Alan M. Voorhees Transportation Center

Bicycle and Pedestrian Safety Needs at Grade-Separated Interchanges

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1 Overview and Methods

Throughout New Jersey, pedestrians and bicyclists face challenges at grade-separated highway interchanges. Sidewalks, bike lanes, and shoulders frequently end where secondary roads cross over or under highways. The angle and design speed of on and off-ramps lead drivers to focus primarily on other motor vehicle traffic, giving insufficient attention to non-motorized users. Roadway markings, warning signs and design cues that indicate where bicyclists and pedestrians should travel, and where motorists should yield, are frequently absent.

While design guidelines for integrating bicyclists and pedestrians at at-grade highway intersections are readily available, less information is available for grade-separated interchanges. The objective of this report is to summarize common challenges to pedestrian and bicycle mobility through grade-separated interchanges and to document best practices. The Alan M. Voorhees Transportation Center at Rutgers University (VTC) conducted a literature review of published research and national, state, and regional roadway design guidelines to assess the state of practice in interchange designs that meet the needs of non-motorized users. This review was supplemented by on-site observations conducted at the interchange of Interstate 280 and Pleasant Valley Way in West Orange, New Jersey, to document typical conditions at an interchange in the state. This site was identified by Michael Dannemiller, Senior Planner at the RBA Group, as having a mixed ramp configuration that represents a range of design alternatives.

Expert practitioner interviews are proposed for future research to confirm, revise, and provide greater context to the findings. A draft interview question form and list of proposed interview subjects is included in Appendix 6.2.

The report is organized into six sections:

1.0 Overview and Methods

2.0 Common issues – Explores common issues facing pedestrians and bicyclists at grade-separated highway interchanges

3.0 Summary review of guidelines and literature – Presents a summary of the guidelines and literature review (the full review can be found in Appendix 6.1)

4.0 Best practice recommendations – Presents best practice recommendations extracted from the guidelines and literature review

5.0 Compatibility with the NJDOT *Roadway Design Manual* – Presents an analysis of whether best practices are permitted and/or recommended by New Jersey guidelines

6.0 Appendices

This report was prepared on behalf of the Office of Bicycle and Pedestrian Programs at the New Jersey Department of Transportation, with funding from the Federal Highway Administration. All non-attributed photographs are by VTC.

2 Common issues

VTC identified the following issues facing pedestrians and bicyclists moving through grade-separated interchanges from a review of design guidelines and a site visit. The guidelines and literature review is included as Appendix 6.1.

- Discontinuous facilities
- Free-flowing entry and exit ramps
- Insufficient Lighting
- Unmarked crossings
- Poor sight distance
- Lengthy crossing distances

2.1 Discontinuous facilities

Sidewalks on approach roads may not continue through the interchange, leaving pedestrians without safe facilities or confused about the path to take. Pedestrians walking along the roadway edge face risks from passing motor vehicles.

When bike lanes or shoulders terminate before an interchange, cyclists face similar challenges. Reduced road space and merging motor vehicle traffic create a challenging cycling environment.

Figure 1. Unmarked crossing. Barry Road and I-29, Kansas City, Missouri.

Figure 2. Bicycle lane ends at right-turn only lane. Edwards Mill Road at Wade Avenue, Raleigh, North Carolina. Photographer: Steven Goodridge. Source: www.humantransport.org

2.2 Free-flowing entry and exit ramps

Where entry and exit ramps make a free-flowing transition between the highway and secondary road, it can be difficult for pedestrians and bicyclists to cross due to motor vehicle speeds and insufficient breaks in traffic. Merging drivers are focused on observing oncoming motor vehicle traffic, particularly at sharply angled intersections, and therefore are less observant of pedestrian and bicyclists. These factors contribute to poor pedestrian and bicyclist visibility and poor driver yielding behavior.

Figure 3. Pedestrian crosses on exit ramp. Rt. 27 at Rt. 18, New Brunswick, New Jersey.

Figure 4. Free-flowing entry ramp at Rt. 27 at Rt. 18, New Brunswick, New Jersey.

Figure 5. Aerial showing site of Figures 2 and 3 exit ramp at Rt. 27 at Rt. 18, New Brunswick, New Jersey. Source: New Jersey Department of Environmental Protection.

2.3 Insufficient Lighting

Lighting throughout the interchange is important for visibility, both to enable drivers to see pedestrians and bicyclists and to enable pedestrians and bicyclists to clearly see their travel paths and surfaces. Lighting designed to illuminate the road surface may not sufficiently illuminate the sidewalk and adjacent areas to provide security and surface visibility for pedestrians. In addition, illumination of the crosswalk is needed to enable pedestrians to be seen by approaching drivers.

Figure 6. Typical roadway interchange lighting may not illuminate the pedestrian space. Pleasant Valley Way at I-280, West Orange, New Jersey.

In the underpass shown in Figure 5, pedestrians are dependent on general lighting for vehicular lanes, which may be inadequate for illuminating the sidewalk.

2.4 Unmarked crossings

Unmarked crossing locations may be clear to pedestrians, such as in the photo below where the path is indicated by the continuance of the sidewalk on the opposite side of the ramp. However, drivers may lack visual clues to expect pedestrian crossings. The lack of crosswalk markings and signage also fails to indicate to drivers that pedestrians have the right of way.

Figures 7 and 8. Unmarked pedestrian crossings. I-280 exit ramps and Pleasant Valley Way, West Orange, New Jersey.

2.5 Poor sight distance

On curved free-flowing ramps, poor sight distance can be a pedestrian safety issue. Other factors that contribute to site distance issues include the placement of guardrails, poles, and signal boxes. This example from the I-280 and Pleasant Valley Way interchange in West Orange illustrates how pedestrians have responded to an unmarked crosswalk that, while providing the shortest crossing distance, also features inadequate sight lines and out-of-direction travel. The sidewalk angles to a crossing that connects with a sidewalk on the opposite side. However, pedestrians crossing at that location have a difficult time seeing if cars are headed toward them and are less visible to drivers rounding the corner. No signage warns drivers of the upcoming pedestrian crossing. Instead of using the crosswalk, many pedestrians continue parallel to Pleasant Valley Way, as indicated by a worn path. enabling them to maintain visibility and direction of travel.

Figure 9. Worn path indicates pedestrians prefer to cross ramp parallel to roadway. Pleasant Valley Way at I-280, West Orange, New Jersey.

2.6 Lengthy crossing distance

Ramp terminals at interchanges often have large turning radii to accommodate truck traffic. This can create lengthy crossing distances for pedestrians, and pedestrians may not have enough time to safely cross in the presence of motor vehicle traffic. Seniors, children, and others who have lower walking speeds may find crossing particularly difficult.

Figure 10. Lengthy crossing distance. Pleasant Valley Way at I-280, West Orange, New Jersey.

3 Summary review of guidelines and literature

While at-grade highway intersection design guidelines accommodating bicyclists and pedestrians are readily available, less information exists for grade-separated interchanges. VTC conducted a literature review of published research and national, state, and regional roadway design guidelines to assess the state of practice in interchange designs that meet the needs of non-motorized users. A summary of this literature review is presented below. A comprehensive review of guidelines and literature can be found in Appendix 6.1.

3.1 Design guidelines

Current national design guidelines do not provide detailed recommendations for non-motorized accommodation at grade-separated interchanges. The American Association of State Highway and Transportation Officials (AASHTO) publishes *A Policy on Geometric Design of Highways and Streets*, the primary national reference for roadway design. These documents lack detailed guidance on bicycle and pedestrian facilities in grade-separated interchanges. The main recommendation is to separate non-motorized modes from vehicular traffic. (AASHTO 2004b)

For bicyclists, the separate AASHTO *Guide for the Development of Bicycle Facilities* is cited in AASHTO's *Policy on Geometric Design of Highways and Streets*. (AASHTO 2004b) The bicycle guide is currently undergoing revision. Feedback collected for the revision indicates that a third of practitioners would like more detailed guidance for specific interchange types, such as cloverleafs and single-point urban interchanges. (Petritsch) Diagrams in the current guide indicate bicycle lane striping both through and ending at interchanges. (AASHTO 1999, Petritsch)

For pedestrians, current recommendations in AASHTO's *Guide for the Planning, Design, and Operation of Pedestrian Facilities* include direct connections where possible, as well as the provision of crosswalks, adequate lighting and sight distances, warning signage, pedestrian-actuated signals or stop or yield signs at crossings, slower speed limits at urban interchanges, channelization islands as refuges, and right-angle intersections for ramps. (AASHTO 2004a, b)

The Institute of Transportation Engineers also provides guidance on the types of interchanges and their impacts on bicyclists and pedestrians, but it does not provide detailed guidance on the "special treatments" recommended to mitigate these impacts. (Leisch and Mason)

3.2 Research and practice

3.2.1 General

Several state highway design manuals provide more detailed design recommendations for interchanges than those in AASHTO. The range of information provided in state manuals ranges from general recommendations that pedestrians and bicyclists be accommodated

to diagrams such as a slip turn lane design with tighter angles that slow motor vehicles, improve non-motorized user visibility, and may improve yielding behavior.

The *KIDPA Interchange Bicycle/Pedestrian Safety Study* (Kentuckiana Regional Planning and Development Agency 2007) presents a literature review similar in scope to the one presented in this study, conceptual improvement plans for five regional interchanges, and a toolbox of issues and alternatives for ten interchange types. The toolbox has potential to be a useful guide beyond the KIDPA region.

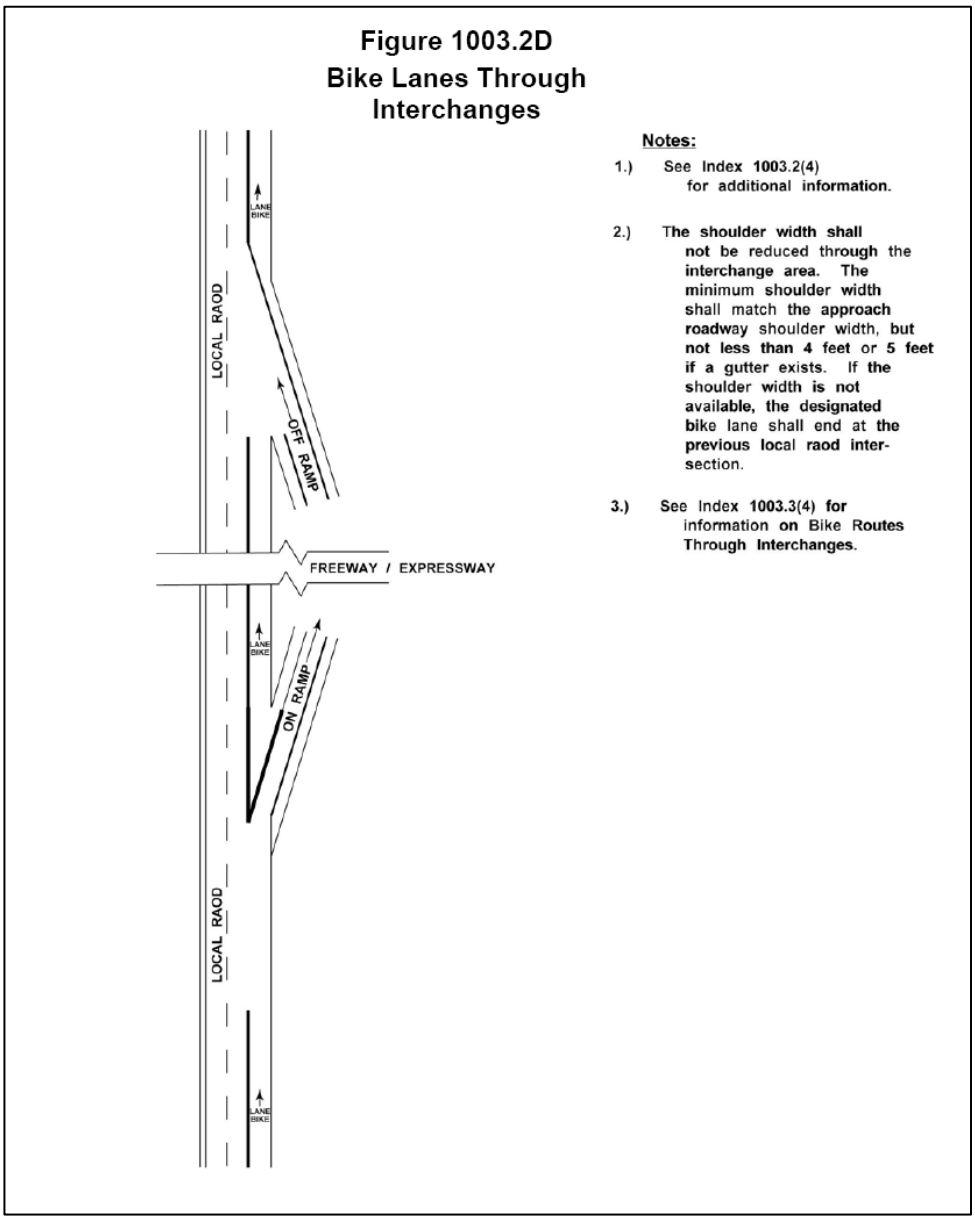


Figure 11. Example of diagram from the California Department of Transportation *Highway Design Manual*.

