendations are based on a comprehensive study of bicycle facilities done by TPI for the NJDOT. Whereas most of these facilities and practices will be seen as just innovative at this time, it is recommended to encourage further research with the goal of including the facilities and practices within our future standards. Furthermore it should be noted that the recommendations are solely recommendations and not specific in their definitions. Prior to implementation of any of these facilities additional study and consideration of the existing environment and conditions at the exact location is strongly suggested.

Cycle Tracks

Cycle tracks are designated cycle facilities and should be located immediately adjacent to the roadway where there is considerable amount of traffic. The construction of cycle tracks appears to have a modest traffic calming effect on both cyclists and motorists. Generally a curb (depending on speed and volumes) should separate cyclists and drivers as well as cyclists and pedestrians from each other.



Picture 39: Ingolstadt, Germany (MK)



Picture 40: Mainz, Germany (MK)

Cycle tracks with curb separation

- ❑ If speeds between 20-37 mph, and
- ❑ if volumes greater than 5000 AADT.
- ❑ Function well on roads with signalized intersections and minor side roads.
- ❑ Curbs should be extensively used on urban land service highways if there is a considerable amount of traffic and speeds are greater than 30mph.
- ❑ Curbs should also be considered for speeds between 20 and 30mph, especially with high traffic volumes.
- ❑ With high traffic volumes and many parked cars it is often a good idea to separate motor vehicles and bicycles by implementing cycle tracks.
- ❑ On free sections of road, curb heights along the carriageway should measure between 7 and 12cm and between 5 and 9cm between the cycle track and sidewalk. These heights give a number of advantages. Most motorists refrain from parking on the cycle track. Vehicles exiting and entering properties take place at low speeds and drainage functions well. Cyclists rarely cycle on the sidewalk, and pedestrians notice when they leave the sidewalk (avoids collisions with cyclists).



Picture 41: Amsterdam, The Netherlands (PS)



Picture 42: Germany (MK)

A bicycle lane may be a solution if motor vehicle speeds are 30mph or less, only moderate traffic volumes and modest need for parking. Such lanes can reduce a perceived risk by cyclists if it has different pavement or color (see 'Color Paved Lanes' section).

Curbs should not be implemented on high-speed roads, buffers/dividing verges should be

considered here.

Cycle tracks with dividing verge separation (edge, border such as grass)

- ❑ If speeds greater than 37mph, and
- ❑ if volumes greater than 5000 AADT (or lower if speeds are high), and
- ❑ if few intersections.

Cycle Track Width

- ❑ 7 feet recommended
- ❑ 5.5 feet minimum.

Accident risk for cyclists falls with increased width of cycle tracks and increased width of separating verge on highways. For cycle tracks that are part of a separated cycle-footway the widths should be 6 feet and 5 feet respectively.

Cycle tracks should be the priority bicycle facility implemented throughout New Jersey. Cycle tracks improve safety, comfort and lower perceived risk. Cycle tracks also enhance level of service experienced by cyclists twice as much as cycle lanes and can lead to more bicycle traffic. Separated bicycle facilities (by curb or other barrier) are highly recommended in higher speed and high volume - mostly rural - areas.



Picture 43: Cycle track with dividing verge, Germany (MK)



Picture 44: Cycle track with dividing verge, Denmark (DK)



**Picture 45: Cycle track with dividing verge,
Denmark (DK)**



Picture 46: Cycle track with dividing verge, Denmark (DK)

Separated bicycle facilities are generally considered safer than striped bike lanes, however, minimum design standards must be met for these facilities to be safe, otherwise bike lanes could provide greater safety in some situations.

Bike Lane

- If low speeds, 30mph or less and,
- if low volumes, 8000 AADT or less, and
- if only modest need for parking, and
- on urban roads with no shops and few intersections.

Bike Lane Width

- 4 feet absolute minimum and only if no parking;
- 5 feet recommended minimum and if adjacent to parking;
- 6 feet if high cyclists volumes to provide reasonable overtaking conditions.