3.2.2 Single-point urban interchange

A single point urban interchange (SPUI) is similar to a diamond interchange, except that the two intersections of a diamond are combined into a single intersection, allowing opposing left turn movements. Single point urban interchanges are treated separately in the review due to the large, recent body of published research indicating that they pose particular challenges for pedestrians and bicyclists. This design is inherently difficult for pedestrians due to insufficient crossing breaks in the signal phasing caused by the opposing left turn movements, as well as long crossing distances. Making the crossing more amenable for pedestrians by adjusting these variables reduces the efficiency for motor vehicles. Existing guidance recommends pedestrian over- or underpasses for SPUIs, however these are often cost-prohibitive and impractical solutions. The California Department of Transportation presents a compact SPUI that may be better for bicyclists and pedestrians in its *Single Point Interchange Planning, Design and Operations Guidelines*. (California 2001)

3.2.3 Research in progress

Two National Cooperative Highway Research Program projects in progress bear watching for their relevance to pedestrian and bicyclist interchange crossing issues. The projects focus on design guidelines for multimodal channelized right-turn lanes (NCHRP 03-89, *Design Guidance for Channelized Right-Turn Lanes*) and crossing solutions for visually-impaired pedestrians at channelized turn lanes and roundabouts (NCHRP 03-78A, *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Visual Disabilities*).

4 Best practice recommendations

The following best practice recommendations were extracted from existing guidelines and literature.

- Mark crosswalks where ramp terminals intersect local roads
- Provide adequate lighting
- Design for direct connections
- Use appropriate warning signage
- Eliminate free-flow right turns
- Use stop signs or signals for pedestrian crossings
- Ramp terminals should intersect local roads at right angles
- Use only single right-turn lanes
- Right-turn slip lanes should use tighter angles
- Avoid single-point urban interchange (SPUI) designs
- Stripe bicycle lanes

4.1 Mark crosswalks where ramp terminals intersect local roads

Marked crosswalks help to make pedestrian crossings more visible to drivers and designate where pedestrians should cross. Stop bars indicate to drivers where they should stop at a signalized intersection before a crosswalk. In-pavement vehicle detection should be placed outside of the crosswalk.

Figure 12. Striped crosswalk at I-280 ramp terminus and Pleasant Valley Way, West Orange, New Jersey.

4.2 Provide adequate lighting for visibility

To ensure that drivers can more easily see pedestrians and pedestrians can see their walking surfaces, adequate overhead lighting should be provided through the interchange.

In addition to the expectation that AASHTO warrants should be met for lighting, New Jersey's *Roadway Design Manual* also specifies that additional lighting should be considered where sidewalks provide for pedestrian crossings at ramp terminals and entrances (Sec. 11.03.1) and where underpasses have pedestrian traffic (Sec. 11.03.7). The manual does not specifically address bicyclists.

Figure 13. Lighting on Rt. 18 at Rt. 27. New Brunswick, New Jersey.

4.3 Design for direct connections

The paths for pedestrians and bicyclists should be as direct, convenient and obvious as possible to ensure their use for safety. Routes that involve significant out-of-direction travel or grade changes discourage use, and pedestrians and cyclists may elect to use less safe routes, negating the safety benefit of the bike/ped facility. Direct paths also minimize the distance pedestrians and bicyclists must travel, which reduces travel time and exposure to inclement weather. Some pedestrians, such as the disabled or elderly, may be affected to a greater degree by longer, less direct connections.

Figure 14. Continuous bike lane. Philadelphia, Pennsylvania.

4.4 Use appropriate warning signage

Appropriate signage can provide clear direction to and aid drivers in interactions with pedestrians and bicyclists. Stop or yield signs alert drivers at pedestrian crossings, and unsignalized crossings should be marked with pedestrian crossing warning signs for drivers. Signs can alert pedestrians to turning motor vehicles and crosswalk locations.

Figure 15. Yield to bikes sign at beginning of right turn lane to on-ramp. Barry Road at I-29, Kansas City, Missouri. Photographer: Eric Rogers

Figure 16. Pedestrian crossing warning sign in advance of a crosswalk on a highway exit ramp. Route 18 at Route 27, New Brunswick, New Jersey.

4.5 Eliminate free-flow right turns for motor vehicles. Ramp terminals should use stop signs or signals to facilitate pedestrian crossings

W11-2

Figure 17. Pedestrian crossing sign. *Manual on Uniform Traffic Control Devices (MUTCD)*, Federal Highway Administration.

Where possible, eliminating free-flow right turns at locations with more frequent pedestrian crossings improves safety at non-motorized crossings by slowing stopping drivers. Free-flowing turns are associated with high vehicular speeds that are especially dangerous for pedestrians.

To assist non-motorized crossings, drivers should be slowed or stopped at ramp terminals by either stop or yield signs or signals. Pedestrian crossing signs should also be used to alert drivers to the possibility of people crossing on foot where appropriate.

Figure 18. Ramp terminal with stop sign and an unmarked pedestrian crossing in advance of the stop sign. I-280 and Pleasant Valley Way, West Orange, New Jersey.

For new construction, diamond interchanges meet these recommendations. cloverleaf or partial cloverleaf (parclo) interchanges are more likely to employ free-flowing ramps that do not follow this recommendation.

At urban interchanges, slower speed limits (such as 20 m.p.h.) can also be used to slow drivers through crossings. Pedestrian-actuated signals and signal heads, where pedestrian volumes warrant, can help alert drivers to the presence of pedestrians and direct pedestrians on their crossings. To ensure accessibility, any new pedestrian signals should include audible and vibrating indicators. If the pedestrian signal must be actuated by the pedestrian, a locator tone should indicate the location of the push button.

4.6 Ramp terminals should intersect local roads at right angles

Bringing ramp terminals to a right-angle intersection with local roads can allow for easier crossings by pedestrians and bicyclists. The design can then be treated as an urban intersection. The right-angle intersection slows motor vehicles, narrows the crossing distance, and increases visibility for all.

For new construction, diamond interchanges meet these recommendations. Cloverleaf or partial cloverleaf (parclo) interchanges are more likely to employ free-flowing ramps that do not follow this recommendation.

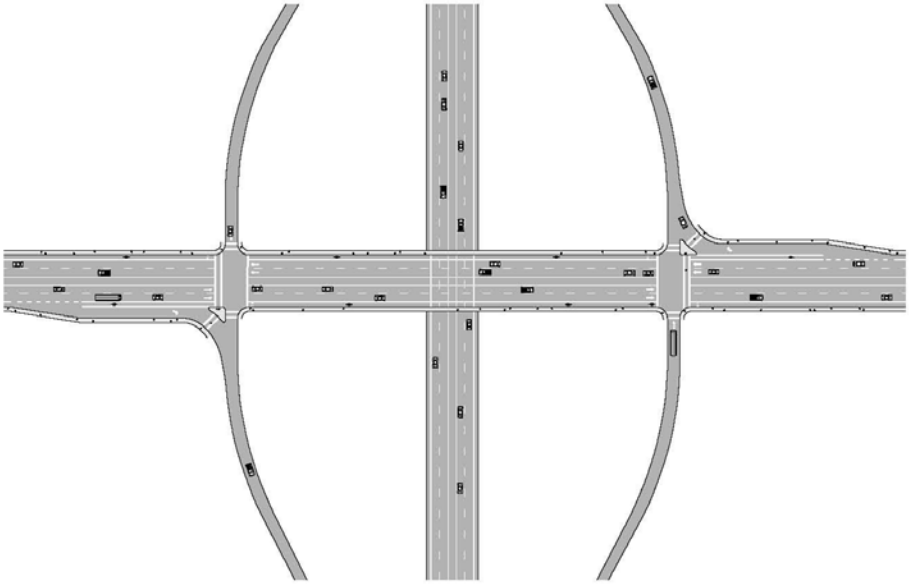


Figure 19. Urban-style right-angle intersections at interchange. Oregon Department of Transportation.

The New Jersey *Roadway Design Manual* recommends avoiding sharp curves where ramp terminals intersect local streets and slip ramps to two-way local streets because of limited sight distance; it "is often better to provide a near 90 degree intersection with stop sign control." (Sec. 7.04.5)

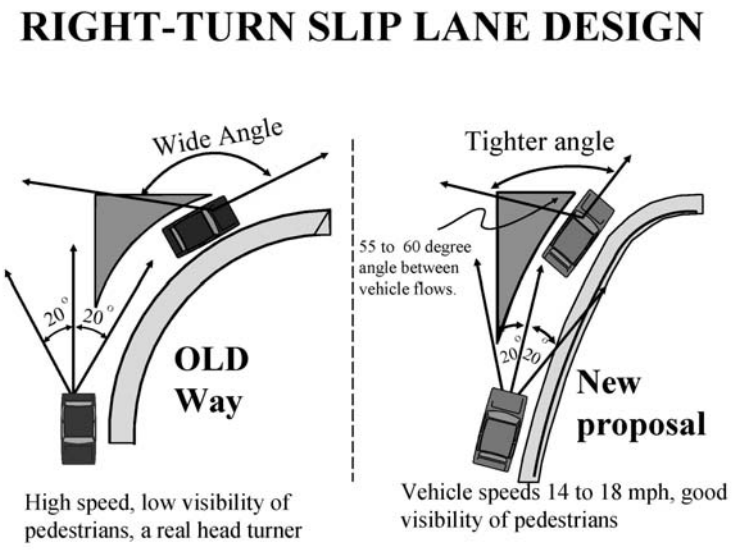
4.7 Only single right-turn lanes should be used

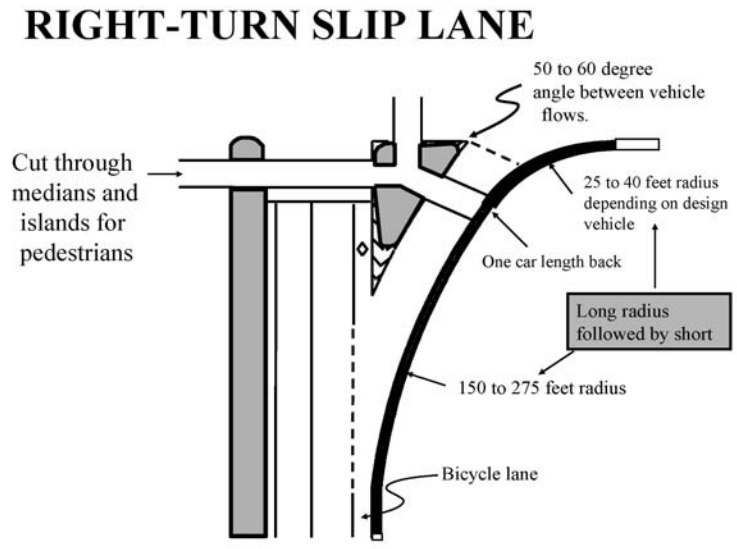
Two lanes of turning vehicular traffic increases pedestrian crossing distance. If an additional lane is needed, a combination through-turn lane could be used with a channelization island to separate it from the dedicated turn lane and to provide a refuge for pedestrians.