Mixed Traffic

- In urban settings only,
- if desired speed 20mph or less, and
- if low volumes, 5000 AADT or less,
- if many intersections (crossing facilities recommended),
- downhill before an intersection.

- ❑ The travel lane shall be at least 10 feet wide;
- ❑ 11 foot lanes for designated truck routes;
- ❑ 12 foot lanes for designated bus routes.



Picture 47: Mixed Traffic with parking (DK)



Picture 48: Mixed Traffic (DK)

Mixed travel is a solution when the width for a cycle track or lane is not available and volumes and speed allow for mixed travel. However, marking of safety stripes (marked for cycle use but also usable by motor vehicles) is always recommended.

Paved Shoulder

- ❑ If low volumes, 6000 AADT or less,
- ❑ if speeds 50mph or less, and
- ❑ if only few expected cyclists.

Broad paved shoulders may be a solution in small towns with through traffic and few expected cyclists and on highways with limited motor vehicle traffic. However, do not widen a roadway to provide a shoulder for cyclists; always consider implementing cycle tracks and sidewalks. Shoulders on land service highways are not necessary and the space should always be considered for sidewalk and bicycle facility implementation.

Paved Shoulder Width

- ❑ 3 feet minimum including edge line.

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Picture 49: Broad paved shoulder (DK)



Picture 50: Paved shoulder and Bus Bay (DK)

Wide Outside Lane

- If there is no other option to provide minimum separation, and
- if speeds are ≤ 30 mph, and
- if only modest need for parking.
- Width shall be 14 feet.

Widening lanes on land service highways should generally not be recommended to accommodate cyclists. Instead, strong consideration should be given to the implementation of sidewalks and bicycle facilities.

Cycle Safety Strip

- Broken line or color marking (e.g. red) of the area close to the curb as visual signal to car drivers to drive at a suitable distance from the curb, and a signal to cyclists to ride close to the curb.
- Improvised solution in places with low cycle volumes and limited space, where a cycle track or lane is not possible to implement.
- If vehicular volumes are between 5,000-10,000 vpd,
- if truck traffic 500 per day or less (or less than 5%),
- if two-lane roadway width is at minimum 23 feet wide but no more than 28 feet, of which the width of the safety strip should be at least 4 feet (5 feet desirable), and remaining width for vehicular traffic is at least 15 feet but no greater than 18 feet.

- ❑ Recommended width 5 feet (1.70m), minimum width 4 feet (1.25m). (DK - 2 feet min.).



**Picture 51: Cycle Safety Strip
(ADFC)**

Bike lanes or safety strips are better than mixed travel (except where minimum width of lane or strip can't be provided and as a result speeds are reduced) and should be considered in conjunction with speed reductions or other safety measures whenever separated paths cannot be implemented.

Cycle-Footway

(Similar to cycle tracks but generally at grade with sidewalk and not separated by curb, however, different pavement often provided.)

- ❑ If moderate bicycle and pedestrian traffic, and
- ❑ if not much space.

Sidewalk Cycling

- ❑ If sparse bicycle and pedestrian traffic expected, and
- ❑ if not much space available.

- ❑ Possible for children.

Sidewalk Cycling Width

- ❑ 8.2 feet minimum in town/ villages/ urban areas
- ❑ 6.6 feet minimum in rural areas.



**Picture 52: Cycle-Footway with Effective Separation
(DK)**



Picture 53: Sidewalk Cycling (DK)

Color Paved Lanes

- ❑ Provide fewer disturbances for bicycle traffic from motor vehicles, and cyclists are positive towards it.
- ❑ Important on cycle lanes broader than 6 feet as these may be mistaken for parking or traffic lanes.
- ❑ Colored cycle lane pavement can be continued through intersections marked as a cycle crossing.