Figure 20. Single right turn lane with bicycle lane to the left. Barry Road at I-29, Kansas City, Missouri. Photographer: Eric Rogers

4.8 Right-turn slip lanes should use tighter angles

When right-turn slip lanes are provided, they should be designed using tighter angles to slow turning motor vehicles and increase visibility for drivers and crossing pedestrians. A channelization island should be used with a more vertical, elongated design (Burden and Wallwork). Marked crosswalks should be provided to cut through the island, and curb ramps must be used for accessibility. The pedestrian cut-through in the channelization island can assist visually-impaired pedestrians by providing wayfinding assistance.





Figures 21 and 22. Right-turn slip lane design. Dan Burden and Michael Wallwork, *Handbook for walkable communities*. This version of the graphic was taken from a PowerPoint presentation and differs only cosmetically from the one in *Handbook for walkable communities*.

4.9 Single-point urban interchanges (SPUIs) should be avoided

SPUI designs pose challenges for pedestrians due to the long crossing distance and continuous nature of motor vehicle turning movements. There is often an insufficient break in conflicting traffic to cross an SPUI on foot due to the nature of its signal phasing. These challenges primarily occur when crossing the secondary roadway, not the ramps to and from the primary highway.

If a SPUI design is used, pedestrian crossing facilities should be constructed at the nearest cross street to either side of the interchange. For at-grade crossings within the interchange, crossings should be structured in two phases of left-turns, with a median to separate the two phases and provide refuge for those crossing. Pedestrian-activated signals can assist crossings through the longer distances. Typically, pedestrian signal phases are not used in this interchange design because of the negative impact on green time for motor vehicle movements. Over- or underpasses may need to be constructed to move bicyclists through the interchange. A compact SPUI design can facilitate crossings by bicyclists and pedestrians by reducing the number of lanes to be crossed (often six to eight lanes at many SPUIs).

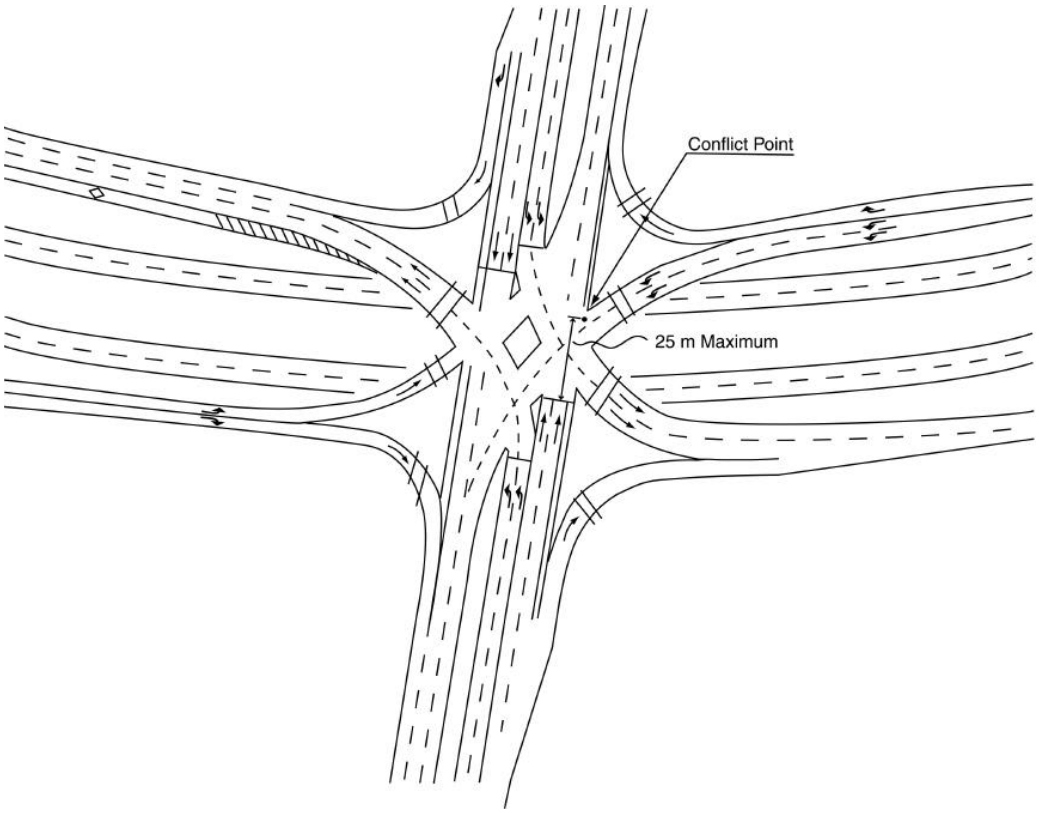
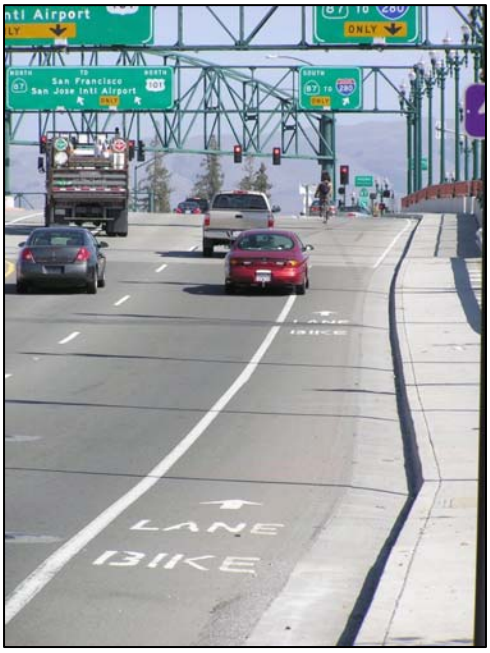


Figure 23. Compact Single Point Urban Interchange. California Department of Transportation.

4.10 Stripe bicycle lanes

Marking bicycle lanes helps both bicyclists and motorists by reducing confusion and increasing safety in the interchange. Striped bicycle lanes are appropriate for both retrofitted and new interchanges. If a bicycle-compatible shoulder or bicycle lane cannot be extended through the interchange due to insufficient width, then the bicycle lane should end at the previous intersection. Bicycle lanes or shoulders should be placed on the left side of right turn lanes to minimize conflicts with drivers; otherwise bicyclists conflict with merging motor vehicles. Bicycle lanes should be striped through an interchange; a dashed line could be used for the bike lane through merge areas with a return to solid striping after the interchange.



Figures 24 and 25. Striped bike lane on Taylor Street SPUI overpass at Highway 87, San Jose, California. Photographer: John Brazil

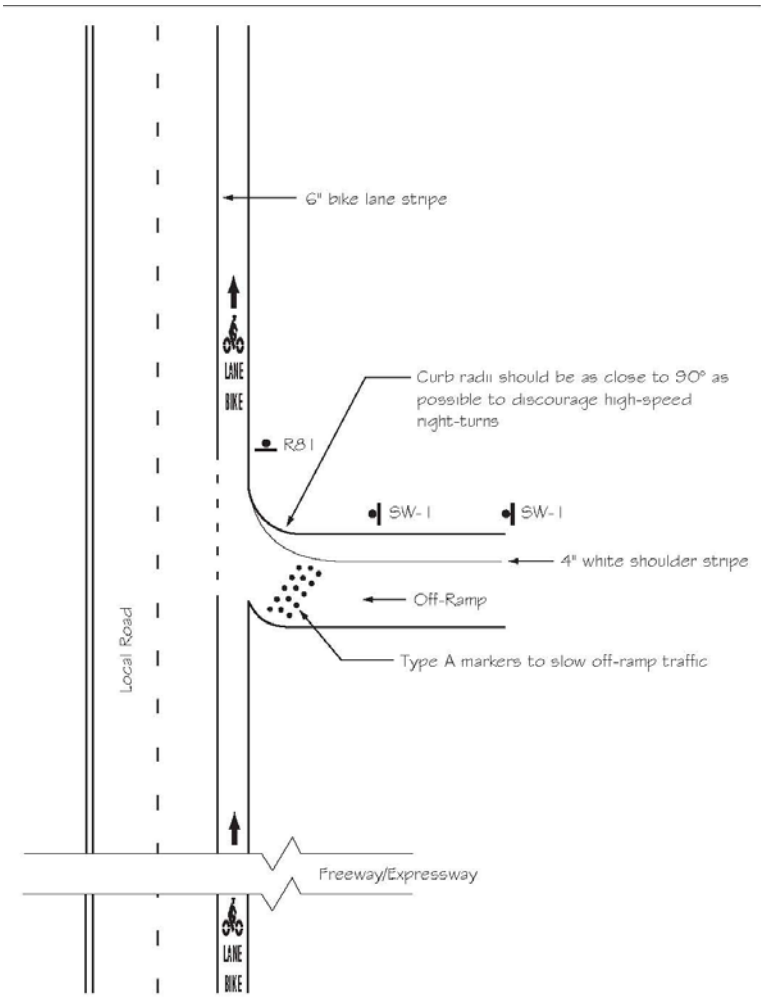
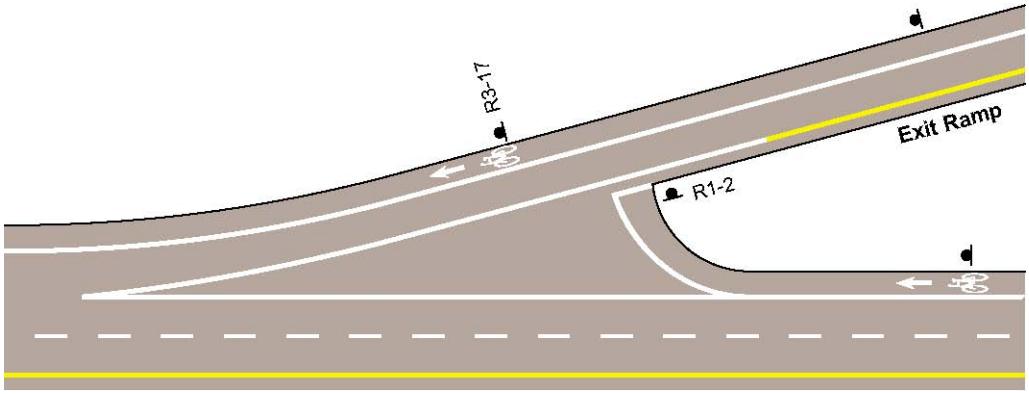


Figure 26. Off-ramp merge with arterial. Santa Clara Valley Transportation Authority.



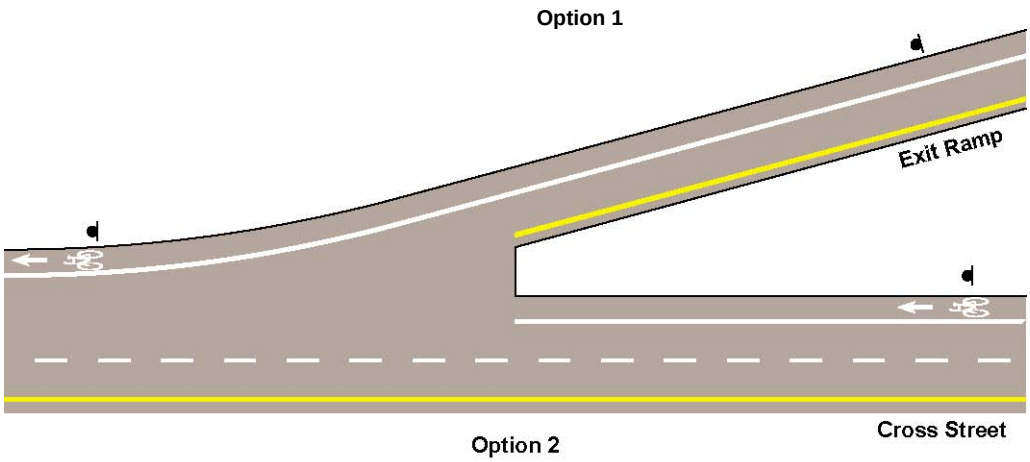


Figure 27. Bicycle crossing of interchange ramp. AASHTO, 1999.