Picture 54: Blue Bike Lane Pavement (DK)

Parking

- ❑ Either parking should take place in parking lanes and bays or motor vehicle speed shall not exceed 20mph.
- ❑ Parking should not be placed on just one side of a roadway (except in one-way streets). Parking provided on just one side of a two-way roadway encourages dangerous crossing maneuvers by motorists and thus creates safety hazards for cyclists as well.
- ❑ Parking bays should be 8' wide.
- ❑ Prohibiting parking leads to accident reductions although it may increase speed.
- ❑ If parking is located between a cycle lane and a traffic lane, the cycle lane should be at least 7' wide.
- ❑ If angle/ perpendicular parking, speed should be ≤ 12 mph.

Finally, the following section provides recommendations based on the analysis of intersection treatments to accommodate bicyclists.

Intersections - Cyclists Proceeding Straight

- ❑ If speeds 20mph or less, generally no special treatment is necessary.^{vii}
- ❑ If mixed traffic (only recommended in low-speed (up to 20mph) urban or residential settings), a short cycle lane can be established over the last 66-164 feet (20-50m) before an intersection to lower perceived risk and provide greater ease of passage.
- ❑ Even in low speed zones, if bicycle facilities are provided on the approach, a cycle facility should continue through the intersection.



Picture 55: Cycle track continued as colored lane through intersection (MK)

- ❑ If speeds higher than 20mph, cycling facilities should generally be extended on or across an intersection especially at minor side roads and modest amount of traffic.
- ❑ A marked cycle lane extended through an intersection is beneficial:
 - If two-lane roadway and vehicular volumes 18,000 vpd or less, and
 - If four-lane roadway and vehicular volumes 25,000 vpd or less.

Beyond those volumes bike lanes are not safe enough.

^{vii} Note: Speed limits of 20mph or less are commonly applied in some European countries through traffic calming initiatives.



Picture 56: Blue bike lane crossing marked through intersection (DK)



Picture 57: Blue bike lane crossing marked through intersection (DK)

- ❑ Separated facilities should only be considered at signalized intersections, where bicycle travel has a separate green phase from turning motor vehicle travel. Such a provision shall not increase waiting time for cyclists.



Picture 58: Separate cycle facility at signalized intersection, The Netherlands (PS)



Picture 59: Separate cycle facility at signalized intersection, Germany (MK)

- ❑ At priority intersections on busy, possibly major 4-lane roads, consideration should be given to lead cycle tracks 16-26 feet (consider design vehicle) away from the road and lead it over the side road on a raised surface (see images 24 and 25).
- ❑ This (bending-out) provides streaming space between the main roadway and the bicycle crossing. If there is regular bus and truck turning movements, the bending out will be needed to meet such space requirements but should not exceed 50 feet.
- ❑ The widely bending out of cycle tracks (\Rightarrow 50 feet) must be avoided. This is only acceptable in situations where the cycle track lies far from the parallel running main roadway and is no longer considered part of that same road.
- ❑ Cycle tracks and lanes should be brought up to the stop line and continue, as for example a blue cycle crossing, provided there is a right turn lane for motorists (see images 27 and 28).



Picture 60: Bend-out cycle track and sidewalk
(urban setting) (DK)



Picture 61: Bend-out cycle track
(suburb of Amsterdam) (PS)



Picture 62: Merge with right-turning vehicles long before the intersection (DK)



Picture 63: Cycle track becomes broken bike lane before intersection with right-turn motor vehicle lane (DK)



Picture 64: Blue Crossing (DK)

- ❑ Staggered stop lines should be provided to make bicyclists and pedestrians more visible in connection with a signal change. (See images 65 & 66).
- ❑ Parked cars, stopped buses or any other obstructions should not occur closer than 66 feet before or after an intersection. Downhill between 80-100 feet depending on grade level.



Picture 65: Staggered Stop Lines, Munich, Germany (MK)



Picture 66: Staggered Stop Lines, Koeln, Germany (MK)

- ❑ At priority intersections on highways a separated cycle track or path should nearly always be interrupted and continue as lanes or colored marking through the intersection.