5 Compatibility of best practices with the NJDOT *Roadway Design Manual*

The NJDOT *Roadway Design Manual* sets the standard for state roadway design, and is frequently adopted as the de facto standard by county and local governments. Therefore, it is critical that the Manual both permit and promote better practice in interchange design.

The Manual opens with a commitment from NJDOT to consider design for all road users, not just drivers:

> *In conceiving, scoping and designing projects, the NJDOT will consider the needs of all road users and neighbors. This includes pedestrians, bicyclists, and neighbors, such as residents, and businesses, as well as drivers.*

Although the Manual does not specifically address accommodating bicyclists and pedestrians at grade-separated interchanges, overall it is compatible with the best practices described in Section 4.0 above. Two sections of the manual that relate to this topic are discussed below.

5.1.1 Interchanges

Section 7 of the Manual addresses interchanges. The guidelines for interchange ramps (Sec. 7.04.5) include recommendations that are more accommodating for pedestrians. In the Ramps subsection titled "Location of Ramp Intersection on Cross Road," the Manual recommends avoiding sharp curves where an off ramp terminal intersects the local street and recommends that it "**is often better to provide a near 90 degree intersection with stop sign control**." This recommendation agrees with the best practice to use stop signs or signals at ramp terminals and for ramp terminals to intersect local roads at right angles.

Stop controlled ramp terminals at right angles to the local roads assist bicyclists and pedestrians by slowing vehicular traffic, narrowing the crossing distance for those on foot or a bicycle, and increasing visibility for both drivers and non-motorized travelers.

This section of the Manual also recognizes that ramp speeds must be lower than those on throughways, but it could be strengthened by emphasizing that in areas with higher levels of pedestrian activity, it is especially important to minimize ramp speeds.

This subsection also recommends avoiding the use of slip ramps to "a local parallel two-way street… because of limited sight distance usually encountered at the merge with the local street traffic." Improving sight distance for drivers in these situations improves the visibility of pedestrians and bicyclists. The Manual could be further strengthened by including the right-turn slip lane design specified by Burden and Wallwork for situations where slip lanes/ramps are used. The tighter turning radius in their right-turn slip lane design slows vehicular traffic and increases visibility for crossing pedestrians.

5.1.2 Lighting

Section 11 on Highway Lighting Systems has specific guidelines for pedestrians, but does not address bicyclists. The Warrants for Highway Lighting subsection (Sec. 11.03.1) directs designers to AASHTO warrants for lighting, as well as specifying additional considerations that would warrant lighting:

- On acceleration lanes where "sidewalks exist to permit pedestrians to cross at the entrance or terminal of a ramp." (Sec. 11.03.1)
- "On highways, which are not illuminated, underdeck lighting shall be provided for underpasses having pedestrian traffic. The average maintained illuminance shall be .8 footcandle." (Sec. 11.03.7)

Adequate lighting is critical for the safety of both bicyclists and pedestrians so that they can be seen by drivers and so they have clear views of their traveling surfaces. Lighting should both illuminate the people and the surfaces on which they travel.

6 Conclusion

The objective of this report is to summarize common challenges to pedestrian and bicycle mobility through grade-separated interchanges and to document best practices. The best practices presented in this report have not been categorized as those that apply primarily to new construction and those that apply to existing facilities and new construction. It is recognized that, due to cost, certain design alternatives are not feasible for retrofit of an existing interchange. The best practices that would be most cost-effective for an existing interchange are:

- Mark crosswalks where ramp terminals intersect local roads
- Provide adequate lighting
- Use appropriate warning signage
- Use stop signs or signals for pedestrian crossings
- Stripe bicycle lanes

The remaining best practice recommendations address interchange ramp and lane configuration that would likely be difficult to retrofit.

Moving forward in the design and construction of new interchanges, it is important for best practices for bicyclists and pedestrian to be considered in the Concept Development stage of project development. Bicycle and pedestrian demand in the project area should be evaluated using the NJDOT Bicycle and Pedestrian Master Plan tool or other accepted engineering practice that takes into account observed bicycle and pedestrian activity, accident history, motor vehicle traffic volumes, land use types and land use density. The review of the NJDOT *Roadway Design Manual* in Section 5 concluded that best practice recommendations are not in conflict with NJDOT design standards. The key for new construction is routine consideration of bicyclist and pedestrian needs during the early phases of design.

Two areas for further research have been identified:

- Conduct a survey of engineering and planning professionals to determine the level of knowledge and adoption of the best practices, as well as any barriers to their implementation. A draft interview outline has been included in Appendix 8.2.
- Conduct a design case study of New Jersey interchanges, modeled on the *KIDPA interchange bicycle/pedestrian safety study* conducted by PB Americas, Inc. for the Kentuckiana Regional Planning and Development Agency. This case study would provide New Jersey specific illustrations of how bicycle and pedestrian interchanges can be retrofit, as well as build the knowledge capacity of NJDOT and their engineering consultants in this topic area.

7 References

American Association of State Highway and Transportation Officials. 1999. *Guide for the development of bicycle facilities.* Washington, D.C.: AASHTO.

---. 2004a. *Guide for the planning, design, and operation of pedestrian facilities.* Washington, D.C.: AASHTO.

---. 2004b. *A policy on geometric design of highways and streets*. (5th ed.) Washington, D.C.: AASHTO.

Burden, Dan and Michael Wallwork. N.d.*Handbook for walkable communities*. Olympia, WA: Washington State Department of Transportation.

California Department of Transportation. 2006.*Highway design manual*. Sacramento, CA: California Department of Transportation. < http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm >.

---. 2001. *Single point interchange planning, design and operations guidelines*. June 15, 2001. Sacramento, CA: California Department of Transportation.

Dorothy, Paul W., Thomas L. Maleck, and Laura Aylsworth-Bonzelet. 1997. Field analysis of operation and design of single-point urban interchanges. *Transportation Research Record No. 1579: Geometric Design and Its Effects on Operations*: 11-17. Washington, D.C.: National Academy Press.

Federal Highway Administration. *Selecting roadway design treatments to accommodate bicycles.* (FHWA-RD-92-073 report) <http://safety.fhwa.dot.gov/PED_BIKE/bike/bsol_plan.htm>

Kentuckiana Regional Planning and Development Agency. 2007. *KIDPA interchange bicycle/pedestrian safety study*. Louisville, KY: Kentuckiana Regional Planning and Development Agency.

Leisch, Joel P. (principal author), and John M. Mason, Jr. (editor). 2005. *ITE freeway and interchange geometric design handbook.* Washington, D.C.: Institute of Transportation Engineers.

Massachusetts Highway Department. 2006. *Project development and design guidebook.* Boston, MA: Massachusetts Highway Department. <http://www.vhb.com/mhdGuide/mhd_GuideBook.asp>

Messer, C. J., et al. 1991. *Single point urban interchange design and operations analysis*. Washington, D.C.: Transportation Research Board.

Mid-Ohio Regional Planning Commission. 1999. *Pedestrian facilities best practices*. Columbus, OH: Mid-Ohio Regional Planning Commission. < http://www.morpc.org/web/transportation/bikeped/pedestrianbp.html >

New Jersey Department of Transportation. 1996a. *Bicycle compatible roadways and bikeways planning and design guidelines.* Trenton, NJ: New Jersey Department of Transportation. <http://www.state.nj.us/transportation/publicat/>

---. 1996b. *Pedestrian compatible planning and design guidelines.* Trenton, NJ: New Jersey Department of Transportation. < http://www.state.nj.us/transportation/publicat/>

---. *Roadway design manual.* Trenton, NJ: New Jersey Department of Transportation. <http://www.state.nj.us/transportation/eng/documents/RDME/>

New York Department of Transportation. 2006. *Highway design manual*. Chapter 18: Pedestrian Facility Design, Rev. 49. March 30, 2006. Albany, NY: New York Department of Transportation. <https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm>

Oregon Department of Transportation. 1995. *Oregon bicycle and pedestrian plan*. Salem, OR: Oregon Department of Transportation. <http://www.oregon.gov/ODOT/HWY/BIKEPED/planproc.shtml>

Petritsch, Theodore A. 2005. *Updating the AASHTO guide for the development of bicycle facilities.* Washington, D.C.: National Cooperative Highway Research Program. < http://www4.nationalacademies.org/trb/crp.nsf/All+Projects/NCHRP+20-07#187 >

Qureshi, Mohammad, et al. 2004. *Design of single point urban interchanges.* Jefferson City, MO: Missouri Department of Transportation.

Santa Clara Valley Transportation Authority. 1999. *Bicycle technical guidelines*. San Jose, CA: Santa Clara Valley Transportation Authority.
<http://www.vta.org/news/vtacmp/Bikes/Bike%20Tech%20Guidelines.pdf>

8 Appendix

8.1 Literature and Guidelines Review

8.2 Interview outline (draft)

8.1 Guidelines and Literature Review

The following guidelines have been reviewed for their application to pedestrian and bicyclist accommodation through grade-separated interchanges.

8.1.1 New Jersey Guidelines

New Jersey Department of Transportation. 1996a. *Bicycle compatible roadways and bikeways planning and design guidelines.* Trenton, NJ: New Jersey Department of Transportation. <http://www.state.nj.us/transportation/publicat/>

These design guidelines do not specifically address moving bicyclists safely through interchanges or their associated ramps, although intersections and highways are discussed separately.

New Jersey Department of Transportation. 1996b. *Pedestrian compatible planning and design guidelines.* Trenton, NJ: New Jersey Department of Transportation. < http://www.state.nj.us/transportation/publicat/>

These guidelines do not provide much detail about accommodating pedestrians at interchanges, although information is included separately for intersections, highways, and pedestrian over and underpasses. Interchanges are included in a summary of problems with pedestrian facilities and solutions. For the problem of "difficult and hazardous pedestrian movement through interchange area," the guidelines provide the following potential solutions:

- The solution with the most potential effectiveness is to "provide sidewalk and markings on all new interchanges accessible to peds." This "should become routine practice, required in state/local guidelines." (9) It is considered moderate in cost and implementation barriers and to have a positive impact on other groups.
- Providing barriers to separate pedestrian walkways and vehicular traffic lanes could have moderate levels of effectiveness and cost and minimal impact on other road users, but their implementation is seen as more challenging.
- Where interchanges lack sidewalks or shoulders, pedestrians could be routed to medians and away from the "hazardous ramp crossings." The guidelines note that this potential solution would mostly apply at full or partial cloverleaf interchanges. It would be low cost, moderately effective, and have a low impact on other road users. (9)

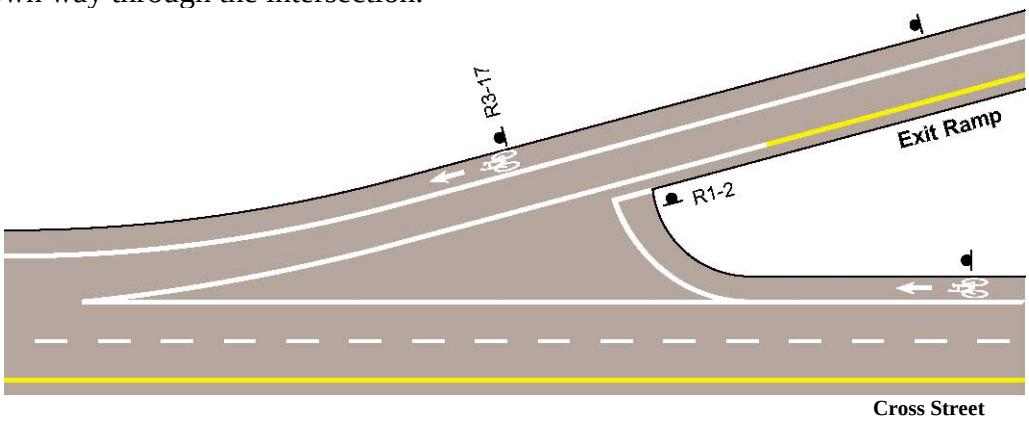
New Jersey Department of Transportation. *Roadway design manual.* Trenton, NJ: New Jersey Department of Transportation. <http://www.state.nj.us/transportation/eng/documents/RDME/>

This manual acknowledges that all road users, including pedestrians and bicyclists, need to be considered in project design. The section covering interchanges does not make any specific mention of or recommendations for bicyclists or pedestrians.

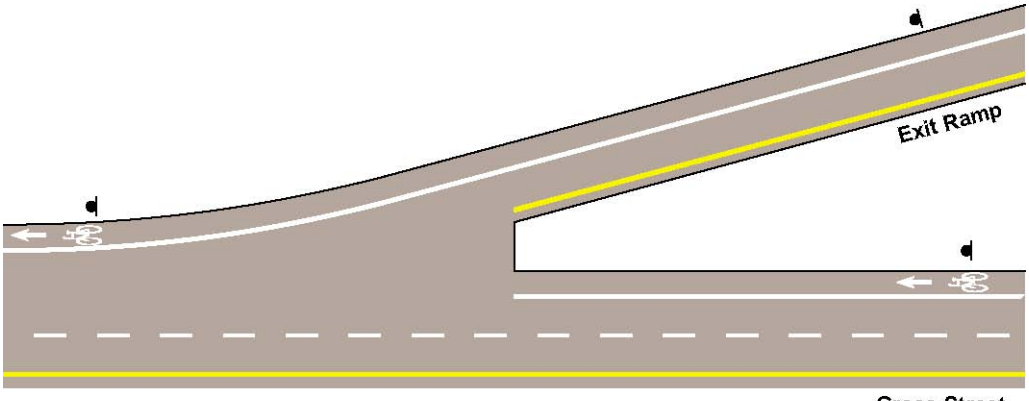
8.1.2 National Guidelines

American Association of State Highway and Transportation Officials. 1999. *Guide for the development of bicycle facilities.* Washington, D.C.: AASHTO.

Although AASHTO's *A Policy on Geometric Design of Highways and Streets* refers to the *Guide for the Development of Bicycle Facilities* for bicycle guidelines, the current version of the guide does not provide many detailed recommendations for accommodating bicyclists through interchanges. It acknowledges the hazards of these conflict points and notes that interchanges "should be designed to limit the conflict areas or to eliminate unnecessary uncontrolled ramp connections to urban roadways." (62) When the bicycle route must cross an interchange, the guideline includes two option diagrams, one for continuing a bike lane through the interchange and one for discontinuing the bicycle markings and "allowing" the bicyclist to make his or her own way through the intersection.



Option 1



Option 2

This 1999 guide is being revised. According to the March 2005 report about the revision scope (Petritsch), the majority of users of the manual who responded to a survey done to determine potential revisions to the next edition felt the current manual provided enough guidance about interchanges. However, about a third of the respondents wanted more detailed guidance for interchanges, including specific concerns with cloverleaf and single-point urban interchanges and multi-lane ramps. Work on this revision was anticipated to begin in 2007 but has not yet been assigned to a contractor.
[http://rip.trb.org/browse/dproject.asp?n=11822]

American Association of State Highway and Transportation Officials. 2004a. *Guide for the planning, design, and operation of pedestrian facilities*. Washington, D.C.: AASHTO.

This guide discusses pedestrian accommodations at grade-separated crossings by focusing mostly on over and underpasses. An "Expressway Ramps" section makes the following recommendations:

- Use right-angle intersections at the ramp and cross street to improve visibility and reduce crossing distance. (78)
- Use stop or yield signs or signals to slow or stop drivers where pedestrians will cross.
- Design exits for 20 mph at urban ramp-street intersections.
- "Pedestrian crossing warning signs should be used at unsignalized ramp-street intersections"
- Use "accessible channelization islands" between left and right turns where diamond-style ramps intersect streets to provide a pedestrian refuge. (79)

American Association of State Highway and Transportation Officials. 2004b. *A policy on geometric design of highways and streets*. (5th ed.) Washington, D.C.: AASHTO.

This manual (commonly referred to as "the Green Book") provides standard roadway guidance and is one of the main sources of design guidance. Separation between the modes to minimize conflict is preferable. Where such separation is not possible, the site "should be studied and alternate designs considered to determine the most appropriate arrangement of structures and ramps to accommodate bicycle and pedestrian traffic through the interchange area." (743) For bicyclists, the Green Book refers to the AASHTO *Guide for Development of Bicycle Facilities* and does not provide additional detailed guidance in this manual. (101) For pedestrians, the guidelines include consideration early in the design process; the provision of sidewalks as far from the road as possible and in the most direct connection; adequate sight distance for both drivers and pedestrians; overhead lighting for the ramp crossings; and, when vehicular traffic does not allow enough gaps for pedestrians to cross, pedestrian-actuated signals or an over- or underpass.

Federal Highway Administration. *Selecting roadway design treatments to accommodate bicycles.* (FHWA-RD-92-073 report) <http://safety.fhwa.dot.gov/PED_BIKE/bike/bsol_plan.htm>

This manual is referenced in state and regional guidelines, but it refers users to the AASHTO *Guide to the Development of Bicycle Facilities* for design guidance on highways and bicycle accommodations. That manual, as referenced above, is currently being revised, and the existing edition does not provide much detailed guidance for interchanges.

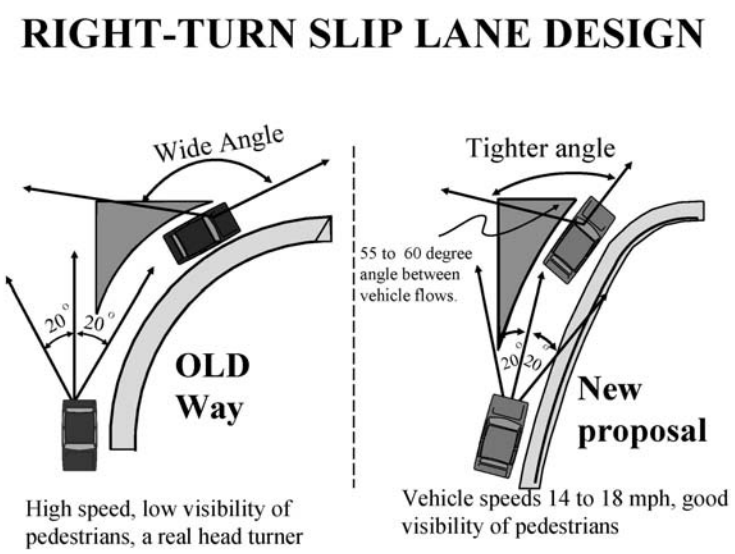
Leisch, Joel P. (principal author), and John M. Mason, Jr. (editor). 2005. *ITE freeway and interchange geometric design handbook.* Washington, D.C.: Institute of Transportation Engineers.

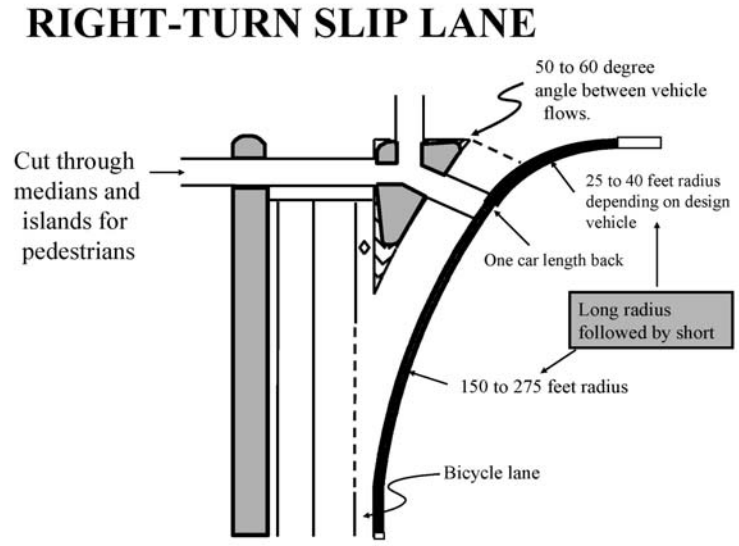
This handbook from the Institute of Transportation Engineers acknowledges the importance of accommodating pedestrians and bicyclists, but states that "Often this is more easily accomplished with a new interchange than with a retrofit of an existing one." (117) Some interchange designs work better for pedestrians and bicyclists, and the "two diamond forms, the single-point diamond and the roundabout are not conducive to the accommodation of pedestrians and bicyclists." (118) Most cloverleaf designs (including partial-cloverleafs) "require special treatment to accommodate pedestrians and bicyclists," (118) but the handbook does not detail what these "special treatments" are. A tight-urban diamond design works better for non-motorized traffic than the single-urban diamond, but the tight-urban diamond must be staged in two phases for pedestrians to cross. (188) Pedestrian signals are not generally needed in this design unless vehicular traffic making right turns are not signalized and there is enough pedestrian traffic to warrant a separate signal. The handbook does not include diagrams or other illustrations to assist with implementing the recommendations.

8.1.3 State and Regional Guidelines

Burden, Dan and Michael Wallwork. N.d. *Handbook for walkable communities*. Olympia, WA: Washington State Department of Transportation.

Burden and Wallwork recommend that when right-turn slip lanes are used, they should be designed according to the following diagrams to assist pedestrians in crossing safely:





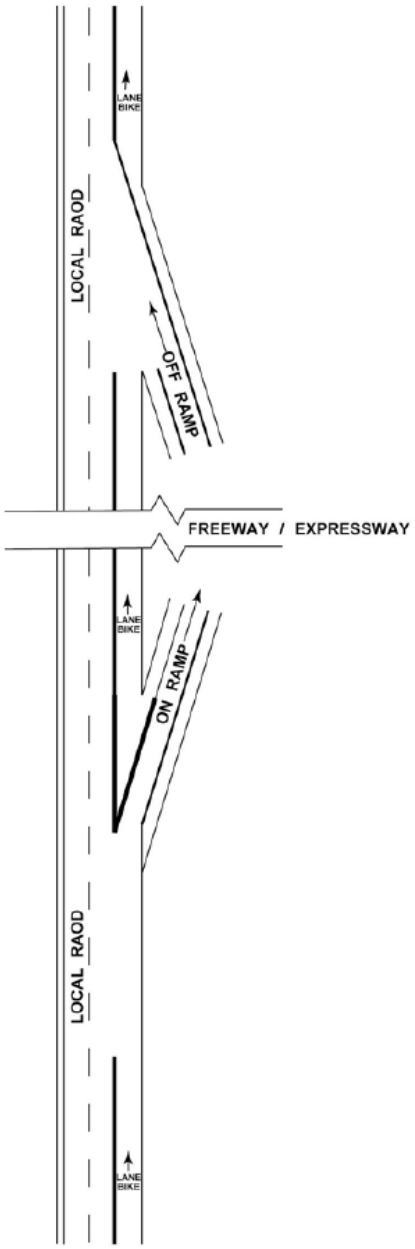
While Burden and Wallwork's right-turn slip lane design applies primarily to at-grade intersections, the angles and turning radii could be applied to an entry or exit ramp at a grade-separated interchange. The *Handbook*'s slip lane recommendations are incorporated into guides for at least two states: *Pedestrian Facilities Handbook: Incorporating Pedestrians Into Washington's Transportation System* from the Washington State Department of Transportation and *Florida Pedestrian Planning and Design Handbook* by the Florida Department of Transportation. The Institute of Transportation Engineers uses this recommendation from Burden and Wallwork in its report, *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities.*

California Department of Transportation. 2006. *Highway design manual*. Sacramento, CA: California Department of Transportation. < http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm >.