Picture 67: Interrupted cycle track (DK)

- ❑ Free right-turn lanes for motor vehicles with safety islands and no signals are particularly dangerous for cyclists (and pedestrians) proceeding straight; situations like these should be tried to be avoided or reconstructed.

Intersections - Cyclists Turning Right

- ❑ Separate facilities for right turning cyclists at uncontrolled intersections are not necessary.
- ❑ At controlled intersections separate facilities are generally needed to ensure a smooth flow of bicycle traffic turning right.
- ❑ If a cycle route carries on straight ahead, additional facilities for cyclists turning right are less crucial since right-turning cyclists can then benefit from the priority ruling of cyclists proceeding straight.
- ❑ At signalized junctions with enough room, a right-turn lane (possibly wide radii) can be established for cyclists before the signal so they can avoid the light. (See image 33).
- ❑ Corner radii for vehicular traffic shall be as small as possible.



Picture 68: Pre-right-turn for cyclists to avoid signal, but not pedestrians (DK)

Intersections - Cyclists Turning Left

- ❑ Provision of left-turning cycle lane at an uncontrolled intersection depends on motor vehicle volume turning left (space in left lane).
- ❑ In low-speed zones, if no bicycle facilities are provided on the approach but the approach has the right-of-way, bicycle facilities for left-turning cyclists shall be provided.
- ❑ At controlled intersections a cycle lane shall be provided for left-turning cyclists.
- ❑ In general, next to left-turning vehicle lanes, a left-turn cycle lane shall be provided.



Picture 69: Cycle lane for left-turning cyclists (DK)



Picture 70: Broken cycle lane through intersection, Germany (MK)

- ❑ Merging of cyclists with motor vehicles shall ideally happen at least 164 feet (50m) before an intersection and at a minimum 98 feet (30m) after an intersection. This shall depend on speed and volume of motorized traffic.
- ❑ The average speed (85th percentile) of motorized traffic in the area of merging shall not be higher than 20mph (speed difference between average cyclist and cars shall not be more than 6mph).
- ❑ Merge lanes shall have a minimum width of 13 feet.
- ❑ Cyclists turning-left by crossing the path of motor vehicles proceeding straight is not applicable for major road intersections (speed greater 20mph).
- ❑ For a safe merging movement, cyclists shall not be allowed to cross more than one traffic lane.
- ❑ Merging shall not be used where many child cyclists are expected.
- ❑ At intersections with traffic lights, cyclists turning left must have the opportunity of crossing in two stages besides the possibility of weaving (children and elderly).
- ❑ Advanced (staggered) stop lines for cyclists (in conjunction with recessed stop lines for motor vehicles) shall be provided at all signalized intersections. The stop line for motor vehicle traffic shall be recessed up to 16 feet in relation to the pedestrian crossing.
- ❑ An advanced stop box with bicycle symbol shall be placed ahead of a motor vehicle stop line if an intersection has two- or less approach lanes and if the red phase exceeds the green phase (by much).



Picture 71: Advanced Stop Box, Koeln, Germany (MK)



Picture 72: Advanced Stop Box (DK)

- ❑ Advanced cycle green phase should be considered where cycle volumes are anticipated.
- ❑ A refuge island should be provided where cyclists may not be able to turn left during one signal phase. Such situations should, however, be avoided whenever possible.
- ❑ Minimum width/ length of a safety island should be 6 feet, 8 feet desirable.^{viii}



Picture 73: Refuge Island/ Median (MK)

Intersections - Other/ Vehicular Lane Treatment

- ❑ Straight-through lanes should not become right-turn lanes at intersections because this would require dangerous lane shifts by cyclists.

Right-of-Way

- ❑ If through cycle route runs on or alongside one of the crossing roads, right-of-way should favor cyclists.
- ❑ If distributor cycle route runs on or alongside one of the crossing roads, right-of-way should favor cyclists if bicycle volume is considerably high.
- ❑ On access cycle routes right-of-way for cyclists is not necessary.

^{viii} The average bicycle length is about 6 feet, therefore a minimum refuge island width of 6 feet is recommended herein.