In the manual's Traffic Interchanges chapter, Caltrans recommends: “Where a separate right-turn lane is provided at ramp terminals, the turn lane should not continue as a 'free' right unless pedestrian volumes are low, the right-turn lane continues as a separate full width lane for at least 60 m prior to merging and access control is maintained for at least 60 m past the ramp intersection. Provision of the 'free' right should also be precluded if left-turn movements of any kind are allowed within 125 m of the ramp intersection.” (Ch. 500-20)

This manual provides a diagram of bike lanes through interchanges (Fig. 1003.2D) and directs designers to provide interchange accommodations that “will minimize confusion by motorists and bicyclists.” (Ch. 1000-18) Additional directions include: “The shoulder width shall not be reduced through the interchange area. The minimum shoulder width shall match the approach roadway shoulder width, but not less than 4 feet or 5 feet if a gutter exists. If the shoulder width is not available, the designated bike lane shall end at the previous local road intersection.” (Ch. 1000-18)

Figure 1003.2D
Bike Lanes Through Interchanges



Notes:

1.) See Index 1003.2(4) for additional information.

2.) The shoulder width shall not be reduced through the interchange area. The minimum shoulder width shall match the approach roadway shoulder width, but not less than 4 feet or 5 feet if a gutter exists. If the shoulder width is not available, the designated bike lane shall end at the previous local raod intersection.

3.) See Index 1003.3(4) for information on Bike Routes Through Interchanges.

California Highway Design Manual, 2006

Massachusetts Highway Department. 2006. *Project development and design guidebook*. Boston, MA: Massachusetts Highway Department. <http://www.vhb.com/mhdGuide/mhd_GuideBook.asp>

The *Interchanges* chapter of the Massachusetts Highway Department guide discusses accommodating bicyclists and pedestrians and the advantages of different interchange

designs for these users (2006). It states that diamond-type ramps and signalized ramp terminals are preferable in areas with high pedestrian and bicycle activity.

"Unlike diamond interchanges and partial cloverleafs, full cloverleafs do not employ 90-degree intersections. Pedestrian and bicycle movements along cross streets are more difficult to accommodate safely at full cloverleaf interchanges than at partial cloverleaf or diamond interchanges because vehicular movements are usually free-flow." (7-20)

Diagrams from AASHTO 1999 are included as examples of designs for higher bicyclist and pedestrian volumes.

Mid-Ohio Regional Planning Commission. 1999. *Pedestrian facilities best practices*. Columbus, OH: Mid-Ohio Regional Planning Commission.
< http://www.morpc.org/web/transportation/bikeped/pedestrianbp.html >

This guide recommends: "The design of the interchange at exit and entrance ramps to freeways should slow the traffic at the intersection and place crosswalks at an angle where the drivers are facing the crosswalk and attention is not entirely focused on merging with traffic. Interchanges with access ramps connecting to local streets at a right angle are easiest for pedestrians to negotiate." (38)

Their guide notes pedestrian demand needs to be incorporated into interchange design; the assumption that there will be no pedestrian demand, such as in suburban locations, is often incorrect, and the interchanges create obstacles for pedestrians. (57) The MORPC report points out that if facilities for pedestrians aren't considered to be convenient and direct, they won't be used enough to provide safety benefits. (59)

Where urban interchanges create problems for pedestrians, potential "treatments include providing pedestrian information/directional signing, installing pedestrian crossing signals, illuminating the interchange/walkway areas, installing motor vehicle warning signs, marking crosswalks, regulating traffic speeds and movements, channelizing vehicular and pedestrian traffic, (57) constructing pedestrian barriers, utilizing overpasses and underpasses to separate pedestrian traffic, and installing traffic signals." (58) To mitigate the hazard of high-speed traffic where off-ramps intersect urban streets, the following measures could be used: "proper intersection design; grade separation, where appropriate; and/or adequate traffic-control devices (e.g., signs and signals) to reduce motor vehicle speeds and alert pedestrians and motorists." (58) Rural interchanges may indeed have significantly less pedestrian use, so more crossings away from the interchanges should be used.

Dual right-turn lanes are especially difficult for crossings and should be used only when absolutely necessary; an alternative is to use one right-turn lane and one through/turn lane with an island separating the two lanes to provide pedestrian refuge. (60)

New York Department of Transportation. 2006. *Highway design manual*. Chapter 18: Pedestrian Facility Design, Rev. 49. March 30, 2006. Albany, NY: New York Department of Transportation.
<https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm>

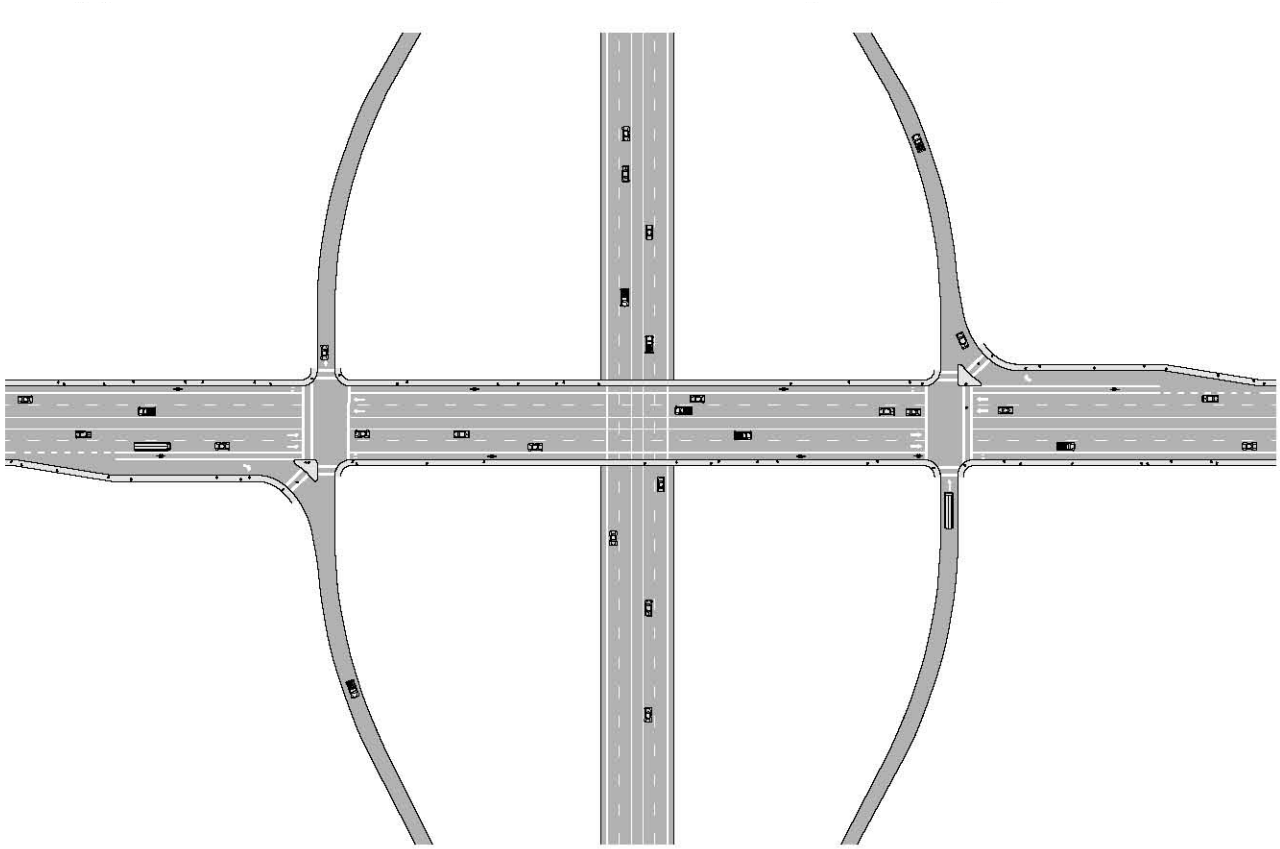
Continuous right turns, which are used "to maximize vehicular efficiency through signalized intersections, including single-point urban interchanges," are not recommended for locations where "where high pedestrian activity may occur" or "where higher percentages of children or the elderly may need to navigate through the interchange." (18-36) If these turns must be used, pedestrian visibility must be maximized and yield-to-pedestrian signs and pedestrian-activated signals should be considered. Single-point urban interchanges (SPUIs) can be the "most dangerous" interchange type for pedestrians because of the vehicular speeds, longer crossings and signal cycles, and that motor vehicles "approach pedestrians from behind."

No diagrams or additional specifications for pedestrians are included in the manual.

Oregon Department of Transportation. 1995. *Oregon bicycle and pedestrian plan*. Salem, OR: Oregon Department of Transportation.
<http://www.oregon.gov/ODOT/HWY/BIKEPED/planproc.shtml>

The Interchanges section of Oregon's Bicycle and Pedestrian Plan is based on some basic principles that include the expectation, "The expected path of pedestrians and bicyclists must be obvious and logical, with minimal out-of-direction travel and grade changes." (133) Both "convenience and safety" should be considered for pedestrians and bicyclists when planning interchanges. If facilities aren't convenient for pedestrians and bicyclists to use, they won't provide any safety benefits.

The plan notes that the easiest interchange design for pedestrians and bicyclists is access ramps that connect to local streets at right angles; the ramps then follow standard urban intersection design, minimizing the distance pedestrians and bicyclists must cross, enhancing their visibility, and stopping vehicular traffic with signals. The plan provides a basic diagram of an overview of urban right-angle intersections at an interchange. Traffic islands are recommended to reduce pedestrian crossing distance, and lighting is needed for dark conditions. If the interchange must also accommodate large truck traffic, the plan suggests the use of compound curves.



Urban-style right-angle intersections at interchange

Rural interchanges tend to be more difficult for pedestrians and bicyclists because of higher motor vehicle speeds. The plan calls out “free-flowing right turns and dual left- or right-turns” as being more difficult for non-motorized traffic, but it does not provide specifications for mitigation other than “special designs… that allow pedestrians and bicyclists to cross ramps in locations with good visibility” and low vehicular speeds. (134)

If it is not possible to safely accommodate pedestrians and bicyclists at grade, the plan recommends the consideration of a grade-separated crossing; it cautions, however, that these facilities are expensive and tend to not be used if too inconvenient.