- ❑ Within built-up areas cycle tracks with their own alignment may be given right-of-way over crossing traffic (without speed limiting measures), when the road concerned has a limited function and a maximum peak-hour volume of 250 mv/hour at low speeds (85th percentile \leq 20mph).
- ❑ If 85th percentile lies between 20-30mph the speed of motorized traffic can be reduced best by implementing speed control humps positioned at the bicycle crossing. This solution is applicable if road has moderate traffic function and peak-hour volumes of 400-600 mv/hour. If speeds are higher the cyclists can no longer force a right-of-way.
- ❑ If a through cycle route crosses an access bus route, bicycle traffic shall be given right-of-way over bus traffic; if the bus route coincides with a road for motorized traffic, the conditions for an intersection of a cycle route and road for motorized traffic apply.
- ❑ At intersections traffic should submit right-of-way to traffic coming from the right. It is desirable that on all roads within built-up areas with a max speed \Rightarrow 30mph the right-of-way is regulated by traffic signs and/ or road marking. This means that it is very desirable from the point of view of promoting bicycle use to create \leq 20mph speeds (at least parts of) residential areas and possibly introduce 20mph zones.

Roundabouts

- ❑ Mixed travel is acceptable if single-lane, low speed ($<$ 20mph) and $<$ 8,000 vpd.
- ❑ If $>$ 2,000 vpd on a side road, an intersection shall be reconstructed as a roundabout or signals recommended.
- ❑ Cycle lanes not recommended.
- ❑ Outside diameter should not be greater than 98 feet (single-lane), and the inner ring shall only be allowed to be used by trucks and buses and therefore have a different pavement (e.g. cobblestone); the entry/ exit roads should have a fairly wide radii.
- ❑ If higher speed, multi-lane and greater volumes, separation should be considered.



Picture 74: Blue bike lane an option in roundabouts (MK)



Picture 75: Broken bike lane not ideal since the space is more likely to be used by motor vehicles (DK)

Signals and Detection

- ❑ Environmentally sound travel modes should ideally have priority in signal phasing.
- ❑ Left-turn stages for motorists reduce accidents between left-turning vehicles and oncoming cyclists at large intersections with many traffic lanes.
- ❑ At intersections with tracks or lanes to the stop line, a separate cyclist signal can reduce accidents between both users.
- ❑ Signals for cyclists should generally be placed before an intersection and should include a yellow signal.
- ❑ If the green signal phase for cyclists is short only to ensure faster motor vehicle turning movement, it should be extended in length.
- ❑ If the green signal phase for cyclists is short, cyclists may benefit from two subsequent green phases.
- ❑ Where intersections are located within short distances, a "green wave" (continuous green) for cyclists should be considered without necessarily providing the same for motor vehicles.
- ❑ A good way to detect cyclists is to establish a combination of loop detectors and a separate cyclist push-button placed on a low post at the stop line.

- ❑ By inserting loop detectors in the cycle track/ lane some way before and up by the stop line, cyclists can be detected sufficiently early for the signal to change from red to green or to extend the green time so that the cyclist does not have to stop.
- ❑ With regard to the introduction of detection-strips a minimum length of 49 feet (15m) applies. A minimum length of 16 feet (5m) applies on application on pressure points alone, because of the need of roadway marking (arrows).
- ❑ At some intersections cyclists turning left can be detected only by placing loop detectors in front of the stop line. To prevent crossing cyclists from activating the signal unnecessarily, the loop detector must be activated for at least two seconds.
- ❑ Induction slopes are better than detection strips, however, where it is not possible to implement induction slopes such as on bridges etc. detection strips are sufficient. The cyclists shall under no circumstances be forced to get off the bicycle to activate the signal.

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Photo Resources

VTPI – Voorhees Transportation Policy Institute Photo Collection

MK – Michael King, Traffic Calmer and Architect

PS – Petra Staats

DK – *Danish Collection of Cycle Concepts*

DB – Dan Burden's *Walkable Communities* Slide Collection