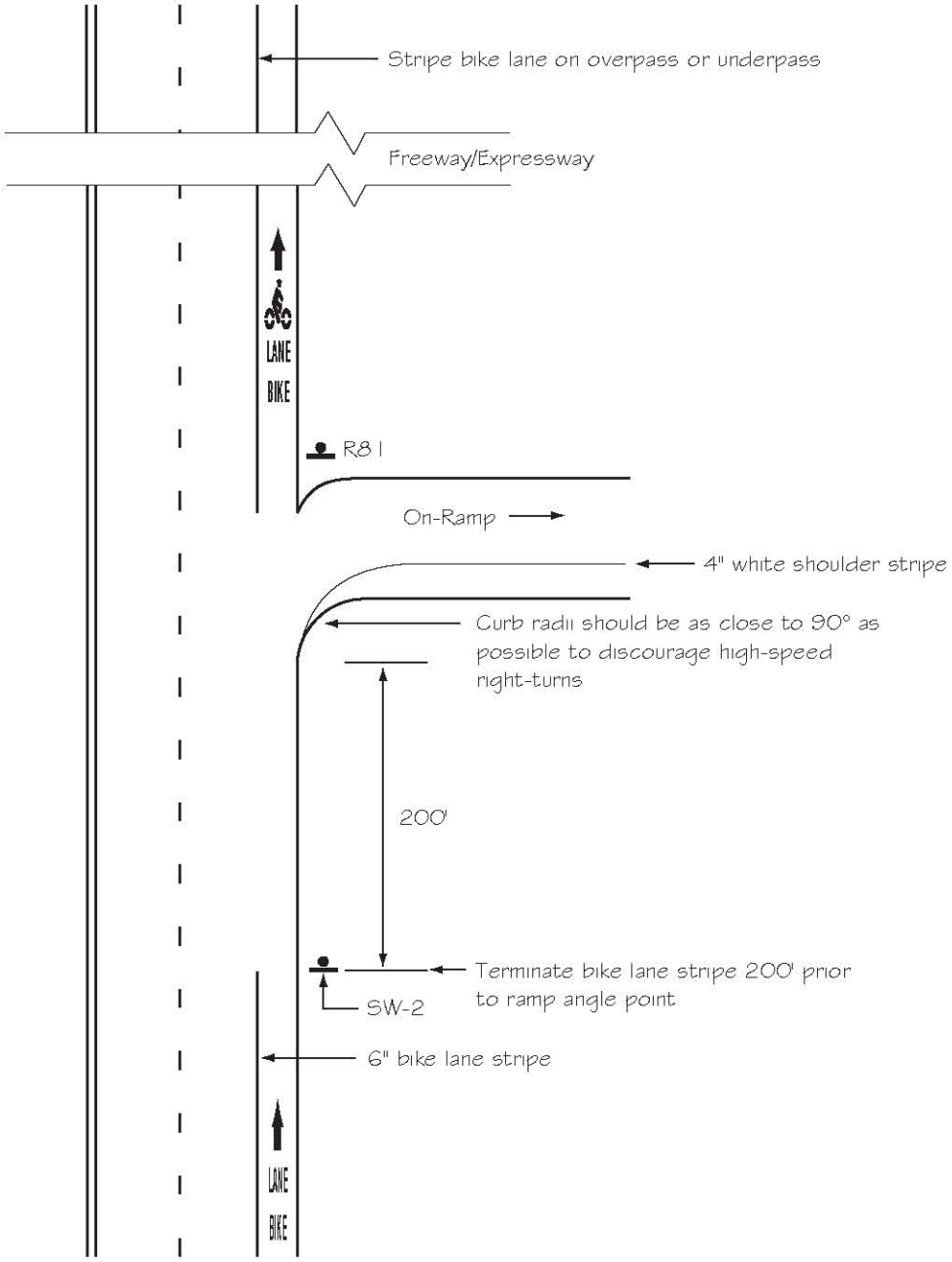
Guard rails should be flared at the corners to assist with the visibility of pedestrians at ramp terminals. Sidewalks and bicycle lanes should be continued on either side of the intersection for continuous linkage.

Santa Clara Valley Transportation Authority. 1999. *Bicycle technical guidelines*. San Jose, CA: Santa Clara Valley Transportation Authority. <**http://www.vta.org/news/vtacmp/Bikes/Bike%20Tech%20Guidelines.pdf**>

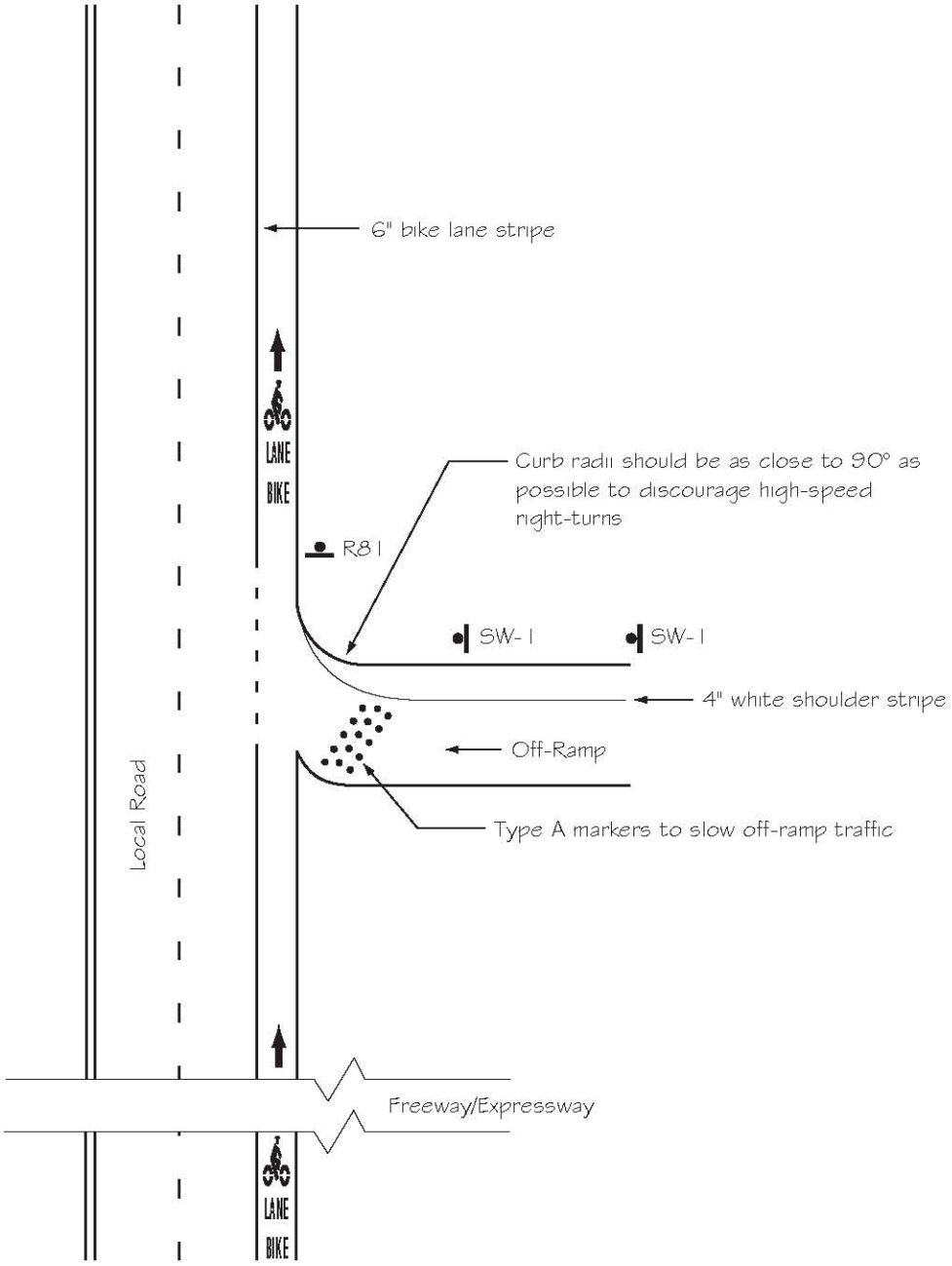
This guide recommends SPUIs should not be constructed if they cannot accommodate bicyclists with enough clearance time to ensure their safe passage through the intersection; the standard clearance interval for SPUIs do not provide enough time. Dual roundabout interchanges are possible alternatives to SPUIs. (19)

The VTA guidelines include the following diagrams:

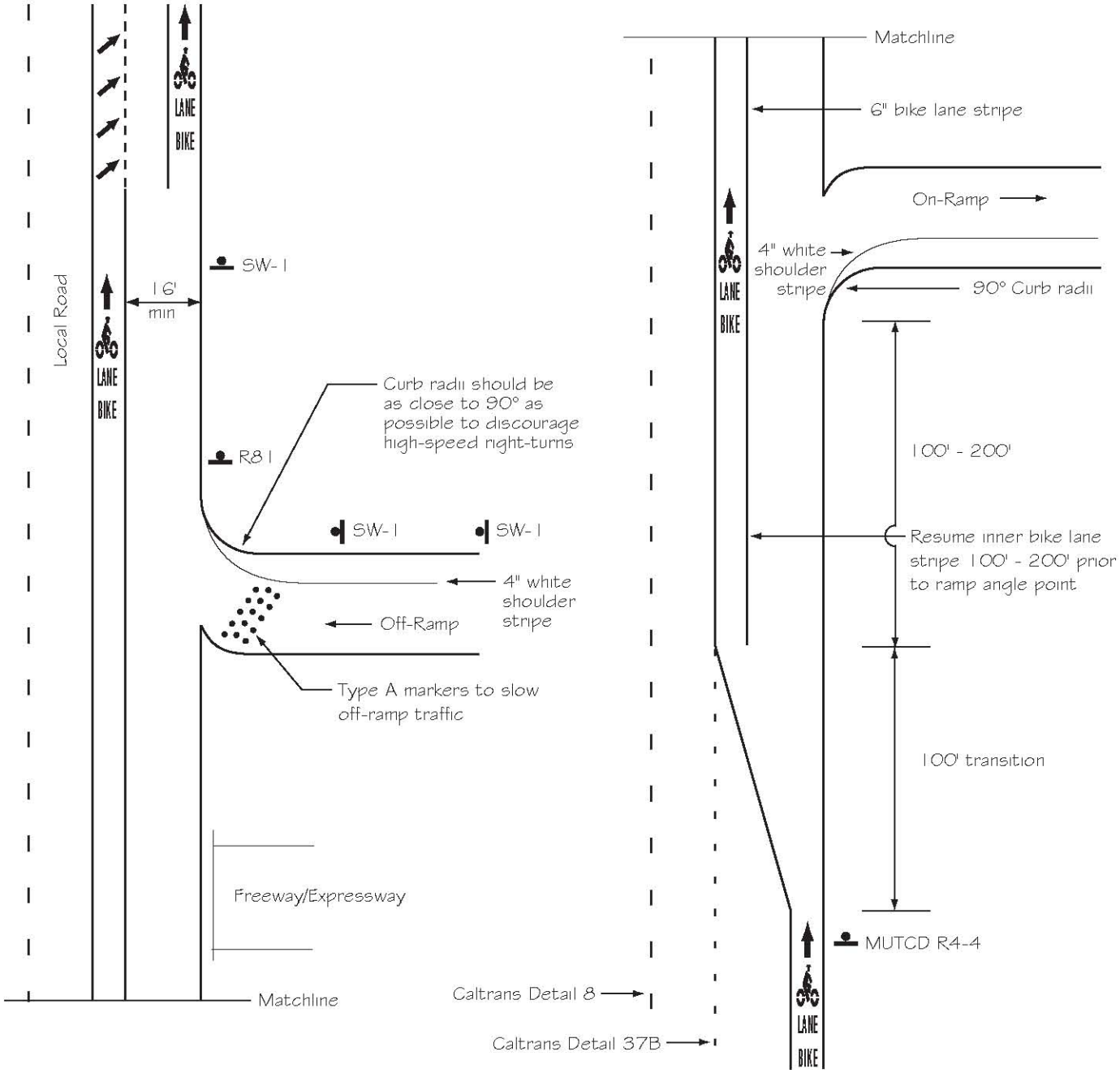
- Specifications for bicyclists and both an on-ramp (F. 13)
- Off-ramp merge with an arterial road (F. 14)
- Freeway overpass with an acceleration/deceleration lane (F. 16).



On-Ramp Merge with Arterial



Off-Ramp Merge with Arterial



Freeway Overpass with Acceleration/Deceleration Lane

8.1.4 Research and Practice

8.1.4.1 General

Kentuckiana Regional Planning and Development Agency. 2007. *KIDPA interchange bicycle/pedestrian safety study*. Louisville, KY: Kentuckiana Regional Planning and Development Agency.

The purpose of this study, completed in December 2007 by PB Americas, Inc. for the Kentuckiana Regional Planning and Development Agency, was to develop a set of best practices for improving bicycle and pedestrian safety through high speed, high volume freeway interchanges. Elements of the study include a literature search of policies and guidelines, interviews with local stakeholders, development of concept plans for improvements at five representative "case study" interchanges, and development of a toolbox for use by planners and engineers.

The literature review found that there is not one definitive source of best design practices for bicycle and pedestrian safety at interchanges. California, Oregon, and Florida documentation provided the most guidance. Common themes include moving bicyclists and pedestrians on the same cycle as motor vehicles, providing continuity of facilities through the interchange, the threat of free flow ramps, reducing motor vehicle on ramps by changing the approach or departure angle, providing right angle crossings, and providing refuge areas for long crossings.

Concept plans were prepared for five different interchanges representing the five types found in the region: skewed partial cloverleaf, single point urban interchange, diamond interchange with arterial road going under interstate, and diamond interchange with arterial road going over interstate. Recommended alternatives and cost estimates were prepared for each.

The toolbox consists of a five step checklist that lists different levels of treatments ranging from low-cost to high-cost options. Also included in the toolbox is a section that describes the different challenges and improvement alternatives for each of ten different interchange types.

8.1.4.2 Single point urban interchanges

California Department of Transportation. 2001. *Single point interchange planning, design and operations guidelines*. June 15, 2001. Sacramento, CA: California Department of Transportation.

Bicyclists and pedestrians are more difficult to accommodate in an SPI. Caltrans provides a basic illustration of a compact SPI to accommodate bicyclists with a minimized intersection. (25)

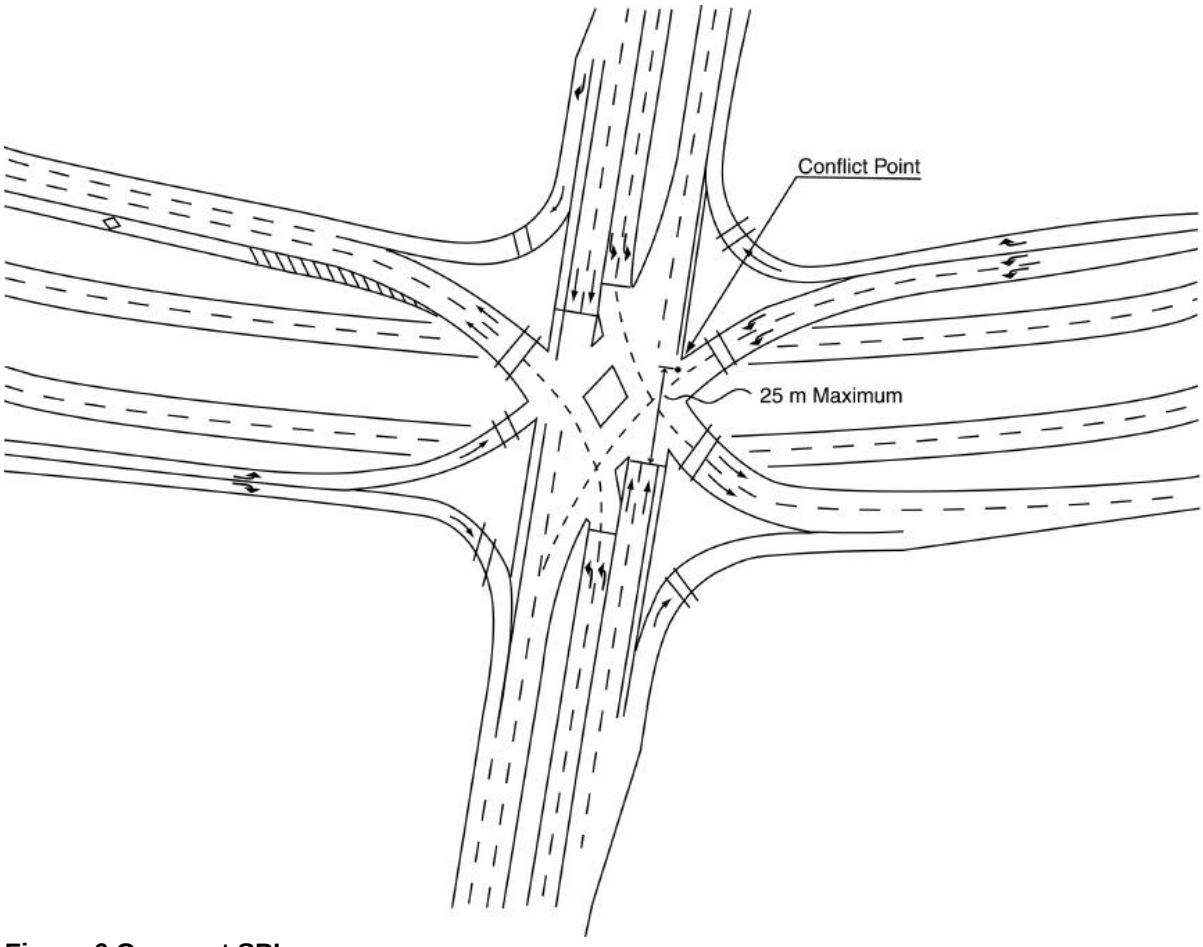


Figure 6 Compact SPI

This design uses single free right turn lanes so that non-motorized traffic only has to cross one lane. If another SPI design is used instead of the compact SPI, the guideline states that an adjacent separate facility (such as an under or overpass) must be provided for bicyclists. (11) Push buttons should be used to assist pedestrians with making the often-lengthy crossings through SPIs. (12)

Dorothy, Paul W., Thomas L. Maleck, and Laura Aylsworth-Bonzelet. 1997. Field analysis of operation and design of single-point urban interchanges. ***Transportation Research Record No. 1579: Geometric Design and Its Effects on Operations*****: 11-17. Washington, D.C.: National Academy Press.**

Michigan's Department of Transportation was faced with the need to upgrade and rehabilitate older, pre-Interstate interchanges. This report reviewed single-point urban interchanges as an alternative to Michigan's current urban diamond interchange design. The authors discuss concerns about pedestrian accessibility in the process of reviewing the SPUI design.

The study surveyed the other state DOTs about their SPUI design and operation. Follow-up interviews were done with DOTs who responded to the survey, and then

the researchers conducted field reviews of interchanges. The Minnesota DOT contact, a traffic engineer in Duluth, "reported that pedestrians did not have a problem." (13) This is in contrast to other concerns expressed throughout the report's literature review and field reviews that SPUIs made travel more difficult for pedestrians. However, no additional information was provided to determine: if the Minnesota design especially accommodated pedestrians, if Duluth didn't have as many pedestrians in that location, or if the traffic engineer simply didn't hear of or observe the problems.

From the field reviews, the researchers concluded that pedestrian accommodations "varied greatly from site to site." (15) There were simply no pedestrians in some of the locations. It was not generally difficult for pedestrians to walk parallel to the crossroad and cross the ramp. However, actually crossing that crossroad was generally difficult for pedestrians due to the road's width (commonly six to eight lanes) and the constant vehicular traffic through the interchange. Even where pedestrians were prohibited, they often crossed anyway because of a lack of alternative crossing opportunities and distant intersections. Concrete channelization for the motor vehicles often provided unofficial medians for pedestrians when they could not complete their crossings through the intersection.

Although the study mentions different designs in use in other states, it does not provide specifics of them or any diagrams of the different designs and their impacts on pedestrians.

Messer, C. J., et al. 1991. *Single point urban interchange design and operations analysis*. Washington, D.C.: Transportation Research Board.

At the time of publication, the single-point urban interchange (SPUI) was still relatively new. The size of the interchange and its three phases of signals for drivers work against the ability of pedestrians to easily cross on a signal. (31)

This report documented current practice and made guideline recommendations for SPUIs. Most agencies surveyed for this report didn't provide marked crosswalks across the cross road. Instead, "Crossing at the next downstream intersection is implied." (98)

Without signal phasing specifically for pedestrians, any pedestrians would need to cross in two stages, the first to cross half of the road to the median during a left-turn phase and the second to cross the remaining distance. This two-part crossing is also noted in the MoDOT report. However, this report does not present it as an ideal solution: "Firsthand experience indicates that this crossing movement can be both difficult and stressful for the pedestrian." (31)

Although a pedestrian overpass is also mentioned as a potential solution to the crossing challenge, this option is expensive. Lighting of the entire interchange is an important help for pedestrian crossings. Sidewalks and marked crosswalks for

"crossing the on- and off-ramps parallel to the cross road" appeared to help pedestrians cross relatively easily. (32) The report recommended that pedestrians be "encouraged to cross the street at the first downstream signalized intersection." (99)

Bicyclists are not addressed in this study.

Qureshi, Mohammad, et al. 2004. *Design of single point urban interchanges.* Jefferson City, MO: Missouri Department of Transportation.

This study was done to assist the Missouri Department of Transportation with design guidelines and warrants for the use of single-point urban interchanges by MoDOT. As in the Michigan DOT study, this study notes that SPUIs are not particularly accommodating for pedestrian crossings. The separate phase required for pedestrians reduces the efficiency of the SPUI for vehicular traffic. Crossing the cross roads in a SPUI is difficult for pedestrians because of the constant flow of vehicular traffic and the crossing distance, which is commonly six to eight lanes.

The study summarizes four options for accommodating pedestrians at SPUIs:

- Pedestrian overpasses are usually costly and are less common.
- A separate phase for pedestrian crossings is, based on their review, not usually recommended because it reduces the efficiency for vehicular traffic.
- Crosswalks can be installed at the SPUI or the adjacent intersection to assist with crossing the cross road. This option does not address the concern of the distance pedestrians must cross in a SPUI.
- Pedestrian crossings can be constructed in two stages: "cross half of the cross road during the first left turn phase, wait at the median and then complete the other half movement during the other left turn phase." (5-9)

According to the study, the "literature recommends discouraging pedestrian movements at most SPUIs." (5-9)

In the fourth option for a two-part pedestrian crossing, the median (included in all SPUI designs) should be at least four feet wide, but six feet is preferred. (5-11)

The study made the following recommendations regarding pedestrians: "It is not desirable to provide a pedestrian crosswalk for SPUIs. Providing an additional phase for pedestrian crossing degrades the efficiency of SPUI. When pedestrian volumes are high, a pedestrian overpass should be constructed or a pedestrian crossing should be provided at the adjacent intersection or SPUI should not be selected." (7-2) Additionally, if a pedestrian crossing *is* provided, the median should be six feet wide.

Bicyclists are not addressed in this study.

8.1.4.3 Research in progress

The following research projects in progress could potentially address issues relevant to this topic.

NCHRP 03-89 Design Guidance for Channelized Right-Turn Lanes

This project has issued an RFP for work to begin in January 2008. The research objective is to "develop design guidance for channelized right-turn lanes, based on balancing the needs of passenger cars, trucks, buses, pedestrians (including pedestrians with disabilities), and bicycles."

http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1609

The project will build on work done in NCHRP 03-72 *Lane Widths, Channelized Right Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas*. That project was originally designed to include research on channelizing right turns, but it was eliminated from the project scope due to budgetary concerns. The research done for 03-72 did not explicitly address concerns with grade-separated interchanges.

NCHRP 03-78A Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Visual Disabilities

The objective of this research is to recommend a range of geometric designs, traffic control devices, and other treatments that will make pedestrian crossings at roundabouts and channelized turn lanes useable by pedestrians with vision impairment.

This research project is still ongoing and may result in recommendations that could relate to pedestrians at grade-separated interchanges. The estimated completion date is February 2009.

8.2 Interview outline (draft)

1. Does the attached research summary conform to your understanding of current guidelines and practice for interchange designs that best meet the needs of pedestrians and bicyclists?
    a. What is missing, if anything?
    b. Any additional comments?

2. How does your understanding of better practice relate to the current state of practice? Are better practices being implemented?

3. If current practice does not follow better practice guidelines, why not? (possible reasons include few peds/bikes, poor documentation of current pedestrian and bicycle activity and latent demand, additional cost, unclear design guidelines, competing priorities, lack of comparable built projects)

4. How does the current state of practice vary between newly-constructed interchanges and modifications to existing interchanges?

5. What are the three most important design factors in pedestrian and bicycle mobility in highway interchanges?